M7: Next Generation SPARC

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Oracle
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<table>
<thead>
<tr>
<th>Year</th>
<th>SPARC Processor</th>
<th>Cores</th>
<th>L3 Cache</th>
<th>Technology</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>SPARC T3</td>
<td>16</td>
<td>4MB</td>
<td>40 nm</td>
<td>1.65 GHz</td>
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<td></td>
<td></td>
<td>S2</td>
<td></td>
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<tr>
<td>2011</td>
<td>SPARC T4</td>
<td>8</td>
<td>4MB</td>
<td>40 nm</td>
<td>3.0 GHz</td>
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<tr>
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<td>SPARC T5</td>
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# Oracle’s SPARC Strategy

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<tr>
<th>Extreme Performance</th>
<th>Computing Efficiency</th>
<th>Optimized for Oracle Software</th>
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<tr>
<td>Best Performance and Price-Performance in the Industry</td>
<td>Flexible Virtualization, Designed for Availability</td>
<td>Hardware and Software Engineered, Tested, and Supported Together</td>
</tr>
<tr>
<td>Deliver Services with Faster Speeds, and Lower the Costs for Existing Services</td>
<td>Enable Higher Utilization of Capital Assets, and Reduce Risks to Availability of Data</td>
<td>Deploy Technology Faster, with Less Risk and Lower Costs</td>
</tr>
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</table>

[http://blog.oracle.com/bestperf](http://blog.oracle.com/bestperf)
M7 Processor

- 32 SPARC Cores
  - Fourth Generation CMT Core (S4)
  - Dynamically Threaded, 1 to 8 Threads Per Core

- New Cache Organizations
  - Shared Level 2 Data and Instruction Caches
  - 64MB Shared & Partitioned Level 3 Cache

- DDR4 DRAM
  - Up to 2TB Physical Memory per Processor
  - 2X-3X Memory Bandwidth over Prior Generations

- PCIe Gen3 Support

- Application Acceleration
  - Real-time Application Data Integrity
  - Concurrent Memory Migration and VA Masking
  - DB Query Offload Engines

- SMP Scalability from 1 to 32 Processors
- Coherent Memory Clusters
- Technology: 20nm, 13ML
M7 Core (S4)

- Dynamically Threaded, 1 to 8 Threads
- Increased Frequency at Same Pipeline Depths
- Dual-Issue, OOO Execution Core
  - 2 ALU’s, 1 LSU, 1 FGU, 1 BRU, 1 SPU
  - 40 Entry Pick Queue
  - 64 Entry FA I-TLB, 128 Entry FA D-TLB
  - Cryptographic Performance Improvements
  - 54bit VA, 50bit RA/PA, 4X Addressing Increase
- Fine-grain Power Estimator
- Live Migration Performance Improvements
- Core Recovery
- Application Acceleration Support
  - Application Data Integrity
  - Virtual Address Masking
  - User-Level Synchronization Instructions
M7 Core Cluster

- 4 SPARC Cores Per Cluster
- New L2$ Architecture
  - 1.5X Larger at Same Cycle Count Latency as Prior Generations
  - 2X Bandwidth per Core, >1TB/s Per Core Cluster, >8TB/s per Chip
- 256KB L2-I$
  - Shared by All Cores in Core Cluster
  - 4-way SA, 64B Lines, >500GB/s Throughput
  - 4 Independent Core Interfaces @ >128GB/s Each
- 256KB Writeback L2-D$
  - Each L2-D$ Shared by 2 Cores (Core-pair)
  - 8-way SA, 64B Lines, >500GB/s Throughput per L2-D$
  - 2 Independent Core Interfaces @ >128GB/s per L2-D$
- Core-pair Dynamic Performance Optimizations
  - Doubles Core Execution Bandwidth at Prior Generation Thread Count to Maximize Per-Thread Performance
  - Utilize 8 Threads Per Core to Maximize Core Throughput
M7 Level 3 Cache and On-Chip Network

- 64MB Shared & Partitioned L3$
  - 8MB Local Partitions, Each 8-way SA
  - >25% Reduction in Local L3$ Cycle Latency Compared to Prior Generation (M6)
  - >1.6TB/s L3$ Bandwidth per Chip, 2.5x (T5) to 5X (M6) Over Previous Generations
  - Cache Lines May be Replicated, Migrated or Victimized Between L3$ Partitions
  - HW Accelerators May Directly Allocate into Target L3$ Partitions

- On-Chip Network (OCN)
  - Consists of Request (Rings), Response (Pt-Pt) and Data (Mesh) Interconnects
  - 0.5TB/s Bisection Data Bandwidth
M7 Process Group & Virtualization Affinity

- Solaris Process Group Hierarchy
  - Thread Scheduling Level Corresponding to Core Cluster and Local L3$ Partition
  - Thread Load Balance Across L3$ Partitions
  - Thread Reschedule Affinity
  - Co-location of Threads Sharing Data

