



Intel[®] 440EX AGPset: 82443EX PCI AGP Controller (PAC)

Datasheet

April 1998

Order Number: 290616-001



Information in this document is provided in connection with Intel products. No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted by this document. Except as provided in Intel's Terms and Conditions of Sale for such products, Intel assumes no liability whatsoever, and Intel disclaims any express or implied warranty, relating to sale and/or use of Intel products including liability or warranties relating to fitness for a particular purpose, merchantability, or infringement of any patent, copyright or other intellectual property right. Intel products are not intended for use in medical, life saving, or life sustaining applications.

Intel may make changes to specifications and product descriptions at any time, without notice.

Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order.

The 82443EX may contain design defects or errors known as errata which may cause the products to deviate from published specifications. Such errata are not covered by Intel's warranty. Current characterized errata are available on request.

I²C is a two-wire communications bus/protocol developed by Philips. SMBus is a subset of the I²C bus/protocol and was developed by Intel. Implementations of the I²C bus/protocol or the SMBus bus/protocol may require licenses from various entities, including Philips Electronics N.V. and North American Philips Corporation.

Copies of documents which have an ordering number and are referenced in this document, or other Intel literature may be obtained by:

calling 1-800-548-4725 or

by visiting Intel's website at <http://www.intel.com>.

Copyright © Intel Corporation, 1998

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



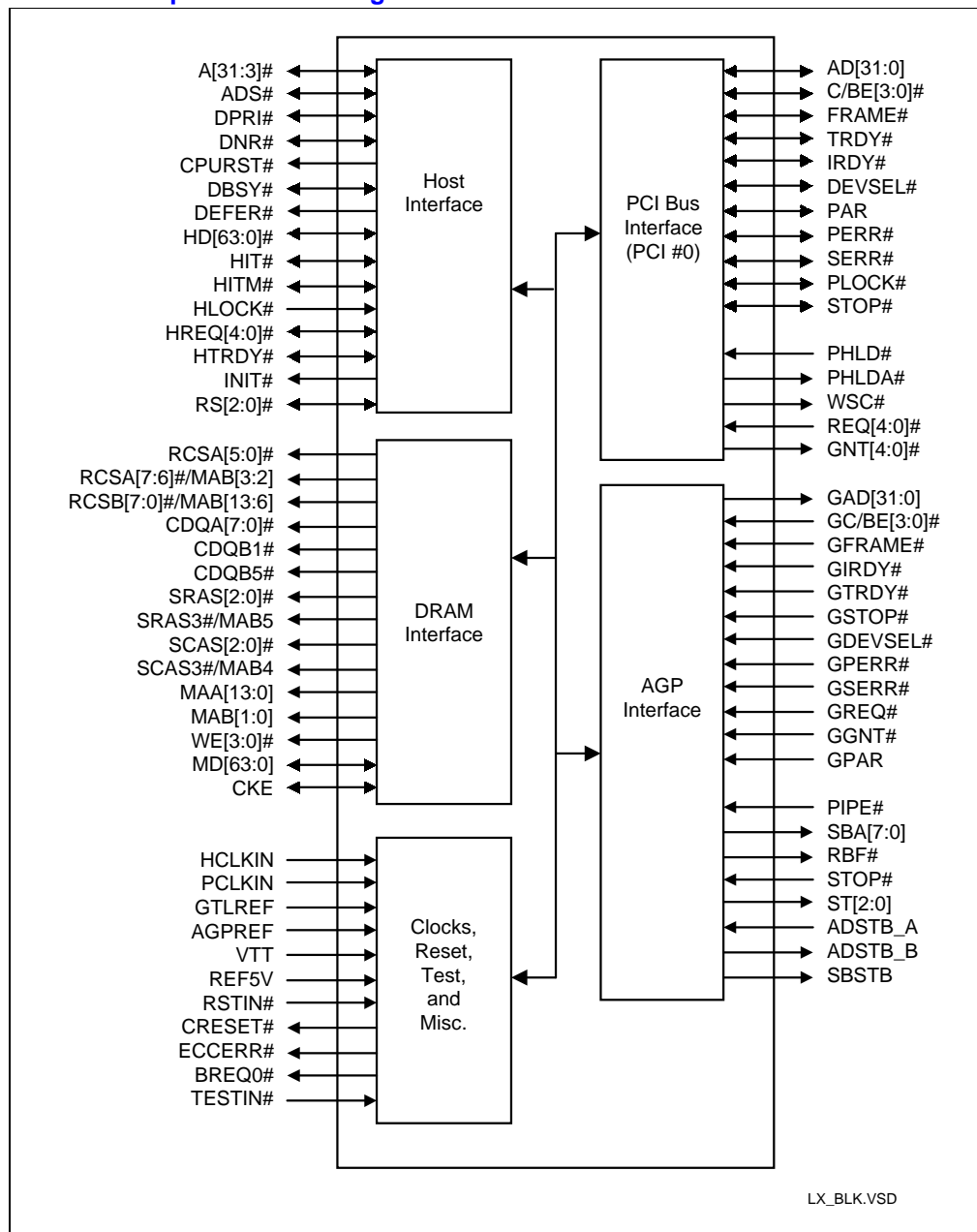
Intel 82443EX Features

- **Supports a Single Pentium® II Processor at a Bus Frequency of 66 MHz**
 - Supports 32-Bit Addressing
 - Optimized In-Order and Request Queue
 - Dynamic Deferred Transaction Support
 - GTL+ Compliant Host Bus Supports WC Cycles
- **Integrated DRAM Controller**
 - EDO (Extended Data Out), and Synchronous DRAM Support
 - Supports a Maximum Memory Size of 256 MB With EDO or SDRAM
 - 64-bit Path to Memory
 - Configurable DRAM Interface
 - Support for Auto Detection of Memory Type: (DIMM Serial Presence Detect)
 - 4 RAS Lines Available
 - Support for 4-, 16- and 64-Mbit DRAM devices
 - Support for Symmetrical and Asymmetrical DRAM Addressing
 - Read-Around-Write Support for Host and PCI DRAM Read Accesses
 - Supports 3.3V DRAMs
- **Accelerated Graphics Port (AGP) Interface**
 - AGP Specification Compliant
 - AGP 66/133 MHz 3.3V Devices Supported
 - Synchronous Coupling to the Host Bus Frequency
- **PCI Bus Interface**
 - PCI Revision 2.1 Interface Compliant
 - Greater Than 100-MBps Data Streaming for PCI-to-DRAM Accesses
 - Integrated Arbiter With Multi-Transaction PCI Arbitration Acceleration Hooks
 - Three PCI Bus Masters are Supported in Addition to the Host and PCI-to-ISA I/O Bridge
 - Delayed Transaction Support
 - PCI Parity Checking and Generation Support
- **Data Buffering For Increased Performance**
 - Extensive CPU-to-DRAM, PCI-to-DRAM, and AGP-to-DRAM Write Data Buffering
 - CPU-to-AGP, PCI-to-AGP, and AGP-to-PCI Data Buffering
 - Write Combining Support for CPU-to-PCI Burst Writes
 - Supports Concurrent Host, PCI, and AGP Transactions to Main Memory
- **System Management Mode (SMM) Compliant**
- **492 Pin BGA Package**

The Intel® 440EX AGPset, 82443EX PCI AGP Controller (PAC) integrates a Host-to-PCI bridge, optimized DRAM controller and data path, and an Accelerated Graphics Port (AGP) interface. AGP is a high performance, component level interconnect, targeted at 3D graphics applications and based on a set of performance enhancements to PCI. The I/O subsystem portion of the PAC platform is based on the PIIX4/PIIX4E, a highly integrated version of the Intel's PCI-to-ISA bridge family. The 82443EX has been developed as the basic PC solution to the standard LX Pentium® II processor platform and is targeted for desktop applications.

The 82443EX may contain design defects or errors known as errata which may cause the products to deviate from published specifications. Current characterized errata are available on request.

82443EX Simplified Block Diagram



Contents

1	Overview	1-1
2	Signal Description	2-1
2.1	PAC Signals.....	2-2
2.1.1	Host Interface Signals.....	2-2
2.1.2	DRAM Interface Signals.....	2-3
2.1.3	PCI Interface Signals	2-4
2.1.4	AGP Interface Signals.....	2-6
2.1.5	Clocks, Reset, and Miscellaneous Signals	2-8
2.2	Power-Up/Reset Strapping Options.....	2-8
2.3	Output/Bi-Directional Signals During Hard Reset	2-9
3	Register Description.....	3-1
3.1	Register Access	3-2
3.1.1	CONFADD—Configuration Address Register.....	3-2
3.1.2	CONFDATA—CONFIGURATION DATA REGISTER	3-3
3.1.3	CONFIGURATION SPACE MECHANISM.....	3-3
3.1.3.1	Routing the Configuration Accesses to PCI or AGP	3-3
3.1.3.2	PCI Bus Configuration Mechanism	3-3
3.1.3.3	Mapping of Configuration Cycles on AGP	3-4
3.2	PCI Configuration Space (Device 0 and Device 1)	3-5
3.3	Register Set—Device 0 (Host-to-PCI Bridge)	3-7
3.3.1	VID—Vendor Identification Register (Device 0).....	3-7
3.3.2	DID—Device Identification Register (Device 0)	3-7
3.3.3	PCICMD—PCI Command Register (Device 0).....	3-8
3.3.4	PCISTS—PCI Status Register (Device 0)	3-9
3.3.5	RID—Revision Identification Register (Device 0)	3-10
3.3.6	SUBC—Sub-Class Code Register (Device 0)	3-10
3.3.7	BCC—Base Class Code Register (Device 0)	3-10
3.3.8	MLT—Master Latency Timer Register (DEVICE 0)	3-11
3.3.9	HDR—Header Type Register (Device 0)	3-11
3.3.10	APBASE—Aperature Base Configuration Register (Device 0)	3-12
3.3.11	CAPPTR—Capabilities Pointer Register (Device 0)	3-12
3.3.12	PACCFG—PAC Configuration Register (Device 0).....	3-13
3.3.13	DBC—DATA BUFFER CONTROL REGISTER (DEVICE 0)	3-14
3.3.14	DRT—DRAM Row Type Register (Device 0)	3-14
3.3.15	DRAMC—DRAM Control Register (Device 0)	3-15
3.3.16	DRAMT—DRAM Timing Register (Device 0)	3-16
3.3.17	PAM—Programmable Attribute Map Registers (PAM[6:0]) (Device 0).....	3-17
3.3.18	DRB—DRAM Row Boundary Registers (Device 0)	3-19
3.3.19	FDHC—Fixed DRAM Hole Control Register (Device 0)	3-20
3.3.20	DRAMXC—DRAM Extended Control Register (Device 0).....	3-21
3.3.21	MBSC—Memory Buffer Strength Control Register (Device 0).....	3-21
3.3.22	MTT—Multi-Transaction Timer Register (Device 0)	3-23
3.3.23	SMRAM—System Management RAM Control Register Device 0).....	3-23

3.3.24	ERRCMD—Error Command Register (Device 0)	3-25
3.3.25	ERRSTS0—Error Status Register 0 (Device 0)	3-26
3.3.26	ERRSTS1—Error Status Register 1 (Device 0)	3-26
3.3.27	RSTCTRL—Reset Control Register (Device 0)	3-26
3.3.28	ACAPID—AGP Capability Identifier Register (Device 0)	3-28
3.3.29	AGPSTAT—AGP Status Register (DEVICE 0)	3-28
3.3.30	AGPCMD—AGP Command Register (Device 0)	3-29
3.3.31	AGPCTRL—AGP Control Register (Device 0)	3-29
3.3.32	APSIZE—Aperature Size (Device 0)	3-30
3.3.33	ATTBASE—Aperature Translation Table Base Register (Device 0)	3-31
3.3.34	AMTT—AGP Interface Multi-Transaction Timer Register (Device 0)	3-32
3.3.35	LPTT—Low Priority Transaction Timer Register (Device 0)	3-32
3.4	AGP Configuration Registers—(Device 1)	3-32
3.4.1	VID1—Vendor Identification Register (Device 1)	3-32
3.4.2	DID1—Device Identification Register (Device 1)	3-33
3.4.3	PCICMD1—PCI-PCI Command Register (Device 1)	3-33
3.4.4	PCISTS1—PCI-PCI Status Register (Device 1)	3-34
3.4.5	RID1—Revision Identification Register (Device 1)	3-34
3.4.6	SUBC1—Sub-Class Code Register (Device 1)	3-34
3.4.7	BCC1—Base Class Code Register (Device 1)	3-35
3.4.8	HDR1—Header Type Register (Device 1)	3-35
3.4.9	PBUSN—Primary Bus Number Register (Device 1)	3-35
3.4.10	SBUSN—Secondary Bus Number Register (Device 1)	3-36
3.4.11	SUBUSN—Subordinate Bus Number Register (Device 1)	3-36
3.4.12	SMLT—Secondary Master Latency Timer Register (Device 1)	3-36
3.4.13	IOBASE—I/O Base Address Register (Device 1)	3-37
3.4.14	IOLIMIT—I/O Limit Address Register (Device 1)	3-37
3.4.15	SSTS—Secondary PCI-PCI Status Register (Device 1)	3-38
3.4.16	MBASE—Memory Base Address Register (Device 1)	3-38
3.4.17	MLIMIT—Memory Limit Address Register (Device 1)	3-39
3.4.18	PMBASE—Prefetchable Memory Base Address Register (Device 1)	3-39
3.4.19	PMLIMIT—Prefetchable Memory Limit Address Register (Device 1)	3-40
3.4.20	BCTRL—PCI-PCI Bridge Control Register (Device 1)	3-40
4	Functional Description	4-1
4.1	System Address Map	4-1
4.1.1	Memory Address Ranges	4-1
4.1.1.1	Compatibility Area	4-1
4.1.1.2	AGP Memory Address Ranges	4-4
4.1.1.3	AGP Graphics Aperture	4-4
4.1.1.4	Address Mapping of PCI Devices on AGP	4-5
4.1.2	System Management Mode (SMM) Memory Range	4-5
4.1.3	Memory Shadowing	4-5
4.1.4	I/O Address Space	4-6
4.1.5	PAC Decode Rules and Cross-Bridge Address Mapping	4-6
4.1.5.1	PCI Interface Decode Rules	4-7
4.1.5.2	AGP Interface Decode Rules	4-7



	4.1.5.3 Legacy VGA and MDA Ranges	4-7
4.2	Host Interface.....	4-8
4.3	DRAM Interface	4-9
	4.3.1 DRAM Organization and Configuration.....	4-10
	4.3.1.1 Configuration Mechanism for DIMMs.....	4-13
	4.3.2 DRAM Address Translation and Decoding	4-14
	4.3.3 Refresh Cycles (CAS# Before RAS#).....	4-16
	4.3.4 DRAM Subsystem Power Management	4-16
	4.3.5 Serial Presence Detect (SPD) For SDRAM	4-17
	4.3.6 Single Clock Command Mode For SDRAM	4-17
	4.3.6.1 Enabling Single Clock Command Mode	4-18
	4.3.6.2 Restrictions For Supporting Single Clock Command Mode	4-18
	4.3.6.3 Conclusion For Single Clock Command Mode Support	4-19
	4.3.7 Support For 2 and 4 Banks SDRAM	4-19
4.4	Data Integrity Support.....	4-19
4.5	PCI Interface	4-20
4.6	AGP Interface	4-20
4.7	Arbitration and Concurrency	4-21
4.8	System Clocking and Reset.....	4-23
	4.8.1 Host Frequency Support	4-23
	4.8.2 Clock Generation and Distribution	4-23
	4.8.3 System Reset.....	4-24
	4.8.4 PAC Reset Structure.....	4-24
	4.8.5 Hard Reset.....	4-24
	4.8.6 Soft Reset	4-26
	4.8.7 CPU BIST	4-26
5	Electrical Characteristics.....	5-1
	5.1 Absolute Maximum Ratings	5-1
	5.2 Power Characteristics	5-2
	5.3 Signal Groupings	5-2
	5.4 D.C. Characteristics	5-4
	5.5 AC Characteristics	5-6
	5.6 82443EX Timing Diagrams	5-10
	5.7 DRAM Timing Relationships With Register Settings	5-13
6	Pin Assignment	6-1
7	Package Specifications.....	7-1

Figures

1-1	Intel® 440EX System Block Diagram.....	1-2
3-1	2. DIMMs and Corresponding DRB Registers	3-19
3-2	Soft Reset and BIST Hard Reset Timing	3-27
4-1	Detailed Memory System Address Map	4-2
4-2	82443EX Configuration (Small Memory Array).....	4-11
4-3	Single Clock Mode Disabled.....	4-18
4-4	Single Clock Mode Enabled.....	4-18
4-5	PCI Bus Arbiter	4-22
4-6	PAC and PIIX4.....	4-23
4-7	Reset Structure for Intel® 440EX AGPset with PIIX4	4-25
4-8	PAC Hard Reset Timing	4-25
5-1	2.5V Clocking Interface.....	5-10
5-2	3.3V Clocking Interface.....	5-10
5-3	Valid Delay From Rising Clock Edge.....	5-11
5-4	Setup and Hold Time to Clock	5-11
5-5	Float Delay.....	5-11
5-6	Pulse Width.....	5-11
5-7	Strobe/Data Turnaround Timings	5-12
5-8	AGP 133 Timing Diagram	5-12
5-9	Page Hit with SCLT=0, SRCD=1, SRPT=1	5-14
5-10	Page Hit with SCLT=1, SRCD=1, SRPT=1	5-15
5-11	Page Miss with SCLT=1, SRCD=1, SRPT=0	5-15
5-12	Page Miss with SCLT=1, SRCD=1, SRPT=1	5-16
5-13	Row Miss-4 with SCLT=1, SRCD=0, SRPT=1	5-16
5-14	Row Miss-4 with SCLT=0, SRCD=1, SRPT=1	5-17
5-15	Row Miss-4 with SCLT=1, SRCD=1, SRPT=1	5-17
5-16	Row Miss-5 with SCLT=1, SRCD=1, SRPT=1	5-18
6-1	PAC Pinout (Top View).....	6-2
6-2	PAC Pinout (Top View).....	6-3
7-1	PAC Package Dimensions (492 BGA).....	7-1
7-2	PAC Package Dimensions (492 BGA).....	7-2



Tables

2-1	Host Interface Signals.....	2-2
2-2	DRAM Interface Signals.....	2-3
2-3	PCI Interface Signals	2-4
2-4	AGP Signals.....	2-6
2-5	Clocks, Reset, Reference Voltage, and Miscellaneous Signals	2-8
2-6	Signals During Reset	2-9
3-1	PCI Configuration Space—Device 0 (Host-to-PCI Bridge)	3-5
3-2	PCI Configuration Space—Device 1 (“Virtual” PCI-to-PCI Bridge)	3-6
3-3	Attribute Bit Assignment.....	3-17
3-4	PAM Registers and Associated Memory Segments	3-18
3-5	SMRAM Space Cycles.....	3-24
4-1	Legacy Programming Considerations.....	4-8
4-2	Minimum (Upgradable) and Maximum Memory Size for Each Configuration.....	4-12
4-3	DRAM Address Translation	4-14
4-4	82443EX EDO DRAM Addressing.....	4-15
4-5	PAC SDRAM Addressing.....	4-15
4-6	Restrictions For Single Clock Command Mode Support.....	4-19
5-1	Power Characteristics	5-2
5-2	Signal Groups	5-3
5-3	D.C. Characteristics	5-4
5-4	HOST Clock Timing, 66 MHz.....	5-6
5-5	CPU Interface Timing, 66 MHz	5-6
5-6	DRAM Interface Timing, 66 MHz (Configuration #1)	5-6
5-7	DRAM Interface Timing, 66 MHz (Configuration #2)	5-7
5-8	PCI Clock Timing, 33 MHz.....	5-7
5-9	PCI Interface Timing, 33 MHz.....	5-8
5-10	AGP Interface Timing, 66/133 MHz	5-8
5-11	AGP Interface Timing, 133 MHz	5-9
5-12	Miscellaneous Signals	5-10
5-13	AC Timing Measurement Points	5-12
5-14	EDO Timing Performance Summary	5-13
5-15	SDRAM Timing Performance Summary	5-14
6-1	82443EX Alphabetical Pin Assignment.....	6-4
6-2	82443EX Pinout (Power, Ground, and No Connects).....	6-7
7-1	PAC Package Dimensions (468 BGA).....	7-3

PAC integrates a Host-to-PCI bridge, optimized DRAM controller and data path, and an Accelerated Graphics Port (AGP) interface. The AGP is a high performance, component level interconnect, targeted at 3D graphics applications and based on a set of performance enhancements to PCI. The I/O subsystem portion of the PAC platform is based on PIIX4 or PIIX4E. These components are highly integrated versions of Intel's PCI-to-ISA bridge family.

Note: Throughout this document the term “PIIX4” will be used when referring to either PIIX4 or PIIX4E.

PAC has been developed as a low-cost alternative to the standard Intel® 440LX Pentium® II processor platform and is targeted for desktop applications. The PAC component includes the following functions and capabilities:

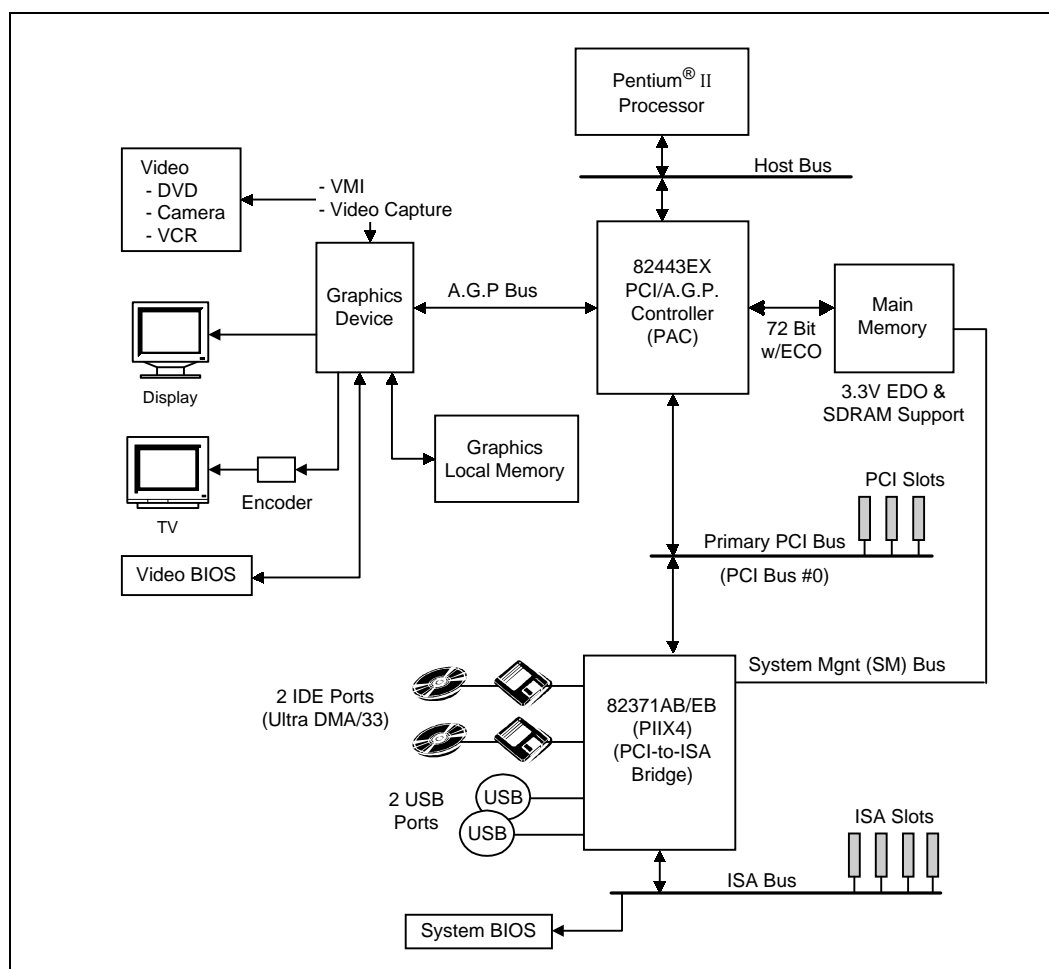
- Support for a single Pentium® II processor configuration
- 64-bit GTL+ based Host Interface
- 32-bit Host address Support
- 64-bit Main Memory Interface with optimized support for SDRAM
- 32-bit PCI Bus Interface with integrated PCI arbiter
- AGP Interface with up to 133-MHz data transfer capability
- Extensive Data Buffering between all interfaces for high throughput and concurrent operations

Figure 1-1 shows a block diagram of a typical platform based on the Intel® 440EX AGPset. The PAC host bus interface supports a single Pentium II processor at 66 MHz. The physical interface design is based on the GTL+ specification. The PAC provides an optimized 64-bit DRAM interface. This interface supports 3.3V DRAM technologies. The PAC provides the interface to a PCI bus operating at 33 MHz. This interface implementation is compliant with PCI Rev 2.1 Specification. The PAC utilizes the full featured Accelerated Graphics Port interface. The PAC AGP interface implementation is based on the AGP Specification Rev 1.0, and it can support up to 133-MHz data transfer rates.

PAC is designed to support the PIIX4 I/O bridge. PIIX4 is a highly integrated multi-functional component that supports the following functions and capabilities:

- PCI Rev 2.1 compliant PCI-to-ISA Bridge with support for 33-MHz PCI operations
- Deep Green Desktop Power Management Support
- Enhanced DMA controller
- 8259 Compatible Programmable Interrupt Controller
- System Timer functions
- Integrated IDE controller with Ultra DMA/33 support
- USB host interface with support for two USB ports
- System Management Bus (SMB) with support for DIMM Serial Presence Detect

Figure 1-1. Intel® 440EX System Block Diagram



Host Interface

The Pentium II processor supports a second level cache size of 256K or 512K. All cache control logic is provided in the Pentium II processor. PAC supports a maximum of 32-bit address or 4-GB memory address space from the processor perspective. PAC provides bus control signals and address paths for transfers between the processor's host bus, PCI bus, Accelerated Graphics Port and main memory. The PAC supports a 4-deep in-order queue (i.e., it provides support for pipelining of up to four outstanding transaction requests on the host bus). Due to the system concurrency requirements, along with support for pipelining of address requests from the host bus, the PAC supports general request queuing for all three interfaces (Host, AGP and PCI).

In Host-to-PCI transfers, depending on the PCI address space being accessed, the address will be either translated or directly forwarded on the PCI bus. If the access is to a PCI configuration space, the processor I/O cycle is mapped to a configuration cycle. If the access is to a PCI I/O or memory space, the processor address is passed without modification to the PCI bus, unless it hits a certain PCI memory address range (later referred in a document as the AGP Aperture or Graphics Aperture) dedicated for graphics memory address space. If this space, or a portion of it, is mapped to main memory, then the address will be translated via the AGP address remapping mechanism. The request will also be forwarded to the DRAM subsystem. Host cycles forwarded to AGP are defined by the AGP address map.

PAC also receives requests from PCI bus and AGP bus initiators for access to main memory. If a target address is within the graphics aperture, then the request is translated into the appropriate memory address. AGP accesses destined to the graphics aperture are not snooped on the host bus because coherency of aperture data is maintained by software. All accesses to the aperture, from the Host, PCI or AGP, are translated using the AGP address remapping mechanism.

DRAM Interface

The PAC integrates a main memory controller that supports a 64-bit DRAM interface. The DRAM controller supports the following features:

- **DRAM type.** Extended Data Out (EDO) and Synchronous (SDRAM); DRAM controller optimized for dual-bank SDRAM organization
- **Memory Size.** SDRAM: 8 MB to 256 MB with four memory rows EDO: 8 MB to 256 MB with four memory rows
- **Addressing Type.** Symmetrical and Asymmetrical addressing
- **Memory Modules:** Single and double density DIMMs
- **Configurable DRAM Interface (EX Configuration: Small Memory Array)**
 - Support for single and double-sided x8 and x16 DIMMs only
 - Copy of MA[13:2] signals supplied by the PAC (no external buffers required on MA signals)
 - 4 Row, 2 DS DIMM socket configuration
- **DRAM device technology.** 4 Mbit, 16 Mbit and 64 Mbit
- **DRAM Speeds.** 50 ns and 60 ns for asynchronous and equivalent (EDO DRAM) SDRAM 66-MHz parameters for synchronous memory.
- The Intel® 440EX AGPset also provides a DIMM plug-and-play support via Serial PD (Presence Detect) mechanism. This is supported via the PIIX4 SMB interface.

Accelerated Graphics Port (AGP) Interface

The Intel® 440EX supports the full featured AGP interface. The PAC AGP implementation is compatible with the Accelerated Graphics Port Specification 1.0. PAC supports only a synchronous AGP interface, coupling to the host bus frequency. The AGP interface can reach a theoretical ~532 Mbytes/sec transfer rate. The actual bandwidth will be limited by the capability of the PAC memory subsystem.

PCI Interface

The PAC PCI interface is 33-MHz Revision 2.1 compliant and supports up to three external PCI bus masters in addition to the I/O bridge (PIIX4). PAC supports only synchronous PCI coupling to the host bus frequency.

Read/Write Buffers

PAC defines a sophisticated data buffering scheme to support the required level of concurrent operations and provide adequate sustained bandwidth between DRAM subsystem and all other system interfaces (CPU, AGP and PCI).

System Clocking

PAC operates the host interface at 66 MHz, PCI at 33 MHz and AGP at 66/133 MHz. Coupling between all interfaces and internal logic is done in a synchronous manner. PAC is not designed to support host bus frequencies lower than 66 MHz. The PAC clocking scheme uses an external clock synthesizer (which produces reference clocks for the host, AGP and PCI interfaces).

Signal Description

2

This section provides a detailed description of each signal for the PAC. The signals are arranged in functional groups according to their associated interface.

The “#” symbol at the end of a signal name indicates that the active, or asserted state occurs when the signal is at a low voltage level. When “#” is not present after the signal name, the signal is asserted when at the high voltage level.

The terms “assertion” and “negation” are used extensively. This is done to avoid confusion when working with a mixture of “active-low” and “active-high” signals. The term **assert** or **assertion**, indicates that the signal is active, independent of whether that level is represented by a high or low voltage. The term **negate**, or **negation** indicates that a signal is inactive.

The following notations are used to describe the signal type:

I	Input pin
O	Output pin
OD	Open Drain Output pin. This pin requires a pull-up to an appropriate voltage
I/O	Bi-directional input/output pin

The signal description also includes the type of buffer used for the particular signal:

GTL+	Open Drain GTL+ interface signal. Refer to the GTL+ I/O Specification for complete details
PCI	PCI bus interface signals. These signals are compliant with the PCI 5.0V Signaling Environment DC and AC Specifications
AGP	AGP interface signals. These signals are compatible with AGP Signaling Environment DC and AC Specifications
LVTTTL	Low Voltage TTL compatible signals. These are also 3.3V inputs and outputs.

Note that the Pentium II processor address and data bus signals are logically inverted signals. In other words, the actual values are inverted of what appears on the Pentium II processor bus. All control signals follow normal convention. A 0 (low voltage) indicates an active level if the signal is followed by # symbol, and a 1 (high voltage) indicates an active level if the signal has no # suffix.

2.1 PAC Signals

2.1.1 Host Interface Signals

Table 2-1. Host Interface Signals (Sheet 1 of 2)

Name	Type	Description
A[31:3]#	I/O GTL+	Address Bus: A[31:3]# connect to the processor address bus. During host cycles, the A[31:3]# are inputs. PAC drives A[31:3]# during snoop cycles on behalf of PCI and AGP initiators. Note that the address signals are inverted on the CPU bus.
ADS#	I/O GTL+	Address Strobe: The CPU bus owner asserts ADS# to indicate the first of two cycles of a request phase.
BPRI#	O GTL+	Priority Agent Bus Request: PAC is the only Priority Agent on the CPU bus. This signal is used to obtain the ownership of the address bus. Unless the HLOCK# signal was asserted, BPRI# has priority over symmetric bus requests and causes the current symmetric owner to stop issuing new transactions.
BNR#	I/O GTL+	Block Next Request: Used to block the current request bus owner from issuing a new request. This signal is used to dynamically control the CPU bus pipeline depth.
CPURST#	O GTL+	CPU Reset. The CPURST# pin is an output from PAC. PAC generates this signal based on the RSTIN# input signal (from PIIX4). The CPURST# allow the CPU(s) to begin execution in a known state.
DBSY#	I/O GTL+	Data Bus Busy: Used by the data bus owner to hold the data bus for transfers requiring more than one cycle.
DEFER#	O GTL+	Defer: PAC will generate a deferred response. PAC will also use the DEFER# signal to indicate a retry response on the CPU bus.
DRDY#	I/O GTL+	Data Ready: Asserted for each cycle that data is transferred.
HD[63:0]#	I/O GTL+	Host Data: These signals are connected to the CPU data bus. Note that the data signals are inverted on the CPU bus.
HIT#	I/O GTL+	Hit: Indicates that a caching agent holds an unmodified version of the requested line. Also, the target may extend the snoop window by driving HIT# in conjunction with HITM#.
HITM#	I/O GTL+	Hit Modified: Indicates that a caching agent holds a modified version of the requested line and that this agent assumes responsibility for providing the line. It is also driven in conjunction with HIT# to extend the snoop window.
HLOCK#	I GTL+	Host Lock: HLOCK# provides a mechanism to insure that cycles on the Host bus are atomic. All cycles initiated while HLOCK# is asserted are guaranteed atomic. (i.e., no PCI or AGP-snoopable access to DRAM is allowed when HLOCK# signal is asserted by the CPU.)
HREQ[4:0]#	I/O GTL+	Request Command: Asserted during both clocks of request phase. In the first clock, the signals define the transaction type to a level of detail that is sufficient to begin a snoop request. In the second clock, the signals carry additional information to define the complete transaction type.
HTRDY#	I/O GTL+	Host Target Ready: Indicates that the target of the CPU bus transaction is able to enter the data transfer phase.
INIT#	O LVTTTL	Initialization. This is the output signal generated by the PAC after a CPU shutdown bus cycle, or after a soft reset is initiated by writing to the reset control register.

Table 2-1. Host Interface Signals (Sheet 2 of 2)

Name	Type	Description																				
RS[2:0]#	I/O GTL+	Response Signals: Indicates type of response according to the following table:																				
		<table><tr><th>RS[2:0]</th><th>Response type</th><th>RS[2:0]</th><th>Response type</th></tr><tr><td>000</td><td>Idle state</td><td>100</td><td>Hard Failure</td></tr><tr><td>001</td><td>Retry response</td><td>101</td><td>No data response</td></tr><tr><td>010</td><td>Deferred response</td><td>110</td><td>Implicit Writeback</td></tr><tr><td>011</td><td>Reserved</td><td>111</td><td>Normal data response</td></tr></table>	RS[2:0]	Response type	RS[2:0]	Response type	000	Idle state	100	Hard Failure	001	Retry response	101	No data response	010	Deferred response	110	Implicit Writeback	011	Reserved	111	Normal data response
		RS[2:0]	Response type	RS[2:0]	Response type																	
		000	Idle state	100	Hard Failure																	
		001	Retry response	101	No data response																	
		010	Deferred response	110	Implicit Writeback																	
011	Reserved	111	Normal data response																			
HCLKIN	I LVTTL (2.5V)	Host Clock In: See <i>Clocks, Reset, and Miscellaneous Signals</i> Section.																				

NOTE:

1. All of the signals in the host interface are described in the Pentium II Processor data book. The preceding table highlights PAC specific uses of these signals.

2.1.2 DRAM Interface Signals

Table 2-2. DRAM Interface Signals (Sheet 1 of 2)

Signal	Type	Description
RCSA[3:0]#	O LVTTTL	Row Address Strobe 3-0 (EDO): These signals are used to latch the row address into the memory array. Each signal is used to select one DRAM row. These signals drive the DRAM array directly without any external buffers. Chip Select 3-0 (SDRAM): For the memory row configured with SDRAM, these pins perform the function of selecting the particular SDRAM components during the active state. These signals have programmable buffer strengths for optimization under different signal loading conditions.
CDQA[7:0]#	O LVTTTL	Column Address Strobe (EDO): For EDOs, these signals are used to latch the column address into the memory array (CAS signals). They drive the DRAM array directly without external buffering. Input/Output Data Mask (SDRAM): These pins act as synchronized output enables during read cycles and as byte enables during write cycles. In the case of write cycles, byte masking functions are performed during the same clock that write data is driven (i.e., 0 clock latency). Same function for Configuration #1 and Configuration #2. These signals have programmable buffer strengths for optimization under different signal loading conditions.
SRAS[1:0]#	O LVTTTL	SDRAM Row Address Strobe (SDRAM): The SRAS[1:0]# signals are multiple copies (for loading purposes) of the same logical SRASx signal used to generate SDRAM command. These commands are encoded on SRASx/SCASx/WE signals. When SRASx is sampled active at the rising edge of the SDRAM clock, the row address is latched into the SDRAMs. These signals have programmable buffer strengths for optimization under different signal loading conditions.
SCAS[1:0]#	O LVTTTL	SDRAM Column Address Strobe (SDRAM): The SCAS[1:0]# signals are multiple copies (for loading purposes) of the same logical SCASx signal used to generate SDRAM commands. These commands are encoded on SRASx/SCASx/WE signals. When SCASx is sampled active at the rising edge of the SDRAM clock, the column address is latched into the SDRAMs. These signals have programmable buffer strengths for optimization under different signal loading conditions.

