An Introduction to the SPEC High Performance Group and their Benchmark Suites

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Content

• Intro to SPEC and SPEC HPG
• The SPEC Benchmark Philosophy
• SPEC HPG Benchmarks
• Users and Use Cases
• Case Studies at Indiana University
• The SPEC Result Repository
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Standards Performance Evaluation Corporation (SPEC)

• SPEC is a non-profit corporation formed to "establish, maintain and endorse a standardized set of relevant benchmarks that can be applied to the newest generation of high-performance computers"

• Composed of four groups
  – Graphics and Workstation Performance Group (GWPG)
  – High Performance Group (HPG)
  – Open Systems Group (OSG)
  – Research Group (RG)

• www.spec.org
The SPEC Consortium: Members and Associates

SPEC Members:

SPEC Associates:
Academia Sinica, Institute of Information Science * Argonne National Laboratory * Charles University * China Academy of Telecommunication Research * Department of Veterans Affairs - Corporate Data Center Operations * Dresden University of Technology ZIH * fortiss GmbH * Indiana University * Institute for Information Industry Taiwan * JAIST * Karlsruhe Institute of Technology * Leibniz Rechenzentrum - Germany * National University of Singapore * Oak Ridge National Laboratory * Ohio State University * Pennsylvania State University * Purdue University * RWTH Aachen University * Technische Universität Darmstadt * Technische Universität Dresden * Tsinghua University * University of Aizu - Japan * University of California - Berkeley * University of Cologne * University of Houston * University of Illinois at Urbana-Champaign * University of Maryland * University of Miami * University of Pavia * University of Texas at Austin * University of Tsukuba * University of Wuerzburg * Virginia Polytechnic Institute and State University *

SPEC Research Group:
Advanced Strategic Technology LLC * bankmark UG * Barcelona Supercomputing Center * Charles University * Cisco Systems * Cloudera, Inc * Compileflows * Delft University of Technology * Dell * fortiss GmbH * Friedrich-Alexander-University Erlangen-Nuremberg * Goethe University Frankfurt, Big Data Lab * Hewlett-Packard * Huawei * IBM * Imperial College London * Indian Institute of Technology, Bombay * Institute for Information Industry, Taiwan * Institute of Communication and Computer Systems/NTUA * Intel * Karlsruhe Institute of Technology * Kiel University * MICROsoft Corporation * MITRE Corporation * NICTA * Nova-Tec Consulting GmbH * Oracle * Purdue University * Red Hat * RWTH Aachen University * Salesforce.com * San Diego Supercomputing Center * San Francisco State University * SAP AG * Siemens Corporation * Technische Universität Darmstadt * Technische Universität Dresden * The MITRE Corporation * Umea University * University of Alberta * University of Coimbra * University of Florence * University of Lugano * University of Minnesota * University of North Florida * University of Paderborn * University of Pavia * University of Stuttgart * University of Texas at Austin * University of Wuerzburg * VMware *
SPEC High Performance Group (HPG)

• Develops benchmarks to represent high-performance computing applications for standardized, cross-platform performance evaluation.

• Benchmarks
  – SPEC OMP2012
  – SPEC MPI2007
  – SPEC ACCEL
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SPEC Benchmark Philosophy

• The result of a SPEC benchmark is always a SPEC score.
  – Higher is better

• This score is always in relation to a reference machine.
  – