AMD Athlon™ Northbridge with 4x AGP and Next Generation Memory Subsystem

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Advanced Micro Devices, Sunnyvale, CA

* AMD Athlon was formerly code-named AMD-K7
Outline of the Talk

- Introduction
- Architecture
- Clocking and Gearbox
- Performance
- Silicon Statistics
- Conclusion
Introduction

- NorthBridge: “Electronic traffic cop” that directs data flow between the main memory and the rest of the system

- Bridge the gap between processor speed and memory speed
  - Higher bandwidth busses
    - Example: AGP 2.0, EV6 and AMD Athlon system bus
  - Better memory technology
    - Example: Double data rate SDRAM, RDRAM
System Block Diagram

AMD Athlon System Bus

200 MHz, 64 bits
Scaleable to 400 MHz

NorthBridge

100MHz for PC-100 SDRAM
200MHz for DDR SDRAM
533-800MHz for RDRAM

66MHz, 32 bits
(1x,2x,4x)

AGP Bus

AMD Athlon System Bus

SouthBridge

33MHz, 32 bits

PCI Bus

100MHz for PC-100 SDRAM
200MHz for DDR SDRAM
533-800MHz for RDRAM

Graphics Device

PCI Devices

IDE USB Serial Port Printer Port

NorthBridge

SouthBridge

PCI Bus

ISA Bus

DRAM

AMD Athlon

CPU

CPU

IDE USB Serial Port Printer Port

NorthBridge

SouthBridge

PCI Bus

ISA Bus

AMD Athlon

CPU

CPU

IDE USB Serial Port Printer Port

NorthBridge

SouthBridge

PCI Bus

ISA Bus

AMD Athlon

CPU

CPU

IDE USB Serial Port Printer Port

NorthBridge

SouthBridge

PCI Bus

ISA Bus

AMD Athlon

CPU

CPU

IDE USB Serial Port Printer Port
Features of the AMD Athlon Northbridge

- Can support one or two AMD Athlon or EV6 processors
- 200MHz data rate (scaleable to 400MHz), 64-bit processor interface
- 33MHz, 32-bit PCI 2.2 compliant interface
- 66MHz, 32-bit AGP 2.0 compliant interface supports 1x, 2x and 4x data transfer modes
- Versions for SDRAM, DDR SDRAM and RDRAM memory
- Single bit error correction and multiple bit error detection (ECC)
- Distributed Graphics Aperture Remapping Table (GART)
- Power management features including powerdown self-refresh of SDRAM and PCI master grant suspend
Architecture

Different versions for PC100 SDRAM, DDR SDRAM and RDRAM

Control Data

L2 Cache

BIU0

BIU1

CFG

PCI

MRO

MCT

PLLS

AGP

Memory

Optional

L2 Cache

PCI Slots

AGP Master

AMD Athlon

AMD Athlon
Bus Interface Unit (BIU)

• Processor interface; one per processor
• The AMD Athlon Front side bus:
  – high performance point-to-point bus
  – non-multiplexed command, address, data and reply/snoop interfaces
  – double-data rate transfers on address and data busses
  – split transaction bus: up to 24 outstanding operations per processor
  – source synchronized clocking to compensate for PC board propagation delays
BIU Block Diagram

AMD Athlon System Bus

AMD Athlon

I/O

Xmt

Rcv

Other BIU or PCI or APC

PCI / APC

DRAM

Other BIU, PCI & APC

MRO, PCI & APC

Probe FIFO

PCI / APC Write FIFO

Memory Write FIFO

Transaction Agent

Mem Read FIFO

PCI / APC Read FIFO

Done

Other BIU

MRO, PCI & APC

DRAM

PCI / APC
Accelerated Graphics Port (AGP)

- 1x, 2x and 4x data transfer rates in pipelined and side band addressing (SBA) modes
- Fast Write implementation for CPU to AGP master write transfers
- Distributed GART mechanism using 3 fully associative translation lookaside buffers (TLBs)
- Dynamically compensated AGP 2.0 compliant I/O buffers
- Independent R/W data buffers
  - Reordering of high priority over low priority transactions
AGP Block Diagram

AGP I/O

AGP Bus

AGP Write Data

AGP Data FIFOs

Mem Write Data

AGP Read Data

AGP Bus

AGP Write Data

AGP Address

AGP Queues

GART Xlat

WrQ

RdQ

AXQ

Mem Req

Mem Read Data

Addr

SBA Xlat

SBA Seq

Seq

Arb

AGP Read Data

AGP Data

Write Fifo 8x144

Read Fifo 32x128

SDI

AMD
PCI Controller

- The PCI arbiter supports five external PCI masters plus the SouthBridge
- PCI to memory traffic is coherent w.r.t. the processor caches
- Consecutive processor cycles to sequential PCI addresses are chained together into one burst PCI cycle
- Same controller block is instantiated to handle the AGP PCI Protocol (APC block)
Memory Request Organizer (MRO)

- Request crossbar responsible for scheduling memory read and write requests from CPU, PCI and AGP
- Serves as the coherence point
- Requests are reordered to minimize page conflicts and maximize page hits
- Anti-starvation mechanism by aging of entries
- Arbitration bypassed during idle conditions to improve latency
SDRAM Memory Controller