Table 2-2. DRAM Interface Signals (Sheet 2 of 2)

Signal	Type	Description
MAA[13:0]	O LVTTTL	Memory Address A (EDO/SDRAM): MAA[13:0] is used to provide the multiplexed row and column address to DRAM. External buffering is not required for these signals. These signals have programmable buffer strengths for optimization under different signal loading conditions.
WE[1:0]#	O LVTTTL	Write Enable Signal (EDO/SDRAM): The WE[1:0]# signals are multiple copies (for loading purposes) of the same logical WEx# signal used to generate write strobe for EDO or SDRAM command. These commands are encoded on SRASx/SCASx/ WEx# signals. These signals drive the DRAM array directly without any external buffers. These signals have programmable buffer strengths for optimization under different signal loading conditions.
MD[63:0]	I/O LVTTTL	Memory Data (EDO/SDRAM): These signals are used to interface to the DRAM data bus. These signals are internally connected to 20 kΩ pull-down resistors. These signals have programmable buffer strengths for optimization under different signal loading conditions.
CKE	I/O LVTTTL	Clock Enable (SDRAM): This signal is used to enable/disable the SDRAM clock (internally within the SDRAM component). When “high,” it enables normal SDRAM operation. When “low,” it deactivates the SDRAM clock and the SDRAM components enter Power Down Mode. Note that all SDRAM banks must be pre-charged before CKE is negated. The SDRAM Power Down Mode is used only for the PAC DRAM array power management. The CKE signal must be externally buffered, using a CMOS buffer, if SDRAM power management capability is utilized. Note that starting with the assertion of RSTIN#, and until 4 clocks of the CPURST# signal negation, this signal will be controlled as an input to allow sampling of the strap attached to this pin. CKE is connected to a 20 kΩ internal pull-down resistor.

2.1.3 PCI Interface Signals

Table 2-3. PCI Interface Signals (Sheet 1 of 2)

Name	Type	Description
Standard PCI Signals		
AD[31:0]	I/O PCI	PCI Address/Data: These signals are connected to the PCI address/data bus. Address is driven with FRAME# assertion and data is driven or received on following clocks.
DEVSEL#	I/O PCI	Device Select: Assertion indicates that a PCI target device has decoded its address as the target of the current access. PAC asserts DEVSEL# if the current access is: within Main Memory within the AGP aperture resides on the AGP interface a configuration cycle targeting the PAC As an input, this signal indicates whether a device on the bus has been selected.
FRAME#	I/O PCI	Frame: Assertion indicates the address phase of a PCI transfer. Negation indicates that one more data transfer is desired by the cycle initiator.
IRDY#	I/O PCI	Initiator Ready: Asserted when the initiator is ready for a data transfer.

Table 2-3. PCI Interface Signals (Sheet 2 of 2)

Name	Type	Description																																				
C/BE[3:0]#	I/O PCI	Command/Byte Enable: The command is driven with FRAME# assertion. Byte enables corresponding to supplied or requested data are driven on following clocks. PCI Bus command encoding and types are listed below. <table><tr><th>C/BE[3:0]#</th><th>Command Type</th><th>C/BE[3:0]#</th><th>Command Type</th></tr><tr><td>0000</td><td>Interrupt Acknowledge</td><td>1000</td><td>Reserved</td></tr><tr><td>0001</td><td>Special Cycle</td><td>1001</td><td>Reserved</td></tr><tr><td>0010</td><td>I/O Read</td><td>1010</td><td>Configuration Read</td></tr><tr><td>0011</td><td>I/O Write</td><td>1011</td><td>Configuration Write</td></tr><tr><td>0100</td><td>Reserved</td><td>1100</td><td>Memory Read Multiple</td></tr><tr><td>0101</td><td>Reserved</td><td>1101</td><td>Reserved (Dual Addr Cyc)</td></tr><tr><td>0110</td><td>Memory Read</td><td>1110</td><td>Memory Read Line</td></tr><tr><td>0111</td><td>Memory Write</td><td>1111</td><td>Memory Write and Invalidate</td></tr></table>	C/BE[3:0]#	Command Type	C/BE[3:0]#	Command Type	0000	Interrupt Acknowledge	1000	Reserved	0001	Special Cycle	1001	Reserved	0010	I/O Read	1010	Configuration Read	0011	I/O Write	1011	Configuration Write	0100	Reserved	1100	Memory Read Multiple	0101	Reserved	1101	Reserved (Dual Addr Cyc)	0110	Memory Read	1110	Memory Read Line	0111	Memory Write	1111	Memory Write and Invalidate
C/BE[3:0]#	Command Type	C/BE[3:0]#	Command Type																																			
0000	Interrupt Acknowledge	1000	Reserved																																			
0001	Special Cycle	1001	Reserved																																			
0010	I/O Read	1010	Configuration Read																																			
0011	I/O Write	1011	Configuration Write																																			
0100	Reserved	1100	Memory Read Multiple																																			
0101	Reserved	1101	Reserved (Dual Addr Cyc)																																			
0110	Memory Read	1110	Memory Read Line																																			
0111	Memory Write	1111	Memory Write and Invalidate																																			
PAR	I/O PCI	Parity: A single parity bit is provided over AD[31:0] and C/BE[3:0]. Even parity is generated across AD[31:0] and C/BE[3:0]#.																																				
PERR#	I/O PCI	PCI Parity Error: Pulsed by an agent receiving data with bad parity one clock after PAR is asserted. PAC generates PERR# active if it detects a parity error on the PCI bus and the PERR# Enable bit in the PCICMD register is set.																																				
PLOCK#	I/O PCI	Lock: Used to establish, maintain, and release resource locks on PCI.																																				
TRDY#	I/O PCI	Target Ready: Asserted when the target is ready for a data transfer.																																				
SERR#	I/O PCI	System Error: PAC asserts this signal to indicate an error condition. The SERR# assertion by the PAC is enabled globally via the SERRE bit of the PCICMD register. SERR# is asserted under the following conditions: 1. PAC asserts SERR# for one clock when it detects a target abort during PAC initiated PCI cycle. 2. PAC can also assert SERR# when a PCI parity error occurs during the address phase if Parity Error Enable (register 04h, bit 6), SERR Enable (register 04h, bit 8), and SERR# on PCI Parity Error (register 90h, device 3) are set. 3. PAC can assert SERR# when it samples PERR# asserted on the PCI bus. This capability is controlled by bit 3 of the ERRCMD register. 4. PAC can assert SERR# when it detects assertion of G-SERR# input signal. This capability is controlled by bit 5 of the ERRCMD register.																																				
STOP#	I/O PCI	Stop: Asserted by the target to request the master to stop the current transaction.																																				
PCLKIN	I LVTTTL	PCI Clock In: See <i>Clocks, Reset, and Miscellaneous Signals</i> Section.																																				
PCI Arbitration Signals																																						
PHLD#	I PCI	PCI Hold: This signal comes from the PIIX4. It is the PIIX4 request for PCI bus ownership. PAC will flush and disable the CPU to PCI write buffers before granting the PIIX4 the PCI bus via PHLDA#. This ensures prevention of a bus deadlock condition between PCI and ISA.																																				
PHLDA#	O PCI	PCI Hold Acknowledge: This signal is driven by the PAC to grant PCI bus ownership to the PIIX4 after CPU to PCI post buffers have been flushed and disabled.																																				
REQ[2:0]#	I PCI	PCI Bus Request: REQ[2:0]# are the PCI bus request signals used as inputs by the internal PCI arbiter. If any of the REQ[x]# signals are NOT used, these inputs must be pulled up to Vcc3.																																				
GNT[2:0]#	O PCI	PCI Grant: GNT[2:0]# are the PCI bus grant output signals generated by the internal PCI arbiter.																																				

NOTE:

1. All PCI interface signals conform to the PCI specification, Revision 2.1.

2.1.4 AGP Interface Signals

The AGP interface consists of a set of signals similar to PCI called AGP FRAME# Protocol signals. In addition, there are 16 new signals added that constitute the AGP sideband interface. The sections below are organized in five groups: 1.) AGP Sideband Addressing Signals, 2.) AGP Sideband Flow Control Signals, 3.) AGP Sideband Status Signals, 4.) AGP Sideband Clocking Signals (Strobes), and 5.) AGP FRAME# Protocol Signals.

Table 2-4. AGP Signals (Sheet 1 of 2)

Name	Type	Description
AGP Sideband Addressing Signals¹		
PIPE#	I AGP	Pipelined Operation: PIPE# is asserted by the current master to indicate a full width address is to be queued by the target. The master queues one request each rising clock edge while PIPE# is asserted. When PIPE# is negated, no new requests are enqueued across the AD bus. PIPE# is a sustained tri-state signal from a <i>master (graphics controller)</i> and is an input to the PAC.
SBA[7:0]	I AGP	Sideband Address bus: SBA[7:0] provide an additional bus to pass addresses and commands to the PAC from the AGP master.
AGP Sideband Flow Control Signals		
RBF#	I AGP	Read Buffer Full: RBF# indicates if the master is ready to accept previously requested low priority read data. When RBF# is asserted, PAC is not allowed to return (low priority) read data to the AGP master.
AGP Sideband Status Signals		
ST[2:0]	O AGP	Status Bus: ST[2:0] provide information from the arbiter to an AGP master on what it may do. ST[2:0] only has meaning to the master when its GNT# is asserted. When GNT# is negated these signals have no meaning and must be ignored. ST[2:0] Description 000 Indicates that previously requested low priority read data is being returned to the master. 001 Indicates that previously requested high priority read data is being returned to the master. 010 Indicates that the master is to provide low priority write data for a previous enqueued write command. 011 Indicates that the master is to provide high priority write data for a previous enqueued write command. 100 Reserved 101 Reserved 110 Reserved 111 Indicates that the master has been given permission to start a bus transaction. The master may enqueue AGP requests by asserting PIPE# or start a PCI transaction by asserting GFRAME#. ST[2:0] are always outputs from PAC and inputs to the master.
AGP Sideband Clocking Signals (Strobes)		
ADSTB_A	I/O (t/s) AGP	AD Bus Strobe A: Provides timing for double clocked data on GAD[15:0]. The agent that is providing data drives this signal. This signal has been labeled ADSTB_A in some documents.
ADSTB_B	I/O (t/s) AGP	AD Bus Strobe B: Provides timing for double clocked data on the GAD[31:16]. The agent that is providing data drives this signal. This signal has been labeled ADSTB_B in some documents.

Table 2-4. AGP Signals (Sheet 2 of 2)

Name	Type	Description
SBSTB	I AGP	Sideband Strobe: Provides timing for SBA[7:0]. It is always driven by the AGP compliant master.
AGP FRAME# Protocol Signals (similar to PCI)²		
GFRAME#	I/O AGP	AGP Frame: Assertion indicates the address phase of a AGP FRAME# protocol transfer. Negation indicates that one more data transfers are desired by the cycle initiator. GFRAME# remains negated by an internal pull up resistor.
GIRDY#	I/O AGP	AGP Initiator Ready: For AGP Frame# protocol transactions, this signal is asserted when the initiator is ready for a data transfer. It indicates that the AGP compliant master is ready to provide <i>all</i> write data for the first block of a sideband transaction.
GTRDY#	I/O AGP	AGP Target Ready: For AGP Frame# protocol transactions, this signal is asserted when the target is ready for a data transfer. It indicates the AGP compliant target is ready to provide read data for the first block of a sideband transaction.
GSTOP#	I/O AGP	AGP Stop: Asserted by the target to request the master to stop the current transaction.
GDEVSEL#	I/O AGP	AGP Device Select: Assertion indicates that a AGP target device has decoded its address as the target of the current access. PAC asserts DEVSEL# if the current access is: <ul style="list-style-type: none"> within Main Memory resides on the PCI interface As an input, this signal indicates whether a device on the bus has been selected.
GPERR#	I/O AGP	AGP Parity Error: Pulsed by an agent receiving data with bad parity one clock after GPAR is asserted.
GSERR#	I AGP	AGP System Error: May be used by AGP master to report a catastrophic error. Routed internally within PAC to the primary PCI bus SERR# signal (direct connection between GSERR# 66-MHz signal and SERR# 33-MHz signal is not possible).
GREQ#	I AGP	AGP Bus Request: Used to request access to the bus to initiate an AGP request.
GGNT#	O AGP	AGP Grant (additional information is provided on ST[2:0]): The additional information indicates that the selected master is the recipient of previously requested read data (high or normal priority). It is to provide write data (high or normal priority) for a previously enqueued write command or has been given permission to start an AGP bus transaction.
GAD[31:0]	I/O AGP	AGP Address / Data: The standard address and data lines. Address is driven with FRAME# assertion; data is driven or received in following clocks.
GC/BE[3:0]#	I/O AGP	AGP Command / Byte Enables: For FRAME# protocol transactions, the command is driven with FRAME# assertion. Byte enables corresponding to supplied or requested data are driven on following clocks. The encoding is the same as for PCI transactions. Provides command information (different commands than PCI) when requests are being enqueued using PIPE#. These signals provide valid byte information during AGP write transactions and is driven by the master. The target drives "0000" during the return of AGP read data and is ignored by the AGP compliant master.
GPAR	I/O AGP	AGP Parity: A single parity bit is provided over AD[31:0] and C/BE[3:0]#. Even parity is generated across AD[31:0] and C/BE[3:0]#. Not used on AGP sideband transactions.

NOTES:

1. **AGP Addressing Signals.** This section of the table contains two mechanisms to enqueue requests by the AGP master. Note that the master can only use one mechanism. When PIPE# is used to enqueue addresses

the master is not allowed to enqueue addresses using the SB bus. For example, during configuration time, if the master indicates that it can use either mechanism, the configuration software will indicate which mechanism the master will use. Once this choice has been made, the master continues to use the mechanism selected until the master is reset (and reprogrammed) to use the other mode. This change of modes is not a dynamic mechanism, but rather a static decision when the device is first being configured after reset.

2. **AGP FRAME# Protocol Signals (similar to PCI):** These signals, for the most part, are redefined when used in AGP transactions using AGP sideband protocol extensions. For transactions on the AGP interface using FRAME# protocol, these signals preserve PCI semantics. The exact role of these signals during AGP sideband transactions is defined in this section of the table.
 - a. RSTIN# is used to reset AGP interface logic within the PAC. The AGP agent will use a system PCIRST# signal provided by the I/O bridge (i.e., PIIX4) as an input to reset its internal logic.
 - b. LOCK# signal is not supported on the AGP interface (even for FRAME# protocol operations).
 - c. **Pins During AGP FRAME# protocol Transactions.** Signals described in a previous table behave according to PCI 2.1 specifications when used to perform AGP FRAME# protocol transactions on the AGP Interface.

2.1.5 Clocks, Reset, and Miscellaneous Signals

Table 2-5. Clocks, Reset, Reference Voltage, and Miscellaneous Signals

Name	Type	Description
HCLKIN	I LVTTTL (2.5V)	Host Clock In: This pin receives a buffered host clock. This clock is used by all of the PAC logic that is in the Host clock domain.
PCLKIN	I LVTTTL	PCI Clock In: This is a buffered PCI clock reference that is synchronously derived by an external clock synthesizer component from the host clock (divide-by-2). This clock is used by all of the PAC logic that is in the PCI clock domain.
GTLREF	I	GTL+ Reference Voltage: This is the reference voltage derived from the termination voltage to the pull-up resistors and determines the noise margin for the signals. This signal goes to the reference input of the GTL+ sense amp on each GTL+ input or I/O pin.
AGPREF	I	AGP Reference Voltage.
V _{TT}	I	GTL+ Termination Reference Voltage.
REF5V	I	5V Reference Voltage: This reference pin provides a reference voltage for the 5V safe PCI Bus interface.
RSTIN#	I TTL	Reset Input: This input is controlled by the I/O bridge (i.e., PIIX4). It is activated for both power-on reset sequences and software-invoked reset sequences. This signal is used as a trigger for the PAC generated CPURST# signal. The RSTIN# is synchronous to 33-MHz PCI clock. Upon detection of RSTIN# assertion, PAC asserts the CPURST# signal. PAC holds CPURST# asserted for 1 msec after detecting the negation of RSTIN#. RSTIN# (PCIRST#) must be inverted and routed to OE# on the DIMM sockets as well as the OE# on the tri-state buffer that is buffering CKE.
CRESET#	O LVTTTL	CHIP RESET: This signal is a delayed version of CPURST#. CRESET# is asserted with CPURST# and its negation is delayed for 2 Host Clocks.
BREQ0#	O GTL+	Symmetric Agent Bus Request: Asserted by PAC when CPURST# is asserted to configure the symmetric bus agents. BREQ0# is negated 2 host clocks after CPURST# is negated.

2.2 Power-Up/Reset Strapping Options

There are no strapping options on the 82443EX.

2.3 Output/Bi-Directional Signals During Hard Reset

Table 2-6 shows the PAC signal state during a hard reset (CPURST# driven low by the PAC).

Table 2-6. Signals During Reset

Signal Name	State	Signal Name	State
Host Signals		STOP#	Tri-state
A[31:3]	not driven ¹	TRDY#	Tri-state
ADS#	not driven	GDEVSEL#	Tri-state
BNR#	not driven	GFRAME#	Tri-state
BPRI#	not driven	GGNT#	Tri-state
CPURST#	driven active	GIRDY#	Tri-state
DBSY#	not driven	GPERR#	Tri-state
DEFER#	not driven	GREQ#	—
DRDY#	not driven	GSERR#	Tri-state
HIT#	not driven	GSTOP#	Tri-state
HITM#	not driven	GTRDY#	Tri-state
HLOCK#	not driven	PIPE#	Tri-state
HREQ[4:0]#	not driven	SBA[7:0]	Tri-state
HTRDY#	not driven	RBF#	—
INIT#	not driven ²	ST[2:0]	Low
RS[2:0]	not driven	AD_STBA	Tri-state
BREQ0#	Low ³	AD_STBB	Tri-state
HD[63:0]#	not driven	SBSTB	Tri-state
PCI Signals and PCI Sideband Signals		DRAM Signals	
AD[31:0]#	Low	CDQA[7:0]#	High
C/BE[3:0]#	Low	RCSA[3:0]#	High
PAR	Low	MAA[13:0]	Low
DEVSEL#	Tri-state	WE[1:0]#	High
FRAME#	Tri-state	SRAS[2:0]#	High
GNT[2:0]#	Tri-state	SCAS[2:0]#	High
IRDY#	Tri-state	MD[63:0]	Low
PERR#	Tri-State	CKE	Strapped Value
PHLD#	—	AGP Signals and AGP Sideband Signals	
PHLDA#	Tri-state	GAD[31:0]#	Low
PLOCK#	Tri-state	GC/BE[3:0]#	Low
REQ[2:0]#	—	GPAR	Low
SERR#	Tri-state	Miscellaneous Signals	
		CRESET	Low

NOTES:

1. 2.INIT is driven active (low) for a software generation of BIST.
2. 3.BREQ0# must stay asserted (low) for a minimum of 2 host clocks after the rising edge of CPURST#. PAC then releases (tri-states) the BREQ0# signal.
3. 4.“—” is “don’t care.”

Register Description

3

PAC contains two sets of software accessible registers, accessed via the Host CPU I/O address space:

1. Two control registers that are I/O mapped in the CPU I/O space. These registers provide access to PCI and Accelerated Graphics Port (AGP) configuration space.
2. Two sets of configuration registers residing within PAC are partitioned into two “logical” PCI device register sets (“logical” since they reside within a single physical package). The first being dedicated to the Host-to-PCI Bridge function (controls the PCI, DRAM and AGP functions, and other AGPset operating parameters). The second set being dedicated to the standard PCI-to-PCI Bridge function that controls the AGP interface address mapping and PCI-standard configuration parameters of AGP (i.e., AGP is seen as another PCI bus from a configuration point of view).

Note: This configuration scheme is necessary to accommodate the existing and future software configuration model. (The term “virtual” is used to designate that no real physical embodiment of the PCI-to-PCI Bridge functionality exists within PAC, but that PAC internal configuration register sets are organized in the particular manner to create that impression to the standard configuration software.) PAC supports PCI configuration space access using the mechanism denoted as configuration mechanism 1 in the PCI specification.

PAC registers (both Control and Configuration registers) are accessible by the Host CPU. The registers can be accessed as Byte, Word (16-bit), or DWord (32-bit) quantities, with the exception of CONFADD which can only be accessed as a DWord. All multi-byte numeric fields use “little-endian” ordering (i.e., lower addresses contain the least significant parts of the field). The following nomenclature is used for access attributes:

RO	Read Only. If a register is read only, writes to this register have no effect.
R/W	Read/Write. A register with this attribute can be read and written.
R/WC	Read/Write Clear. A register bit with this attribute can be read and written. However, a write of 1 clears (sets to 0) the corresponding bit and a write of 0 has no effect.

Some of the PAC registers described in this section contain reserved bits. Software must deal correctly with fields that are reserved. On reads, software must use appropriate masks to extract the defined bits and not rely on reserved bits being any particular value. On writes, software must ensure that the values of reserved bit positions are preserved. That is, the values of reserved bit positions must first be read, merged with the new values for other bit positions, and then written back. Note the software does not need to perform read, merge, write operations for the configuration address register.

In addition to reserved bits within a register, PAC contains address locations in the configuration space of the Host-PCI Bridge function that are marked “Reserved.” PAC responds to accesses to these address locations by completing the host cycle. Software should not write to reserved configuration locations in the device-specific region (above address offset 3Fh).

During a hard reset, PAC sets its internal configuration registers to predetermined default states. The default state represents the minimum functionality feature set required to successfully bring up the system. Hence, it does not represent the optimal system configuration. It is the responsibility of

the system initialization software (usually BIOS) to properly determine the DRAM configurations, operating parameters and optional system features that are applicable, and to program PAC registers accordingly.

3.1 Register Access

PAC contains two registers that reside in the CPU I/O address space—the Configuration Address (CONFADD) Register and the Configuration Data (CONFDATA) Register. The Configuration Address Register enables/disables the configuration space and determines what portion of configuration space is visible through the Configuration Data window.

3.1.1 CONFADD—Configuration Address Register

I/O Address: 0CF8h Accessed as a DWord
 Default Value: 00000000h
 Access: Read/Write

CONFADD is a 32-bit register accessed only when referenced as a DWord. A Byte or Word reference will “pass through” the Configuration Address Register onto the PCI bus as an I/O cycle. The CONFADD register contains the Bus Number, Device Number, Function Number, and Register Number for which a subsequent configuration access is intended.

Bit	Descriptions
31	Configuration Enable (CFGE). 1 = Enable. 0 = Disable.
30:24	Reserved.
23:16	Bus Number (BUSNUM). When BUSNUM is programmed to 00h, the target of the Configuration Cycle is either the PAC or the PCI Bus that is directly connected to the PAC, depending on the Device Number field. If the BUSNUM=00 and PAC is not the target, a type 0 Configuration Cycle is generated on PCI. If BUSNUM≠00 and < SBUSN, a type 1 configuration cycle is generated on PCI with the BUSNUM mapped to AD[23:16] during the address phase. If BUSNUM > SBUSN, a type 1 Configuration Cycle is generated on the AGP Interface with BUSNUM mapped to AD[23:16] during the address phase. If SUBUSN > BUSNUM=SBUSN, a type 0 Configuration Cycle is generated on the AGP Interface.
15:11	Device Number (DEVNUM). This field selects one agent on the PCI bus selected by the Bus Number. During a Type 1 Configuration cycle this field is mapped to AD[15:11]. During a Type 0 PCI Configuration Cycle, this field is decoded and one of AD[31:11] is driven to a 1. During a Type 0 AGP Configuration Cycle, this field is decoded and one of GAD[31:16] is driven to a 1. PAC is always Device Number 0 for the Host Bridge entity and Device Number 1 for the “virtual” PCI-PCI Bridge device, and therefore, its AD11 and AD12 pins are used internally as a corresponding logical IDSELs during PCI configuration cycles. Note that AD11 and AD12 MUST NOT be connected to any other PCI bus device as IDSEL signals.
10:8	Function Number (FUNCNUM). This field is mapped to AD[10:8] during PCI configuration cycles. This allows the configuration registers of a particular function in a multi-function device to be accessed. PAC responds only to configuration cycles with a function number of 000b; all other function number values attempting access to the PAC (Device Number=0 and 1, Bus Number=0) will generate a master abort.
7:2	Register Number (REGNUM). This field selects one register within a particular Bus, Device, and Function as specified by the other fields in the Configuration Address Register. This field is mapped to AD[7:2] during PCI configuration cycles.
1:0	Reserved.

3.1.2 CONFDATA—CONFIGURATION DATA REGISTER

I/O Address: 0CFCh
 Default Value: 00000000h
 Access: Read/Write

CONFDATA is a 32-bit/16-bit/8-bit read/write window into configuration space. The portion of configuration space that is referenced by CONFDATA is determined by the contents of CONFADD.

Bit	Descriptions
31:0	Configuration Data Window (CDW). If bit 31 of CONFADD is 1 any I/O reference that falls in the CONFDATA I/O space will be mapped to configuration space using the contents of CONFADD.

3.1.3 CONFIGURATION SPACE MECHANISM

PAC supports two bus interfaces—PCI and AGP. The AGP interface is treated as a second PCI interface. Note that AGP address space and AGP's interface standard PCI-style configuration parameters are controlled via internal "virtual" PCI-to-PCI Bridge entity that is seen by the PCI configuration software as a Device 1 residing on the PCI Bus #0. The following sections describe the configuration space mapping mechanism associated with both interfaces.

3.1.3.1 Routing the Configuration Accesses to PCI or AGP

Routing of configuration accesses to AGP is controlled via the PCI-to-PCI bridge standard mechanism using information contained within : PRIMARY BUS NUMBER, SECONDARY BUS NUMBER and SUBORDINATE BUS NUMBER registers of the AGP's internal "virtual" PCI-to-PCI Bridge device. Detailed description of the mechanism for translating CPU's I/O bus cycles to configuration cycles on one of the two buses is described below. For the purpose of distinguishing between PCI configuration cycles targeted to PCI and AGP configuration space, a PCI bus 0 is frequently referred to within this document as a Primary PCI.

3.1.3.2 PCI Bus Configuration Mechanism

The PCI Bus defines a slot based "configuration space" that allows each device to contain up to 8 functions with each function containing up to 256 8-bit configuration registers. The PCI specification defines two bus cycles to access the PCI configuration space—Configuration Read and Configuration Write. While memory and I/O spaces are supported directly by the CPU, configuration space is supported via mapping mechanism implemented within PAC. The PCI specification defines two mechanisms to access configuration space, Mechanism 1 and Mechanism 2. PAC supports only Mechanism 1.

The configuration access mechanism makes use of the CONFADD Register and CONFDATA Register. To reference a configuration register, a DWord I/O write cycle is used to place a value into CONFADD that specifies the PCI bus, the device on that bus, the function within the device, and a specific configuration register of the device function being accessed. CONFADD[31] must be 1 to enable a configuration cycle. CONFDATA then becomes a window into the four bytes of configuration space specified by the contents of CONFADD. Any read or write to CONFDATA will result in the Host Bridge translating CONFADD into a PCI configuration cycle.

Type 0 Access: If CONFADD[BUSNUM]=0, a Type 0 configuration cycle is performed on Primary PCI bus (i.e., bus #0). CONFADD[10:2] are mapped directly to AD[10:2]. The DEVNUM field is decoded onto AD[31:16]. The Host Bridge entity within PAC is accessed as a Device 0 on the Primary PCI bus segment and “virtual” PCI-to-PCI bridge entity is accessed as a Device 1 on the Primary PCI bus. If accessing internal configuration registers within the Host-Bridge entity, PAC asserts AD11 during a configuration cycle and claims the cycle itself. If accessing internal configuration registers within the PCI-to-PCI Bridge entity, PAC asserts AD12 and then claims the cycle itself. To access PCI Device #2 PAC asserts AD13, for PCI Device #3 PAC asserts AD14, and so forth up to PCI Device #20 for which PAC asserts AD31 for PCI Type 0 Configuration Cycles. Only one AD line is asserted at a time. All device numbers higher than 20 cause a type 0 configuration access with no IDSEL asserted, which results in a master abort. To access AGP Device #0 PAC will assert GAD16, to access AGP Device #1 PAC will assert GAD17, for AGP Device #2 PAC will assert GAD18, and so forth up to Device #15 for which will assert GAD31. Only one GAD line is asserted at a time. All device numbers higher than 15 cause a Type 0 AGP configuration access with no IDSEL asserted, which result in a Master Abort.

Type 1 Access: If the CONFADD[BUSNUM]≠0 but NOT within the range defined as:

$$\text{SUBORDINATE-BUS-NUMBER} \geq \text{range} \geq \text{SECONDARY-BUS-NUMBER},$$

then a Type 1 Configuration cycle is performed on the Primary PCI bus (i.e., BUS #0). Note that SECONDARY-BUS-NUMBER and SUBORDINATE-BUS-NUMBER are values contained within the corresponding configuration registers of PAC “virtual” PCI-to-PCI Bridge entity. CONFADD[23:2] are mapped directly to AD[23:2]. AD[1:0] are driven to 01 to indicate a Type 1 Configuration cycle. All other lines are driven to 0.

3.1.3.3 Mapping of Configuration Cycles on AGP

From the AGPset configuration perspective, AGP is another PCI bus interface residing on a Secondary Bus side of the “virtual” PCI-to-PCI Bridge embedded within PAC. On the Primary Bus side the “virtual” PCI-to-PCI bridge is attached to the BUS #0. Therefore the Secondary side would be denoted as a BUS#1 in the system where configuration software would scan devices on the PCI bus #0 going from the lowest (0) to the highest (20) device number. The “virtual” PCI-to-PCI bridge entity is used to map Type #1 PCI Bus Configuration cycles directed to BUS #0 onto the Type #0 or Type #1 configuration cycles on the AGP interface based on the following rule:

If the CONFADD[BUSNUM]≠0 but within the range defined as:

$$\text{SUBORDINATE-BUS-NUMBER} \geq \text{range} \geq \text{SECONDARY-BUS-NUMBER}$$

then Type 0 or Type 1 Configuration cycles are performed on AGP If the Bus Number matches a SECONDARY-BUS-NUMBER of the “virtual” PCI-TO-PCI device, then Type 0 configuration cycles are executed on the AGP Otherwise, Type 1 cycles are performed on AGP

To prepare for mapping of the configuration cycles on AGP, the initialization software will go through the following sequence:

1. Scan all devices residing at the Primary PCI bus (i.e., bus #0) using Type 0 configuration accesses.
2. For every device residing at bus #0 which implements PCI-to-PCI bridge functionality, it will configure the secondary bus of the bridge with the appropriate number and scan further down the hierarchy. (This process will include the configuration of the “virtual” PCI-TO-PCI Bridge within PAC used to map the AGP address space in a software standard manner.)

3.2 PCI Configuration Space (Device 0 and Device 1)

PAC is implemented as a dual PCI device residing within a single physical component:

- Device 0=Host Bridge (includes PCI bus #0 interface, Main Memory Controller, Graphics Aperture control, PAC specific AGP control registers).
- Device 1=“Virtual” PCI-to-PCI Bridge (includes mapping of AGP space and standard PCI interface control functions of the PCI-to-PCI Bridge).

Table 3-1 shows the configuration space for Device 0. Shows PAC configuration space for Device #1. Corresponding configuration registers for both devices are mapped as devices residing at the Primary PCI bus (bus #0). The configuration registers layout and functionality for the Device 0 is implemented with a high level of compatibility with a previous generation of PCIsets (i.e., Intel® 440FX PCIset). Configuration registers of PAC Device 1 are based on the standard configuration space template of a PCI-to-PCI Bridge.

Table 3-1. PCI Configuration Space—Device 0 (Host-to-PCI Bridge) (Sheet 1 of 2)

Address Offset	Register Symbol	Register Name	Power Down Default Value	Access
00–01h	VID	Vendor Identification	8086h	RO
02–03h	DID	Device Identification	7180h	RO
04–05h	PCICMD	PCI Command Register	0006h	R/W
06–07h	PCISTS	PCI Status Register	0290h	RO, R/WC
08	RID	Revision Identification	00h	RO
0Ah	SUBC	Sub-Class Code	00h	RO
0Bh	BCC	Base Class Code	06h	RO
0Dh	MLT	Master Latency Timer	00h	R/W
0Eh	HDR	Header Type	00h	RO
10–13h	APBASE	Aperture Base Address	00000008h	R/W
34h	CAPPTR	Capabilities Pointer	A0h	RO
50–51h	PACCFG	PAC Configuration	8000h	R/W
53h	DBC	Data Buffering Control	83h	R/W
55–56h	DRT	DRAM Row Type	0000h	R/W
57h	DRAMC	DRAM Control	01h	R/W
58h	DRAMT	DRAM Timing	00h	R/W
59–5Fh	PAM[6:0]	Programmable Attribute Map (7 registers)	00h	R/W
60–67h	DRB[7:0]	DRAM Row Boundary (8 registers)	01h	R/W
68h	FDHC	Fixed DRAM Hole Control	00h	R/W
6A–6Bh	DRAMXC	DRAM Extended Mode Select	0000h	R/W
6C–6Fh	MBSC	Memory Buffer Strength Control Register	55555555h	R/W
70h	MTT	Multi-Transaction Timer	00h	R/W
72h	SMRAM	System Management RAM Control	02h	R/W
90h	ERRCMD	Error Command Register	00h	R/W
91h	ERRSTS0	Error Status Register 0	00h	R/WC

Table 3-1. PCI Configuration Space—Device 0 (Host-to-PCI Bridge) (Sheet 2 of 2)

Address Offset	Register Symbol	Register Name	Power Down Default Value	Access
92h	ERRSTS1	Error Status Register 1	00h	R/WC
93h	RSTCTRL	Reset Control Register	00h	R/W
A0–A3h	ACAPID	AGP Capability Identifier	00100002h	RO
A4–A7h	AGPSTAT	AGP Status Register	1F000203h	R/W
A8–ABh	AGPCMD	AGP Command Register	00000000h	R/W
B0–B3h	AGPCTRL	AGP Control Register	00000000h	R/W
B4h	APSIZE	Aperture Size Control Register	0000h	R/W
B8–BBh	ATTBASE	Aperture Translation Table Base Register	00000000h	R/W
BC	AMTT	AGP MTT Control Register	00h	R/W
BDh	LPTT	AGP Low Priority Transaction Timer Reg.	00h	R/W

Table 3-2. PCI Configuration Space—Device 1 (“Virtual” PCI-to-PCI Bridge)

Address Offset	Register Symbol	Register Name	Power Down Default Value	Access
00–01h	VID1	Vendor Identification	8086h	RO
02–03h	DID1	Device Identification	7181h	RO
04–05h	PCICMD1	PCI Command Register	0000h	R/W
06–07h	PCISTS1	PCI Status Register	02A0h	RO, R/WC
08	RID1	Revision Identification	00h	RO
0Ah	SUBC1	Sub-Class Code	04h	RO
0Bh	BCC1	Base Class Code	06h	RO
0Eh	HDR1	Header Type	01h	RO
18h	PBUSN	Primary Bus Number Register	00h	RO
19h	SBUSN	Secondary Bus Number	00h	R/W
1Ah	SUBUSN	Subordinate Bus Number	00h	R/W
1Bh	SMLT	Secondary Bus Master Latency Timer	00h	R/W
1Ch	IOBASE	I/O Base Address Register	F0h	R/W
1Dh	IOLIMIT	I/O Limit Address Register	00h	R/W
1E–1Fh	SSTS	Secondary Status Register	02A0h	R/W
20–21h	MBASE	Memory Base Address Register	FFF0h	R/W
22–23h	MLIMIT	Memory Limit Address Register	0000h	R/W
24–25h	PMBASE	Prefetchable Memory Base Address Reg.	FFF0h	R/W
26–27h	PMLIMIT	Prefetchable Memory Limit Address Reg.	0000h	R/W
3E–3Fh	BCTRL	Bridge Control Register	0000h	R/W

3.3 Register Set—Device 0 (Host-to-PCI Bridge)

3.3.1 VID—Vendor Identification Register (Device 0)

Address Offset: 00–01h
Default Value: 8086h
Attribute: Read Only

The VID Register contains the vendor identification number. This 16-bit register combined with the Device Identification Register uniquely identifies any PCI device. Writes to this register have no effect.

Bit	Description
15:0	Vendor Identification Number. This is a 16-bit value assigned to Intel. Intel VID=8086h.