- Oracle Virtualization Manager (OVM)
  - Process Group Provisioning Applied to Logical Partitions
  - Minimize L3$ Thrashing Between Virtual Machine Instances, Improve QoS
M7 Fine-grain Power Management

- **On-die Power Estimator Per Core**
  - Generates Dynamic Power Estimates By Tracking Internal Core Activities
  - Estimates Updated at 250 Nanosecond Intervals

- **On-die Power Controller**
  - Estimates Total Power of Cores and Caches on a Quadrant Basis (2 Core Clusters + 2 L3$ Partitions)
  - Accurate to within a Few Percent of Measured Power
  - Individually Adjusts Voltage and/or Frequency within Each Quadrant Based on Software Defined Policies

- **Performance @ Power Optimizations**
  - Highly Responsive to Workload Temporal Dynamics
  - Can Account for Workload Non-uniformity Between Quadrants

- **Quadrants May be Individually Power Gated**
M7 Memory and I/O

- 4 DDR4 Memory Controllers
  - 16 DDR4-2133/2400/2667 Channels
  - Very Large Memory, Up to 2TB per Processor
  - 160GB/s (DDR4-2133) Measured Memory Bandwidth (2X to 3X Previous Generations, T5 and M6)
  - DIMM Retirement Without System Stoppage

- Memory Links to Buffer Chips
  - 12.8Gbps/14.4Gbps/16Gbps Link Rates
  - Lane Failover with Full CRC Protection

- Speculative Memory Read
  - Reduces Local Memory Latency by Prefetching on Local L3$ Partition Miss
  - Dynamic per Request, Based on History (Data, Instruction) and Threshold Settings

- PCIe Gen3
  - 4 Internal Links Supporting >75GB/s
  - >2X Previous Generations, T5 and M6
M7 Processor Performance

- M6 Baseline
- Memory BW
- Int Throughput
- OLTP
- Java
- ERP
- FP Throughput

[Chart showing performance metrics for different categories]
Real-time Data Integrity Checking in Test & Production Environments

- Version Metadata Associated with 64Byte Aligned Memory Data
- Metadata Stored in Memory, Maintained Throughout the Cache Hierarchy and All Interconnects
- Memory Version Metadata Checked Against Reference Version by Core Load/Store Units
- HW Implementation, Very Low Overhead

Enables Applications to Inspect Faulting References, Diagnose and Take Appropriate Recovery Actions

Safeguards Against Invalid/Stale References and Buffer Overruns for Solaris and DB Clients

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**M7 Application Data Integrity**

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<th>M7 Memory &amp; Caches</th>
<th>M7 Core Pipeline Execution</th>
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<tr>
<td>version 64Bytes</td>
<td>ld ... version address</td>
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**Version Miscompare**

Reference Versions

**Safeguards Against Invalid/Stale References and Buffer Overruns for Solaris and DB Clients**
M7 Concurrent Fine-grain Memory Migration

- Hardware Support For Fine Grain Access Control
  - Applicable to Fine-grain Objects and Large Memory Pages
  - Bypasses Operating System Page Protection Overheads
  - Scales with Threads and Memory Bandwidth
- Deterministic Memory Access Conflict Resolution
  - Memory Metadata of Relocating Objects Are Marked for Migration
  - User Level Trap on Detection of Memory Reference with Migrating Version

Enables Concurrent and Continuous Operation
M7 Virtual Address (VA) Masking

Masked by Effective Address Hardware

- Allow Programs to Embed Metadata in Upper Unused Bits of Virtual Address Pointers
  - Applications Using 64-bit Pointers Can Set Aside 8, 16, 24 or 32 Bits
  - Addressing Hardware Ignores Metadata

- Enables Managed Runtimes (e.g. JVM's) to Embed Metadata for Tracking Object Information
  - Caches Object State Table Information into Object Pointer (Pointer Coloring)
  - Eliminates De-reference and Memory Load from Critical Path
M7 Database In-Memory Query Accelerator

- Hardware Accelerator Optimized for Oracle Database In-Memory
  - Task Level Accelerator that Operates on In-Memory Columnar Vectors
  - Operates on Decompressed and Compressed Columnar Formats

- Query Engine Functions
  - In-Memory Format Conversions
  - Value and Range Comparisons
  - Set Membership Lookups

- Fused Decompression + Query Functions Further Reduce Task Overhead, Core Processing Cycles and Memory Bandwidth per Query
M7 Query Accelerator Engine

- Eight In-Silicon Offload Engines
- Cores/Threads Operate Synchronous or Asynchronous to Offload Engines
- User Level Synchronization Through Shared Memory
- High Performance at Low Power
M7 Accelerator Fine-grain Synchronization

- Core Thread Initiates a Query Plan Task to Offload Engine

- User-Level LDMONITOR, MWAIT
  - Halts Hardware Thread for Specified Duration
  - Thread is Re-activated Once Duration Expires or Monitored Memory Location is Updated

