AMD Bulldozer

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Outline

• Bulldozer Module
  • History
  • Pipeline Stages
  • Features

• Benchmarks
• Performance Flaw with Windows 7
• Applications
• The future
Release

• Predecessor – Phenom II (February 2009, used K10 microarchitecture)
• Bulldozer released in October 2011
Alpha 21264 Microprocessor

- Designed in 1996
- Bulldozer borrows architectural design

Bulldozer Module

- Each module has 2 integer cores and a single FPU
- All modules share a single L3 Cache

http://images.anandtech.com/doci/4955/BDArch.png
Bulldozer Module

- Architecture known as Clustered Multi-Thread
- Bulldozer vs. Intel Hyperthreading
- Offers more cores with less overhead per core
- Much larger focus on core count and parallel workloads while single threaded performance was largely ignored
Fetch

- Single L1 instruction cache shared between two integer cores
- Cache is 64KB 2-way Set Associative
- In Phenom II, 64KB I-cache per core
- Can fetch 4 instructions at a time
Branch Prediction

- Predicted at the same time as fetching
- Completely separated from the Fetch hardware
- Stalls in fetching will not affect the branch prediction
- Uses a prediction queue so it can keep going even when the system is stalled
Decode

- Two integer cores will share a 4-wide instruction decoder
- Higher width than Phenom II when a single core is active, but as more cores are active it falls behind
- Relies on the fact that few programs are fetch-decode bound
- Each x86 instruction translated into 1 or 2 macro-operations and then queued
Operation Fusion

- After the decode stage some operations are fused together
- Compare-test, test-branch operations are combined to increase IPC
- First done by Intel in 2003, first time for AMD
Integer Cores

- Each core has 16KB of write through L1 data cache
- Separate schedulers and register files
- Two ALU/AGU ports compared to three in Phenom II
- Shared Unified 2 MB L2 Cache

http://www.anandtech.com/show/4955/the-bulldozer-review-amd-fx8150-tested/2
Shared FP Core

- Independent scheduler
- Multithreaded, fully out-of-order execution
- Two 128-bit multiply accumulate units
- Single 128-bit high bandwidth load-store unit
- Added SSE4 and AVX instruction support
- Throughput has not increased over Phenom II, but can use more instructions
Clock Speed

- Many design decisions were made in an effort to improve clock speed
- Fewer resources for each core while adding features
- Low number of gates per pipeline stage = higher clock speeds
- Aimed for 30% increase in clock speed over Phenom II, got only 9%
- Yield issues?
Turbo Core

- If half or fewer cores are active the active cores can go to max turbo clock frequencies
- If more cores are active then the cores may go to an intermediate turbo frequency

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Cache and Memory Latencies

SiSoft Sandra 2011 SP5 Cache / RAM Latencies
In Nanoseconds (Lower is Faster)

- FX-8150 (4.6GHz): L1 = 0.9, L2 = 6.6, L3 = 22.6, Main Memory = 72.8
- FX-8150 (Stock): L1 = 1.1, L2 = 8.4, L3 = 24.6, Main Memory = 78.7
- X6 1100T: L1 = 0.9, L2 = 4.7, L3 = 20.24, Main Memory = 80.6
- i7-2600K: L1 = 1.2, L2 = 3.6, L3 = 11.7, Main Memory = 66.1

Benchmarks – Single Threaded

Cinebench 11.5 - Single Threaded
Score in CBmarks - Higher is Better

Single Core AIDA64 Queens Benchmark
AIDA64 Queens Score - Higher is Better

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### Benchmarks – Multi-Threaded

#### Cinebench 11.5 - Multi-Threaded

<table>
<thead>
<tr>
<th>Processor</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Core i7 2600K (3.4GHz)</td>
<td>6.86</td>
</tr>
<tr>
<td>AMD FX-8150 (3.6GHz)</td>
<td>5.99</td>
</tr>
<tr>
<td>AMD Phenom II X6 1100T BE (3.3GHz)</td>
<td>5.9</td>
</tr>
<tr>
<td>Intel Core i5 2500K (3.3GHz)</td>
<td>5.42</td>
</tr>
<tr>
<td>Intel Core i5 2400 (3.1GHz)</td>
<td>5.07</td>
</tr>
<tr>
<td>AMD Phenom II X4 975 BE (3.6GHz)</td>
<td>4.23</td>
</tr>
</tbody>
</table>