3.3.2 DID—Device Identification Register (Device 0)

Address Offset: 02–03h
Default Value: 7180h
Attribute: Read Only

This 16-bit register combined with the Vendor Identification register uniquely identifies any PCI device. Writes to this register have no effect.

Bit	Description
15:0	Device Identification Number. This is a 16-bit value assigned to the PAC Host Bridge (i.e., Device 0). DID=7180h.

3.3.3 PCICMD—PCI Command Register (Device 0)

Address Offset: 04–05h
 Default: 0006h
 Access: Read/Write

This 16-bit register provides basic control over PAC's PCI interface ability to respond to PCI cycles. The PCICMD Register enables and disables the SERR# signal, parity checking (PERR# signal), PAC response to PCI special cycles, and enables and disables PCI bus masters' accesses to main memory.

Bit	Description
15:9	Reserved.
8	SERR# Enable (SERRE). 1 = PAC SERR# signal driver is enabled and SERR# is asserted for all relevant bits set in the ERRSTS and PCISTS as controlled by the corresponding bits of the ERRCMD register. 0 = SERR# is never driven by PAC. SERR# is asserted under the following conditions: <ol style="list-style-type: none"> 1. PAC asserts SERR# when it detects a target abort during a PAC-initiated PCI cycle. 2. PAC can also assert SERR# when a PCI parity error occurs during the address phase as controlled by bits 8 and 6 of PAC PCICMD register. 3. PAC can assert SERR# when it samples PERR# asserted on the PCI bus. This capability is controlled by bit 3 of the ERRCMD register. NOTE: This bit only controls SERR# for the PCI bus (Device 0). Device 1 has its own SERRE bit (PCICMD1 register) to control error reporting for bus conditions occurring on the AGP bus.
7	Reserved.
6	Parity Error Enable (PERRE). PERRE controls PAC PCI interface response to the PCI parity errors during the data phase when PAC receives the data (i.e., during reads on the PCI bus and PAC is the initiator and during writes when PAC is a target on the PCI bus). 1 = Parity errors are reported on the PERR# signal. Note that when PERRE = 1, address parity is reported via SERR# mechanism (if enabled via SERRE bit) and not via PERR# pin. 0 = No parity errors are reported by PAC PCI interface via PERR# or SERR# signals. (Note that other types of error conditions can be still signaled via SERR# mechanism.)
5:0	Reserved.

3.3.4 PCISTS—PCI Status Register (Device 0)

Address Offset: 06–07h
Default Value: 0290h
Access: Read Only, Read/Write Clear

PCISTS is a 16-bit status register that reports the occurrence of a PCI master abort and PCI target abort on the PCI bus. PCISTS also indicates the DEVSEL# timing that has been set by PAC hardware for target responses on the PCI bus. Bits [15:12] and bit 8 are read/write clear and bits [10:9] are read only.

Bit	Description
15	Detected Parity Error (DPE)—R/WC. Software sets DPE to 0 by writing a 1 to this bit. 1 = Indicates PAC detection of a parity error in either the data or address phase of the Primary PCI bus transactions. Note that the function of this bit is not affected by the PERRE bit.
14	Signaled System Error (SSE)—R/WC. Software sets SSE to 0 by writing a 1 to this bit. 1 = When PAC PCI interface logic asserts the SERR# signal, this bit is set to a 1.
13	Received Master Abort Status (RMAS)—R/WC. Software resets this bit to 0 by writing a 1 to it. 1 = When PAC terminates a PCI bus transaction (PAC is a PCI master) with an unexpected master abort, this bit is set to a 1. Note that master abort is the normal and expected termination of PCI special cycles.
12	Received Target Abort Status (RTAS)—R/WC. Software resets RTAS to 0 by writing a 1 to it. 1 = When a PAC-initiated PCI transaction is terminated with a target abort, RTAS is set to 1. PAC also asserts SERR# if enabled in the ERRCMD register.
11	Reserved.
10:9	DEVSEL# Timing (DEVT)—RO. This 2-bit field indicates the timing of the DEVSEL# signal when PAC responds as a target on the PCI Bus. 01b = Medium (Hardwired). Indicates the time when a valid DEVSEL# can be sampled by the initiator of the PCI cycle.
8	Data Parity Detected (DPD)—R/WC. Software sets DPD to 0 by writing a 1 to this bit. 1 = This bit is set to a 1, when all of the following conditions are met: 1. PAC asserted PERR# or sampled PERR# on the PCI Bus. 2. PAC was the initiator for the operation in which the error occurred on the PCI bus. 3. The PERRE bit in the Primary PCI Command register is set to 1.
7:0	Reserved.

3.3.5 RID—Revision Identification Register (Device 0)

Address Offset: 08h
 Default Value: See Stepping Information.
 Access: Read Only

This register contains the revision number of PAC Device 0. These bits are read only and writes to this register have no effect.

Bit	Description
7:0	Revision Identification Number. This is an 8-bit value that indicates the revision identification number for PAC Device 0. 03h = Hardwired

3.3.6 SUBC—Sub-Class Code Register (Device 0)

Address Offset: 0Ah
 Default Value: 00h
 Access: Read Only

This register contains the Sub-Class Code definition for PAC.

Bit	Description
7:0	Sub-Class Code (SUBC). 00h = Host Bridge.

3.3.7 BCC—Base Class Code Register (Device 0)

Address Offset: 0Bh
 Default Value: 06h
 Access: Read Only

This register contains the Base Class Code definition for PAC.

Bit	Description
7:0	Base Class Code (BASEC). 06h = Bridge device.

3.3.8 MLT—Master Latency Timer Register (DEVICE 0)

Address Offset: 0Dh
Default Value: 00h
Access: Read/Write

MLT is an 8-bit register that controls the amount of time PAC, as a PCI bus master, can burst data on the PCI Bus. The count value is an 8-bit quantity. However, MLT[2:0] are 0 when determining the count value. PAC MLT is used to guarantee to the PCI agents (other than PAC) a minimum amount of the system resources.

Bit	Description
7:3	Master Latency Timer Count Value for PCI Bus Access. The number of clocks programmed in the MLT represents the guaranteed time slice (measured in PCI clocks; 33 MHz for standard PAC configurations) allotted to PAC, after which it must complete the current data transfer phase and surrender the bus as soon as its bus grant is removed. For example, if the MLT is programmed to 18h, the value is 24 PCI clocks. The default value of MLT is 00h and disables this function.
2:0	Reserved.

3.3.9 HDR—Header Type Register (Device 0)

Offset: 0Eh
Default: 00h
Access: Read Only

This register identifies the header layout of the configuration space. No physical register exists at this location.

Bit	Description
7:0	Header Type. This read only field always returns 0 when read and writes have no effect.

3.3.10 APBASE—Aperture Base Configuration Register (Device 0)

Offset: 10–13h
 Default: 00000008h
 Access: Read/Write, Read Only

The APBASE is a standard PCI Base Address register that is used to request the size of the Graphics Aperture. The standard PCI Configuration mechanism defines the base address configuration register in the way that only a fixed amount of space can be requested (dependent on which bits are hardwired to 0 or behave as hardwired to 0). To allow for flexibility, an additional register called APSIZE is used as a “back-end” register to control which bits of the APBASE will behave as hardwired to 0.

Bit	Description																																																								
31:28	Upper Programmable Base Address bits (R/W). These bits (default = 0) locate the range size which is selected by the lower bits (that are either hardwired to 0 or behave as hardwired to 0 depending on the contents of the APSIZE register).																																																								
27:22	Lower “Hardwired”/Programmable Base Address bits. These bits behave as a hardwired or as a programmable depending on the contents of the APSIZE register as defined below: <table><tr><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>Aperture Size</th></tr><tr><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>4 MB</td></tr><tr><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>0</td><td>8 MB</td></tr><tr><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>0</td><td>0</td><td>16 MB</td></tr><tr><td>R/W</td><td>R/W</td><td>R/W</td><td>0</td><td>0</td><td>0</td><td>32 MB</td></tr><tr><td>R/W</td><td>R/W</td><td>0</td><td>0</td><td>0</td><td>0</td><td>64 MB</td></tr><tr><td>R/W</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>128 MB</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>256 MB</td></tr></table> <p>Bits [27:22] are controlled by bits [5:0] of the APSIZE register. For example, if bit APSIZE[5] = 0, APBASE[27] = 0. If APSIZE[5] = 1, APBASE[27] = R/W. The same applies, correspondingly, to other bits. The default for APSIZE[5:0] (000000b) forces the APBASE[27:22] default to be 000000b (i.e., all bits respond as hardwired to 0).</p> <p>NOTE</p> <p>When programming the APSIZE register such that APBASE register bits change from “read only” to “read/write,” the value of those bits is undefined and must be written first to have a known value.</p>	27	26	25	24	23	22	Aperture Size	R/W	R/W	R/W	R/W	R/W	R/W	4 MB	R/W	R/W	R/W	R/W	R/W	0	8 MB	R/W	R/W	R/W	R/W	0	0	16 MB	R/W	R/W	R/W	0	0	0	32 MB	R/W	R/W	0	0	0	0	64 MB	R/W	0	0	0	0	0	128 MB	0	0	0	0	0	0	256 MB
27	26	25	24	23	22	Aperture Size																																																			
R/W	R/W	R/W	R/W	R/W	R/W	4 MB																																																			
R/W	R/W	R/W	R/W	R/W	0	8 MB																																																			
R/W	R/W	R/W	R/W	0	0	16 MB																																																			
R/W	R/W	R/W	0	0	0	32 MB																																																			
R/W	R/W	0	0	0	0	64 MB																																																			
R/W	0	0	0	0	0	128 MB																																																			
0	0	0	0	0	0	256 MB																																																			
21:0	Reserved.																																																								

3.3.11 CAPPTR—Capabilities Pointer Register (Device 0)

Offset: 34h
 Default: A0h
 Access: Read Only

The CAPPTR provides the offset that is the pointer to the location where AGP standard registers are located.

Bit	Description
7:0	Pointer to the start of AGP standard register block. Default Value = A0h

3.3.12 PACCFG—PAC Configuration Register (Device 0)

Offset: 50–51h
Default: 8000h
Access: Read/Write, Read Only

PACCFG is a 16-bit register that is used for indicating the system level configuration.

Bit	Description															
15	WSC# Handshake Disable—R/W. This bit disables the internal WSC# handshake mechanism for the configurations in which an I/O APIC is NOT used as a system interrupt controller. 1 = Disable (default) 0 = Enable.															
14:11	Reserved.															
10	PCI Agent to Aperture Access Disable—R/W. This bit is used to prevent access to the aperture from the primary PCI side (i.e., PAC PCI interface does not respond as a target with DEVSEL# if the access is within the aperture). This bit is don't care if bit 9 is 0. 1 = Disable. 0 = Enable. If this bit is 0 (default) and bit 9 of this register is 1, then accesses to the aperture are enabled for the primary PCI side.															
9	Aperture Access Global Enable—R/W. This bit is used to prevent access to the aperture from any port (CPU, PCI or AGP) before aperture range is established by the configuration software and appropriate translation table in the main DRAM has been initialized. 1 = Enable. It must be set after the system is fully configured for aperture accesses. 0 = Disable (Default). NOTE: This bit globally controls accesses to the aperture and that bit 10 provides the next level of control for accesses originated from the primary PCI side.															
8:6	Reserved															
5	MDA Present—R/W. This bit works with the VGA Enable bit in the BCTRL register of device 1 to control the routing of CPU initiated transactions targeting MDA compatible I/O and memory address ranges. When the VGA Enable bit is set to 1, and this bit is reset to 0, references to MDA resources are sent to AGP In all other cases references to MDA resources are sent to PCI. MDA resources are defined as the following: Memory: 0B0000h–0B7FFFh I/O: 3B4h, 3B5h, 3B8h, 3B9h, 3BAh, 3BFh, (including ISA address aliases, A[15:10] are not used in decode) Any I/O reference that includes the I/O locations listed above, or their aliases, will be forwarded to PCI even if the reference includes I/O locations not listed above. The following table shows the behavior for all combinations of the MDA present and VGA forward bits: <table><tr><th>VGA</th><th>MDA</th><th>Behavior</th></tr><tr><td>0</td><td>0</td><td>All references to MDA and VGA go to PCI</td></tr><tr><td>0</td><td>1</td><td>Reserved</td></tr><tr><td>1</td><td>0</td><td>All references to VGA go to AGP—MDA-only (I/O 3BFh and aliases) references go to PCI</td></tr><tr><td>1</td><td>1</td><td>VGA references go to AGP; MDA references go to PCI</td></tr></table>	VGA	MDA	Behavior	0	0	All references to MDA and VGA go to PCI	0	1	Reserved	1	0	All references to VGA go to AGP—MDA-only (I/O 3BFh and aliases) references go to PCI	1	1	VGA references go to AGP; MDA references go to PCI
VGA	MDA	Behavior														
0	0	All references to MDA and VGA go to PCI														
0	1	Reserved														
1	0	All references to VGA go to AGP—MDA-only (I/O 3BFh and aliases) references go to PCI														
1	1	VGA references go to AGP; MDA references go to PCI														
4:0	Reserved.															

3.3.13 DBC—DATA BUFFER CONTROL REGISTER (DEVICE 0)

Address Offset: 53h
 Default Value: 83h
 Access: Read/Write

This 8-bit register allows for PAC buffer control.

Bit	Description
7	Reserved.
6	CPU-to-PCI IDE Posting Enable (CPIE). 1 = Enable. 0 = Disable (default). When disabled, the cycles are treated as normal I/O write transactions.
5	WC Write Post During I/O Bridge Access Enable (WPIO). 1 = Enable. When enabled, posting of WC transactions to PCI occur, even if the I/O bridge has been granted access to the PCI bus via corresponding arbitration and buffer management protocol (PHLD#/PHLDA#/WSC#). 0 = Disable (default). NOTE: USWC Write posting should only be enabled if a USWC region is located on the PCI bus.
4:0	Reserved.

3.3.14 DRT—DRAM Row Type Register (Device 0)

Address Offset: 55–56h
 Default Value: 0000h
 Access: Read/Write

This 16-bit register identifies the type of DRAM (SDRAM, EDO) used in each row or if the row is empty, and should be programmed by BIOS for optimum performance. It also identifies if a particular row is left unpopulated and the total number of rows populated in the system. The hardware uses these bits to determine the correct cycle timing to use before a DRAM cycle is run.

Bit	Description
15:0	DRAM Row Type (DRT). Each pair of bits in this register corresponds to the DRAM row identified by the corresponding DRB register.
	DRT bits Corresponding DRB register DRT bits Corresponding DRB register
	DRT[1:0] DRB0, row 0 DRT[9:8] DRB4, row 4
	DRT[3:2] DRB1, row 1 DRT[7:6] DRB3, row 3
	DRT[5:4] DRB2, row 2
	The value programmed in each DRT pair of bits uniquely identifies the DRAM timings used for the corresponding row.
	DRT pair DRAM Type
	00 EDO
	01 Reserved
	10 SDRAM
11 Empty Row	

3.3.15 DRAMC—DRAM Control Register (Device 0)

Address Offset: 57h
Default Value: 01h
Access: Read/Write

This 8-bit register controls main memory operating modes and features. The timing parameters assume 66-MHz host bus.

Bit	Description
7:6	Reserved.
5	DRAM EDO Auto-Detect Mode Enable (DEDM). 1 = Enable a special timing mode for BIOS to detect EDO DRAM type on a row-by-row basis. 0 = Disable (default).
4	SDRAM Power Management Support Enable (SPME). SDRAM power management capability is supported as described in the <i>DRAM Interface Section (DRAM Subsystem Power Management Sub-Section.)</i> 1 = Enable. 0 = Disable (default).
3	Reserved.
2:0	DRAM Refresh Rate (DRR). The DRAM refresh rate is adjusted according to the frequency selected by this field. When the refresh rate is selected as 'normal,' then the refresh rate is based on configuration information stored in PACCFG register bit 14. 000 = Refresh Disabled 001 = Normal 010–1 1 1 = Reserved. NOTE 1. Refresh is also disabled via this field, and that disabling refresh results in the eventual loss of DRAM data. 2. Changing the DRR value will reset the refresh request timer.

3.3.16 DRAMT—DRAM Timing Register (Device 0)

Address Offset: 58h
 Default Value: 00h
 Access: Read/Write

This 8-bit register controls main memory DRAM timings.

Bit	Description
7	SDRAM RAS to CAS Delay (SRCD). This bit defines the delay in assertion of CAS# (SCAS#) from the assertion of RAS# (SRAS#) in 66-MHz clocks. 1 = 2 clock delay 0 = 3 clock delay (default)
6	SDRAM CAS Latency (SCLT). This bit defines the CLT timing parameter of SDRAM expressed in 66-MHz clocks. 1 = 2 clocks 0 = 3 clocks (default)
5	SDRAM RAS Precharge Time (SRPT). This bit defines the RAS precharge requirements for the SDRAM memory type in 66-MHz clocks. 1 = 2 clocks 0 = 3 clocks (default)
4	EDO DRAM Read Burst Timing (DRBT). The DRAM read burst timings are controlled by the DRBT field. Slower rates may be required in certain system designs to support loose layouts or slower memories. Most system designs will be able to use one of the faster burst mode timings. The timing used depends on the type of DRAM on a per-row basis, as indicated by the DRT register. 1 = Read Rate is x222 0 = Read Rate is x333 (default)
3	EDO DRAM Write Burst Timing (DWBT). The DRAM write burst timings are controlled by the DWBT field. Slower rates may be required in certain system designs to support loose layouts or slower memories. Most system designs will be able to use one of the faster burst mode timings. The timing used depends on the type of DRAM on a per-row basis, as indicated by the DRT register. 1 = Write Rate is x222 0 = Write Rate is x333 (default)
2	EDO RAS Precharge Time (RPT). This bit defines the RAS precharge requirements for the EDO memory type in 66-MHz clocks. 1 = 3 clocks. 0 = 4 clocks (default)
1	EDO RAS to CAS Delay (RCD). This bit defines the delay in assertion of CAS# (SCAS#) from assertion of RAS# (SRAS#) in 66-MHz clocks. 1 = 2 clock delay. 0 = 3 clock delay (default)
0	MA Wait State (MAWS). This bit selects FAST or SLOW MA bus timing. Note that SLOW timing is equal to FAST +1, in terms of clock numbers for EDO. For SDRAM, FAST timing means zero MA wait state. This setting will enable PAC to support a Single Clock Command Mode. SLOW means one MA wait state, which forces PAC to support the normal operation (one command per two clocks). 1 = FAST 0 = SLOW (default)

3.3.17 PAM—Programmable Attribute Map Registers (PAM[6:0]) (Device 0)

Address Offset: 59 (PAM0)–5Fh (PAM6)
Default Value: 00h
Attribute: Read/Write

PAC allows programmable memory attributes on 13 Legacy memory segments of various sizes in the 640-KB to 1 MB address range. Seven Programmable Attribute Map (PAM) Registers are used to support these features. Cacheability of these areas is controlled via the MTRR registers in the Pentium II processor. Two bits are used to specify memory attributes for each memory segment. These bits apply to both host accesses and PCI/AGP initiator accesses to the PAM areas. These attributes are:

- RE** Read Enable. When RE = 1, the host/AGP read accesses to the corresponding memory segment are claimed by PAC and directed to main memory. Conversely, when RE = 0, the read access is directed to PCI.
- WE** Write Enable. When WE = 1, the host/AGP write accesses to the corresponding memory segment are claimed by PAC and directed to main memory. Conversely, when WE = 0, the write access is directed to PCI.

The RE and WE attributes permit a memory segment to be read only, write only, read/write, or disabled (i.e., if a memory segment has RE = 1 and WE = 0, the segment is read only). Each PAM Register controls two regions, typically 16 KB. Each of these regions has a 4-bit field. The 4 bits that control each region have the same encoding and are defined in [Table 3-3](#).

Table 3-3. Attribute Bit Assignment

Bits [7, 3] Reserved	Bits [6, 2] Reserved	Bits [5, 1] WE	Bits [4, 0] RE	Description
X	X	0	0	Disabled. DRAM is disabled and all accesses are directed to PCI. PAC does not respond as a PCI target for any read or write access to this area.
X	X	0	1	Read Only. Reads are forwarded to DRAM and writes are forwarded to PCI for termination. This write protects the corresponding memory segment. PAC will respond as a PCI target for read accesses but not for any write accesses.
X	X	1	0	Write Only. Writes are forwarded to DRAM and reads are forwarded to the PCI for termination. PAC will respond as a PCI target for write accesses but not for any read accesses.
X	X	1	1	Read/Write. This is the normal operating mode of main memory. Both read and write cycles from the host are claimed by PAC and forwarded to DRAM. PAC will respond as a PCI target for both read and write accesses.

As an example, consider a BIOS that is implemented on the expansion bus. During the initialization process, BIOS can be shadowed in main memory to increase the system performance. When a BIOS is copied in main memory, it should be copied to the same address location. To shadow BIOS, the attributes for that address range should be set to write only. BIOS is shadowed by first doing a read of that address. This read is forwarded to the expansion bus. The host then does a write of the same address, which is directed to main memory. After BIOS is shadowed, the attributes for that memory area are set to read only so that all writes are forwarded to the expansion bus.

Table 3-4 shows the PAM registers and the associated attribute bits:

Table 3-4. PAM Registers and Associated Memory Segments

PAM Reg.	Attribute Bits				Memory Segment	Comments	Offset
PAM0[3:0]	Reserved						59h
PAM0[7:4]	R	R	WE	RE	0F0000h–0FFFFFFh	BIOS Area	59h
PAM1[3:0]	R	R	WE	RE	0C0000h–0C3FFFh	ISA Add-on BIOS ¹	5Ah
PAM1[7:4]	R	R	WE	RE	0C4000h–0C7FFFh	ISA Add-on BIOS ¹	5Ah
PAM2[3:0]	R	R	WE	RE	0C8000h–0CBFFFh	ISA Add-on BIOS ¹	5Bh
PAM2[7:4]	R	R	WE	RE	0CC000h–0CFFFFh	ISA Add-on BIOS ¹	5Bh
PAM3[3:0]	R	R	WE	RE	0D0000h–0D3FFFh	ISA Add-on BIOS	5Ch
PAM3[7:4]	R	R	WE	RE	0D4000h–0D7FFFh	ISA Add-on BIOS	5Ch
PAM4[3:0]	R	R	WE	RE	0D8000h–0DBFFFh	ISA Add-on BIOS	5Dh
PAM4[7:4]	R	R	WE	RE	0DC000h–0DFFFFh	ISA Add-on BIOS	5Dh
PAM5[3:0]	R	R	WE	RE	0E0000h–0E3FFFh	BIOS Extension	5Eh
PAM5[7:4]	R	R	WE	RE	0E4000h–0E7FFFh	BIOS Extension	5Eh
PAM6[3:0]	R	R	WE	RE	0E8000h–0EBFFFh	BIOS Extension	5Fh
PAM6[7:4]	R	R	WE	RE	0EC000h–0EFFFFh	BIOS Extension	5Fh

NOTE:

1. The C0000h to CFFFFh segment can be used for SMM space if enabled by the SMRAM register.

DOS Application Area (00000h–9FFFFh)

The DOS area is 640 KB in size and is further divided into two parts. The 512 KB area at 0 to 7FFFFh is always mapped to the main memory controlled by PAC, while the 128 KB address range from 080000 to 09FFFFh can be mapped to PCI or to main DRAM. By default this range is mapped to main memory and can be declared as a main memory hole (accesses forwarded to PCI) via PAC FDHC configuration register.

Video Buffer Area (A0000h–BFFFFh)

This 128 KB area is not controlled by attribute bits. The host-initiated cycles in this region are always forwarded to either PCI or AGP bus for termination. Routing of accesses is controlled by AGPCTRL register (Device 1). This area can be programmed as SMM area via the SMRAM register. When used as a SMM space this range can not be accessed from PCI or AGP

Expansion Area (C0000h–DFFFFh)

This 128 KB area is divided into eight 16 KB segments which can be assigned with different attributes via PAM control register. The C0000–DFFFFh segment can be used for SMM space by programming the SMRAM register. If C0000–DFFFFh segment is used for SMRAM, the PAM register values are not used and are treated as don't care. When used as a SMM space, this range can not be accessed from PCI or AGP

Extended System BIOS Area (E0000h–EFFFFh)

This 64 KB area is divided into four 16 KB segments that can be assigned different attributes via the PAM registers.

System BIOS Area (F0000h–FFFFFh)

This area is a single 64 KB segment which can be assigned with different attributes via the PAM registers.

3.3.18 DRB—DRAM Row Boundary Registers (Device 0)

Address Offset: 60–67h
Default Value: 01h
Access: Read/Write

PAC supports four physical rows of DRAM. The width of a row is 64 bits. The DRAM Row Boundary Registers define upper and lower addresses for each DRAM row. Contents of these 8-bit registers represent the boundary addresses in 8-MB granularity. For example, a value of 01h indicates 8 MB.

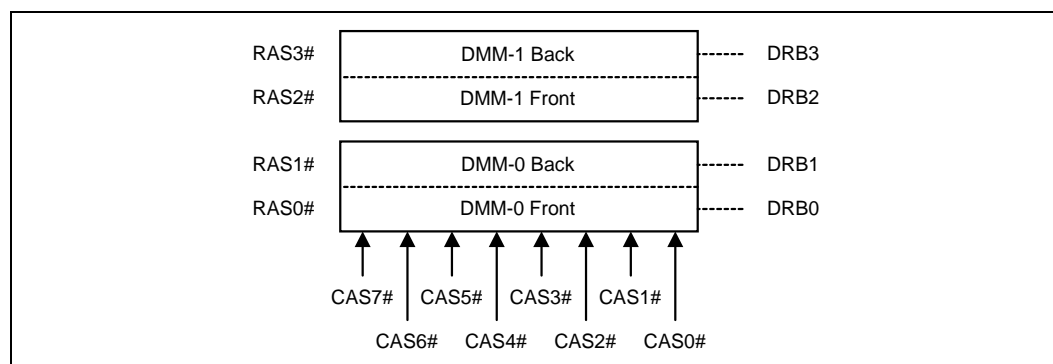
- 60h DRB0 = Total memory in row0 (in 8 MB)
- 61h DRB1 = Total memory in row0 + row1 (in 8 MB)
- 62h DRB2 = Total memory in row0 + row1 + row2 (in 8 MB)
- 63h DRB3 = Total memory in row0 + row1 + row2 + row3 (in 8 MB)
- 64h DRB4 = Total memory in row0 + row1 + row2 + row3 + row4 (in 8 MB)

The DRAM array can be configured with 1M x 64, 2M x 64, 4M x 64, 8M x 64 and 16M x64 single or double-sided DIMMs. Each register defines an address range that cause a particular RAS# line (or CS# in the SDRAM case) to be asserted (e.g., if the first DRAM row is –8 MB, accesses within the 0- to 8-MB range cause RAS0#/CS0# to be asserted). The DRAM Row Boundary (DRB) registers are programmed with an 8-bit upper address limit value. This limit is compared to bits [30:23] of the requested address, for each row, to determine if DRAM is being targeted.

Bit	Description
7:0	Row Boundary Address. This 8-bit value is compared against address lines A[30:23] to determine the upper address limit of a particular row (i.e., DRB minus previous DRB = row size).

Row Boundary Address

Figure 3-1. 2. DIMMs and Corresponding DRB Registers



The following 2 examples describe how the DRB Registers are programmed for cases of single-sided and double-sided DIMMs on a motherboard with 4 DIMM sockets.

Example #1 Single-sided DIMMs. Assume a total of 16 MB of DRAM are required using single-sided 1 MB x 64 DIMMs. Since the memory array is 64-bits wide, two DIMMs are required.

DRB0 = 01h	populated (1 DIMM, 8 MB this row)
DRB1 = 01h	empty row (empty side of single-sided DIMM)
DRB2 = 02h	populated (1 DIMM, 8 MB this row)
DRB3 = 02h	empty row (empty side of single-sided DIMM)
DRB4 = 02h	empty row (empty socket)
DRB5 = 02h	empty row (empty socket)
DRB6 = 02h	empty row (empty socket)
DRB7 = 02h	empty row (empty socket)

Example #2 Mixed Single-/Double-sided DIMMs. As another example, consider the requirements that a system is initially shipped with 8 MB of memory using one 1M x 64 DRAM DIMM and the rest of the memory array should be upgradable to a maximum supported memory of 200 MB. This can be handled by further populating the array with one 8M x 64 single-sided DIMM (one row) and one 16M x 64 double-sided DIMM (two rows), yielding a total of 200 MB of DRAM. The DRB Registers are programmed as follows:

DRB0 = 01h	populated with 8 MB (1 MB x 64 single-sided DRAM DIMM)
DRB1 = 01h	empty row (empty side of single-sided DIMM)
DRB2 = 09h	populated with 64 MB (8M x 64 single-sided DIMM)
DRB3 = 09h	empty row (empty side of single-sided DIMM)
DRB4 = 11h	populated with 64 MB (1/2 16M x 64 double-sided DIMM)
DRB5 = 19h	populated with 64 MB (1/2 16M x 64 double-sided DIMM)
DRB6 = 19h	empty row (empty socket)
DRB7 = 19h	empty row (empty socket)

3.3.19 FDHC—Fixed DRAM Hole Control Register (Device 0)

Address Offset: 68h
 Default Value: 00h
 Access: Read/Write

This 8-bit register controls 2 fixed DRAM holes: 512 KB–640 KB and 15 MB–16 MB.

Bit	Description
7:6	Hole Enable (HEN). This field enables a memory hole in DRAM space. Host cycles matching an enabled hole are passed on to PCI. PCI cycles matching an enabled hole will be ignored by PAC (no DEVSEL#). Note that a selected hole is not remapped. 00 = None 01 = 512 KB–640 KB (128 KB) 10 = 15 MB–16 MB (1 MB) 11 = Reserved
5:0	Reserved.

3.3.20 DRAMXC—DRAM Extended Control Register (Device 0)

Address Offset: 6A–6Bh
Default Value: 0000h
Access: Read/Write

Bit	Description
15:8	Reserved.
7:5	SDRAM Mode Select. Bits[7:5] Operating Mode 000 Normal Operating Mode (default) 001 NOP Command Enabled (NOPCE). This overrides the output values of SRAS#, SCAS#, and WE# to be 1 1 1 (i.e., a NOP command). When in this mode, the only SDRAM operation that PAC will perform is a NOP command. 010 All Banks Pre-charge Command Enable (ABPCE). This overrides the output values of SRAS#, SCAS#, and WE# to be 0 1 0 (i.e., Pre-charge command). When in this mode the only SDRAM operation that PAC will perform is a Pre-charge command. 011 Mode Register Set Command Enable (MRSCE). This overrides the output values of SRAS#, SCAS#, and WE# to be 0 0 0 (i.e., MRS command). When in this mode the only SDRAM operation that PAC will perform is a MRS command. 100 CBR Cycle Enable (CBRC). This overrides the output values of SRAS#, SCAS#, and WE# to be 0 0 1 (i.e., Refresh command). When in this mode the only SDRAM operation that PAC will perform is a Refresh command. 101–11X Reserved.
4	Reserved.
3:2	Page Timeout Select (PTOS). Clock Counts are elapsed time waiting for a new Request in the REQW State. 00 = 16 Clocks (default) 01 = Reserved 10 = Reserved 11 = Reserved
1:0	Close Both Banks Control (CBBC) 00 = Close Both Banks on Arb Switch PageMiss (default) 01 = Reserved 10 = Reserved 11 = Reserved

3.3.21 MBSC—Memory Buffer Strength Control Register (Device 0)

Address Offset: 6C–6Fh
Default Value: 55555555h
Access: Read/Write

This register programs the various DRAM interface signal buffer strengths, based on memory configuration (Configuration #1 or Configuration #2), DRAM type (EDO or SDRAM), DRAM density (x4, x8, x16, or x32), DRAM technology (16 Mb or 64 Mb), and rows populated.

Bit	Description
31:30	MAA[1:0] Buffer Strength. This field sets the buffer strength for MAA[1:0]. 00 = 48 mA 01 = 42 mA 10 = 22 mA 11 = Reserved
29:28	Reserved
27:26	MD[63:0] Buffer Strength. This field sets the buffer strength of the MD[63:0] pin. 00 = 42 mA 01 = 38 mA 10 = 33 mA 11 = Reserved
25:24	RCSA[0]# Buffer Strength. This field sets the buffer strength for RCSA[0]# pins. 00 = 48 mA 01 = 42 mA 10 = 22 mA 11 = Reserved
21:20	MAA[13:2] Buffer Strength. This field sets the buffer strength of the MAA[13:2] pin. 00 = 48 mA 01 = 42 mA 10 = 22 mA 11 = Reserved
19:18	RCSA[1]# Buffer Strength. This field sets the buffer strength for RCSA[1]# pins. 00 = 48 mA 01 = 42 mA 10 = 22 mA 11 = Reserved
17:16	RCSA[2]# Buffer Strength. This field sets the buffer strength for RCSA[2]# pins. 00 = 48 mA 01 = 42 mA 10 = 22 mA 11 = Reserved
15:14	RCSA[3]# Buffer Strength. This field sets the buffer strength for RCSA[3]# pins. 00 = 48 mA 01 = 42 mA 10 = 22 mA 11 = Reserved
9:8	CDQA[5,1]# Buffer Strength. This field sets the buffer strength of the CDQA[5,1]# pins. 00 = 42 mA 01 = 38 mA 10 = 33 mA 11 = Reserved

Bit	Description
7:6	CDQA[7:6,4:2,0]# Buffer Strength. This field sets the buffer strength of the CDQA[7:6,4:2,0]# pins. 00 = 42 mA 01 = 38 mA 10 = 33 mA 11 = Reserved

NOTE:

1. WE#[3:0], SRAS#[1:0] and SCAS#[1:0] are no longer programmable. Their strength will be hard-wired to 42 mA (medium strength).

3.3.22 MTT—Multi-Transaction Timer Register (Device 0)

Address Offset: 70h
Default Value: 00h
Access: Read/Write

MTT is an 8-bit register that controls the amount of time that PAC arbiter allows a PCI initiator to perform multiple back-to-back transactions on the PCI bus. PAC MTT mechanism is used to guarantee the fair share of the PCI bandwidth to an initiator that performs multiple back-to-back transactions to fragmented memory ranges (and as a consequence it can not use long burst transfers).

Bit	Description
7:3	Multi-Transaction Timer Count Value. The number of clocks programmed in this field represents the guaranteed time slice (measured in PCI clocks) allotted to the current agent, after which PAC will grant the bus as soon as other PCI initiators request the bus. The default value of MTT is 00h and disables this function. The MTT value can be programmed with 8 clock granularity in the same manner as the MLT register. For example, if the MTT is programmed to 18h, then the selected value corresponds to the time period of 24 PCI clocks.
2:0	Reserved.

3.3.23 SMRAM—System Management RAM Control Register (Device 0)

Address Offset: 72h
Default Value: 02h
Access: Read/Write

The System Management RAM Control Register controls how accesses to this space are treated. The Open, Close, and Lock SMRAM Space bits function only when the SMRAM enable bit is set to a 1. Also, the OPEN bit should be reset before the LOCK bit is set. Table 12 summarizes the operation of SMRAM space cycles targeting SMI space addresses.

Bit	Description
7	Reserved.
6	SMM Space Open (DOPEN). 1 = When DOPEN = 1 and DLCK = 0, SMM space DRAM is made visible even when host cycle does not indicate SMM mode access via EXF4#/AB7# signal. This is intended to help BIOS initialize SMM space. Software should ensure that DOPEN = 1 is mutually exclusive with DCLS = 1. When DLCK is set to 1, DOPEN is set to 0 and becomes read only.
5	SMM Space Closed (DCLS). 1 = When DCLS = 1, SMM space DRAM is not accessible to data references, even if host cycle indicates SMM mode access via EXF4#/AB7# signal. Code references may still access SMM space DRAM. This will allow SMM software to reference "through" SMM space to update the display even when SMM space is mapped over the VGA range. Software should ensure that DOPEN = 1 is mutually exclusive with DCLS = 1.
4	SMM Space Locked (DLCK). 1 = When DLCK is set to 1, DOPEN is set to 0 and both DLCK and DOPEN become read only. DLCK can be set to 1 via a normal configuration space write but can only be cleared by a power-on reset. The combination of DLCK and DOPEN provide convenience with security. The BIOS can use the DOPEN function to initialize SMM space and then use DLCK to "lock down" SMM space in the future so that no application software (or BIOS itself) can violate the integrity of SMM space, even if the program has knowledge of the DOPEN function.
3	SMRAM Enable (SMRAME). 1 = Enable. When enabled, PAC provides 128 KB of DRAM accessible at the A0000h address or 64 KB of DRAM accessible at the C0000h address during Pentium II processor SMM space accesses (as indicated in the second clock of request phase on EXF4#/Ab7# signal). 0 = Disable.
2:0	SMM Space Base Segment (DBASESEG). This field programs the location of SMM space. "SMM DRAM" is not remapped. It is simply "made visible" if the conditions are right to access SMM space, otherwise the access is forwarded to PCI. 010 = A0000h–BFFFFh. 100 = C0000h–CFFFFh. All other values are reserved. PCI initiators are not allowed access to SMM space and PAM bits for C0000h–CFFFFh range are don't care.

Table 3-5. SMRAM Space Cycles

SMRAME	DLCK	DCLS	DOPEN	Pentium II Processor SMM Mode Request (0 = active)	Code Fetch	Data Reference
0	X	X	X	X	PCI	PCI
1	0	0	0	0	DRAM	DRAM
1	0	X	0	1	PCI	PCI
1	0	0	1	X	DRAM	DRAM
1	0	1	0	0	DRAM	PCI
1	0	1	1	X	INVALID	INVALID
1	1	0	0	0	DRAM	DRAM
1	1	X	0	1	PCI	PCI
1	1	1	0	0	DRAM	PCI

3.3.24 ERRCMD—Error Command Register (Device 0)

Address Offset: 90h
Default Value: 00h
Access: Read/Write

This 8-bit register controls PAC responses to various system errors. The actual assertion of SERR# or PERR# is enabled via the PCI Command register.

Bit	Description
7	SERR# on AGP Non-snoopable access outside of Graphics Aperture. 1 = Enable. When this bit is set to a 1, and bit 2 of the ERRSTS1 register transitions from a 0 to a 1 (during an AGP access to the address outside of the graphics aperture), then an SERR# assertion event will be generated. 0 = Disable (default) reporting of this condition.
6	SERR# on AGP Non-snoopable Access to the Location Outside of Main DRAM Ranges and Aperture Range. 1 = Enable. When bit 6 = 1 and an AGP agent generates an access using enhanced AGP protocol (i.e., PAC must accept the request without qualification with decode logic since there is no protocol mechanism to reject it) and access is not directed to either main memory range or the aperture range, then bit 1 of the ERRSTS1 register is set and SERR# asserted. 0 = Disable (default). When disabled, this condition is not reported via SERR#. PAC ignores A[35:32] of SBA cycles, and therefore will not signal SERR# on accesses over 4G (unless the alias below 4G does not fall within main DRAM or the aperture).
5	SERR# on Access to Invalid Graphics Aperture Translation Table Entry. 1 = Enable. When bit 5=1 and access to an invalid entry of the Graphics Aperture Translation Table stored in the main DRAM occurs, then bit 0 of the ERRSTS1 register will be set and SERR# will be asserted. 0 = Disable (default). Recommended programming value. NOTES: 1. The processor may do a speculative read to the aperture area that could hit an invalid entry in the Graphics Aperture Remapping Table Entry. Since the code actually did not want this data, the entry at this location may or may not be valid. If the entry happens to be invalid and the bit that generates SERR# on access to invalid Graphics Aperture Translation Table Entry (ERRCMD Register, Address Offset 90h, Bit 5) is enabled, then PAC will generate SERR#. 2. This spurious generation of SERR# could result in unwanted error messages and/or system hangs. Disabled is the recommended value of this bit.
4	SERR# on Receiving Target Abort. 1 = Enable. PAC asserts SERR# upon receiving a target abort on either the Primary PCI or AGP 0 = Disable. PAC does not assert SERR# upon receipt of a target abort (default).
3	SERR# on PCI Parity Error. 1 = Enable. PAC asserts SERR# upon sampling PERR# or GPERR# asserted. 0 = Disable. PAC does not assert SERR# upon receipt of a parity error via the PERR# or GPERR# pins (default).
2:0	Reserved.

3.3.25 ERRSTS0—Error Status Register 0 (Device 0)

Address Offset: 91h
 Default Value: 00h
 Access: Read Only, Read/Write Clear

This 8-bit register is used to report DRAM ECC error conditions. SERR# is generated on a zero to one transition of any of these flags (if enabled by the ERRCMD register). ECC is not supported in the 82443EX.

Bit	Description
7:0	Reserved

3.3.26 ERRSTS1—Error Status Register 1 (Device 0)

Address Offset: 92h
 Default Value: 00h
 Access: Read Only, Read/Write Clear

This 8-bit register is used to report AGP error conditions. SERR# is generated on a zero to one transition of any of these flags (if enabled by the ERRCMD register).

Bit	Description
7:3	Reserved
2	AGP non-snoopable access outside of Graphics Aperture. 1 = Indicates that an AGP access occurred to the address that is outside of the graphics aperture range. Software has to write 1 to clear this bit.
1	AGP non-snoopable access to the location outside of main DRAM ranges and aperture range. Software has to write a 1 to clear this bit. 1 = Indicates that an AGP read access is not destined for main DRAM ranges (visible from AGP) or to the aperture. PAC guarantees that the first access outside of DRAM will always receive a SERR# (provided the feature is enabled). SERR# may or may not be asserted for subsequent accesses outside DRAM depending on the delay between the abnormal cycles.
0	Access to Invalid Graphics Aperture Translation Table Entry(AIGATT)(R/WC). Software has to write a 1 to clear this bit. 1 = Indicates that DRAM access to aperture resulted in an invalid translation table entry.

3.3.27 RSTCTRL—Reset Control Register (Device 0)

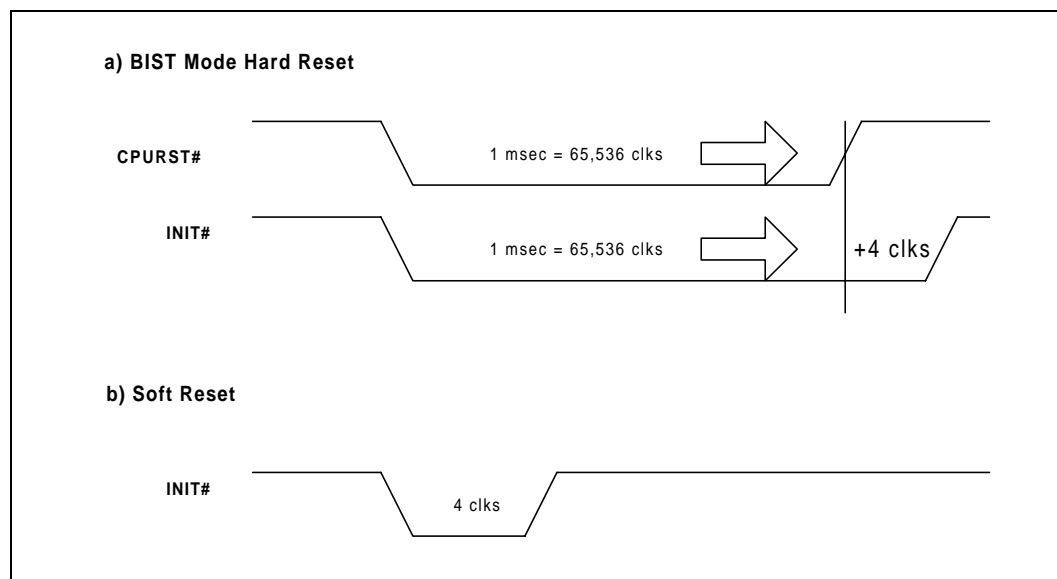
Address Offset: 93h
 Default Value: 00h
 Access: Read/Write

The RSTCTRL Register is used to initiate host soft reset or host Built-in Self Test (BIST) mode hard reset.

Note: This register is only used to initiate soft reset or BIST mode hard reset. An I/O access to 0CF9h within PIIX4 I/O bridge should be used to initiate a hard reset.

Bit	Description															
7:4	Reserved.															
3	BIST Enable (BISTE). 1 = Enable. Enables the host Built-in Self Test to be activated during a subsequent BIST mode hard reset sequence. During BIST mode hard reset, the PAC will assert CPURST# for 1 msec. INIT# will be asserted with CPURST# and negated 4 clocks after CPURST# is negated. 0 = Disable NOTE: BISTE and CSRE should not be 1 simultaneously.															
2	Soft Reset CPU (RCPU). This bit is used to initiate a reset to the CPU. During soft reset, PAC asserts INIT# for 4 clocks (Figure 3). <table><tr><th>BISTE</th><th>CSRE</th><th>Result</th></tr><tr><td>0</td><td>0</td><td>Nothing</td></tr><tr><td>0</td><td>1</td><td>Soft Reset</td></tr><tr><td>1</td><td>0</td><td>BIST Mode Hard Reset</td></tr><tr><td>1</td><td>1</td><td>Reserved</td></tr></table> NOTES: 1. BISTE and CSRE should not be 1 simultaneously. 2. If the CPU is to be placed into BIST mode hard reset, BISTE must be set to 1 <i>BEFORE RCPU is written to</i> . 3. If the CPU is to be placed into soft reset, CSRE must be set to 1 <i>BEFORE RCPU is written to</i> . 4. If PAC activates the CPU's BIST function, a hard reset must then be initiated (after BIST completion). The BIST mode sets the IOQ depth of the processor and PAC to 1. This is not a valid operating condition for PAC.	BISTE	CSRE	Result	0	0	Nothing	0	1	Soft Reset	1	0	BIST Mode Hard Reset	1	1	Reserved
BISTE	CSRE	Result														
0	0	Nothing														
0	1	Soft Reset														
1	0	BIST Mode Hard Reset														
1	1	Reserved														
1	CPU Soft Reset Enable (CSRE). This bit is used to determine if the CPU will be soft reset when a 1 is written to RCPU. During soft reset, PAC asserts INIT# for 4 clocks. NOTE: BISTE and CSRE should not be 1 simultaneously.															
0	Reserved.															

Figure 3-2. Soft Reset and BIST Hard Reset Timing



3.3.28 ACAPID—AGP Capability Identifier Register (Device 0)

Address Offset: A0–A3h
 Default Value: 00100002h
 Access: Read Only

This register provides a standard identifier for AGP capability.

Bit	Description
31:24	Reserved.
23:20	Major AGP Revision Number. This field provides a major revision number of the AGP specification to which this version of PAC conforms. This number is hardwired to value of “0001” (i.e., implying Rev 1.x)
19:16	Minor AGP Revision Number. This field provides a minor revision number of the AGP specification to which this version of PAC conforms. This number is hardwired to value of “0000” (i.e., implying Rev x.0). Together with major revision number this field identifies PAC as an AGP REV 1.0 compliant device.
15:8	Next Capability Pointer. AGP capability is the first and the last capability described with this mechanism, and therefore, these bits are hardwired to 0 to indicate the end of the capability linked list.
7:0	AGP Capability ID. This field identifies the linked list item as containing AGP registers. This field has a value of 0010b assigned by the PCI SIG.

3.3.29 AGPSTAT—AGP Status Register (DEVICE 0)

Address Offset: A4–A7h
 Default Value: 1F000203h
 Access: Read/Write, Read Only

This register provides control of the AGP operational parameters and reports AGP device capability/status.

Bit	Description
31:24	AGP Request Queue Depth—RO. This field contains the maximum number of AGP command requests PAC is configured to manage. The lower 6 bits of this field reflect the value programmed in AGPCTRL[12:10]. Only discrete values of 32, 16, 8, 4, 2 and 1 can be selected via AGPCTRL. Upper bits are hardwired to 0. Default = 1Fh
23:10	Reserved.
9	AGP Side Band Addressing Supported. Hardwired to 1. 1 = Indicates that PAC supports side band addressing.
8:2	Reserved.
1:0	AGP Data Transfer Rates Supported. Hardwired to 11b. This field indicates the data transfer rates supported by PAC. Note that this field applies to both AD bus and SBA bus. 11 = Bit 0 = 1X, Bit 1 = 2X. Both 1x and 2x clocking are supported by PAC.

3.3.30 AGPCMD—AGP Command Register (Device 0)

Address Offset: A8–ABh
Default Value: 00000000h
Access: Read/Write

This register reports AGP device capability/status.

Bit	Description
31:10	Reserved.
9	AGP Side Band Enable. 1 = Enable 0 = Disable (Default)
8	AGP Enable. 1 = Enable. When this bit is set to a 0, PAC ignores all AGP operations, including the sync cycle. Any AGP operations received (queued) while this bit is 1, will be serviced even if this bit is subsequently reset to 0. If this bit transitions from a 1 to a 0 on a clock edge in the middle of an SBA command being delivered in 1X mode, the command will be serviced. When this bit is set to a 1, PAC responds to AGP operations delivered via PIPE#. In addition, when this bit is set to a 1, PAC responds to AGP operations delivered via SBA, if the AGP Side Band Enable bit is also set to 1. 0 = Disable (Default)
7:2	Reserved.
1:0	AGP Data Transfer Rate. One (<i>and only one</i>) bit in this field must be set to indicate the desired data transfer rate. <Bit 0: 1X, Bit 1: 2X>. The same bit must be set on both master and target. Default = 00b Configuration software will update this field by setting only one bit that corresponds to the capability of the AGP master (after that capability has been verified by accessing the same functional register within the AGP master's configuration space). NOTE: This field applies to AD and SBA buses.

3.3.31 AGPCTRL—AGP Control Register (Device 0)

Address Offset: B0–B3h
Default Value: 00000000h
Access: Read/Write

This register provides additional control of the AGP interface capability.

Bit	Description
31:14	Reserved.
13	Graphics Aperture Write-AGP Read Synchronization Enable (CGAS). 1 = PAC ensures that all writes to the Graphics Aperture, posted in the Global Write Buffer, are retired to DRAM before PAC will initiate any CPU-to-AGP cycle. This can be used to ensure synchronization between the CPU and AGP master. 0 = No synchronization is guaranteed (default).
12:10	Reserved.
9:8	Expedite Transaction Throttle Timer. These bits define the operations of the counter used to internally throttle the expedited transaction stream by masking the internal signal that indicates expedited request operations are pending. 00 = no throttling (Default) 01 = Reserved 10 = 192 clocks on—64 clocks off 11 = Reserved
7	GTLB Enable. 1 = Enable. Enables normal operations of the Graphics Translation Lookaside Buffer. 0 = Disable (default). GTLB is flushed (i.e., all entry valid bits cleared). This disables fetching and storing of new entries into the GTLB. Also, accesses that require translation bypass the GTLB.
6:0	Reserved.

3.3.32 APSIZE—Aperature Size (Device 0)

Address Offset: B4h
 Default Value: 0000h
 Access: Read/Write

This register determines the effective size of the Graphics Aperture used in the particular PAC configuration. This register can be updated by PAC-specific BIOS configuration sequence before the PCI standard bus enumeration sequence takes place. If the register is not updated the aperture is set to the default size of 256 MB. The size of the table that will correspond to a 256-MB aperture is not practical for most applications. Therefore, these bits must be programmed to a smaller, more practical value. This forces an adequate address range to be requested from the PCI configuration software via ABASE register.

Bit	Description																
7:6	Reserved.																
5:0	<p>Graphics Aperture Size. When a particular bit of this field is 0, it forces the corresponding bit of the bit field ABASE[27:22] to behave as “hardwired” to 0. When a bit is 1, it allows the corresponding bit of the ABASE[27:22] to be read/write accessible. Only the following combinations are allowed:</p> <table> <tr> <th>Bits[5:0]</th><th>Aperture Size</th></tr> <tr> <td>11 1111b</td><td>4 MB</td></tr> <tr> <td>11 1110b</td><td>8 MB</td></tr> <tr> <td>11 1100b</td><td>16 MB</td></tr> <tr> <td>11 1000b</td><td>32 MB</td></tr> <tr> <td>11 0000b</td><td>64 MB</td></tr> <tr> <td>10 0000b</td><td>128 MB</td></tr> <tr> <td>00 0000b</td><td>256 MB</td></tr> </table> <p>The default for APSIZE[5:0] = 000000b forces default APBASE[27:22] = 000000b (maximum aperture size of 256 MB).</p> <p>NOTE: When programming the APSIZE register such that APBASE register bits change from “read only” to “read/write,” the value of those bits is undefined and must be written first to have a known value.</p>	Bits[5:0]	Aperture Size	11 1111b	4 MB	11 1110b	8 MB	11 1100b	16 MB	11 1000b	32 MB	11 0000b	64 MB	10 0000b	128 MB	00 0000b	256 MB
Bits[5:0]	Aperture Size																
11 1111b	4 MB																
11 1110b	8 MB																
11 1100b	16 MB																
11 1000b	32 MB																
11 0000b	64 MB																
10 0000b	128 MB																
00 0000b	256 MB																

3.3.33 ATTBASE—Aperture Translation Table Base Register (Device 0)

Address Offset: B8–BBh
Default Value: 00000000h
Access: Read/Write

This register provides the start address of the Graphics Aperture Translation Table, which is located in main system memory. This value is used by PAC Graphics Aperture Address Translation logic (including the GTLB logic) to obtain the appropriate address translation entry. This is required during the translation of the aperture address into a corresponding physical DRAM address. Note that address provided via ATTBASE is 4-KB aligned.

Bit	Description
31:12	Translation Table Base Address. This field contains a pointer to the base of the translation table. This table is used to map memory space addresses in the aperture range to addresses in main memory.
11:0	Reserved.

3.3.34 AMTT—AGP Interface Multi-Transaction Timer Register (Device 0)

Address Offset: BCh
 Default Value: 00h
 Access: Read/Write

AMTT is an 8-bit register that controls the amount of time that PAC arbiter allows an AGP master, using PCI protocol, to perform multiple back-to-back transactions on the AGP interface. The AMTT mechanism applies to CPU-to-AGP transactions as well, and it guarantees the CPU a fair share of the AGP interface bandwidth.

Bit	Description
7:3	Multi-Transaction Timer Count Value.
2:0	Reserved.

3.3.35 LPTT—Low Priority Transaction Timer Register (Device 0)

Address Offset: BDh
 Default Value: 00h
 Access: Read/Write

LPTT is an 8-bit register similar in a function to AMTT. This register is used to control the minimum tenure on the AGP for low priority data transaction (both reads and writes) issued using PIPE# or SB mechanisms.

Bit	Description
7:3	Low Priority Transaction Timer Count Value.
2:0	Reserved.

3.4 AGP Configuration Registers—(Device 1)

3.4.1 VID1—Vendor Identification Register (Device 1)

Address Offset: 00–01h
 Default Value: 8086h
 Attribute: Read Only

The VID1 register contains the vendor identification number for function 1. This 16-bit register combined with the Device Identification Register uniquely identify any PCI device. Writes to this register have no effect.

Bit	Description
15:0	Vendor Identification Number. This is a 16-bit value assigned to Intel. Intel VID = 8086h.

3.4.2 DID1—Device Identification Register (Device 1)

Address Offset: 02–03h
Default Value: 7181h
Attribute: Read Only

This 16-bit register combined with the Vendor Identification register uniquely identifies any PCI device. Writes to this register have no effect.

Bit	Description
15:0	Device Identification Number. This is a 16-bit value assigned to PAC Device 1. PAC Device 1 DID = 7181h.

3.4.3 PCICMD1—PCI-PCI Command Register (Device 1)

Address Offset: 04–05h
Default: 0000h
Access: Read/Write

This 16-bit register provides basic control over the “virtual” PCI-to-PCI bridge entity embedded within PAC. In this way, PAC AGP interface is handled by the standard control mechanism of the PCI-to-PCI bridge, where AGP corresponds to the Secondary Bus of the bridge.

Bit	Description
15:9	Reserved.
8	SERR# Enable (SERRE1). 1 = Enable. PAC common SERR# signal driver (common for Primary PCI and AGP) is enabled for the error conditions that occurred on the AGP (including GSERR# assertion and parity errors), and SERR# is asserted for all relevant bits set in the PCISTS1. If both SERRE and SERRE1 are reset to 0, then SERR# is never driven by PAC. Also, if this bit is set and the Parity Error Response Enable Bit (Register 3Eh, Device #1, Bit 0) is set, then PAC will report ADDRESS parity errors on AGP (when it is potential target). 0 = Disable.
7:0	Reserved.

3.4.4 PCISTS1—PCI-PCI Status Register (Device 1)

Address Offset: 06–07h
 Default Value: 02A0h
 Access: Read Only, Read/Write Clear

PCISTS1 is a 16-bit status register that reports the occurrence of error conditions associated with the primary side of the “virtual” PCI-to-PCI bridge in PAC.

Bit	Description
15	Reserved.
14	Signaled System Error (SSE1)—R/WC. 1 = When PAC asserts the SERR# signal due to error condition on the AGP side (i.e., GSERR# activated), this bit is also set to 1. Software sets SSE1 to 0 by writing a 1 to this bit.
13:0	Reserved.

3.4.5 RID1—Revision Identification Register (Device 1)

Address Offset: 08h
 Default Value: 03h
 Access: Read Only

This register contains the revision number of PAC Device 1. These bits are read only and writes to this register have no effect. This value is hardwired to 03h.

Bit	Description
7:0	Revision Identification Number. This is an 8-bit value that indicates the revision identification number for PAC Device 1.

3.4.6 SUBC1—Sub-Class Code Register (Device 1)

Address Offset: 0Ah
 Default Value: 04h
 Access: Read Only

This register contains the device programming interface information related to the Sub-Class Code definition for PAC device 1.

Bit	Description
7:0	Sub-Class Code (SUBC1). This is an 8-bit value that indicates the category of bridge for PAC device #1. 04h = Indicate a PCI-to-PCI Bridge.

3.4.7 BCC1—Base Class Code Register (Device 1)

Address Offset: 0Bh
 Default Value: 06h
 Access: Read Only

This register contains the device programming interface information related to the Base Class Code definition for PAC device 1.

Bit	Description
7:0	Base Class Code (BASEC). This is an 8-bit value that indicates the Base Class Code for PAC device #1. 06h = Indicates a bridge device.

3.4.8 HDR1—Header Type Register (Device 1)

Offset: 0Eh
 Default: 01h
 Access: Read Only

This register identifies the header layout of the configuration space. No physical register exists at this location.

Bit	Description
7:0	Header Type (HEADT). This read only field always returns 01h when read. Writes have no effect.

3.4.9 PBUSN—Primary Bus Number Register (Device 1)

Offset: 18h
 Default: 00h
 Access: Read Only

This register identifies that the “virtual” PCI-PCI bridge is connected to bus #0.

Bit	Description
7:0	Bus Number. The value of this 8-bit register is always 00h.

3.4.10 SBUSN—Secondary Bus Number Register (Device 1)

Offset: 19h
 Default: 00h
 Access: Read/Write

This register identifies the bus number assigned to the second bus side of the virtual PCI-PCI bridge (i.e., to the A.G.P.).

Bit	Description
7:0	Bus Number. This field is programmed by the PCI configuration software to allow mapping of configuration cycles to AGP Default = 00h.

3.4.11 SUBUSN—Subordinate Bus Number Register (Device 1)

Offset: 1Ah
 Default: 00h
 Access: Read/Write

This register identifies the subordinate bus, if any, that resides at the level below AGP

Bit	Description
7:0	Bus Number. This field is programmed by the PCI configuration software to allow mapping of configuration cycles to AGP Default = 00h.

3.4.12 SMLT—Secondary Master Latency Timer Register (Device 1)

Address Offset: 1Bh
 Default Value: 00h
 Access: Read/Write

This register controls the bus tenure of PAC on the AGP interface in the same way that the MLT controls access to the primary PCI bus.

Bit	Description
7:3	Secondary MLT Counter Value. Default = 00000b (i.e., SMLT disabled)
2:0	Reserved.

3.4.13 IOBASE—I/O Base Address Register (Device 1)

Address Offset: 1Ch
 Default Value: F0h
 Access: Read/Write

This register controls the CPU to AGP I/O access routing based on the following formula:

$$\text{IO_BASE} \leq \text{address} \leq \text{IO_LIMIT}$$

Only the upper 4 bits are programmable. For the purpose of address decode, address bits A[11:0] are treated as 0. Thus the bottom of the defined I/O address range will be aligned to a 4-KB boundary.

Bit	Description
7:4	I/O Address Base. Corresponds to A[15:12] of the I/O address. Default = 1111b
3:0	Reserved.

3.4.14 IOLIMIT—I/O Limit Address Register (Device 1)

Address Offset: 1Dh
 Default Value: 00h
 Access: Read/Write

This register controls the CPU to AGP I/O access routing based on the following formula:

$$\text{IO_BASE} \leq \text{address} \leq \text{IO_LIMIT}$$

Only the upper 4 bits are programmable. For the purpose of address decode, address bits A[11:0] are assumed to be FFFh. Thus, the top of the defined I/O address range will be at the top of a 4-KB aligned address block.

Bit	Description
7:4	I/O Address Limit. Corresponds to A[15:12] of the I/O address. Default = 0000b
3:0	Reserved.

3.4.15 SSTS—Secondary PCI-PCI Status Register (Device 1)

Address Offset: 1E–1Fh
 Default Value: 02A0h
 Access: Read Only, Read/Write Clear

SSTS is a 16-bit status register that reports the occurrence of error conditions associated with the secondary side (i.e., AGP side) of the “virtual” PCI-to-PCI bridge in PAC.

Bit	Description
15	Detected Parity Error (DPE1)—R/WC. 1 = Indicates PAC detection of a parity error in either the data or address phase. Software resets this bit to 0 by writing a 1 to it. Note that the function of this bit is not affected by the PERRE1 bit.
14	Received System Error (SSE1)—R/WC. 1 = PAC detects GSERR# assertion on AGP. Software resets this bit to 0 by writing a 1 to it.
13	Received Master Abort Status (RMAS1)—R/WC. 1 = PAC terminated a Host-to-AGP with an unexpected master abort. Software resets this bit to 0 by writing a 1 to it.
12	Received Target Abort Status (RTAS1)—R/WC. 1 = PAC-initiated transaction on AGP is terminated with a target abort. Software resets RTAS1 to 0 by writing a 1 to it.
11:9	Reserved.
8	Data Parity Detected (DPD1)—R/WC. This bit is set to a 1, when all of the following conditions are met. Software resets this bit to 0 by writing a 1 to it. 1. PAC asserted GPERR# or sampled GPERR# asserted. 2. PAC was the initiator for the operation in which the error occurred. 3. The SPERRE bit in the BCTRL register is set to 1.
7:0	Reserved.

3.4.16 MBASE—Memory Base Address Register (Device 1)

Address Offset: 20–21h
 Default Value: FFF0h
 Access: Read/Write

This register controls the CPU to AGP non-prefetchable memory access routing based on the following formula:

$$\text{MEMORY_BASE} \leq \text{address} \leq \text{MEMORY_LIMIT}$$

This register must be initialized by the configuration software. For address decode, address bits A[19:0] are assumed to be 0. Thus, the bottom of the defined memory address range will be aligned to a 1-MB boundary.

Bit	Description
15:4	Memory Address Base. Corresponds to A[31:20] of the 32-bit memory address. Default = FFFh
3:0	Reserved. Read as 0s.

3.4.17 MLIMIT—Memory Limit Address Register (Device 1)

Address Offset: 22–23h
Default Value: 0000h
Access: Read/Write

This register controls the CPU to AGP non-prefetchable memory access routing based on the following formula:

$$\text{MEMORY_BASE} \leq \text{address} \leq \text{MEMORY_LIMIT}$$

This register must be initialized by the configuration software. For address decode, address bits A[19:0] are assumed to be FFFFh. Thus, the top of the defined memory address range will be at the top of a 1-MB aligned memory block.

Bit	Description
15:4	Memory Address Limit. Corresponds to A[31:20] of the 32-bit memory address. Default = 000h
3:0	Reserved. Read as 0s.

3.4.18 PMBASE—Prefetchable Memory Base Address Register (Device 1)

Address Offset: 24–25h
Default Value: FFF0h
Access: Read/Write

This register controls the CPU to AGP prefetchable memory accesses routing based on the following formula:

$$\text{MEMORY_BASE} \leq \text{address} \leq \text{MEMORY_LIMIT}$$

This register must be initialized by the configuration software. For address decode, address bits A[19:0] are assumed to be 0. Thus, the bottom of the defined memory address range will be aligned to a 1-MB boundary.

Bit	Description
15:4	Memory Address Base. Bits [15:4] corresponds to A[31:20] of the 32-bit memory address. Default = FFFh
3:0	Reserved. Read as 0s.

3.4.19 PMLIMIT—Prefetchable Memory Limit Address Register (Device 1)

Address Offset: 26–27h
 Default Value: 0000h
 Access: Read/Write

This register controls the CPU to AGP prefetchable memory accesses routing based on the following formula:

$$\text{MEMORY_BASE} \leq \text{address} \leq \text{MEMORY_LIMIT}$$

This register must be initialized by the configuration software. For address decode, address bits A[19:0] are assumed to be FFFFh. Thus, the top of the defined memory address range will be at the top of a 1-MB aligned memory block.

Bit	Description
15:4	Memory Address Limit. Corresponds to A[31:20] of the 32-bit memory address. Default = 000h
3:0	Reserved. Read as 0s.

3.4.20 BCTRL—PCI-PCI Bridge Control Register (Device 1)

Address Offset: 3E–3Fh
 Default: 0000h
 Access: Read/Write

This register provides extensions to the PCICMD1 register that are specific to PCI-to-PCI bridges. The BCTRL provides additional control for the secondary interface (i.e., AGP). It also provides bits that affect the overall behavior of the “virtual” PCI-to-PCI bridge embedded within PAC (e.g., VGA compatible address ranges mapping).

Bit	Description
15:11	Reserved.
10	Discard Timer Status. 1 = Indicates that a delayed transaction has been discarded. When set, this bit can be cleared by writing a 1 to it.
9	Secondary Discard Timer Enable. 1 = Enable. Enables the Discard Timer for delayed transactions on the AGP (initiated by the AGP agent using PCI protocol). The counter starts once the delayed transaction request is ready to complete (i.e., read data is pending on the top of the AGP outbound queue). If the AGP agent does not repeat the transaction before the counter expires after 1024 clocks (66 MHz), PAC will delete the delayed transaction from its queue and set the Discard Timer Status bit. 0 = Disable.
8:4	Reserved.
3	VGA Enable. Controls the routing of CPU-initiated transactions targeting VGA compatible I/O and memory address ranges. 1 = Enable. When enabled, PAC forwards the following CPU accesses to the AGP: <ul style="list-style-type: none"> Memory accesses in the range 0A0000h to 0BFFFFh I/O addresses where A[9:0] are in the ranges 3B0h to 3BBh and 3C0h to 3DFh (inclusive of ISA address aliases—A[15:10] are not decoded) When enabled, forwarding of these CPU issued accesses is independent of the I/O address and memory address ranges defined by the base and limit registers. Forwarding of these accesses is also independent of the settings of bit 2 (ISA Enable) of this register if this bit is a 1. 0 = Disable (default). VGA compatible memory and I/O range accesses are not forwarded to AGP unless they are mapped to AGP via I/O and memory range registers defined above (IOBASE, IOLIMIT, MBASE, MLIMIT, PMBASE, PMLIMIT), they are mapped to primary PCI.
2	ISA Enable. Modifies the response by PAC to an I/O access issued by the CPU that targets ISA I/O addresses. This applies only to I/O addresses that are enabled by the IOBASE and IOLIMIT registers. 1 = Enable. PAC blocks the forwarding of I/O transactions addressing the last 768 bytes in each 1-KB block to AGP. This occurs even if the addresses are within the range defined by the IOBASE and IOLIMIT. Instead of going to AGP, these cycles are forwarded to primary PCI where they are claimed by the ISA bridge. 0 = Disable (default). All addresses defined by the IOBASE and IOLIMIT for the CPU I/O transactions will be mapped on AGP.
1	System Error Enable. This bit controls forwarding of the GSERR# from the AGP side to SERR# on the primary PCI. 1 = Enable. SERRE1 bit of PCICMD1 is set, and the bridge detects the assertion of GSERR# on the AGP interface. PAC then asserts SERR# on the primary PCI. 0 = Disable (default). Forwarding of GSERR# to the primary SERR# is disabled.
0	Parity Error Response Enable. This bit controls PAC response to parity errors on the AGP interface. PAC generates parity on AGP even if error reporting is disabled. 1 = Enable. Enables parity error reporting on the AGP interface via GPERR# and detection. 0 = Disable (default). PAC ignores address and data parity errors on the AGP interface. In addition, this bit enables the reporting of address parity errors via SERR#, provided that the SERRE1 bit of the PCICMD1 register (Register 04–05h, Device #1, bit 8) is set.

Functional Description

4

4.1 System Address Map

A Pentium® II processor based system with the Intel® 440EX AGPset supports 4 GB of addressable memory space and 64 KB of addressable I/O space. The lower 1 MB of the addressable memory is divided into regions that can be individually controlled with programmable attributes such as disable, read/write, write only, or read only (see Register Description section for details). This section describes memory space partitioning and function. The I/O address space mapping is explained at the end of this section.

In this section, it is assumed that all of the compatibility memory ranges reside on the PCI bus, except VGA ranges that can be potentially mapped on AGP. Thus, the phrase “forwarded to PCI” refers to the PCI bus, unless the AGP bus is specifically named.

Note: The Pentium II processor supports addressing of memory ranges larger than 4 GB. PAC claims any access over 4 GB and terminates the transaction (without forwarding it to the PCI bus). Host writes are terminated by completing the host cycle and discarding the data. Host reads are terminated by returning all zeros on the host bus. Note that PCI Dual Address Cycle Mechanism (DAC) that allows addressing of >4-GB range is not supported by PAC (either on PCI or on the AGP interface).

4.1.1 Memory Address Ranges

The memory address map (Figure 4-1) represents the maximum 64 GB of CPU address space. PAC supports 4 GB of main memory. Accesses to memory space below 4 GB and above top of DRAM, to the compatibility video buffer range, to the programmable holes and to the memory window (if enabled) are forwarded to the PCI. Note that if the memory holes are enabled below the top of main memory area, then the corresponding DRAM ranges are not remapped.

4.1.1.1 Compatibility Area

This area is divided into the following address regions:

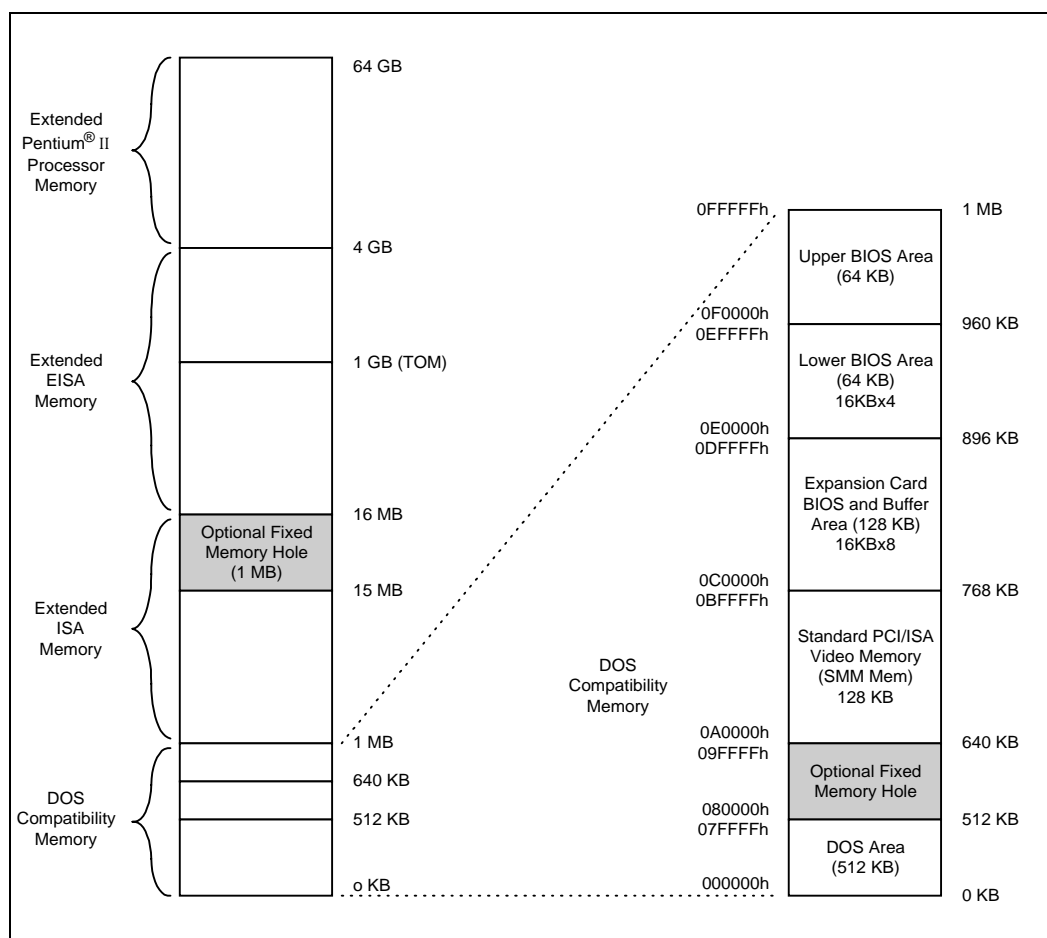
- 0–512-KB DOS Area
- 512-KB–640-KB DOS Area—Optional ISA/PCI Memory
- 640-KB–768-KB Video Buffer Area
- 768-KB–896-KB in 16-KB sections (total of 8 sections)—Expansion Area
- 896-KB–960-KB in 16-KB sections (total of 4 sections)—Extended System BIOS Area
- 960-KB–1-MB Memory (BIOS Area)—System BIOS Area

There are thirteen ranges which can be enabled or disabled independently for both read and write cycles and one (512 KB–640 KB) which can be mapped to either main DRAM or PCI.