- Controls up to 3 PC100 SDRAM or 4 DDR SDRAM DIMMs. 16, 64, 128 and 256Mb densities supported
- Open page policy with 4 banks open
- Peak bandwidth = 800MB/sec (PC100 SDRAM), 1.6GB/sec (DDR)
Rambus Memory Controller

- One 16-bit RDRAM channel with up to 32 devices distributed across 3 RIMMs. 64, 128 and 256Mb densities supported
- Rambus RMC uses a closed page policy, but can keep banks open with special chained commands
- Memory address mapped to reduce adjacent bank conflicts
- Peak bandwidth = 1.6GB/sec using 800MHz RDRAMs
Clocking and Gear Boxes

- Many clock domains have to be supported
  - 66 MHz peripheral (PCI and AGP) logic clock
  - 66 / 133 / 266 MHz 1x / 2x / 4x AGP clock
  - 66 / 100 / 133 MHz Core logic clock, AMD Athlon bus clock and SDRAM clock
- Gear box logic is used to synchronize data transfers between two clock domains
- The gearbox logic is correct by design for holdtime across clock domains
- The Rambus RAC synchronizes with the RMC using a different gearbox design
Slow to Fast Clock Domain

Sample points on the FastCLK domain

Slow clock domain

Gear Box Module

Fast clock domain
Fast to Slow Clock Domain

- **FastCLK** (100 MHz)
- **SlowCLK** (66 MHz)

**Data**:
- **Phase 2**: D0, D1
- **Phase 3**: D2, D3
- **Phase 1**: D4

**LatchEn**

**Latched Data**:
- **Phase 2**: D0
- **Phase 3**: D1
- **Phase 1**: D3, D4

**Sample points on the FastCLK domain**

**Combinational Logic**

**Gear Box Module**

Fast clock domain

Slow clock domain

**Flop**

**Latch**

**Combinational Logic**

**Flop**
Performance

• Bypassing:
  – Can bypass MRO and BIU under low system loads for 25% reduction in latency of CPU reads from main memory
  – Overall performance boost equivalent to ~1/2 CPU speed bin on Ziff-Davis WinBench® benchmark

• SPECint95 and SPECfp95 benchmarks on AMD Athlon and Pentium® III
  – 512K L2 cache, Single PC100 128MB DIMM
Performance

<table>
<thead>
<tr>
<th></th>
<th>Specfp_base95</th>
<th>Specint_base95</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD Athlon™ 600MHz [512K]</td>
<td>153%</td>
<td>AMD Athlon™ 600MHz [512K]</td>
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<tr>
<td>AMD Athlon 550MHz [512K]</td>
<td>146%</td>
<td>AMD Athlon 550MHz [512K]</td>
</tr>
<tr>
<td>Pentium® III 550MHz [512K]</td>
<td>100%</td>
<td>Pentium® III 550MHz [512K]</td>
</tr>
</tbody>
</table>

Normalized Pentium® III Performance = 1

Benchmark System Configuration: Diamond 770 using nVidia TNT2 Ultra 150MHz core, 183MHz memory clock 32MB, Western Digital Expert 41800, Single PC-100 128MB DIMM, SoundBlaster Live (Value) Audio, LinkSys HPN100 Ethernet card, Toshiba 6X DVD SD-M1212, Dual Boot Windows® 98 & Windows NT® 4.0 using Norton System Commander. Windows NT 4.0 is installed with SP4, Windows 98 with DX 6.1A build 2150, and nVidia TNT2 Ultra Driver Rev 1.81 under Windows 98 and Windows NT.


* This motherboard is not commercially available at this time.
## Silicon Statistics

<table>
<thead>
<tr>
<th>Chip Version</th>
<th>Tech &amp; Voltage</th>
<th>Max Core Speed</th>
<th>Die Size (pad limited)</th>
<th>No. of Pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDRAM, 1P, 2xAGP</td>
<td>0.35 μ, 3.3V</td>
<td>100 MHz</td>
<td>107 mm²</td>
<td>492</td>
</tr>
<tr>
<td>SDRAM, 2P, 2xAGP</td>
<td>0.35 μ, 3.3V</td>
<td>100 MHz</td>
<td>130 mm²</td>
<td>656</td>
</tr>
<tr>
<td>DDR, 1P, 4xAGP</td>
<td>0.25 μ, 2.5V</td>
<td>133 MHz</td>
<td>133 mm²</td>
<td>553</td>
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<tr>
<td>DDR, 2P, 4xAGP</td>
<td>0.25 μ, 2.5V</td>
<td>133 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDRAM, 1P, 4xAGP</td>
<td>0.25 μ, 2.5V</td>
<td>133 MHz</td>
<td>107 mm²</td>
<td>492</td>
</tr>
</tbody>
</table>
Die photo: SDRAM, 2P, 2xAGP

Approx. 500K gates
11.43x11.43mm²
Conclusions

- Low cost, high performance system solution for the AMD Athlon processor - EV6 in a PC
- Multiprocessing architecture for workstation and server markets
- Design provides for a high degree of concurrency which optimizes throughput under heavy system loads
- Support three memory sub-systems:
  - PC-100 SDRAM
  - Double Data Rate SDRAM
  - Direct Rambus SDRAM