Offload Engine Completion
- Results Written Back to Memory or Target L3$ Partition
- Completion Status Posted to Monitored Memory Location
- MWAIT Detection Hardware Resumes Core Thread Execution
M7 Query Offload Performance Example

- SPARC T5, M7 & Oracle Database In-Memory
- Single Stream Decompression Performance
  - Decompression Stage of Query Acceleration
  - Unaligned Bit-Packed Columnar Formats
  - 1 of 32 Query Engine Pipelines
- M7 Hardware Accelerator Fuses Decompression Output with Filtering Operations
  - Further Accelerates the “WHERE” Clause in SQL Query
  - In-line Predicate Evaluation Preserves Memory Bandwidth
- Business Analytics Performed at System Memory Bandwidth
SPARC Accelerated Program

- Enables Third Party Software to Utilize SPARC Application Acceleration Features
- Application Data Integrity Support in Future Solaris and DB Memory Allocators, Compiler and Tools Chain
- Future Solaris Support for Memory Migration and Virtual Address (VA) Masking
- Query Engine Software Libraries
M7 SMP Scalability

- Fully Connected 8 Processor SMP
  - Up to 256 Cores, 2K Threads, 16TB Memory
  - >1TB/s Bisection Payload Bandwidth
- Fully Connected 2/4 Processor SMP Utilizing Link Trunking
- Directory-based Coherence
- 16Gbps to 18Gbps Link Rates
- Link Level Dynamic Congestion Avoidance
  - Alternate Path Data Routing
  - Based on Destination Queue Utilization
- Link Level RAS
  - Auto Frame Retry
  - Auto Link Retrain
  - Single Lane Failover
M7 SMP Scalability

- SMP Scalability to 32 Processors
  - Up to 1K Cores, 8K Threads
  - Up to 64TB Memory

- 64 Port Switch ASIC's
  - Divided into 2 Switch Groups of 6 Switch ASICs
  - 5.2TB/s Payload Bandwidth
  - 4X Bisection Payload Bandwidth over M6

- Physical Domains of 4 Processors Each
  - Fully Connected Local Topology
  - Dynamically Combine Processor Domains

- Fully Connected Switch Topology
  - 2 Links Connecting Every Processor and Switch
  - Coherence Directory Distributed Among Switches
  - Latency Reduction over M6 Generation

- SMP Interconnect RAS
  - Link Auto Retry & Retrain, Single Lane Failover
  - Link Level Multipathing
  - Operational with 5 of 6 ASIC's per Switch Group
Highly Reliable and Secure Shared Memory Clustering Technology

- Access Remote Node Memory Using Load/Store/Atomics, Relaxed Ordering
- Integrated User Level Messaging and RDMA

Cacheable Memory Segments

- Remote Segments Cached in Local Node Memory & Caches at 64 Byte Granularity
- Load-Hit Latency Accessing Remote Segments Same as Local Node Memory and Caches
- Committed Stores to Remote Segments Update Home Node and Invalidate Remote Nodes

Non-Cacheable Memory Segments

- Always Access Remote Node Memory

Cluster-wide Security

- 64-bit Access Key Per Remote Request
- Memory Version Checking Across Cluster
M7 Coherent Memory Clusters

- Up to 64 Processor Cluster
  - Combinations of 2P, 4P or 8P Server Nodes
  - Leverages M7 SMP HW and Interconnect

- Coherent Memory Cluster Protocol
  - Application Committed Stores Remain Consistent at the Home Node in Face of Requester Failure
  - 2-Party Dialogs for Failure Isolation

- 1.3TB/s Bisection Payload Bandwidth

- Self Redundant Cluster Switch
  - 64 Port Switch ASIC's
  - 6 Switching Paths Between Each Processor Pair, Divided in 2 Groups
  - Fault Tolerant Design Allowing Operation with a Single Switching Path per Group
  - Automatic Link and Switch Failover Without Involving Application Software
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<td>Increased Virtualization Density</td>
<td>Improved Security and Reliability via Real-time Application Data Integrity</td>
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<td>Further Increase Core and Thread Performance</td>
<td>Low Latency Application Migration</td>
<td>Concurrent Object Migration and Pointer Coloring</td>
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<td>Increased Bandwidths Across Caches, Memory, Interconnects and I/O</td>
<td>Flexible Logical and Physical Partitioning</td>
<td>Database In-Memory Columnar Decompression, Query Offload and Coherent Memory Clusters</td>
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Oracle
Acronyms

- ADI: Application Data Integrity
- ALU: Arithmetic Logic Unit
- BRU: Branch Unit
- FA: Fully Associative
- FGU: Floating Point & Graphics Unit
- LSU: Load/Store Unit
- PA: Physical Address
- RA: Real Address
- SA: Set Associative
- SMP: Shared Memory Multiprocessor
- SPU: Stream Processing Unit
- TLB: Instruction or Data Translation Lookaside Buffer
- VA: Virtual Address