DOS Area (00000h–9FFFh)

The DOS area is 640 KB and is divided into two parts. The 512-KB area (0h–7FFFFh) is always mapped to the main memory controlled by PAC. The 128-KB area (080000h–09FFFFh) can be mapped to PCI or to main memory. By default, this range is mapped to main memory and can be declared as a main memory hole (accesses forwarded to PCI) via the FDHC register.

Figure 4-1. Detailed Memory System Address Map



Video Buffer Area (A0000h–BFFFFh)

The 128-KB graphics adapter memory region is normally mapped to a legacy video device on the PCI bus (typically VGA controller). This area is not controlled by attribute bits and CPU-initiated cycles in this region are forwarded to the PCI bus or AGP for termination. This region is also the default region for SMM space.

The BCTRL (PCI-PCI Bridge Control Register) configuration registers of “virtual” PCI-to-PCI Bridge controls whether these accesses will be forwarded to PCI or to AGP. This applies to accesses initiated from any of the system interfaces (i.e., CPU bus, PCI or AGP). Note that for AGP<->PCI accesses, only write operations from PCI to AGP are supported (i.e., AGP -> PCI writes are not supported; PCI<->AGP reads are not supported). For more details see the PCI-to-PCI Bridge Control register description.

Expansion Area (C0000h–DFFFFh)

This 128-KB ISA Expansion region is divided into eight 16-KB segments. Each segment can be assigned one of four Read/Write states: read-only, write-only, read/write, or disabled. Typically, these blocks are mapped through the Primary PCI bridge to ISA space. Memory that is disabled is not remapped. C0000h–CFFFFh is also an optional SMM space.

Extended System BIOS Area (E0000h–EFFFFh)

This 64-KB area is divided into four 16-KB segments. Each segment can be assigned independent read and write attributes so it can be mapped either to main memory or to PCI. Typically, this area is used for RAM or ROM. Memory segments that are disabled are not remapped elsewhere.

System BIOS Area (F0000h–FFFFFh)

This area is a single 64-KB segment and can be assigned read and write attributes. The default is read/write disabled and cycles are forwarded to PCI. By manipulating the read/write attributes, PAC can “shadow” BIOS into the main memory. When disabled, this segment is not remapped.

Extended Memory Area

This memory area is from 1 MB to 4 GB - 1 (100000h to FFFFFFFFh) and is divided into the following regions:

- Main memory from 1 MB to the Top of Memory (maximum of 256 MB using 16-Mbit DRAM technology or 1 GB using 64-Mbit technology)
- PCI Memory space from the Top of Memory to 4 GB with two specific ranges:
 - APIC Configuration Space from FEC0_0000h (4 GB minus 20 MB) to FECF_FFFFh and FEE0_0000h to FEEF_FFFFh.
 - High BIOS area from 4 GB to 4 GB minus 2 MB

Main DRAM Address Range (0010_0000h to Top of Main Memory)

The address range from 1 MB to the top of main memory is mapped to main memory address range controlled by PAC. All accesses to addresses within this range are forwarded to main memory, unless a hole in this range is created via the FDHC register. Accesses within this hole are forwarded to PCI. The range of physical memory disabled by opening the hole is not remapped to the Top of the Memory.

PCI Memory Address Range (Top of Main Memory to 4 GB)

The address range from the top of main memory to 4 GB (top of physical memory space supported by PAC) is normally mapped to PCI. However, the AGP memory window is mapped to the AGP and Graphics Aperture range which is mapped to main memory.

Note: The AGP Memory Window and Graphics Aperture Window override the default decode to PCI of the memory space above the top of the main DRAM.

There are two sub-ranges within this address range defined as APIC Configuration Space and High BIOS Address Range. The AGP Memory Window and Graphics Aperture Window **MUST NOT** overlap with these two ranges. These ranges are described in detail in the following paragraphs.

APIC Configuration Space (FEC0_0000h – FECF_FFFFh, FEE0_0000h – FEEF_FFFFh)

This range is reserved for APIC configuration space which includes the default I/O APIC configuration space. The default Local APIC configuration space is FEE0_0000h to FEEF_0FFFh.

CPU accesses to the Local APIC configuration space do not result in external bus activity since the Local APIC configuration space is internal to the CPU. However, the MTRR's must be programmed to make the Local and I/O APIC range uncacheable (UC). In PAC partitioning, I/O APIC functionality is supported via a stand-alone component residing on the X-bus provided by the PIIX4 I/O bridge.

I/O APIC units are located beginning at the default address FEC0_0000h. The first I/O APIC will be located at FEC0_0000h. Each I/O APIC unit is located at FEC0_x000h where x is I/O APIC unit number 0 through F(hex). This address range is normally mapped to PCI.

The address range between the APIC configuration space and the High BIOS (FEC0_FFFFh to FFE0_0000h) is always mapped to the PCI.

High BIOS Area (FFE0_0000h to FFFF_FFFFh)

The top 2 MB of the Extended Memory Region is reserved for System BIOS (High BIOS), extended BIOS for PCI devices, and the A20 alias of the system BIOS. CPU begins execution from the High BIOS after reset. This region is mapped to the PCI so that the upper subset of this region is alias to the 16-MB minus 256-KB range.

4.1.1.2 AGP Memory Address Ranges

PAC can be programmed to direct memory accesses to the AGP bus interface when addresses are within the appropriate range. This range is divided into two subranges. The first is controlled via the AGP Memory Base Register (AMBASE) and AGP Memory Limit Register (AMLIMIT). The second range is controlled by the AGP Prefetchable Memory Base Register (APMBASE) and AGP Prefetchable Memory Limit Register (APMLIMIT). Decode for these ranges is based on the following concept:

The top 12 bits of the Memory Base and Memory Limit registers correspond to address bits A[31:20] of a memory address. For the purpose of address decoding, PAC assumes that address bits A[19:0] of the memory base are zero and that address bits A[19:0] of the memory limit address are FFFFh. This forces the memory address range to be aligned to 1-MB boundaries and to have a size granularity of 1 MB. The address ranges covered by these registers are defined by the following equation:

$$\text{Base_Address} \leq \text{Address} \leq \text{Limit_Address}$$

The effective size of the range is programmed by the plug-and-play configuration software and depends on the size of memory claimed by the AGP device. Normally these ranges reside above the Top-of-Main Memory and below High BIOS and APIC address ranges. It is essential to support separate Prefetchable ranges to apply WC attributes (from the processor point of view) to that range.

4.1.1.3 AGP Graphics Aperture

Memory-mapped, graphics data structures can reside in a Graphics Aperture. This aperture is an address range defined by the APBASE configuration register of PAC. The APBASE register follows the standard base address register template as defined by the PCI Specification. The size of

the range claimed by the APBASE is programmed via APSIZE Register (programmed by the BIOS before a plug-and-play session is performed). The APSIZE Register allows the selection of an aperture size of 4 MB, 8 MB, 16 MB, 32 MB, 64 MB, 128 MB and 256 MB. By programming the APSIZE to a specific size, the corresponding lower bits of the APBASE are forced to 0. The default value of the APSIZE register forces an aperture size of 4 MB. The aperture address range is naturally aligned.

Note: When programming the APSIZE register such that the APBASE register bits change from “read only” (forced to 0) to “read/write,” the value of those bits is undefined and must be written first to have a known value. Note that the Aperture Size register (Offset B4h, Device 0) programming only effects the accessibility of bits 27:22 in the Aperture Base Register (Offset 10–13h, Device 0).

Accesses within the aperture range are forwarded to main memory. PAC translates the originally issued addresses via a translation table that is maintained in main memory. The aperture range should be programmed as not cacheable in the processor caches.

Note: The plug-and-play software configuration model does not allow overlap of different address ranges. Therefore, the AGP aperture and the AGP Memory Range are independent address ranges that may be contiguous, but not overlapping.

4.1.1.4 Address Mapping of PCI Devices on AGP

The AGP Memory Range registers are used also to allocate a memory address range for the PCI device (i.e., 66-MHz/3.3V PCI agent attached to the AGP port). The same applies in the case of a multi-functional AGP device where one or multiple of the functions are implemented as PCI-only devices.

4.1.2 System Management Mode (SMM) Memory Range

PAC supports the use of main memory as SMM memory when the system management mode is enabled. When this function is disabled, the memory address range A0000h–BFFFFh is normally defined as a video buffer range where accesses are directed to either AGP or PCI and physical DRAM memory is not accessed. When SMM is enabled via SMRAM configuration register the A0000h–BFFFFh range is used as a SMM RAM and no accesses from PCI or AGP bus are allowed. CPU bus cycles executed in SMM mode access the A0000h–BFFFFh range by being mapped to a corresponding physical DRAM address range instead of being forwarded. Before this space is accessed in SMM mode, the corresponding main memory range must be first initialized. This is done using SMRAM register. Opening of SMM space in the 0C0000h–0CFFFFh is also allowed using the SMRAM register.

Note: A PCI or AGP initiator can not access SMM space.

4.1.3 Memory Shadowing

Any block of memory that can be designated as read only or write only can be “shadowed” in main memory. Typically, this is done to allow ROM code to execute more rapidly out of main memory. ROM is used as a read only during the copy process while DRAM is designated write only at the same time. After copying, the DRAM is designated read only so that ROM is shadowed. CPU bus transactions are routed accordingly.

4.1.4 I/O Address Space

PAC does not support the existence of any other I/O devices besides itself on the host bus. PAC generates either PCI or AGP bus cycles for all CPU I/O accesses. PAC contains two internal registers in the CPU I/O space—CONFADD register and CONFDATA register. These locations are used to implement PCI configuration space access mechanism and is described in the Register Description section.

The CPU allows 64 KB to be addressed within the I/O space. PAC propagates the CPU I/O address without any translation on to the destination bus and, therefore, provides addressability for 64-KB locations. Note that the upper three locations past the 64-K boundary can be accessed only during I/O address wrap-around when the CPU bus A16# address signal is asserted. A16# is asserted on the CPU bus when an I/O access is made to 4 bytes from address 0FFFDh, 0FFFEh, or 0FFFFh. A16# is also asserted when an I/O access is made to 2 bytes from address 0FFFFh.

The I/O accesses (other than addresses for PCI configuration space access) are forwarded normally to the PCI bus, unless they are in the AGP I/O address range as defined by the following mechanisms.

AGP Address Mapping

PAC directs I/O accesses to the AGP port if they fall within the AGP I/O address range. This range is defined by the AGP I/O Base Register (AIOBASE) and AGP I/O Limit Register (AIOLIMIT). Decode for these ranges is based on the following concept:

The top 4 bits of the I/O Base and I/O Limit registers correspond to address bits A[15:12] of an I/O address. For the purpose of address decoding, PAC assumes that the lower 12 address bits A[11:0] of the I/O base are zero and that address bits A[11:0] of the I/O limit address are FFFh. This forces I/O address range to be aligned to 4-KB boundary and to have a size granularity of 4 KB. The address range covered by these registers is defined by the following equation:

$$\text{Base_Address} \leq \text{Address} \leq \text{Limit_Address}$$

The effective size of the range is programmed by the plug-and-play configuration software and depends on the size of I/O space claimed by the AGP device. PAC also forwards accesses to the Legacy VGA I/O ranges as defined and enabled by the “virtual” PCI-to-PCI bridge BCTRL and PCICMD1 configuration registers.

Address Mapping of PCI Devices on AGP

The same AGP I/O range is also used to allocate an I/O address range for the PCI device (i.e., agent attached to the AGP port). The same applies in the case of a multi-functional AGP device where one or more of the functions are implemented as PCI-only devices.

4.1.5 PAC Decode Rules and Cross-Bridge Address Mapping

The address map described above applies globally to accesses arriving on any of the three interfaces (i.e., Host bus, PCI, or AGP).

4.1.5.1 PCI Interface Decode Rules

PCI accesses in the PCI range are not accepted. Accesses that do not fall within the PCI range but are within main memory, the AGP range, or the Graphics Aperture range, are forwarded as described above. Note that only PCI memory write accesses within AGP Memory Window ranges (which do not overlap with Graphics Aperture range) are forwarded to AGP PCI cycles that are not claimed by PAC are either subtractively decoded or master-aborted on the PCI.

4.1.5.2 AGP Interface Decode Rules

Cycles Initiated Using PCI Protocol

Accesses between the AGP port and the PCI port are limited to memory writes using the PCI protocol. All AGP memory write cycles will be claimed by PAC. If the addresses are not within the main DRAM range or Graphics Aperture range, the cycle will be forwarded to the PCI bus.

When the AGP master issues a memory read transaction using PCI semantics, the cycle will be claimed by PAC only if the address is within main DRAM range or Graphics Aperture Range. All other memory read requests will be master-aborted as a consequence of PAC not responding to a transaction.

If the agent on AGP issues an I/O, PCI Configuration or PCI Special Cycle transaction, PAC will not respond and the cycle will result in a master-abort.

Cycles Initiated Using AGP Protocol

All cycles initiated using AGP protocol (PIPE# or SBA) must reference main memory (i.e., main DRAM address range or Graphics Aperture range). If a cycle is outside of the main memory range, then it will terminate as follows:

- Reads: return random value.
- Writes: terminated internally without affecting any buffers or main memory.

4.1.5.3 Legacy VGA and MDA Ranges

The legacy VGA memory range A0000h–BFFFFh is mapped either to PCI or AGP depending on the programming of the BCTRL1 and PCICMD1 configuration registers. The same registers control mapping of VGA I/O address ranges. VGA I/O range is defined as addresses where A[9:0] are in the ranges 3B0h to 3BBh and 3C0h to 3DFh (inclusive of ISA address aliases—A[15:10] are not decoded).

The legacy MDA range is not always forwarded with the VGA range. It may be necessary to forward MDA to PCI (for eventual forwarding to ISA) while forwarding VGA to AGP. This would be necessary if an ISA MDA adapter and an AGP VGA adapter were in the system.

[Table 4-1](#) explains the interaction of the ISA Enable, VGA Enable, MDA Enable bits and IOBASE/IOLIMIT registers:

Table 4-1. Legacy Programming Considerations

VGA Enable	IOBASE/IOLIMIT	ISA Enable	MDA Enable	Cycles Forwarded to
0	Outside	0	0	PCI/ISA
0	Outside	0	1	Invalid
0	Outside	1	0	PCI/ISA
0	Outside	1	1	Invalid
0	Inside	0	0	AGP
0	Inside	0	1	Invalid
0	Inside	1	0	PCI/ISA
0	Inside	1	1	Invalid
1	Outside	0	0	PCI/ISA
1	Outside	0	1	PCI/ISA
1	Outside	1	0	PCI/ISA
1	Outside	1	1	PCI/ISA
1	Inside	0	0	PCI/ISA
1	Inside	0	1	PCI/ISA
1	Inside	1	0	PCI/ISA
1	Inside	1	1	PCI/ISA

4.2 Host Interface

The host interface of the 82443EX supports the Pentium® II processor with a bus clock frequency of 66 MHz. PAC implements the address, control, and data bus interfaces for the Intel® 440EX AGPset. Host bus addresses are decoded by PAC for accesses to main memory, PCI memory, PCI I/O, PCI configuration space, and AGP space (memory, I/O and configuration). PAC takes advantage of the pipelined addressing capability of the Pentium II processor to improve overall system performance.

PAC is optimized and supports a uni-processor system only.

PAC interface to the host bus includes a four deep in-order queue to track pipelined bus transactions. When the in-order queue is near full, the CPU bus pipeline is halted by asserting BNR#. BNR# is asserted until the in-order queue begins to drain.

To allow for high speed write capability for graphics, the Pentium II processor has introduced the WC memory type. This provides a write combining buffering mechanism for write operations. A high percentage of graphics transactions are writes to the memory mapped graphics region, normally known as the linear frame buffer. Reads and writes to WC are noncached and can have write side effects.

In the case of graphics, current 32-bit drivers (without modifications) would use Partial Write host bus cycles to update the frame buffer. The highest performance write transaction on the host bus is the Line Write. By combining the several back-to-back Partial write transactions (internal to the CPU) into a Line write transaction on the CPU bus, the performance of frame buffer accesses is greatly improved. To this end, the CPU supports the WC memory. Writes to WC memory can be

buffered and combined in the processor's write combining buffers (WCB). The WCB is flushed after executing a serializing, locked, I/O instruction, or the WCB is full (32 bytes). To extend this capability to the current drivers, it is necessary to set up the linear frame buffer address range to be WC memory type. This can be done by programming the MTRR registers in the CPU. Note that for dual processors, the MTRR must be programmed identically.

If non-contiguous bytes are written to the WCB, upon eviction, a series of write partial transactions will be performed. If a series of contiguous writes are written to a WC memory region (such as a copy) a series of write line transactions will be performed. PAC further optimizes this by providing write combining for CPU-to-PCI or CPU-to-AGP write transactions. If the target of CPU writes is the PCI memory, data is combined and sent to the PCI bus as a single write burst. The same concept applies to CPU writes to AGP memory. The WC writes that target DRAM are handled as regular main memory writes.

Note: The application of the WC memory attribute is not limited to the frame buffer and that PAC implements combining for any CPU-to-PCI or CPU-to-AGP posted write, independent of the WC memory attribute.

The PAC host bridge allows an additional level of concurrency for CPU Write accesses to WC space on PCI during the time when the I/O bridge (i.e., PIIX4) prevents posting of the writes (via PHLD#/PHLDA# protocol) destined to UC (uncacheable space) located on PCI or ISA.

The PAC defers Stop Grant Acknowledge cycles generated by the processor in response to STPCLK# being asserted. The PAC completes the Stop Grant Acknowledge on the PCI bus and then issues a Defer Reply Transaction on the host bus to complete the Stop Grant Acknowledge cycle back to the processor. Once the Stop Grant Acknowledge has been completed on the PCI bus, there may be a delay in issuing the Defer Reply Transaction caused by high priority AGP traffic. This delay prevents the use of clock throttling as defined in the 82371AB PIIX4 with the PAC. Intel® 440EX AGPset system designers should not enable manual (BIOS control) or thermal (THRM# pin active) clock throttling as defined in 82371AB PIIX4 datasheet.

4.3 DRAM Interface

The 82443EX integrates a main memory DRAM controller that supports a 72-bit memory data interface (64-bit memory data). The DRAM types supported are Extended Data Out (EDO), and Synchronous DRAM (SDRAM). PAC generates the Row Address Strobe/Chip Selects (RCSA#), Column Address Strobe/Data Mask (CDQA#), SCAS#, SRAS#, CKE, WE#, and Memory Addresses (MA) for the DRAM array. For CPU/PCI/AGP-to-DRAM cycles, the address and data flows through PAC. PAC generates data on the MD bus for writes, and accepts data on this bus during reads. The PAC DRAM interface operates synchronously to the CPU clock. The DRAM controller interface is fully configurable through a set of control registers.

PAC supports industry standard 64-bit wide DIMM modules with EDO or SDRAM devices. Fourteen memory address signals (MAx[13:0]) allow PAC to support a wide variety of commercially available DIMMs. Both symmetrical and asymmetrical addressing are supported. four RCS# lines permit up to four 64-bit wide rows of DRAM. For write operations of less than a QWord, PAC will perform a byte-wise write. PAC supports 50 ns and 60 ns EDO DRAMs, 66-MHz SDRAMs with CL2 and CL3, and supports both single and double-sided DIMMs.

Refresh functionality (DRAM refresh rate is 1 refresh/15.6 μ s) is provided and there is a seven deep refresh queue with three levels of request priority. The refresh queue can be disabled, resulting in a high priority refresh request for every time-out. If the queue is enabled, the refresh request priority will work as follows:

- The high priority refresh request asserts when the queue is full and takes priority over all other DRAM operations.
- The medium priority request asserts when 4 queue slots are filled and takes priority over all other DRAM operations except AGP expedites.
- Finally, the low priority request asserts when 1 queue slot is filled and only executes if there are no other DRAM operations in progress or pending.

The DRAM interface of PAC is configured by the Aperture Base Configuration Register, Graphics Aperture Remapping Table Base Register, AGP Control Register, PAC Configuration Register, Memory Buffer Strength Control Register, DRAM Control Register, DRAM Timing Register, DRAM Row Type Register, and DRAM Row Boundary (DRB) Registers.

The DRAM configuration registers control the DRAM interface to select EDO DRAM or SDRAM DRAMs, RAS timings, and CAS rates. The four DRB registers define the size of each row in the memory array, enabling PAC to assert the proper $RCSA\#/RCSB\#$ line (Row Address A & B#/Chip Select#), for accesses to the array. PAC closes the page when there are no more DRAM requests and the DRAM arbiter (conceptual) enters the IDLE state. PAC does, however, hold the last accessed memory page open for PCI/AGP-to-DRAM read accesses until there is a page miss or refresh.

Seven Programmable Attribute Map (PAM) registers are used to specify the PCI enable, and read/write status of the memory space between 640 KB and 1 MB. Each PAM Register defines a specific address area enabling the system to selectively mark specific memory ranges as read only, write only, read/write, or disabled. PAC supports one fixed memory hole selectable as either from 512 KB to 640 KB or from 15 MB to 16 MB in main memory. The SMRAM memory space is controlled by the SMRAM control register. This register selects if the SMRAM space is enabled, opened, closed, or locked.

Note: RSTIN# should be inverted and tied to the output enable of the tri-state buffer that drives the CKE signal to the DIMMs. Thus, the tri-state buffer will tri-state and the pull-up resistors will pull CKE high (and the DIMMs can finish the cycle). This causes the SDRAM DIMMs to tri-state.

4.3.1 DRAM Organization and Configuration

In the following discussion the term row refers to a set of memory devices that are simultaneously selected by a $RCSA\#/CS\#$ signal. PAC supports a maximum of 4 rows of memory. A row may be composed of one or more discrete DRAM devices (e.g., planar motherboard memory), or single-sided or double-sided DIMM modules arranged in sockets on the motherboard.

Note: The main DRAM design target is EDO/SDRAM configuration using 168-pin unbuffered DIMMs.

To create a memory array certain rules must be followed. The following set of rules allows for optimum configurations.

Rules for populating a PAC Memory Array

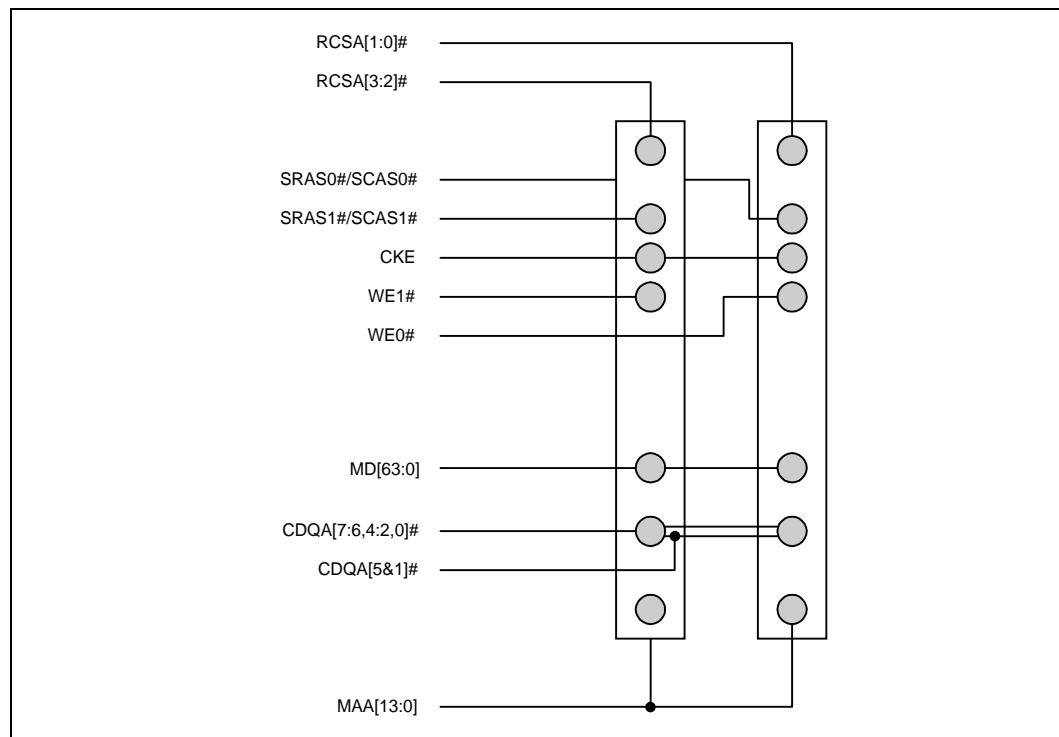
- DIMM sockets can be populated in any order. However, to take advantage of potentially faster MA timing it is recommended to populate sockets in order.
- SDRAM and EDO DIMMs can be mixed within the memory array.
- The DRAM Timing register, which provides the DRAM speed grade control for the entire memory array, must be programmed to use the timings of the slowest DRAMs installed.

PAC (EX) Memory Array Configuration:

PAC offers multiplexed memory interface signals to support a maximum memory size of 256 MB (EDO) or 256 MB (SDRAM).

Memory Configuration: Enables up to 4 rows with two copies of Memory Address signals. Two SRAS#, SCAS# and WE# signals are provided to support 2 DS DIMM sockets. This configuration supports Single-Sided and Double-Sided x8 and x16 DIMMs. The 82443EX Configuration interface signals are shown in [Figure 4-2](#).

Figure 4-2. 82443EX Configuration (Small Memory Array)



In the 82443EX memory configuration, MAA[13:0] is connected to DIMM sockets 0 and 1. No external buffering is needed on the memory control and address signals.

One CKE signal provided by PAC is buffered and connected to each DIMM socket. Use a CMOS buffer to provide copies of the CKE signal. three copies of the WE# signal are provided by PAC, and one is connected to each DIMM socket.

The signal connections shown will support both EDO DRAM and SDRAM in the same memory array.

[Table 4-2](#) provides a summary of the characteristics of memory configurations supported by PAC. Minimum values listed are obtained with single-density DIMMs and maximum values are obtained with double-density DIMMs. The minimum values used are also the smallest upgradable memory size. [Table 4-2](#) assumes Unbuffered EDO DRAM DIMMs and Unbuffered SDRAM DIMMs. The minimum memory size is for one row populated. The maximum memory size is 4 rows.

Table 4-2. Minimum (Upgradable) and Maximum Memory Size for each configuration

DRAM Tech.	DRAM Depth	DRAM Width	DRAM DIMM		DRAM Addressing	Address Size		DRAM Array Size	
			SD	DD		Row	Col	82443EX Config	
4M EDO	1M	4	1Mx72	2Mx72	Symmetric	10	10	---	---
16M EDO	1M	16	1Mx72	2Mx72	Symmetric	10	10	8 MB	64 MB
16M EDO	1M	16	1Mx72	2Mx72	Asymmetric	12	8	8 MB	64 MB
16M EDO	2M	8	2Mx72	4Mx72	Asymmetric	11	10	16 MB	128 MB
16M EDO	2M	8	2Mx72	4Mx72	Asymmetric	12	9	16 MB	128 MB
16M EDO	4M	4	4Mx72	8Mx72	Symmetric	11	11	---	---
16M EDO	4M	4	4Mx72	8Mx72	Asymmetric	12	10	---	---
64M EDO	2M	32	2Mx72	4Mx72	Asymmetric	11	10	16 MB	128 MB
64M EDO	2M	32	2Mx72	4Mx72	Asymmetric	12	9	16 MB	128 MB
64M EDO	2M	32	2Mx72	4Mx72	Asymmetric	13	8	16 MB	128 MB
64M EDO	4M	16	4Mx72	8Mx72	Symmetric	11	11	32 MB	256 MB
64M EDO	4M	16	4Mx72	8Mx72	Asymmetric	12	10	32 MB	256 MB
64M EDO	8M	8	8Mx72	16Mx72	Asymmetric	12	11	64M	256 MB
64M EDO	16M	4	16Mx72	32Mx72	Symmetric	12	12	---	---
16M ¹ SDRAM ¹	1M	16	1Mx72	2Mx72	Asymmetric	11	8	8 MB	64 MB
16M ¹ SDRAM ¹	2M	8	2Mx72	4Mx72	Asymmetric	11	9	16 MB	128 MB
64M ¹ SDRAM ¹	4M	16	4Mx72	8Mx72	Asymmetric	11	10	32 MB	256 MB
64M ¹ SDRAM ¹	4M	16	4Mx72	8Mx72	Asymmetric	13	8	32 MB	256 MB
64M ¹ SDRAM ¹	8M	8	8Mx72	16Mx72	Asymmetric	13	9	64 MB	256 MB
64M ² SDRAM ¹	4M	16	4Mx72	8Mx72	Asymmetric	12	8	32 MB	256 MB
64M ² SDRAM ¹	8M	8	8Mx72	16Mx72	Asymmetric	12	9	64 MB	256 MB

NOTES:

1. 2-bank SDRAM DIMMs.
2. 4-bank SDRAM DIMMs.

Supported DRAM Types

PAC supports both EDO (Extended Data Out) DRAM and SDRAM (Synchronous DRAM). PAC supports 2-KB page size and page mode is always active. PAC supports non-ECC types of EDO and SDRAM.

Extended Data Out (or Hyper Page Mode) DRAM is designed to improve the DRAM read performance. The EDO DRAM holds the memory data valid until the next CAS# falling edge. With EDO, the CAS# precharge overlaps the memory data valid time. This allows CAS# to negate earlier while still satisfying the memory data valid window time.

Synchronous DRAM (SDRAM), as the name suggests, is based on the synchronous interface between the DRAM controller and DRAM components. RAS#, CAS#, WE#, and CS# are pulsed signals driven by the DRAM controller and sampled by the DRAM components at the positive clock edge of an externally supplied clock (synchronous to 66-MHz system clock).

4.3.1.1 Configuration Mechanism for DIMMs

PAC DRAM Controller uses the Serial Presence Detect (SPD) mechanism for memory array configuration, as defined in the JEDEC 168-pin DIMM Standard Specification.

Note: It is very difficult to program the 82443EX DRAM Timing Register (Register 58h, Device #0) and the DRAM Buffer Strength register (Register 6C–6Fh, Device #0) without information garnered using Serial Presence Detect (SPD). Thus, support for SPD in a PAC memory array is required.

The system BIOS must program the DRAM size, type, timing, and buffer strength registers in the 82443EX. It gathers this information by the Serial Presence Detect (SPD) mechanism.

DRAM Configuration is performed by the BIOS, which follows these six steps:

1. The system BIOS must loop through the rows of memory (4 rows for 82443EX Memory Configuration) reading Serial Presence Detect (SPD) data. This will allow it to determine whether each DIMM in the array is single or double sided. The system BIOS must also determine the type of memory contained in each row, and set the DRAM Type registers accordingly (DRT—Device #0, Register 55–56h). Also, note that, at this time, system BIOS should determine the SLOWEST CAS Latency of all of the available SDRAM DIMMs in the array.
2. BIOS must next loop through the rows of memory, initialize and configure each row of SDRAM. Note that the SDRAM DIMMs will ALL be programmed to either CAS Latency=2 or CAS Latency=3; whichever is the SLOWEST DIMM found in step 1.
3. BIOS must next loop through the rows of memory, reading SPD data to determine the DRAM size. The DRB's (DRB[7:0]—device #0, register 60–67h) can now be set. Additionally, several different bytes of SPD data can be read to determine the timing values to be used when programming the memory timing register (DRAMT—device #0, register 58h) and to determine if ECC can be enabled (if all available DIMM's support ECC).
4. BIOS must next program the Memory Buffer Strength Control Register (MBSC—device #0, register 6C–6Fh). To program this register properly, additional bytes of SPD data must be read for each row of memory.
5. BIOS can use the data found in step 3 to program the DRAM timing register (DRAMT—device #0, register 58h).

4.3.2 DRAM Address Translation and Decoding

The 82443EX translates the address received on the host bus to an effective memory or PCI address. This translation takes into account memory holes and the normal host to memory or AGP/PCI address. PAC supports a maximum of 64-Mbit DRAM device. PAC supports the DRAM page size of the smallest density DRAM that can be installed in the system. For 72-bit DIMMs, the overall DRAM DIMM page size is 8 KB. The page offset address is driven over MA[8:0] when driving the column address. MAX[13:0] are translated from the address lines A[26:3] for all memory accesses. The multiplexed row/column address to the DRAM memory array is provided by the MAX[13:0] signals. The MAX[13:0] bits are derived from the host address bus, as defined by Table 4-3, for symmetrical and asymmetrical DRAM devices.

Table 4-3. DRAM Address Translation

		Memory Address													
		13	12	11	10	9	8	7	6	5	4	3	2	1	0
Row Size	Row	A24	A23	A12	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A11
8MB	Col_s			A12	P			A10	A9	A8	A7	A6	A5	A4	A3
	Col_e	A24	A23	A26	A12	A22	A12	A10	A9	A8	A7	A6	A5	A4	A3
16MB	Col_s			A12	P		A23	A10	A9	A8	A7	A6	A5	A4	A3
	Col_e	A24	A23	A26	A12	A12	A23	A10	A9	A8	A7	A6	A5	A4	A3
32MB	Col_s	A24	A23	A12	P	A24	A23	A10	A9	A8	A7	A6	A5	A4	A3
	Col_e	A24	A23	A26	A12	A24	A23	A10	A9	A8	A7	A6	A5	A4	A3
64MB	Col_s	A24	A23	A12	P	A26	A25	A10	A9	A8	A7	A6	A5	A4	A3
	Col_e	A24	A23	A26	A25	A24	A23	A10	A9	A8	A7	A6	A5	A4	A3
128MB	Col_s	A24	A23	A12	P	A26	A25	A10	A9	A8	A7	A6	A5	A4	A3
	Col_e	A24	A23	A26	A25	A24	A23	A10	A9	A8	A7	A6	A5	A4	A3

NOTE:

1. Col_s=SDRAM Column Address Mapping. Col_e=EDO Column Address Mapping. P=denotes the pre-charge bit for SDRAM.

Table 4-4. 82443EX EDO DRAM Addressing

Memory Organization	Addressing	Address Size
4 MB		
1M x 4	Symmetric	10 x 10 ¹
16 MB		
1M x 16	Symmetric	10 x 10
	Asymmetric	12 x 8
2M x 8	Asymmetric	11 x 10
	Asymmetric	12 x 9
4M x 4	Symmetric	11 x 11 ¹
	Asymmetric	12 x 10 ¹
64 MB		
2M x 32	Asymmetric	11 x 10
	Asymmetric	12 x 9
	Asymmetric	13 x 8
4M x 16	Symmetric	11 x 11
	Asymmetric	12 x 10
8M x 8	Asymmetric	12 x 11
16M x 4	Symmetric	12 x 12 ¹

NOTE:

1. Single-Sided Unbuffered DIMMs.

Table 4-5. PAC SDRAM Addressing

Memory Organization	Addressing	Address Size	Bank Select
16 Mb (2-Bank)			
1M x 16	Asymmetric	11 x 8	1
2M x 8	Asymmetric	11 x 9	1
4M x 4	Asymmetric	11 x 10 ¹	1
64 Mb (2-Bank)			
4M x 16	Asymmetric	11 x 10	1
		13 x 8	1
8M x 8	Asymmetric	13 x 9	1
64 Mb (4-Bank)			
4M x 16	Asymmetric	12 x 8	2
8M x 8	Asymmetric	12 x 9	2

NOTE:

1. Single-Sided DIMMs.

4.3.3 Refresh Cycles (CAS# Before RAS#)

PAC supports CAS#-before-RAS# DRAM refresh cycles and generates refresh requests. When a refresh request is generated, it is placed in a 4 entry queue (this queue can be disabled in the DRAM Control Register, offset 57h, bit 6). PAC services a refresh request when the refresh queue is not empty and the controller has no other requests pending. When the refresh queue has accumulated four requests, refresh becomes the highest priority request and is serviced next by PAC.

PAC implements a “smart refresh” algorithm. Refresh is only performed on rows that are populated. In addition, PAC supports refresh staggering to minimize the power surge associated with refreshing a large DRAM array. PAC also supports concurrent refresh cycles in parallel with Host to AGP or PCI cycles.