#### 7-zip Benchmark

<table>
<thead>
<tr>
<th>Processor</th>
<th>MIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD FX-8150 (3.6GHz)</td>
<td>21041</td>
</tr>
<tr>
<td>Intel Core i7 2600K (3.4GHz)</td>
<td>19744</td>
</tr>
<tr>
<td>AMD Phenom II X6 1100T BE (3.3GHz)</td>
<td>18416</td>
</tr>
<tr>
<td>Intel Core i5 2500K (3.3GHz)</td>
<td>14440</td>
</tr>
<tr>
<td>Intel Core i5 2400 (3.1GHz)</td>
<td>13498</td>
</tr>
<tr>
<td>AMD Phenom II X4 975 BE (3.6GHz)</td>
<td>13461</td>
</tr>
</tbody>
</table>

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http://www.anandtech.com/show/4955/the-bulldozer-review-amd-fx8150-tested/7
Power Usage

Power Consumption - Idle
Total System Power Consumption in Watts (Lower is Better)

<table>
<thead>
<tr>
<th>Processor Type</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Core i5 2500K (3.3GHz)</td>
<td>76 W</td>
</tr>
<tr>
<td>Intel Core i5 2400 (3.1GHz)</td>
<td>76.2 W</td>
</tr>
<tr>
<td>Intel Core i7 2600K (3.4GHz)</td>
<td>77.6 W</td>
</tr>
<tr>
<td>AMD FX-8150 (3.6GHz)</td>
<td>84.8 W</td>
</tr>
<tr>
<td>AMD Phenom II X6 1100T (3.3GHz)</td>
<td>109.4 W</td>
</tr>
<tr>
<td>AMD Phenom II X4 975 BE (3.6GHz)</td>
<td>110 W</td>
</tr>
</tbody>
</table>

Power Consumption - Load (x264 HD 3.03 2nd Pass)
Total System Power Consumption in Watts (Lower is Better)

<table>
<thead>
<tr>
<th>Processor Type</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Core i5 2400 (3.1GHz)</td>
<td>131.6 W</td>
</tr>
<tr>
<td>Intel Core i5 2500K (3.3GHz)</td>
<td>133.3 W</td>
</tr>
<tr>
<td>Intel Core i7 2600K (3.4GHz)</td>
<td>155.4 W</td>
</tr>
<tr>
<td>AMD Phenom II X4 975 BE (3.6GHz)</td>
<td>183.8 W</td>
</tr>
<tr>
<td>AMD Phenom II X6 1100T (3.3GHz)</td>
<td>200 W</td>
</tr>
<tr>
<td>AMD FX-8150 (3.6GHz)</td>
<td>229 W</td>
</tr>
</tbody>
</table>

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http://www.anandtech.com/show/4955/the-bulldozer-review-amd-fx8150-tested/8
Scheduling on Windows 7

- Currently the scheduling is not optimal
- Best for unrelated threads to be on different modules, while closely coupled threads are on a single module
Server Applications

• Allocate a virtual machine to each core

• For each server, there can be up to 64 cores per motherboard
  • Bounded by memory constraints
    • Bulldozer supports up to 384 GB per core
    • Memory in that quantity is very expensive

• With current standards, more than one VM is operated per core
  • Current Servers can run 100 VMs on 48 cores
  • When using Bulldozer, there is significant potential for even more VMs to run simultaneously
Future Generations

Delivering multiple generations of greater functionality and improved performance

- **“Piledriver”**
  2nd generation modular core
  - Improved IPC and frequency

- **“Bulldozer”**
  1st generation modular core
  - Flex FP
  - 128/256-bit AVX, XOP and FMA4

- **“Steamroller”**
  3rd generation modular core
  - Greater parallelism

- **“Excavator”**
  4th generation modular core
  - Greater performance

Summary

- Novel architecture
- Optimized for server workloads
- Didn’t quite meet design goals
  - What caused it to fail?
- Partly of a new yearly cadence
Questions?