4.3.4 DRAM Subsystem Power Management

PAC supports desktop-level power management capability. The DRAM controller within PAC supports power management of the DRAM array. Specific power management capability is engaged only when the memory array is populated with SDRAM (this includes mixed EDO/SDRAM memory array configurations), and the SPME bit of the DRAMC Register is set (bit 4 of configuration address 57h). The DRAM power management operates as follows:

PAC enters the SUSPEND state when:

- The SPME bit of the DRAMC Register is set (bit 4 of configuration address 57h).
- PAC completes all pending requests from all request queues, including the refresh queue.
- PAC closes active SDRAM pages according to PAC DRAM Paging Policy.
 - After 4 Host clocks upon entering this state, the SDRAM CKE signal is negated and all memory rows populated with SDRAM enter a Power Down Mode.
 - PAC remains in the SUSPEND state until any request, other than a low priority Refresh request, is pending.
 - When in the SUSPEND regime, refresh requests are not serviced until they become a high-priority, i.e., 4 requests are queued.
 - When a high-priority refresh request is generated (4th request queued), the DRAM controller asserts CKE. Four clocks after CKE is reasserted, the DRAM controller starts servicing refresh requests. Refreshes are serviced back-to-back (all four of them) until the refresh request queue is empty.
 - Four clocks after reaching Idle state the DRAM controller negates CKE again (SDRAM components enter Power Down Mode again). The system stays in this state until 4 refresh requests are accumulated (typically after $4 \times 15.6 \mu\text{sec}$) and then PAC repeats steps 3 & 4.

The SUSPEND state is exited normally after any of the snoopable or non-snoopable request queues present an active request.

4.3.5 Serial Presence Detect (SPD) For SDRAM

A Pentium® II / Intel® 440EX AGPset Platform requires the support of Serial Presence Detect (SPD) for SDRAM DIMMs in the memory array. SPD is needed to gather specific DIMM information to program the Memory Buffer Strength Control Register. This information is ONLY obtainable through Serial Presence Detect.

A 82443EX (PAC) memory subsystem is dependent on the type and size of DRAM in the array. To properly program the DRAM Controller Registers, specific information is needed during Boot time. Information such as DRAM size (x4, x8, or x16), will affect the values programmed in the Memory Buffer Strength Register (Register 6C-6Fh, Device #0).

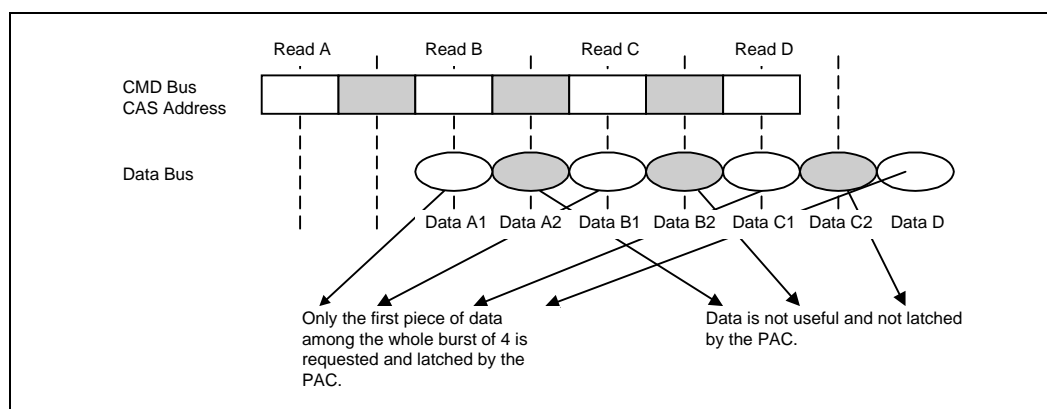
- Why is SPD needed? Previously, a BIOS algorithm could determine DRAM size and type dynamically. Buffer strength programming was limited to memory address signals only, based on the number of rows populated. In the PAC, every memory interface signal's buffer strength is programmable. This allows the PAC to support a wide range of DRAM types and sizes. To program these buffer strengths correctly, the BIOS needs information on DRAM size. For example, signal loading is greater when the array is populated with x4 DRAMs than x16 DRAMs. Thus, memory interface signal strengths will need to be greater.
- Can SPD be Bypassed by disabling a row? This is not an option. If the BIOS detects a row of SDRAM memory which does not support SPD, even if this row is disabled, signal loading from the non-SPD SDRAM DIMM exists, and the MBSR can not be programmed reliably.
- Can an Error Message report a non-SPD DIMM? Video is initialized during BIOS post testing well after DRAM is initialized. If the MBSR is not programmed properly, the BIOS post test will not make it far enough to report the error to the screen.

The memory subsystem must be designed to support Serial Presents Detect to properly program the Memory Buffer Strength Register. Also, ensure the SDRAM DIMMs used comply with the latest SPD JEDEC Specification, revision: December, 1996

4.3.6 Single Clock Command Mode For SDRAM

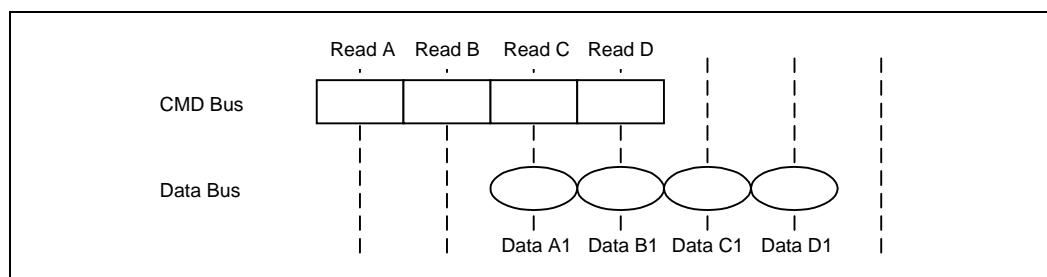
The graphics subsystem will potentially require data transfers of less than or equal to one QWord (8 bytes) per command consecutively during the memory access. One QWord is referred to a piece of data in a 64-bit memory interface. With CAS latency (CLT) equal to 2, there will be a 2 clock (3 clock with CLT=3) delay between the read command and data cycles. Without supporting single clock command mode, the system will not be able to achieve 1111 effective burst rate for this type of data access pattern. As illustrated in [Figure 4-3](#), effective burst rate becomes 2222 with respect to the requested data if single clock command mode is not enabled.

Figure 4-3. Single Clock Mode Disabled



To achieve the burst rate of 1111 during the above scenario, the memory controller needs to support single clock command mode. The output of each command interrupts the ongoing burst or begins at the end of 1st data cycle. With the support of single clock command mode, the timing is shown in Figure 4-4.

Figure 4-4. Single Clock Mode Enabled



Note that the support of SDRAM single clock command mode is an advanced feature for Intel® 440EX AGPset systems on a 3 DIMM design. During a burst pattern of 4 pieces of 64-bit data, if at least the first 2 pieces of data are needed, a Intel® 440EX AGPset system can still achieve a burst rate of x111 for SDRAM operation without supporting or enabling single clock command mode.

4.3.6.1 Enabling Single Clock Command Mode

MA Wait State(MAWS). This bit selects FAST or SLOW MA bus timing. Note that SLOW timing is equal to FAST + 1 in terms of clock numbers for EDO. For SDRAM, FAST timing means zero MA wait state. This setting will enable the PAC to support single clock command mode; SLOW means one MA wait state, which forces the PAC to support the normal operation only (one command per two clocks).

4.3.6.2 Restrictions For Supporting Single Clock Command Mode

To support single clock command mode in the 82443EX memory configuration, the memory controller needs to toggle memory address (CAS assertions) on every clock edge. This tightens memory AC timing requirements on the address signals. Because the loading of SDRAM modules has the direct effect on the AC timing, the maximum loading of memory module is limited while supporting single clock command mode. Table 4-6 shows the population rules and types (x8, x16) of DIMM module that can be supported for running single clock command mode.

Table 4-6. Restrictions For Single Clock Command Mode Support

82443EX Memory config (2DIMMs)			Types of SDRAM module	
DIMM Row#	MAA #2 3/2	MAA #1 1/0	SS/DS x8 DS x16 nonECC	SS x16 DS x32 nonECC
		x	no	yes
	x		no	yes
			no	yes
	x		no	yes
		x	no	yes
	x	x	no	no
	x	x	no	no

NOTE:

1. x means populated, SS means single-sided, DS means double-sided.

4.3.6.3 Conclusion For Single Clock Command Mode Support

For a 2 DIMM design, as shown in [Table 4-6](#), set the MAWS bit to 1 to support SDRAM single clock command mode when DIMM sockets on the MAA copy is populated with:

- maximum 1 row of (0,1,2,3), and/or maximum 1 row of (4,5) for x16, non-ECC SDRAM

4.3.7 Support For 2 and 4 Banks SDRAM

The PAC supports both 2 and 4-bank SDRAM components. However, regardless of populating either 2 or 4-bank SDRAM DIMMs in a Intel® 440EX AGPset system, the SDRAM interface of the PAC can only open 2 pages at any time. The PAC is not able to open 4 pages simultaneously, even a 4-bank SDRAM module is used.

4.4 Data Integrity Support

Several data integrity features are included in PAC. This includes Parity generation and checking on the PCI Bus and AGP (for PCI transactions).

- **PCI Bus.** PAC implements parity generation/checking as defined by the PCI Specification. PAC can generate parity errors via the PERR# pin, if enabled via the PCICMD register. The PCISTS register logs error information related to the PERR# assertion. PERR# error conditions can be reported via the SERR# signal, if enabled in the ERRCMD register.
- **AGP Bus.** For operations on the AGP interface using PCI protocol, PAC supports Parity generation/checking as defined by the PCI Specification. PAC can generate parity errors via the GPERR# pin if this capability is enabled by the PCICMD1 (PCI Command) register. Bits of the PCISTS1 (PCI Status) register provide status information related to the GPERR# assertion. The ERRCMD (Error Command) register provides the capability to configure PAC to propagate GPERR# signaled error conditions onto the system SERR# signal.
- **Main Memory DRAM Protection Modes.** PAC (82443EX) supports non-ECC modes of data protection of the DRAM array: In this mode, there is no provision for protecting the integrity of data within the DRAM array.

4.5 PCI Interface

The PAC Host Bridge provides a PCI Bus interface that is compliant with the *PCI Local Bus Specification*. The implementation is optimized for high-performance data streaming when PAC is acting as either the target or the initiator on the PCI bus.

Note: PAC can generate retry or disconnect cycles when accessed as a PCI target.

Note: PAC can be locked as a PCI target device as defined by the PCI protocol. When locked from the PCI side, PAC disables CPU bus accesses by asserting BPRI#. The PCI-to-DRAM lock can not be established until all pending CPU-to-PCI cycles are complete. The CPU bus BPRI# mechanism is normally used to support deterministic PAC response during PCI reads. Since the first access of a locked PCI sequence must be a read, the same mechanism is used to support deterministic establishment of the lock for DRAM.

Note: PAC supports the Delayed Transaction mechanism defined in the *PCI Local Bus Specification*. The process of latching all information (PCI address and command) required to complete a transaction, terminating with a retry, and then completing the request without holding the bus master in wait states is referred to as a delayed transaction.

Note: When the host accesses the PCI, PAC can retry CPU-to-PCI cycles, if necessary.

Note: PAC does not support the Distributed DMA protocol supported by the PIIX4.

4.6 AGP Interface

For the definition of AGP Interface functionality (protocols, rules and signaling mechanisms, as well as the platform level aspects of AGP functionality), refer to *AGP Interface Specification, Revision 1.0*. This document focuses only on PAC specifics of the AGP interface functionality.

System Coherency/Snooping

The coherency in a system is normally maintained for all accesses directed to main memory (i.e., typically treated as a cacheable memory). The AGP modifies these rules to minimize the overall impact of the coherency management overhead on system performance. It allows accesses to main memory that do not require coherency management (i.e., snoop requests on the host bus).

PCI Operations on AGP

The AGP Interface supports PCI operations as defined by the PCI Specification. Electrically, only 66-MHz PCI operations are supported.

- **Host Bridge Target Operations.** As a target of PCI-initiated cycles via AGP, PAC responds only to memory accesses. These accesses are always directed to DRAM.
 - **Memory Read, Memory Read Line, Memory Read Multiple Operations.** PAC only responds to memory read cycles that target DRAM space. *Reads to the PCI bus from an AGP device are not supported.*
 - **Memory Write, Memory Write and Invalidate Operations.** PAC responds to PCI memory writes that target either the DRAM space or the PCI Bus space.

- **Configuration Read and Write Operations.** AGP generated configuration cycles are ignored by PAC.
- **PAC Disconnect Conditions.** PAC generates disconnect according to the AGP Specification rules when being accessed as a target from the AGP interface (using PCI semantics). The AGP transaction issued using PCI semantics is retried by PAC based on the 32-clock rule only if there is a pending AGP-to-DRAM request issued using AGP protocol semantics (using PIPE# or side-band request).
- **PAC Retry Conditions.** In the absence of AGP requests, a PCI request is kept in wait states until it gets serviced or potentially retried due to buffer management requirements (i.e., CPU-to-AGP writes occurs before AGP-to-DRAM snoopable read gets serviced). PAC, as an AGP target, retries the initial data phase of the PCI access when:
 - PAC DRAM is locked from the CPU side or by an agent on the PCI Bus.
 - There is a CPU-to-AGP posted write data that must be flushed before PAC can service AGP PCI-to-DRAM reads. This also includes CPU-to-AGP deferred writes.
 If, after completing the initial data phase, it takes longer than 8 AGP clock periods to complete the particular data phase, the consecutive data phase(s) are disconnected.
- **Fast Back-to-Back Transactions.** PAC, as a target, accepts fast back-to-back cycles from the AGP master accessing different agents during a back-to-back sequence. *As an initiator, PAC does not generate a fast back-to-back cycle.*
- **Delayed Transaction.** When an AGP-to-DRAM read cycle is retried by PAC, it will be processed internally as a Delayed Transaction. PAC supports the Delayed Transaction mechanism on the AGP interface as defined in the PCI 2.1 Specification.
- **Host Bridge Initiator Operations.** PAC translates valid CPU bus commands and PCI Bus write cycles destined to the AGP bus into AGP bus requests. For all CPU-to-AGP transactions, PAC is a non-caching agent since PAC does not support cacheability on the AGP Bus. However, PAC must respond appropriately to the CPU bus commands that are cache oriented. PAC will forward writes from the PCI bus to the AGP Bus.
- **PCI Compatibility and Restrictions.** The AGP Bus interface implementation is compatible with PCI Specification, Revision 2.1. Transactions that are crossing from the AGP Bus to the PCI Bus are limited *only to memory writes*.

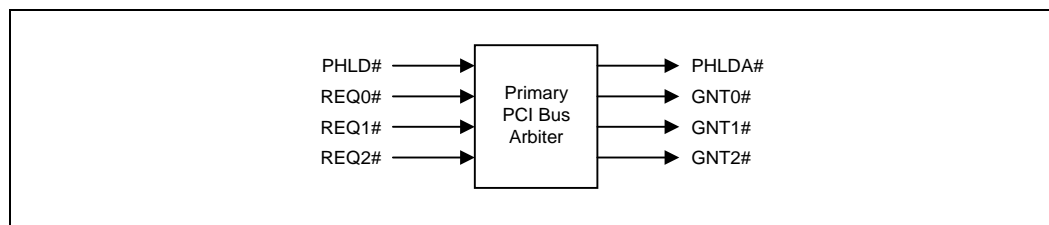
4.7 Arbitration and Concurrency

PAC enhances system performance by providing a high level of concurrency (capability of running multiple operations simultaneously). System buses, as key resources, are arbitrated independently. Independent buses allow multiple transactions to be issued simultaneously. As long as transactions on the independently arbitrated buses do not compete for the common resources, they can proceed in parallel.

PAC distributed arbitration model permits concurrency between the host bus, PCI bus, AGP bus, and the DRAM interface. The arbitration algorithms and policies are designed to fulfill particular requirements of the agents sharing the resources. They may favor different aspects of system performance: low bus/resource acquisition latency, optimized instantaneous peak bandwidth, optimized sustained bandwidth, etc.

For the PCI bus, PAC supports three PCI masters in addition to the PIIX4 I/O bridge (Figure 4-5). REQ[2:0]#/GNT[2:0]# are used for the three PCI masters and PHLDA# are used for PIIX4.

Figure 4-5. PCI Bus Arbiter



The PCI arbiter is based on a round robin scheme. PAC PCI Master interface (i.e., the Host) competes for PCI bus ownership only when it needs to perform CPU-to-PCI or AGP-to-PCI transactions. Since most CPU-to-DRAM and AGP-to-DRAM accesses can occur concurrently with PCI traffic, they do not consume PCI bandwidth. The PAC PCI arbiter uses a complete bus lock mechanism to implement PCI exclusive access operations. The arbiter implements a fairness algorithm in compliance with the PCI Local Bus Specification. The PCI arbiter's bus parking policy allows the current PCI bus owner, except for the I/O bridge, to maintain ownership of the bus as long as no request is present from any other agent.

Multi-Transaction Timer (MTT) Mechanism

The PAC PCI arbiter implements an additional control for providing a guaranteed slice of PCI bus bandwidth for bus agents which perform accesses to fragmented blocks of data and/or have real-time data transfer requirements. This mechanism is called the Multi-Transaction Timer (MTT).

The MTT is a programmable timer that facilitates a guaranteed time slot within which a PCI initiator can execute multiple back-to-back transfers, within the same arbitration cycle, to nonconsecutive regions in memory.

This capability, supported at the AGPset level, enables the implementation of lower cost peripherals. The bandwidth guarantee permits the reduction of on-chip data buffering in peripherals used for multimedia and similar applications (e.g., video capture subsystems, ATM interface, Serial Bus host controllers, RAID SCSI controllers, etc.).

PCI Bus Arbitration Policy and I/O Bridge Support

PAC supports the PIIX4 I/O bridge via the PHLDA# and PHLDA# signals, with or without an external I/O APIC. PIIX4 is a special case of a PCI initiator. Because it functions as a bridge to a standard I/O expansion bus (i.e., ISA bus), it imposes specific arbitration and buffer management requirements to enable optimal concurrency between buses.

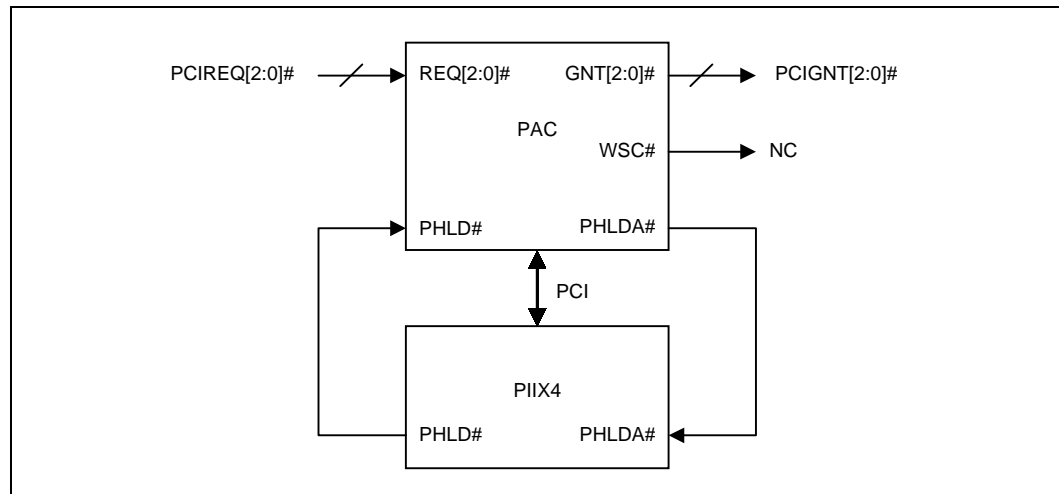
PAC and PIIX4 support the passive release mechanism. This mechanism avoids the shortcoming of early I/O bridges that did not allow other PCI agents to access the PCI bus while an ISA initiator owned the ISA bus. Since ISA initiators occupied the ISA bus for long and non-deterministic periods of time, PCI agents experienced the same long and non-deterministic latencies.

The PAC does not support internal disabling of PCI master bus request signals (REQX# or PHLDA#). The system designer must externally disable PCI master requests if they desire to support processor states which do not allow for snooping of host bus transactions (such as SLEEP).

PAC Configuration Examples

PAC supports one PAC-PIIX4 configuration. This section illustrates detailed signal connections:

Figure 4-6. PAC and PIIX4



4.8 System Clocking and Reset

4.8.1 Host Frequency Support

The Pentium II processor uses a clock ratio scheme where the host bus clock frequency is multiplied by a ratio to produce the processor's core frequency. PAC supports a host bus frequency of 66 MHz. The external synthesizer is responsible for generating the host clock. The Pentium II processor samples four signals: LINT[1:0], (INTR, NMI), IGNNE#, and A20M# on the inactive to active edge of RESET to set the ratio.

4.8.2 Clock Generation and Distribution

PAC receives two outputs of a clock synthesizer on the HCLKIN and PCLKIN pins. PAC uses these signals to clock internal logic and provide clocking control to PAC interfaces.

The clock signal requirements for the host clock are outlined in the 2.5V Processor Clock Driver Specification. The clock skew between two host clock outputs of the synthesizer must be less than 250 ps (@1.25V). The clock skew between two PCI clock outputs of the synthesizer must be less than 500 ps (@1.5V). In addition, the host clocks should always lead the PCI clocks by a minimum of 1 ns and a maximum of 4 ns. PAC requires a 45%/55% maximum output duty cycle. A maximum of 250 ps jitter must be maintained on the host clocks going from cycle to cycle.

PAC does not support stopping of the HCLKIN or PCLKIN clock signals during operation. If either clock is stopped, the PAC must be reset to ensure proper operation.

4.8.3 System Reset

There are two types of system reset. A “hard” reset causes the entire system to reset and is initiated by the PIIX4. A hard reset can be initiated by either PWROK being asserted (from the power supply/reset button) or by writing to the PIIX4 (I/O address CF9h). A “soft” reset only resets the CPU.

A soft reset can be initiated by either PAC or the PIIX4. There are several ways to initiate a soft reset. PIIX4 can initiate a soft reset via a write to the PIIX4 Reset Control Register or an I/O write to port 92h. Additionally, the PIIX4 initiates a soft reset when RCIN# is asserted from the keyboard controller. PAC initiates a soft reset when the RCPUR bit is written. Both the PIIX4 and PAC initiate soft reset via the INIT signal to the processor. Thus, the INIT signal from the PIIX4 should be tied to the INIT signal from PAC and routed to the CPU(s).

4.8.4 PAC Reset Structure

The system reset structure is shown in [Figure 4-7](#).

4.8.5 Hard Reset

Hard Reset is defined as a reset where all the components in the entire system are reset. *There are two sources of hard reset in the system:*

- During Power-up, PWROK asserted (typically by the power supply) 1 ms after the system power has stabilized.
- I/O write to the PIIX4 Reset Control register (I/O address CF9h).

PIIX4 generates a hard reset for the system when the PWROK signal is sampled inactive (low). PIIX4 generates PCIRST# for both the AGP and PCI bus. PAC uses the PCIRST# input connected to the RSTIN# pin to generate CPURST# (for the Pentium II processor(s)), and CRESET# (to the frequency control logic and I/OAPIC). PAC asserts CPURST# and CRESET# when RSTIN# is sampled low, and continues assert CPURST# for 1 msec, and CRESET# for 1 msec plus 2 HCLKINs, after the rising edge of the RSTIN# signal. The assertion of CPURST# must be synchronous to the HCLKIN.

PIIX4 can be programmed to generate a hard reset through the Reset Control register (I/O Address CF9h). PIIX4 drives PCIRST# low for 1 msec and the reset continues as described above.

PAC configuration straps on the CKE pins are sampled on the rising edge of RSTIN#.

Figure 4-7. Reset Structure for Intel® 440EX AGPset with PIIX4

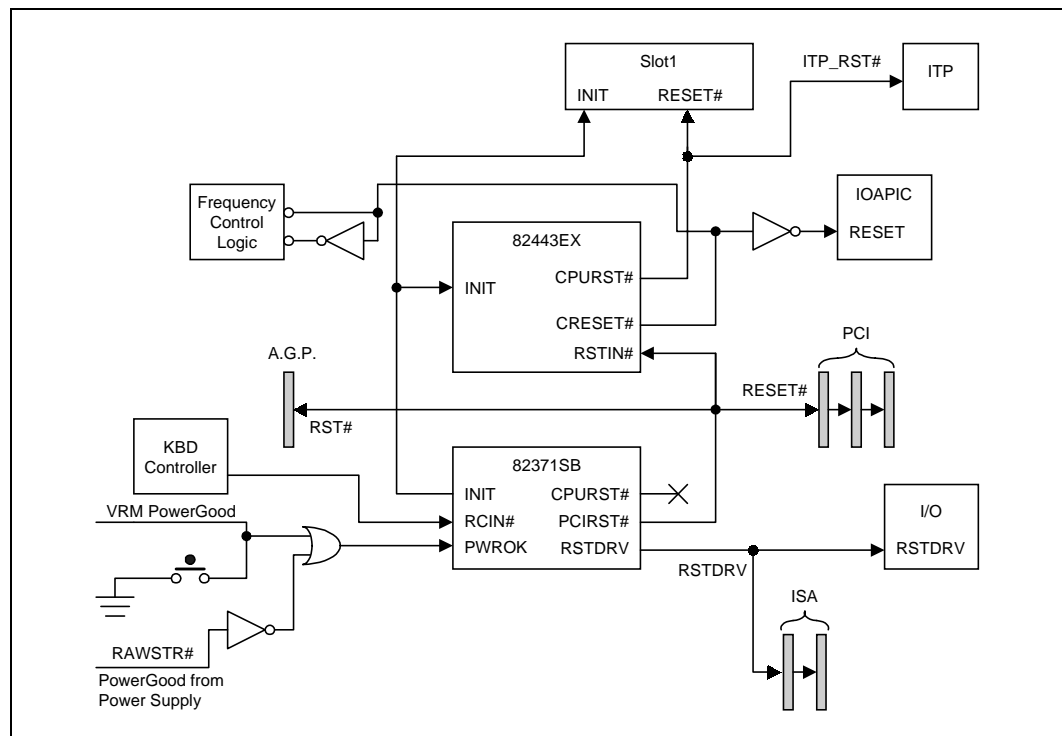
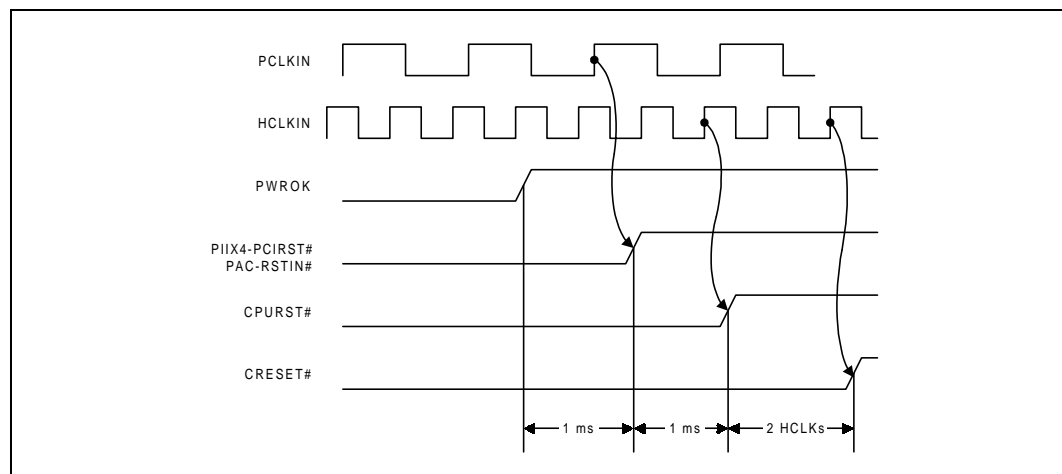


Figure 4-8. PAC Hard Reset Timing



4.8.6 Soft Reset

A soft reset is defined as only resetting the CPU (no other devices in the system are reset). *There are five sources of soft reset in the system:*

- CPU shutdown bus cycle
- I/O write to the PAC Reset Control Register (offset 93h)
- I/O write to the keyboard controller
- I/O write to the PIIX4 port 92h
- I/O write to the PIIX4 Reset Control Register (I/O address CF9h)

When PAC detects a CPU shutdown bus cycle, it terminates the Host bus cycle with a TDRY#, with a no data response type as defined in the Pentium II processor datasheet. PAC then asserts the INIT# output for a minimum of 4 host clocks.

PAC can be programmed to generate a soft reset through the Reset Control Register (configuration offset 93h). PAC asserts INIT# for a minimum of 4 host clocks if bit 3=0, bit 1=1 and bit 2 is written from a 0 to a 1. A soft reset from the keyboard controller will be signaled into the PIIX4 through the RCIN# signal on the PIIX4. The PIIX4 will then generate the INIT signal active. A write to I/O port 92h, bit 0, also causes PIIX4 to assert INIT. A write to the PIIX4 Reset Control Register also causes PIIX4 to assert INIT.

The system combines PAC INIT# output with the PIIX4 INIT output as shown above to generate the INIT# signal for the CPU(s).

4.8.7 CPU BIST

PAC can be programmed to activate BIST mode of the CPU through the Reset Control Register (configuration offset 93h). If PAC activates the CPU's BIST function, a hard reset must then be initiated (after BIST completion). The BIST mode sets the IOQ depth of the processor and PAC to 1. This is not a valid operating condition for PAC.

Electrical Characteristics

5

This chapter contains the electrical and thermal specifications for the 82443EX PCI AGP Compliant Controller (PAC). The specifications include: absolute maximum ratings, thermal characteristics, DC characteristics, AC characteristics, and timing waveforms.

The Pentium® II processor bus introduces a variation of the low voltage GTL (Gunning Transceiver Logic) for signaling. For reliable operation, unused input pins must be tied to an appropriate signal level. Unused GTL+ inputs should be connected to VTT. Unused active low 3.3V tolerant inputs should be connected to 3.3V. Unused active high inputs should be connected to ground (VSS).

5.1 Absolute Maximum Ratings

Case Temperature under Bias	0oC to +100oC
Storage Temperature	-55oC to +150oC
Voltage on GTL+ & 3.3V tolerant Pins with Respect to Ground ²	-0.3 to VCC + 0.3 V
Voltage on PCI and 5.0V tolerant Pins with Respect to Ground	-0.3 to VCC _{PCI} ¹ + 0.3 V
3.3V Supply Voltage with Respect to Vss (VCC)	-0.3 to + 4.3 V
5.0V Supply Voltage with Respect to Vss (5V_BIAS)	-0.5 to + 6.5 V

1. VCC_{PCI} and VCC_{AGP} are the voltage levels on the PCI bus and AGP interface respectively. To ensure long term reliability of the device, worst case AC operating conditions would include supporting an overvoltage of +11.0V and undervoltage of -5.5V
2. Minimum D.C. input is -0.3V. During transitions the inputs may undershoot to -0.8V or overshoot to 0.8V over max VIH for a maximum period of 20 ns.

Warning: Stressing the device beyond the "Absolute Maximum Ratings" may cause permanent damage. These are stress ratings only. Operating beyond the "Operating Conditions" is not recommended and extended exposure beyond "Operating Conditions" may affect reliability.

5.2 Power Characteristics

Table 5-1. Power Characteristics

Functional Operating Range (VTT = 1.5V \pm 10%, Vcc = 3.3V \pm 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Unit	Notes
PEX	Thermal Power Dissipation for 82443EX		3.0	W	Note 1, @ 66 MHz/ 33MHz
I _{LEAK}	5.0V to 3.3V Power Supply Leakage Current		20	uA	Note 2
I _{DDQ}	Quiescent Power Supply Current for 82443EX		30	mA	Note 3, @ 0 MHz/0 MHz
I _{CC-EX}	Power Supply Current for 82443EX		1300	mA	Note 4, @ 66 MHz/33 MHz

NOTES:

1. This specification is a combination of core power (I_{CC}) and power dissipated in the GTL+ outputs and I/O. Please refer to the Application Note, *82443EX Thermal Design Considerations* for more information.
2. This parameter is specified at V_{CC5} (5V_BIAS) - V_{CC3} \leq 2.25V. In addition, to insure a proper power sequencing and protect the PAC internal circuitry, a 1 K Ω series resistor is recommended on the REV5V pin of PAC to 5V power source, and Zener diode is also recommended between 5V and 3.3V power source.
3. This is the maximum supply current consumption when all interfaces are idle and the clock inputs are turned off, typically with HCLKIN/PCLKIN running at 66/33 MHz the I_{DDQ} is 300mA
4. The I_{CC} specification does not include the GTL+ output current to ground Signal Groups

5.3 Signal Groupings

To ease discussion of the AC and DC characteristics, signals on the Intel® 440EX AGPset have been combined into groups of similar characteristics. These will be referred to in all subsequent discussion.

The following notations are used to describe the types of buffers used in Table 20:

GTL+	Open Drain GTL+ interface signal. Refer to the GTL+ I/O Specification for complete details
PCI	PCI bus interface signals. These signals are compliant with the PCI 5.0V Signaling Environment DC and AC Specifications
AGP	AGP interface signals. These signals are compatible with AGP Signaling Environment DC and AC Specifications
LVTTTL	Low Voltage TTL compatible signals. These are also 3.3V inputs and outputs.

Table 5-2. Signal Groups

Signal Group	Signal Type	Signals
(a)	GTL+ I/O	A[31:3]#, HD[63:0]#, ADS#, BNR#, DBSY#, DRDY#, HIT#, HITM#, HREQ[4:0]#, HTRDY#, RS[2:0]#,
(b)	GTL+ Output	CPURST#, BPRI#, DEFER#, BREQ0#
(c)	GTL+ Input	HLOCK#
(d)	LVTTL Input	PCLKIN
(e)	LVTTL(2.5V) Input	HCLKIN
(f)	LVTTL Output	RCSA[3:0]#, CDQA[7:0]#, SRAS[1:0]#, SCAS[1:0]#, MAA[13:0], WE[1:0]#, CRESET#, INIT#
(i)	LVTTL I/O	MD[63:0], CKE
(j)	PCI Output	PHLDA#, GNT[4:0]#
(k)	PCI I/O 5.0V tolerant	AD[31:0], DEVSEL#, FRAME#, IRDY#, C/BE[3:0]#, PAR, PERR#, PLOCK#, TRDY#, STOP#, SERR#
(l)	PCI Input 5.0V tolerant	PHLD#, REQ[4:0]#
(m)	GTL Reference	GTL_REFV
(s)	AGP Reference	VREFAGP
(n)	AGP Input	PIPE#, SBA[7:0], SBSTB, GREQ#, RBF#, GSERR#
(o)	AGP Output	ST[2:0], GGNT#
(p)	AGP I/O	GAD[31:0], GDEVSEL#, GFRAME#, GIRDY#, GTRDY#, GC/BE[3:0]#, GPAR, GPERR#, GSTOP#, ADSTB_A, ADSTB_B
(q)	TTL Input	RSTIN#

5.4 D.C. Characteristics

Table 5-3. D.C. Characteristics (Sheet 1 of 2)

Functional Operating Range (V_{TT} = 1.5V ± 10%, V_{CC} = 3.3V ± 5%; TCASE = 0°C to +100°C)

Symbol	Signal Group	Parameter	Min	Max	Unit	Notes
VIL1	(d),(i)	LVTTTL Input Low Voltage	- 0.3	0.8	V	1
VIH1	(d),(i)	LVTTTL Input High Voltage	2.0	V _{CC} + 0.3	V	2
VIL2	(k),(l)	PCI Input Low Voltage	-0.3	0.8	V	1
VIH2	(k),(l)	PCI Input High Voltage	2.0	V _{CC} + 0.3	V	2
VIL3	(a),(c)	GTL+ Input Low Voltage	-0.3	V _{REF} - 0.2	V	1
VIH3	(a),(c)	GTL+ Input High Voltage	V _{REF} + 0.2	1.8	V	2
VIL4	(p),(n)	AGP Input Low Voltage	-0.5	0.3V _{CC}	V	
VIH4	(p),(n)	AGP Input High Voltage	0.5V _{CC}	V _{CC} + 0.5	V	
VIL5	(q)	TTL Input Low Voltage	-0.3	0.8	V	1
VIH5	(q)	TTL Input High Voltage	2.0	V _{CC} + 0.3	V	2
VIL6	(e)	2.5V LVTTTL Input Low Voltage	-0.3	0.7	V	3
VIH6	(e)	2.5V LVTTTL Input High Voltage	1.7	2.625	V	3
VREFAGP	(s)	AGP Reference Voltage			V	4
VREF	(m)	GTL+ Reference Voltage	2/3V _{TT} - 2%	2/3V _{TT} + 2%	V	5
VOL1	(f)(i)	LVTTTL Output Low Voltage		0.4	V	
VOH1	(f)(i)	LVTTTL Output High Voltage	2.4		V	
VOL2	(j),(k)	PCI Output Low Voltage		0.4	V	
VOH2	(j),(k)	PCI Output High Voltage	2.4		V	
VOL3	(a),(b)	GTL+ Output Low Voltage		0.55	V	
VOH4	(o),(p)	AGP Output Low Voltage		0.1V _{CC}	V	
VOH4	(o),(p)	AGP Output High Voltage	0.9V _{CC}		V	
IOL1	(f)(i)	LVTTTL Output Low Current		3	mA	
IOH1	(f)(i)	LVTTTL Output High Current	-2		mA	
IOL2	(j),(k)	PCI Output Low Current		3	mA	
IOH2	(j),(k)	PCI Output High Current	-2		mA	
IOL3	(o),(p)	AGP Output Low Current		1.5	mA	
IOH3	(o),(p)	AGP Output High Current	-0.5		mA	
IOL4	(a),(b)	GTL+ Output Low Current	32	36	mA	
IIH1	(a),(c),(d), (e),(i),(k),(l), (q)	Input Leakage Current		+ 10	uA	

Table 5-3. D.C. Characteristics (Sheet 2 of 2)
Functional Operating Range (VTT = 1.5V \pm 10%, Vcc = 3.3V \pm 5%; TCASE = 0°C to +100°C)

Symbol	Signal Group	Parameter	Min	Max	Unit	Notes
IIL1	(a),(c),(d), (e),(i),(k),(l), (q)	Input Leakage Current		- 10	uA	
IIH2	(n),(p)	AGP Input Leakage Current		70	uA	V _{IN} = 2.7v
IIL2	(n),(p)	AGP Input Leakage Current		+/- 10	uA	0 < V _{IN} < V _{CC}
ILO1	(a)(b)	GTL+ Output Leakage Current		\pm 15	uA	6
ILO2	(f),(i),(j),(k), (o),(p)	Non-GTL+ Output Leakage Current		\pm 15	uA	6
CIN COUT	(n),(p),(k), (l),(i),(a),(c)	AGP Input Capacitance PCI Input Capacitance DRAM Input Capacitance GTL+ Input Capacitance		5 to 8 6 to 9 5 to 8 5 to 8	pF	FC = 1 MHz

NOTES:

1. Minimum D.C. input is -0.3V. During transitions the inputs may undershoot to -0.8V for a maximum period of 20ns.
2. During transitions, the inputs may overshoot to 0.8V over max V_{IH} for a maximum period of 20ns.
3. This applies to the 2.5V of HCLK IN pin
4. VREFAGP = 0.4V of V_{cc},
5. VREF ranges from 0.9V to 1.1V in the system with the part installed. The system board without the part installed must guarantee a maximum of \pm 2% deviation
6. (0 \leq V_{out} \leq 3.3V +5%)

5.5 AC Characteristics

All the clock-to-output values are specified into 0 pF load, unless otherwise specified.

Table 5-4. HOST Clock Timing, 66 MHz

Functional Operating Range (VTT = 1.5V \pm 10%, Vcc = 3.3V \pm 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Units	Figure
t1	HCLKIN Period	15.0	20.0	ns	Figure 5-1
t2	HCLKIN Period Stability		\pm 250	ps	
t3	HCLKIN High Time	5.3		ns	Figure 5-1
t4	HCLKIN Low Time	5.0		ns	Figure 5-1
t5	HCLKIN Rise Time	0.4	1.6	ns	Figure 5-1
t6	HCLKIN Fall Time	0.4	1.6	ns	Figure 5-1

Table 5-5. CPU Interface Timing, 66 MHz

Functional Operating Range (VTT = 1.5V \pm 10%, Vcc = 3.3V \pm 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Units	Figures
t7	Valid Delay from HCLKIN Rising (tco)	1.25	7.25	ns	Figure 5-3
t8	Input Setup Time to HCLKIN Rising (tsu)	5.0		ns	Figure 5-4
t9	Input Hold Time from HCLKIN Rising (thld)	0.0		ns	Figure 5-4

Table 5-6. DRAM Interface Timing, 66 MHz (Configuration #1)

Functional Operating Range (VTT = 1.5V \pm 10%, Vcc = 3.3V \pm 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Units	Figure	Notes
t10	WE# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t11	MAA[13:2]# Valid Delay from HCLKIN Rising, SDRAM Read/Write cycles	1.5	7.0	ns	Figure 5-3	0 pF
t12	SRAS[1:0]# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t13	SCAS[1:0]# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t14	RCSA[3:0]# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t15	CDQA[7:0]# Valid Delay from HCLKIN Rising	1.5	6.5	ns	Figure 5-3	0 pF
t16	MD[63:0] Valid Delay from HCLKIN Rising	1.0	6.0	ns	Figure 5-3	0 pF
t17	MD[63:0] Setup Time to HCLKIN Rising	1.0		ns	Figure 5-4	note1
t18	MD[63:0] Hold Time from HCLKIN Rising	2.0		ns	Figure 5-4	note1
t19	CKE Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF

Table 5-7. DRAM Interface Timing, 66 MHz (Configuration #2)
Functional Operating Range (VTT = 1.5V ± 10%, Vcc = 3.3V ± 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Units	Figure	Notes
t20	WE# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t21	MAA[13:0]# Valid Delay from HCLKIN Rising, SDRAM Read/Write cycles	1.5	7.0	ns	Figure 5-3	0 pF
t22	SRAS[1:0]# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t23	SCAS[1:0]# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t24	RCSA[3:0]# Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF
t25	CDQA[7:0]# Valid Delay from HCLKIN Rising	1.5	6.5	ns	Figure 5-3	0 pF
t26	MD[63:0] Valid Delay from HCLKIN Rising	1.0	6.0	ns	Figure 5-3	0 pF
t27	MD[63:0] Setup Time to HCLKIN Rising	1.0		ns	Figure 5-4	note1
t28	MD[63:0] Hold Time from HCLKIN Rising	2.0		ns	Figure 5-4	note1
t29	CKE Valid Delay from HCLKIN Rising	1.5	7.0	ns	Figure 5-3	0 pF

NOTE:

1. When EDO is driving, this specification is based on a 100pF load. When SDRAM is driving, this specification is based on a 50pF load.

Table 5-8. PCI Clock Timing, 33 MHz
Functional Operating Range (VTT = 1.5V ± 10%, Vcc = 3.3V ± 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Units	Figure	Notes
t30	PCLKIN Period	30		ns	Figure 5-2	
t31	PCLKIN Period Stability		500	ns		ps
t32	PCLKIN High Time	12.0		ns	Figure 5-2	
t33	PCLKIN Low Time	12.0		ns	Figure 5-2	
t34	HCLKIN Lead Time to PCLKIN	1	6	ns		
t35	PCLKIN Rise Time		3.0	ns	Figure 5-2	
t36	PCLKIN Fall Time		3.0	ns	Figure 5-2	

Table 5-9. PCI Interface Timing, 33 MHz

Functional Operating Range (VTT = 1.5V ± 10%, Vcc = 3.3V ± 5%; TCASE = 0°C to +100°C)

Symbol	Parameter	Min	Max	Units	Figures	Notes
t37	AD[31:0] Valid Delay from PCLKIN Rising	2	11	ns	Figure 5-3	Min: 0 pF Max: 50 pF
t38	AD[31:0] Setup Time to PCLKIN Rising	7		ns	Figure 5-4	
t39	AD[31:0] Hold Time from PCLKIN	0		ns	Figure 5-4	
t40	C/BE[3:0]#, FRAME#, TRDY#, IRDY#, STOP#, PLOCK#, PAR, DEVSEL#, SERR#, PERR# Valid Delay from PCLKIN Rising	2	11	ns	Figure 5-3	Min: 0 pF Max: 50 pF
t41	C/BE[3:0]#, FRAME#, TRDY#, IRDY#, STOP#, PLOCK#, PAR, DEVSEL#, SERR#, PERR# Output Enable Delay from PCLKIN Rising	2		ns		
t42	C/BE[3:0]#, FRAME#, TRDY#, IRDY#, STOP#, PLOCK#, PAR, DEVSEL#, SERR#, PERR# Float Delay from PCLKIN Rising	2	28	ns	Figure 5-5	
t43	C/BE[3:0]#, FRAME#, TRDY#, IRDY#, STOP#, PLOCK#, PAR, DEVSEL#, SERR#, PERR# Setup Time to PCLKIN Rising	7		ns	Figure 5-4	
t44	C/BE[3:0]#, FRAME#, TRDY#, IRDY#, STOP#, PLOCK#, PAR, DEVSEL#, SERR#, PERR# Hold Time from PCLKIN Rising	0		ns	Figure 5-4	
t45	PHLDA# Valid Delay from PCLKIN Rising	2	12	ns	Figure 5-3	Min: 0 pF Max: 50 pF
t47	PHOLD# Setup Time to PCLKIN Rising	12		ns	Figure 5-4	
t48	PHOLD# Hold Time from PCLKIN Rising	0		ns	Figure 5-4	
t49	GNT[2:1]#, GNT0# Valid Delay from PCLKIN Rising	2	12	ns	Figure 5-3	Min: 0 pF Max: 50 pF
t50	REQ[2:1]#, REQ0# Setup Time to PCLKIN Rising	12		ns	Figure 5-4	
t51	REQ[2:1]#, REQ0# Hold Time from PCLKIN Rising	0		ns	Figure 5-4	

Table 5-10. AGP Interface Timing, 66/133 MHz (Sheet 1 of 2)

Symbol	Parameter	Min	Max	Units	Figures	Notes
t52	GAD[31:0], GCBE#[3:0], SBA[7:0] Valid Delay from HCLKIN Rising	1.0	6.0	ns	Figure 5-3	10pF
t53	GAD[31:0], GCBE#[3:0], SBA[7:0] Setup Time to HCLKIN Rising	5.5		ns	Figure 5-4	10pF
t54	GAD[31:0], GCBE#[3:0], SBA[7:0] Hold Time from HCLKIN	0		ns	Figure 5-4	10pF
t55	GFRAME#, GTRDY#, GIRDY#, GSTOP#, GPAR, GDEVSEL#, GPERR#, GSERR#, PIPE#, DBF#, GREQ#, GGNT#, ST[2:0] Valid Delay from HCLKIN Rising	1.0	5.5	ns	Figure 5-3	10pF
t56	GFRAME#, GTRDY#, GIRDY#, GSTOP#, GPAR, GDEVSEL#, GPERR#, GSERR#, PIPE#, DBF#, GREQ#, GGNT#, ST[2:0] Float Delay from HCLKIN Rising	1.0	14.0	ns	Figure 5-5	10pF

Table 5-10. AGP Interface Timing, 66/133 MHz (Sheet 2 of 2)

Symbol	Parameter	Min	Max	Units	Figures	Notes
t57	GFRAME#, GTRDY#, GIRDY#, GSTOP#, GPAR, GDEVSEL#, GPERR#, GSERR#, PIPE#, DBF#, GREQ#, GGNT#, ST[2:0] Setup Time to HCLKIN Rising	6.0		ns	Figure 5-4	10pF
t58	GFRAME#, GTRDY#, GIRDY#, GSTOP#, GPAR, GDEVSEL#, GPERR#, GSERR#, PIPE#, DBF#, GREQ#, GGNT#, ST[2:0] Hold Time from HCLKIN Rising	0		ns	Figure 5-4	10pF

Table 5-11. AGP Interface Timing, 133 MHz

Functional Operating Range (VTT = 1.5V ± 10%, Vcc = 3.3V ± 5%; TCASE = 0°C to +100°C)

Sym	Parameter	Min	Max	Units	Figure	Notes
t59	ADSTBx falling Valid Delay at transmitter from HCLKIN rising.	2	12	ns	Figure 5-8	tTSf, note 1, 2, 3
t60	ADSTBx rising Valid Delay at transmitter from HCLKIN rising.		20	ns	Figure 5-8	tTSr
t61	GAD[31:0], GC/BE[3:0]# Valid Delay before ADSTBx Rise/Fall	1.7		ns	Figure 5-8	tDvb
t62	GAD[31:0] GC/BE[3:0]# Valid Delay after ADSTBx Rise/Fall	1.7		ns	Figure 5-8	tDva
t63	GAD[31:0] GC/BE[3:0]# Float to Active Delay from HCLKIN rising.	-1	9	ns	Figure 5-7	tOND
t64	GAD[31:0], GC/BE[3:0]# Active to Float Delay from HCLKIN rising.	1	12	ns	Figure 5-7	tOFFD
t65	ADSTBx rising Delay Time at transmitter to ADSTBx floating.	6	10	ns	Figure 5-7	tOFFS
t66	ADSTBx active Setup Time at transmitter to ADSTBx falling.	6	10	ns	Figure 5-7	tONS
t67	ADSTBx rising Setup Time at receiver to HCLKIN rising.	6		ns	Figure 5-8	tRSsu
t68	ADSTBx falling Hold Time at receiver to HCLKIN rising.	1		ns	Figure 5-8	tRSh
t69	GAD[31:0], GC/BE[3:0]# Setup Time to ADSTBx Rise/Fall	1		ns	Figure 5-8	tDsu
t70	GAD[31:0] GC/BE[3:0]# Hold Time from ADSTBx Rise/Fall	1		ns	Figure 5-8	tDh
t71	SBSTB rising Setup Time at receiver to HCLKIN rising.	6		ns	Figure 5-8	tRSsu
t72	SBSTB falling Hold Time at receiver to HCLKIN rising.	1		ns	Figure 5-8	tRSh
t73	SBA[7:0] Setup Time at receiver to SBSTB Rise/Fall	1		ns	Figure 5-8	tDsu
t74	SBA[7:0] Hold Time at receiver from SBSTB Rise/Fall	1		ns	Figure 5-8	tDh

NOTES:

- ADSTBx refers to ADSTBA and ADSTBB.
- Specifications are based on a 10pF loading.

Table 5-12. Miscellaneous Signals

Functional Operating Range (VTT = 1.5V ± 10%, Vcc = 3.3V ± 5%; TCASE = 0°C to +100°C)

Sym	Parameter	Min	Max	Units	Figure	Notes
t75	CRESET# Valid Delay time from HLCKIN Rising	1.5	7	ns	Figure 5-3	0pF
t76	RSTIN# Setup time to PCICLK Rising	5		ns	Figure 5-4	0pF
t77	RSTIN# Hold time from PCICLK Rising	1		ns	Figure 5-4	0pF
t78	CPURST# Setup time to HCLKIN Rising	5		ns	Figure 5-4	0pF
t79	CPURST# Hold time from HCLKIN Rising	1		ns	Figure 5-4	0pF
t82	INIT# Low Pulse Width	16		ns	Figure 5-6	HCLKs

5.6 82443EX Timing Diagrams

Figure 5-1. 2.5V Clocking Interface

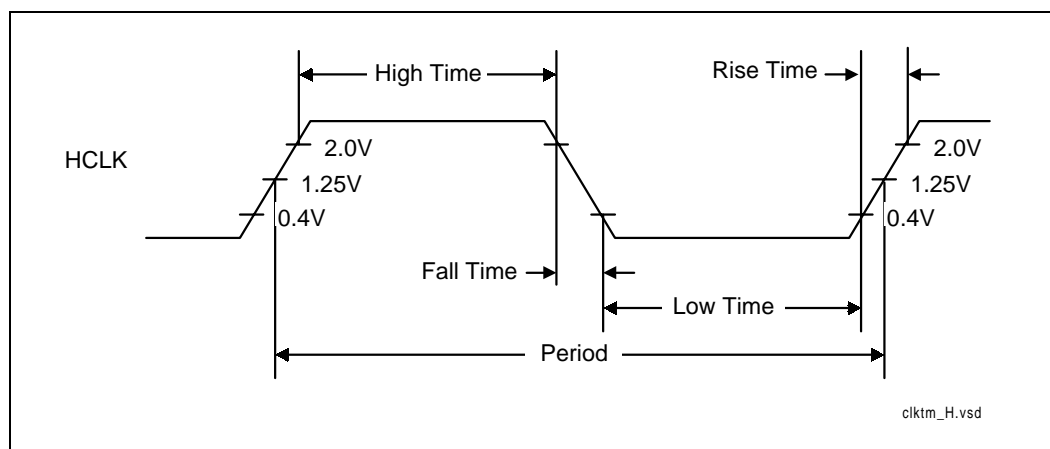


Figure 5-2. 3.3V Clocking Interface

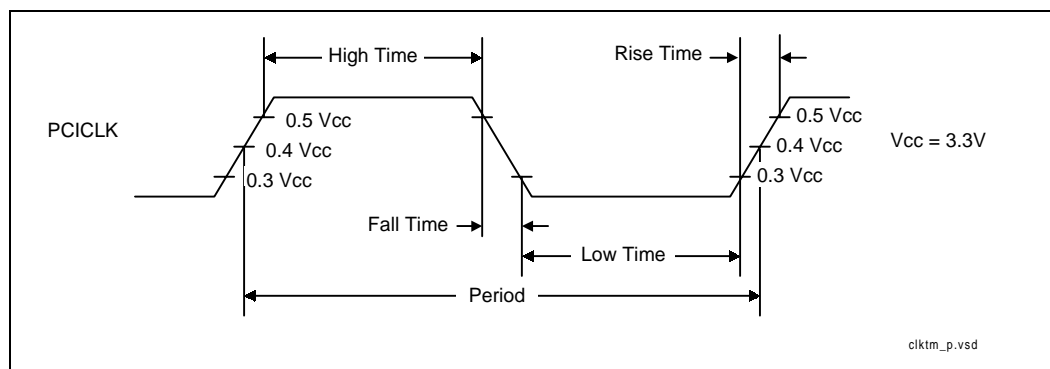
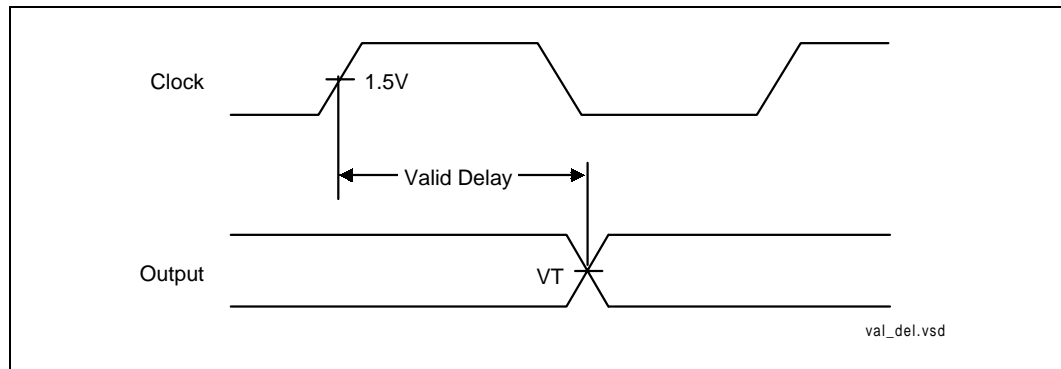


Figure 5-3. Valid Delay From Rising Clock Edge



Note: Please refer table 13 for different measurement point on V_{test} and V_{step} for figure 3, 4, & 5.

Figure 5-4. Setup and Hold Time to Clock

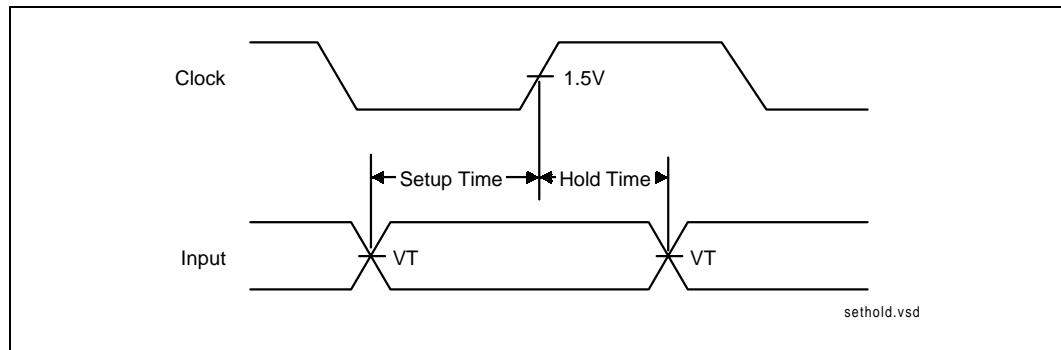


Figure 5-5. Float Delay

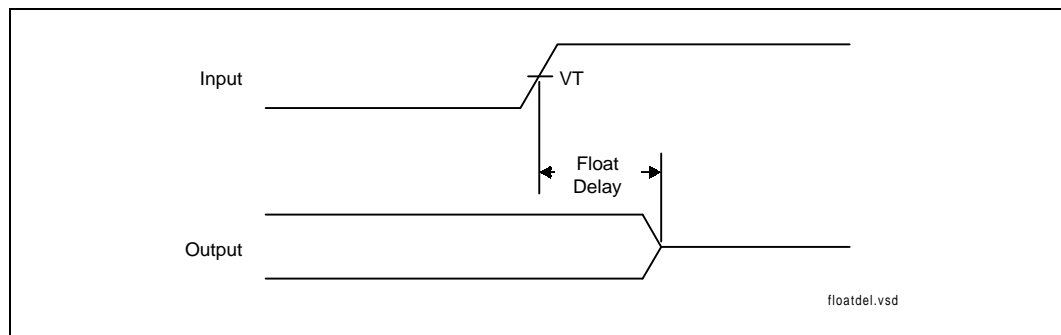


Figure 5-6. Pulse Width

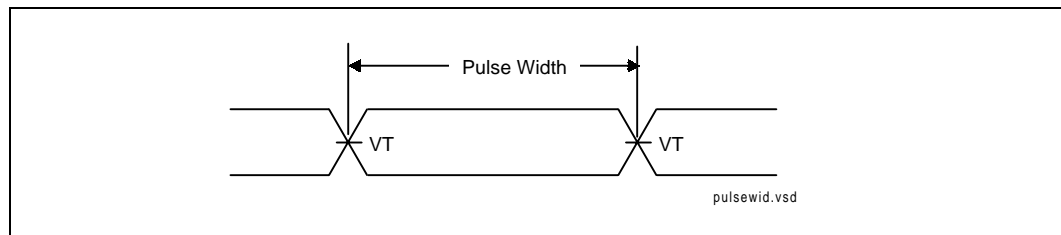


Figure 5-7. Strobe/Data Turnaround Timings

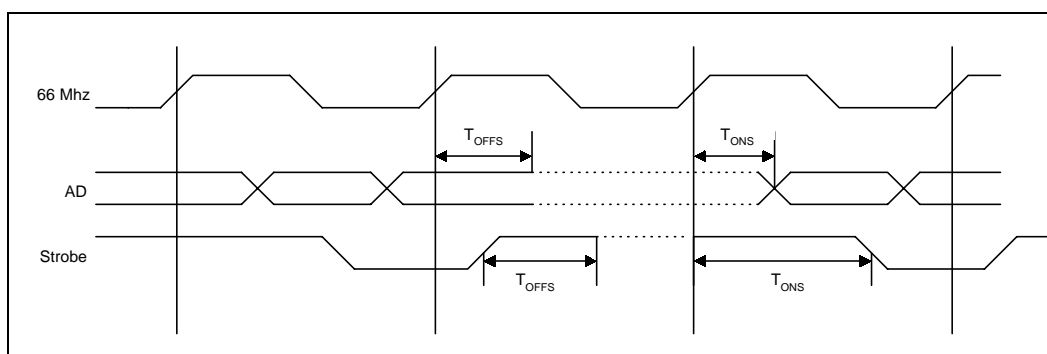


Figure 5-8. AGP 133 Timing Diagram

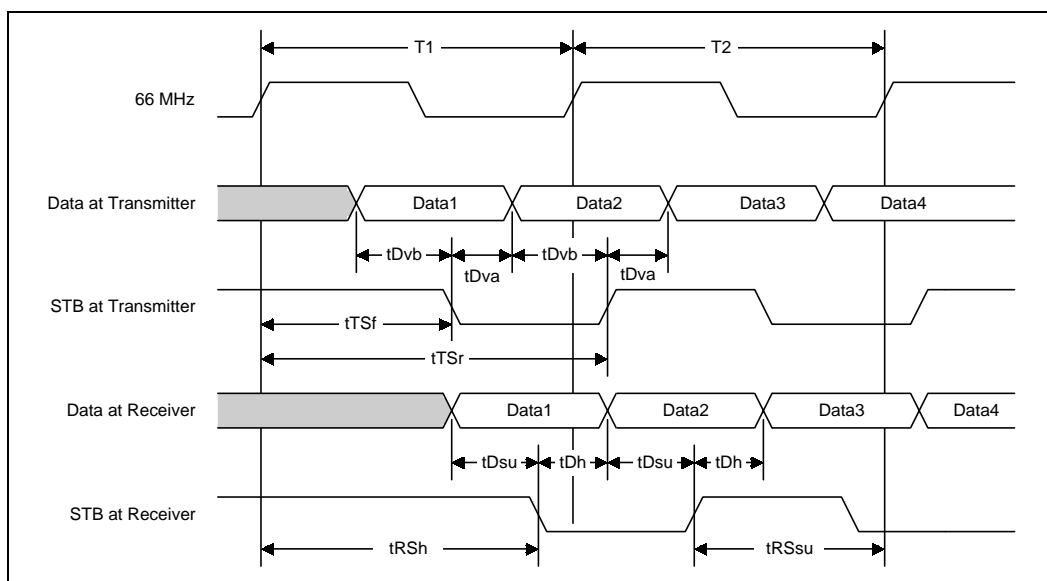


Table 5-13. AC Timing Measurement Points

Clock	V _{test}	V _{step}	Notes
CPU interface HCLK (2.5V)	1.25V	1.0V for GTL+ signal group 1.25V for CMOS, APIC signals	
DRAM interface HCLK (2.5V)	1.25V	1.4V for SDRAM 1.5V for EDO	1
PCI interface PCICLK(3.3V)	1.5V	n/a	2
AGP device HCLK (2.5)	0.4V _{cc}	0.4V _{cc}	3

NOTES:

1. DRAM interface AC timing measurement is relative to 2.5V of HCLK, since the HCLK input to PAC is a 2.5V signal. The DRAM AC timing in Table 7 & 8 are valid for both SDRAM and EDO.
2. Although the PCICLK is a 3.3V clock, the PCI interface of PAC operates in a 5V PCI environment. Via PCI 2.1 spec, the V_{test} is 1.5V.
3. Although the HCLK input of PAC is a 2.5V clock, the AGP interface of PAC operates in a 3.3V environment.

5.7 DRAM Timing Relationships With Register Settings

This section shows the DRAM timing relationship with respect to bit settings in the DRAM Timing (DRAMT) register (address offset 58h). The values in this register affect both leadoff and burst timings. The CPU to DRAM memory read performance summary for EDO and SDRAM are shown in Table 32 and Table 33.

Note:

1. PH is page hit.
2. RM is row miss.
3. PM is page miss.
4. The leadoff clock counts of a back-to-back burst cycle is also shown as a pipeline leadoff
5. All leadoff counts will add one more clock when ECC is enabled.

Table 5-14. EDO Timing Performance Summary

Possible Valid Setting	Affect leadoff			Leadoff Clock Count		Burst Clock Count ⁴	
	RCD ¹ 1(2 clocks) 0(3 clocks)	MAWS ⁵ 1(fast) 0(slow)	RPT ⁶ 1(3 clocks) 0(4 clocks)	First Leadoff (PH/RM ² /RM ³ /PM)	Pipeline Leadoff (PH/RM ³ /PM)	Read	Write
a	0	1	1	8/10/11/13	2/6/8	222 or 333	222 or 333
b	0	1	0	8/10/11/14	2/6/9	222 or 333	222 or 333
c	0	0	1	9/12/13/15	3/7/9	222 or 333	222 or 333
d	0	0	0	9/12/13/16	3/7/10	222 or 333	222 or 333

NOTES:

1. RAS to CAS delay, RCD (bit 1 of Register DRAMT), is always set to 0 for a 3 clock delay to have a positive tRAC margin.
2. Row miss numbers assume that no RAS# is currently active .
3. One more clock should be added if the current RAS# has to be negated and the new RAS# has to be asserted.
4. The EDO burst timing is also determined by the setting DRAMT bits [3,4].
5. MAWS is the EDO Memory Address Wait State. The setting of MAWS affects all cases. When MAWS is set to 0 (slow), an extra clock is added for each CAS# and RAS# assertion.
6. RPT is EDO RAS Precharge time. This only affects a page miss.

Table 5-15. SDRAM Timing Performance Summary

	Affects Leadoff			Leadoff Clock Count		Burst Clock Count
Possible Valid Setting	SCLT ¹ 1(2 clocks) 0(3 clocks)	SRCD ² 1(2 clocks) 0(3 clocks)	SRPT ³ 1(2 clocks) 0(3 clocks)	First Leadoff PH/RM ⁴ / RM ⁵ /PM	Pipeline Leadoff PH/RM ⁵ /PM	Read & Write
a.	1	1	1	8/10/11/12	2/4/5	111
b.	1	1	0	8/10/11/13	2/4/6	111
c.	0	1	1	9/11/12/13	1/5/6	111
d.	1	0	1	8/11/12/13	2/5/6	111
e.	0	1	0	9/11/12/14	1/5/7	111
f.	0	0	0	9/12/13/15	1/6/8	111
g.	1	0	0	8/11/12/14	2/5/7	111
h.	0	0	1	9/12/13/14	1/6/7	111

NOTES:

1. SCLT is SDRAM CAS Latency. The setting of SCLT affects all cases (page hit, page miss, and row miss).
2. SRCD is SDRAM RAS to CAS delay. The setting of this bit affects both page miss and row miss.
3. SRPT is SDRAM RAS precharge time. The setting of this bit affects only page miss.
4. Row miss numbers assume that no RAS# is currently active.
5. Row miss numbers assume that the current RAS# has to be negated and the new RAS# has to be asserted.
6. The same MAWS control bit for EDO timing in register 58h of PAC (device 0) has a different timing effect for SDRAM. All the clock counts are based on MAWS = 1 (fast). When MAWS = 0 (slow), an extra clock is added before each CS# assertion.

Following are the waveforms illustrating the page hit, page miss and row miss with different settings of SCLT, SRCD, SRPT, and MAWS=1.

Figure 5-9. Page Hit with SCLT=0, SRCD=1, SRPT=1

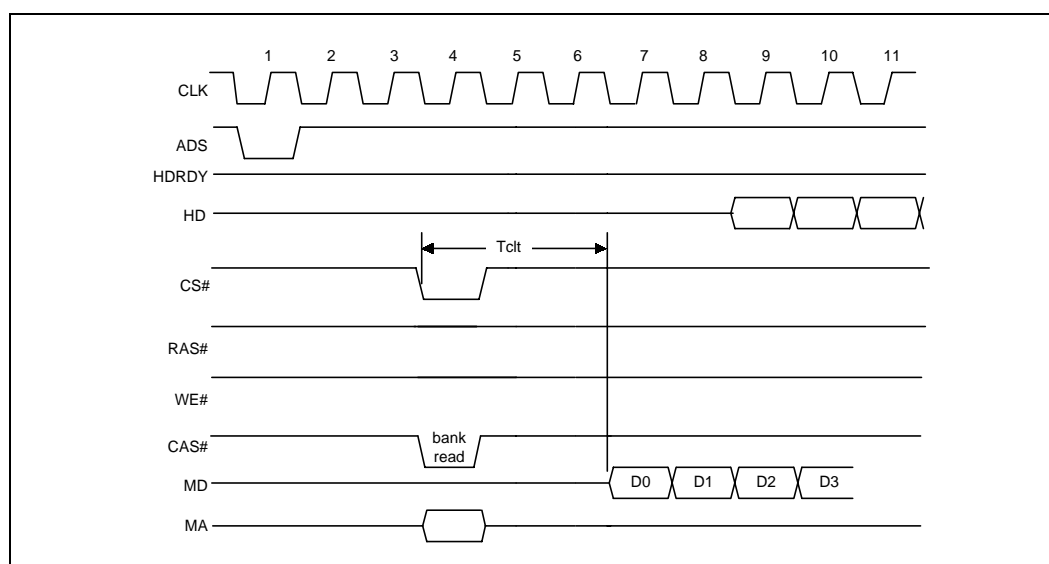


Figure 5-10. Page Hit with SCLT=1, SRCD=1, SRPT=1

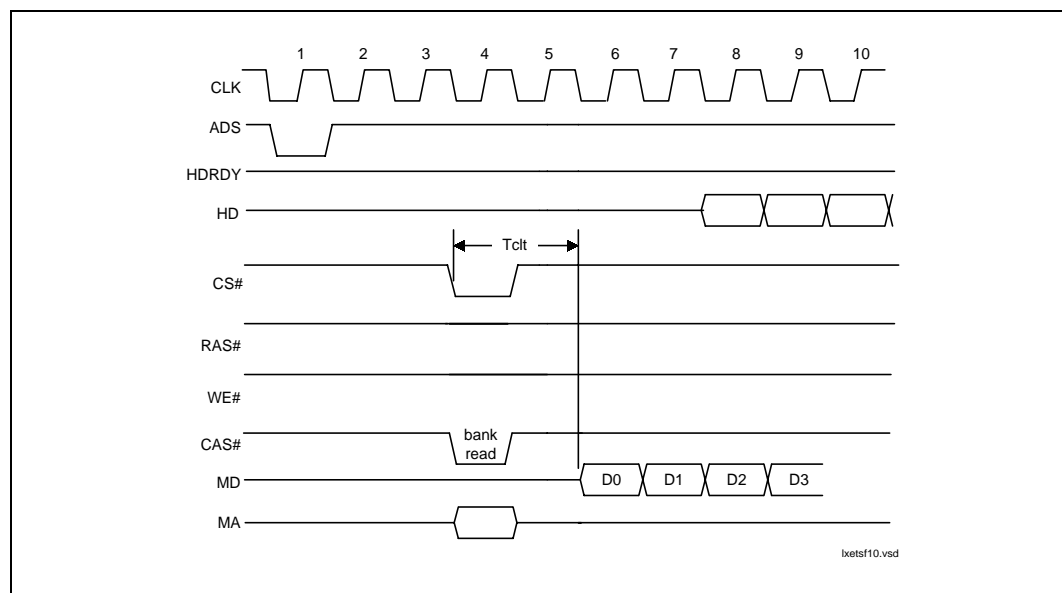


Figure 5-11. Page Miss with SCLT=1, SRCD=1, SRPT=0

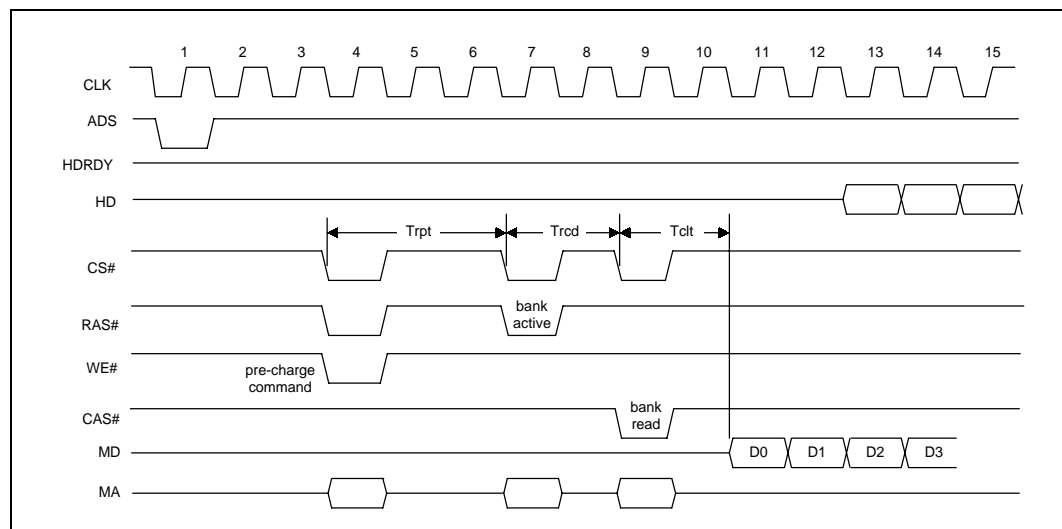


Figure 5-12. Page Miss with SCLT=1, SRCD=1, SRPT=1

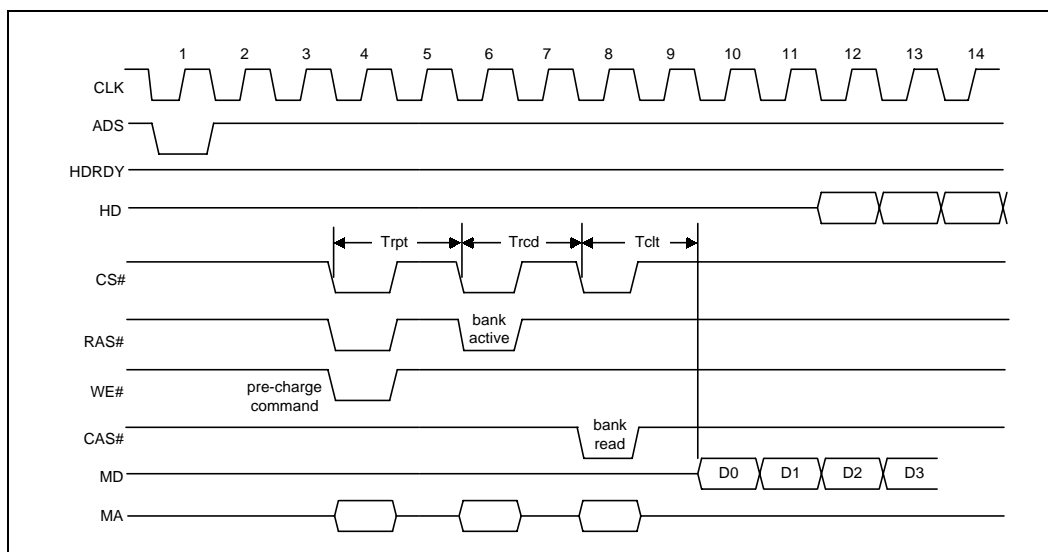


Figure 5-13. Row Miss-4 with SCLT=1, SRCD=0, SRPT=1

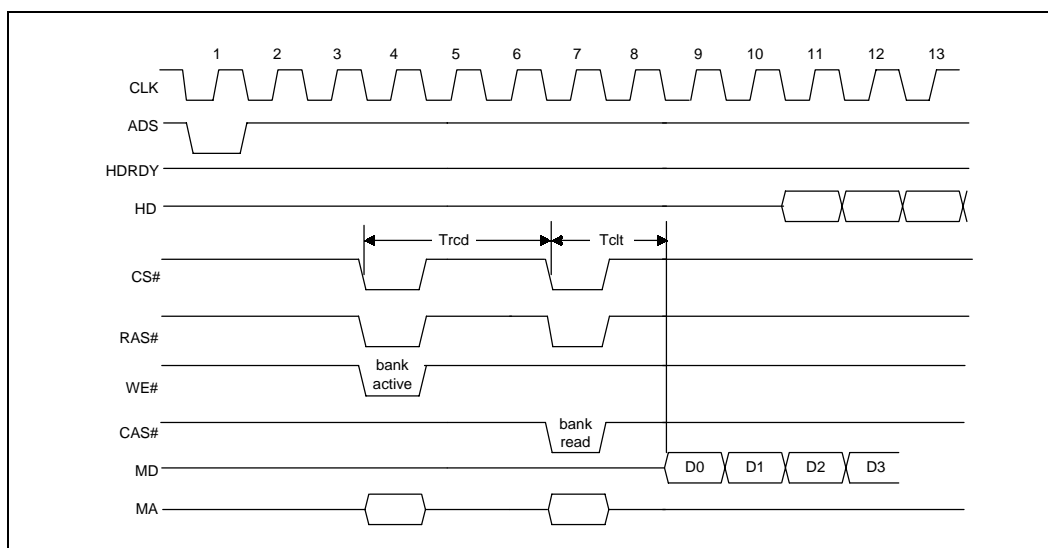


Figure 5-14. Row Miss-4 with SCLT=0, SRCD=1, SRPT=1

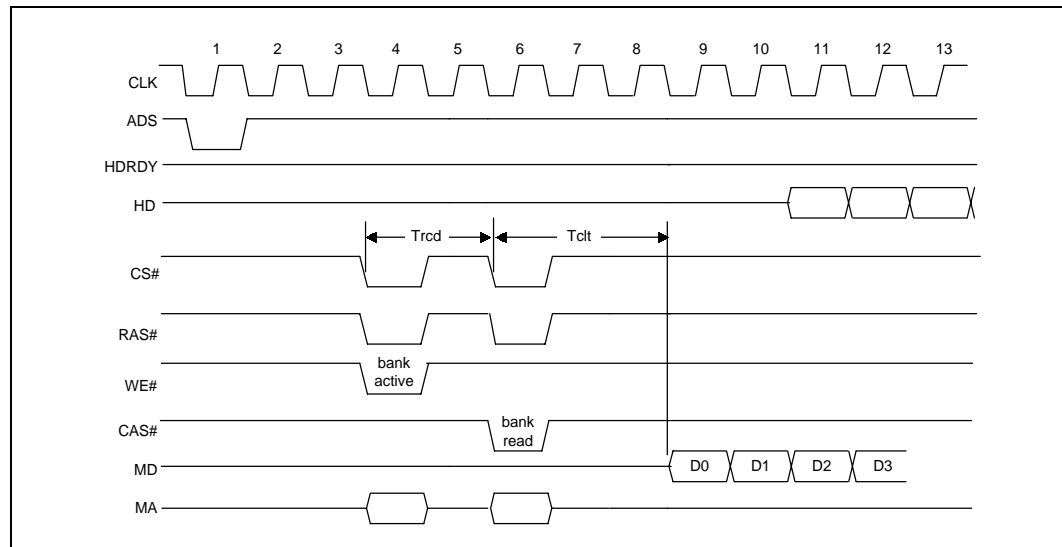


Figure 5-15. Row Miss-4 with SCLT=1, SRCD=1, SRPT=1

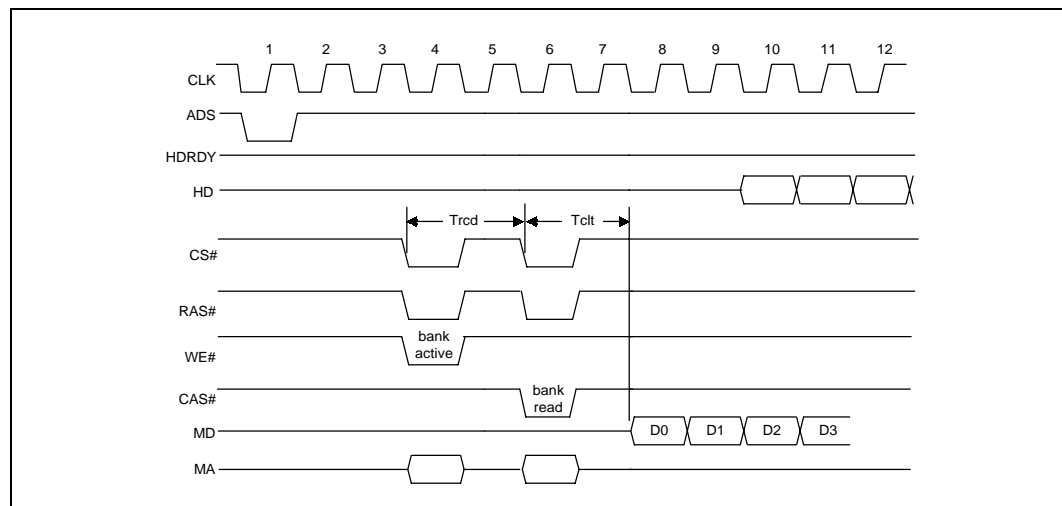
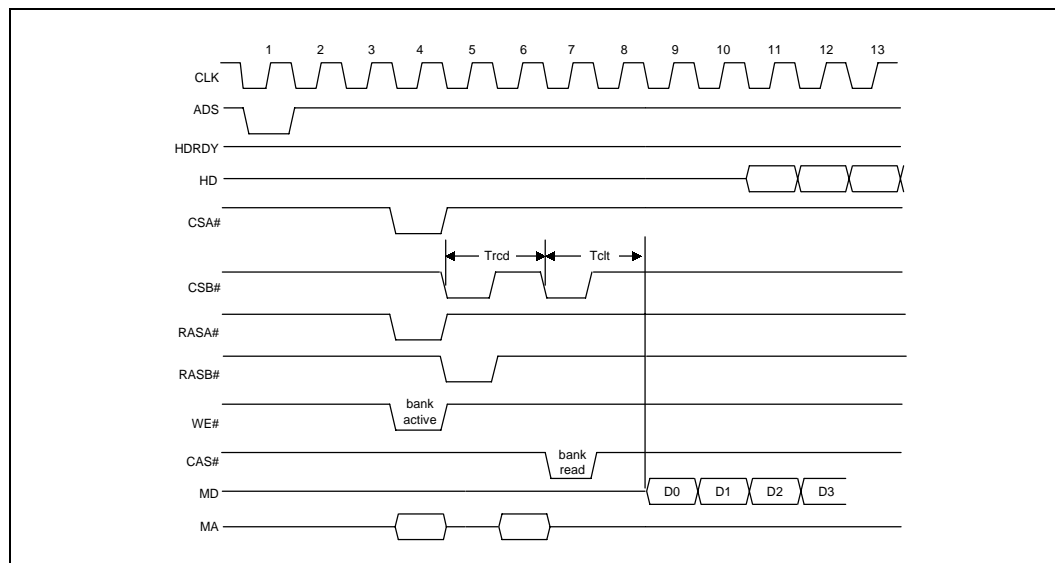


Figure 5-16. Row Miss-5 with SCLT=1, SRCD=1, SRPT=1



Pin Assignment

6

(see following pages)

Figure 6-1. PAC Pinout (Top View)

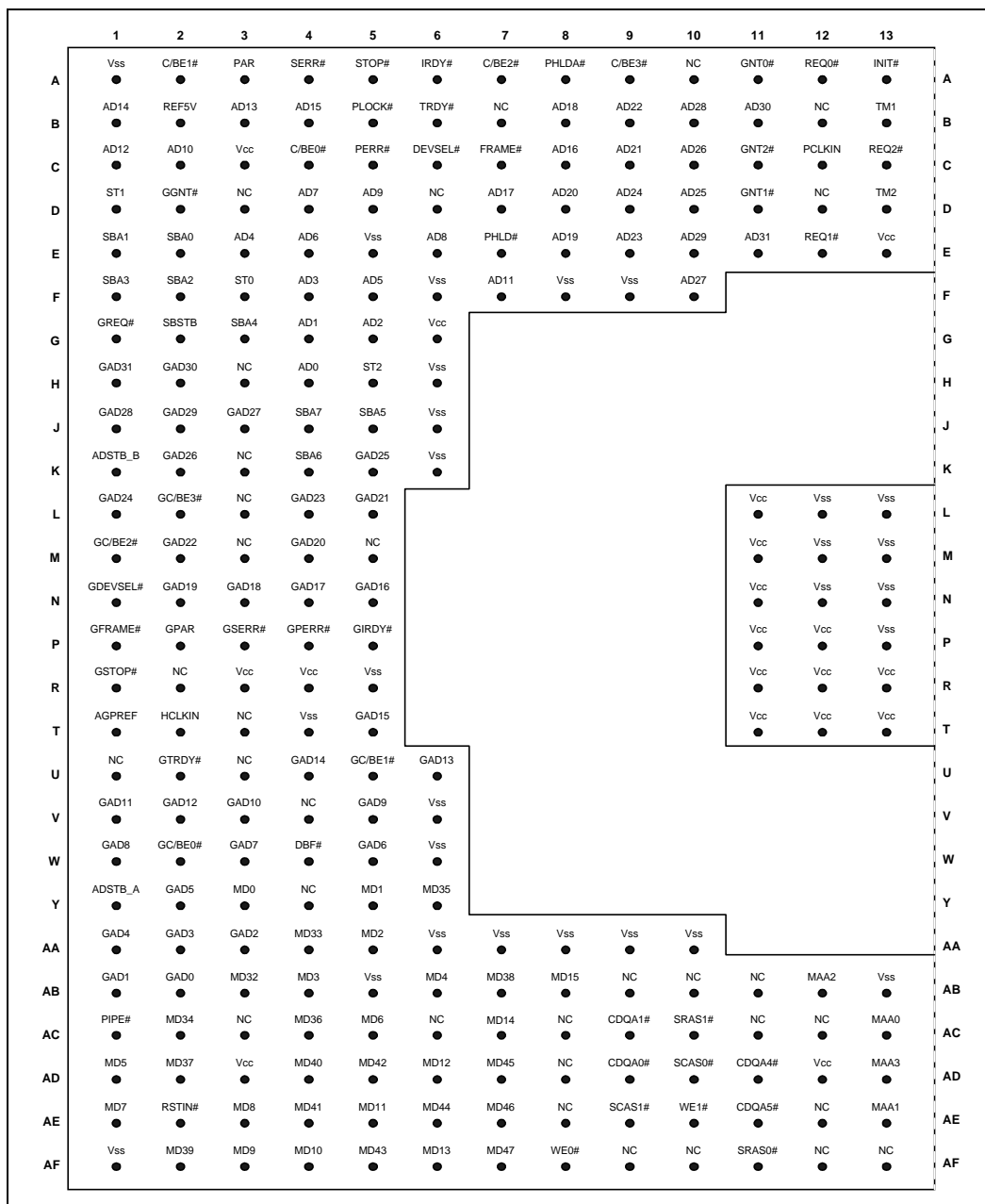


Figure 6-2. PAC Pinout (Top View)

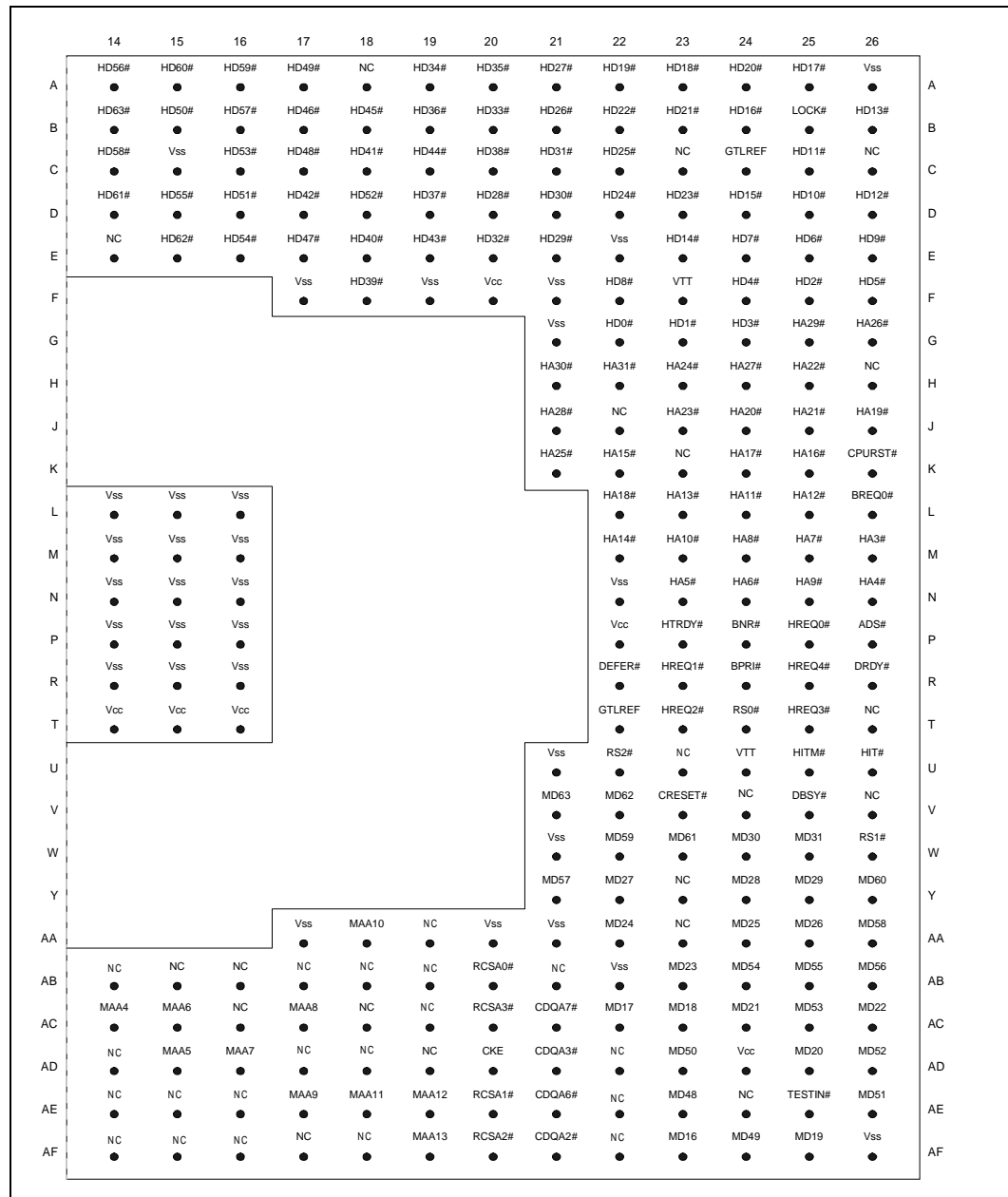


Table 6-1. 82443EX Alphabetical Pin Assignment (Sheet 1 of 4)

Name	Ball #	Type	Name	Ball #	Type	Name	Ball #	Type
AD0	H4	I/O	ADSTB_B	K1	I/O	GAD7	W3	I/O
AD1	G4	I/O	ADS#	P26	I/O	GAD8	W1	I/O
AD2	G5	I/O	AGPREF	T1	I	GAD9	V5	I/O
AD3	F4	I/O	BNR#	P24	I/O	GAD10	V3	I/O
AD4	E3	I/O	BPRI#	R24	O	GAD11	V1	I/O
AD5	F5	I/O	BREQ0#	L26	O	GAD12	V2	I/O
AD6	E4	I/O	C/BE0#	C4	I/O	GAD13	U6	I/O
AD7	D4	I/O	C/BE1#	A2	I/O	GAD14	U4	I/O
AD8	E6	I/O	C/BE2#	A7	I/O	GAD15	T5	I/O
AD9	D5	I/O	C/BE3#	A9	I/O	GAD16	N5	I/O
AD10	C2	I/O	CDQA0#	AD9	O	GAD17	N4	I/O
AD11	F7	I/O	CDQA1#	AC9	O	GAD18	N3	I/O
AD12	C1	I/O	CDQA2#	AF21	O	GAD19	N2	I/O
AD13	B3	I/O	CDQA3#	AD21	O	GAD20	M4	I/O
AD14	B1	I/O	CDQA4#	AD11	O	GAD21	L5	I/O
AD15	B4	I/O	CDQA5#	AE11	O	GAD22	M2	I/O
AD16	C8	I/O	CDQA6#	AE21	O	GAD23	L4	I/O
AD17	D7	I/O	CDQA7#	AC21	O	GAD24	L1	I/O
AD18	B8	I/O	CKE	AD20	O	GAD25	K5	I/O
AD19	E8	I/O	CPURST#	K26	I	GAD26	K2	I/O
AD20	D8	I/O	CRESET#	V23	O	GAD27	J3	I/O
AD21	C9	I/O	DBSY#	V25	I/O	GAD28	J1	I/O
AD22	B9	I/O	DEFER#	R22	I/O	GAD29	J2	I/O
AD23	E9	I/O	DRDY#	R26	I/O	GAD30	H2	I/O
AD24	D9	I/O	DEVSEL#	C6	I/O	GAD31	H1	I/O
AD25	D10	I/O	FRAME#	C7	I/O	GC/BE0#	W2	I/O
AD26	C10	I/O	GAD0	AB2	I/O	GC/BE1#	U5	I/O
AD27	F10	I/O	GAD1	AB1	I/O	GC/BE2#	M1	I/O
AD28	B10	I/O	GAD2	AA3	I/O	GC/BE3#	L2	I/O
AD29	E10	I/O	GAD3	AA2	I/O	GDEVSEL#	N1	I/O
AD30	B11	I/O	GAD4	AA1	I/O	GFRAME#	P1	I/O
AD31	E11	I/O	GAD5	Y2	I/O	GGNT#	D2	O
ADSTB_A	Y1	I/O	GAD6	W5	I/O	GIRDY#	P5	I/O

Table 6-1. 82443EX Alphabetical Pin Assignment (Sheet 2 of 4)

Name	Ball #	Type	Name	Ball #	Type	Name	Ball #	Type
GNT0#	A11	O	HA25	K21	I/O	HD25	C22	I/O
GNT1#	D11	O	HA26	G26	I/O	HD26	B21	I/O
GNT2#	C11	O	HA27	H24	I/O	HD27	A21	I/O
GPAR#	P2	I/O	HA28	J21	I/O	HD28	D20	I/O
GPERR#	P4	I/O	HA29	G25	I/O	HD29	E21	I/O
GREQ#	G1	I	HA30	H21	I/O	HD30	D21	I/O
GSERR#	P3	I	HA31	H22	I/O	HD31	C21	I/O
GSTOP#	R1	I/O	HCLKIN	T2	I	HD32	E20	I/O
GTLREF	C24	I	HD0	G22	I/O	HD33	B20	I/O
GTLREF	T22	I	HD1	G23	I/O	HD34	A19	I/O
GTRDY#	U2	I/O	HD2	F25	I/O	HD35	A20	I/O
HA3	M26	I/O	HD3	G24	I/O	HD36	B19	I/O
HA4	N26	I/O	HD4	F24	I/O	HD37	D19	I/O
HA5	N23	I/O	HD5	F26	I/O	HD38	C20	I/O
HA6	N24	I/O	HD6	E25	I/O	HD39	F18	I/O
HA7	M25	I/O	HD7	E24	I/O	HD40	E18	I/O
HA8	M24	I/O	HD8	F22	I/O	HD41	C18	I/O
HA9	N25	I/O	HD9	E26	I/O	HD42	D17	I/O
HA10	M23	I/O	HD10	D25	I/O	HD43	E19	I/O
HA11	L24	I/O	HD11	C25	I/O	HD44	C19	I/O
HA12	L25	I/O	HD12	D26	I/O	HD45	B18	I/O
HA13	L23	I/O	HD13	B26	I/O	HD46	B17	I/O
HA14	M22	I/O	HD14	E23	I/O	HD47	E17	I/O
HA15	K22	I/O	HD15	D24	I/O	HD48	C17	I/O
HA16	K25	I/O	HD16	B24	I/O	HD49	A17	I/O
HA17	K24	I/O	HD17	A25	I/O	HD50	B15	I/O
HA18	L22	I/O	HD18	A23	I/O	HD51	D16	I/O
HA19	J26	I/O	HD19	A22	I/O	HD52	D18	I/O
HA20	J24	I/O	HD20	A24	I/O	HD53	C16	I/O
HA21	J25	I/O	HD21	B23	I/O	HD54	E16	I/O
HA22	H25	I/O	HD22	B22	I/O	HD55	D15	I/O
HA23	J23	I/O	HD23	D23	I/O	HD56	A14	I/O
HA24	H23	I/O	HD24	D22	I/O	HD57	B16	I/O
GNT0#	A11	O	HA25	K21	I/O	HD25	C22	I/O

Table 6-1. 82443EX Alphabetical Pin Assignment (Sheet 3 of 4)

Name	Ball #	Type	Name	Ball #	Type	Name	Ball #	Type
HD58	C14	I/O	MD02	AA5	I/O	MD35	Y6	I/O
HD59	A16	I/O	MD03	AB4	I/O	MD36	AC4	I/O
HD60	A15	I/O	MD04	AB6	I/O	MD37	AD2	I/O
HD61	D14	I/O	MD05	AD1	I/O	MD38	AB7	I/O
HD62	E15	I/O	MD06	AC5	I/O	MD39	AF2	I/O
HD63	B14	I/O	MD07	AE1	I/O	MD40	AD4	I/O
HIT#	U26	I/O	MD08	AE3	I/O	MD41	AE4	I/O
HITM#	U25	I/O	MD09	AF3	I/O	MD42	AD5	I/O
HREQ0#	P25	I/O	MD10	AF4	I/O	MD43	AF5	I/O
HREQ1#	R23	I/O	MD11	AE5	I/O	MD44	AE6	I/O
HREQ2#	T23	I/O	MD12	AD6	I/O	MD45	AD7	I/O
HREQ3#	T25	I/O	MD13	AF6	I/O	MD46	AE7	I/O
HREQ4#	R25	I/O	MD14	AC7	I/O	MD47	AF7	I/O
HTRDY#	P23	I/O	MD15	AB8	I/O	MD48	AE23	I/O
INIT#	A13	O	MD16	AF23	I/O	MD49	AF24	I/O
IRDY#	A6	I/O	MD17	AC22	I/O	MD50	AD23	I/O
LOCK#	B25	I	MD18	AC23	I/O	MD51	AE26	I/O
MAA0	AC13	O	MD19	AF25	I/O	MD52	AD26	I/O
MAA1	AE13	O	MD20	AD25	I/O	MD53	AC25	I/O
MAA2	AB12	O	MD21	AC24	I/O	MD54	AB24	I/O
MAA3	AD13	O	MD22	AC26	I/O	MD55	AB25	I/O
MAA4	AC14	O	MD23	AB23	I/O	MD56	AB26	I/O
MAA5	AD15	O	MD24	AA22	I/O	MD57	Y21	I/O
MAA6	AC15	O	MD25	AA24	I/O	MD58	AA26	I/O
MAA7	AD16	O	MD26	AA25	I/O	MD59	W22	I/O
MAA8	AC17	O	MD27	Y22	I/O	MD60	Y26	I/O
MAA9	AE17	O	MD28	Y24	I/O	MD61	W23	I/O
MAA10	AA18	O	MD29	Y25	I/O	MD62	V22	I/O
MAA11	AE18	O	MD30	W24	I/O	MD63	V21	I/O
MAA12	AE19	O	MD31	W25	I/O	PAR	A3	I/O
MAA13	AF19	O	MD32	AB3	I/O	PCLKIN	C12	I
MD00	Y3	I/O	MD33	AA4	I/O	PERR#	C5	I/O
MD01	Y5	I/O	MD34	AC2	I/O	PHLD#	E7	I

Table 6-1. 82443EX Alphabetical Pin Assignment (Sheet 4 of 4)

Name	Ball #	Type	Name	Ball #	Type	Name	Ball #	Type
PHLDA#	A8	O	TM2	D13	I	SBSTB	G2	I
PIPE#	AC1	I	RS0#	T24	I/O	SCAS0#	AD10	O
PLOCK#	B5	I/O	RS1#	W26	I/O	SCAS1#	AE9	O
RCSA0#	AB20	O	RS2#	U22	I/O	SERR#	A4	O
RCSA1#	AE20	O	RSTIN#	AE2	I	SRAS0#	AF11	O
RCSA2#	AF20	O	SBA0	E2	I	SRAS1#	AC10	O
RCSA3#	AC20	O	SBA1	E1	I	ST0	F3	O
RBF#	W4	I	SBA2	F2	I	ST1	D1	O
REF5V	B2	I	SBA3	F1	I	ST2	H5	O
REQ0#	A12	I	SBA4	G3	I	STOP#	A5	I/O
REQ1#	E12	I	SBA5	J5	I	TRDY#	B6	I/O
REQ2#	C13	I	SBA6	K4	I	WE0#	AF8	O
TM1	B13	I	SBA7	J4	I	WE1#	AE10	O

Table 6-2. 82443EX Pinout (Power, Ground, and No Connects)

Name	Ball #
V _{CC}	AD3, C3, R3, R4, G6, L11, M11, N11, P11, R11, T11, P12, R12, T12, AD12, E13, R13, T13, T14, T15, T16, F20, P22, AD24
V _{SS}	A1, AF1, T4, E5, AB5, R5, F6, H6, J6, K6, V6, W6, AA6, AA7, F8, AA8, F9, AA9, AA10, L12, M12, N12, L13, M13, N13, P13, AB13, L14, M14, N14, P14, R14, C15, L15, M15, N15, P15, R15, L16, M16, N16, P16, R16, F17, AA17, F19, AA20, F21, G21, U21, W21, AA21, E22, N22, AB22, A26, AF26, W21
V _{TT}	U24, F23
NC	U1, R2, D3, H3, K3, L3, M3, T3, U3, AC3, V4, Y4, M5, D6, AC6, B7, A10, AB10, AB11, AC11, E14, AB15, AB16, AC16, AF17, A18, AC18, AD19, J22, C23, K23, Y23, AA23, AE24, C26, H26, T26, V26, AF9, AC12, AF13, AF10, AE15, AC19, AB17, AE14, AB14, AA19, AF16, AB19, AE16, AF18, AD18, AB18, AD17, AD14, AF14, B12, D12, U23, AF12, AE12, V24, AD8, AE8, AF22, AB21, AC8, AB9, AE22, AD22

NOTES:

1. NC=No Connect
2. V_{TT}=GTL+

Package Specifications

7

This specification outlines the mechanical dimensions for PAC. The package is a 492 ball grid array (BGA).

Figure 7-1. PAC Package Dimensions (492 BGA)

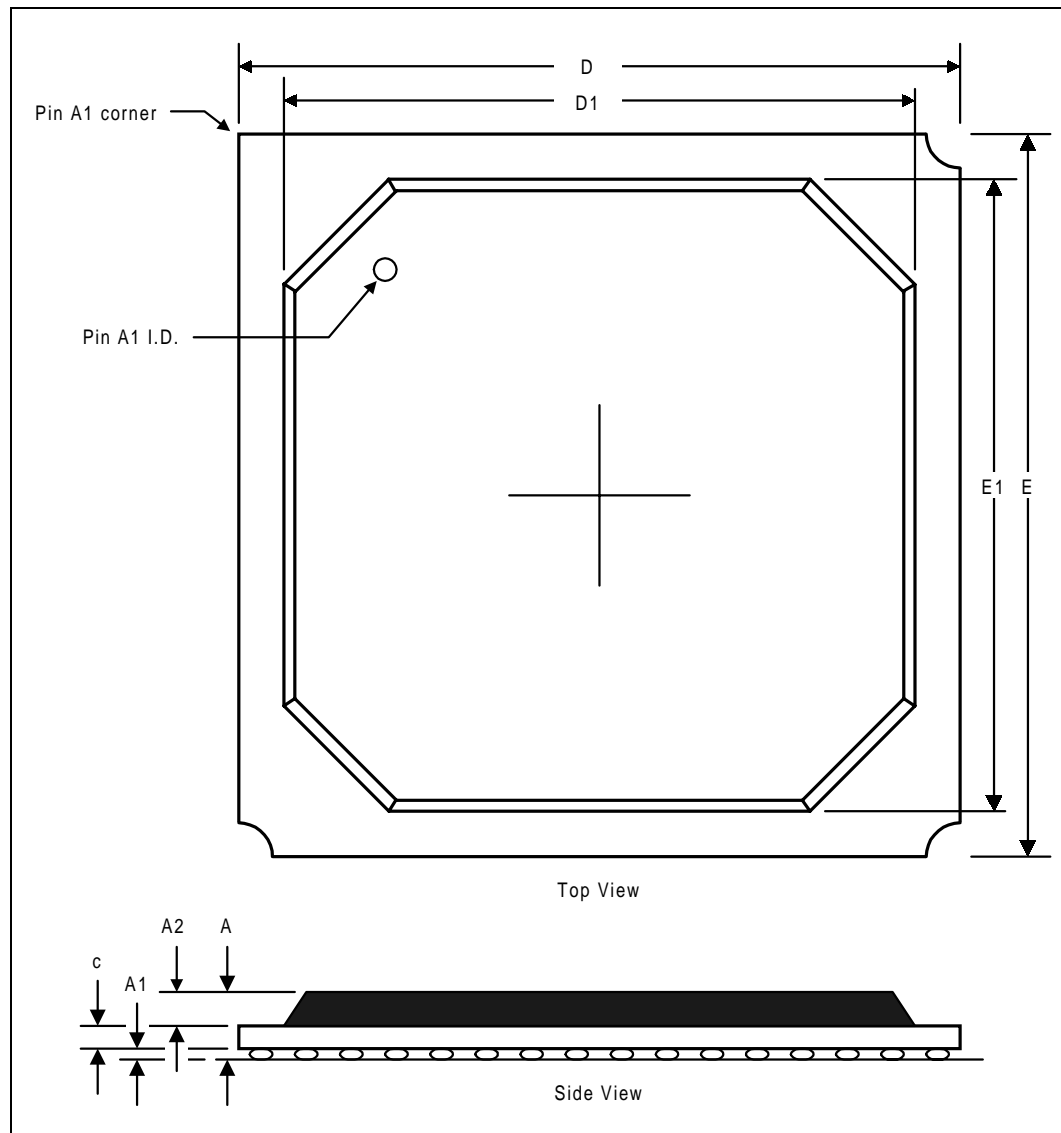


Figure 7-2. PAC Package Dimensions (492 BGA)

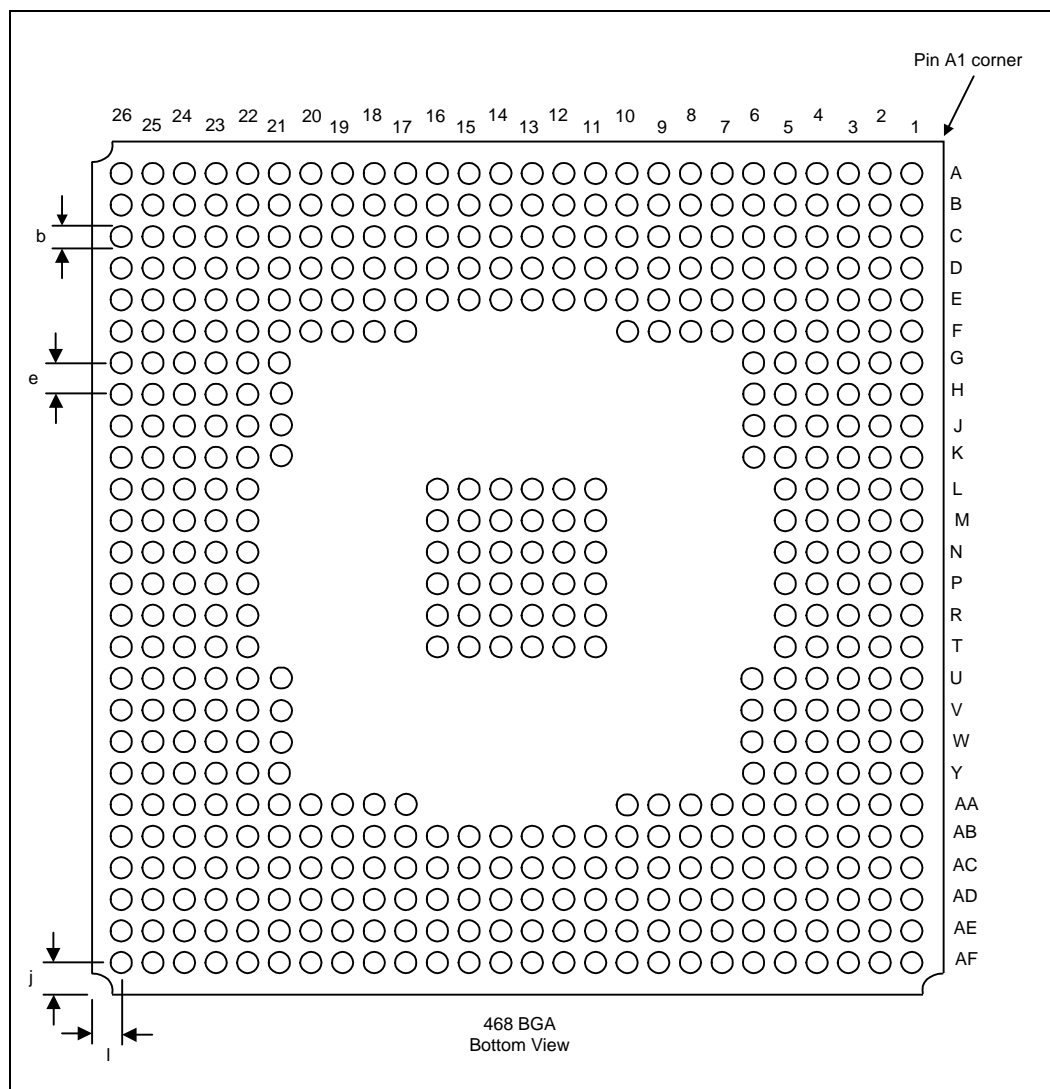


Table 7-1. PAC Package Dimensions (468 BGA)

Symbol	e=1.27 mm (solder ball pitch)			Note
	Min	Nom	Max	
A	2.14	2.33	2.52	
A1	0.50	0.60	0.70	
A2	1.12	1.17	1.22	
D	34.80	35.00	35.20	
D1	29.75	30.00	30.25	
E	34.80	35.00	35.20	
E1	29.75	30.00	30.25	
I	1.63 REF.			
J	1.63 REF.			
M	26 x 26 Matrix			
N	4.92			
b	0.60	0.75	0.90	
c	0.52	0.56	0.60	

UNITED STATES AND CANADA

Intel Corporation
2200 Mission College Boulevard
P.O. Box 58119
Santa Clara, CA 95052-8119
USA
Tel: 408-765-8080

EUROPE

Intel Corporation (U.K.) Ltd.
Pipers Way
Swindon
Wiltshire SN3 1RJ
UK
Tel: +44 (0) 1793 403000

ASIA PACIFIC

Intel Semiconductor Ltd.
32/F Two Pacific Place
88 Queensway, Central
Hong Kong
Tel: (852) 844-4555

JAPAN

Intel Japan K.K.
5-6 Tokodai, Tsukuba-shi
Ibaraki, 300-26
Japan
Tel: +81-298-47-8511

SOUTH AMERICA

Intel Semicondutores do Brazil LTDA
Rua Florida 1703-2 and CJ 22
04565-001-Sao Paulo, SP
Brazil
Tel: 55-11-5505-2296

FOR MORE INFORMATION

To learn more about Intel Corporation
visit our site on the World Wide Web
at <http://www.intel.com/>



* Other brands and names are the property of their respective owners.

Printed in USA/0498/PSA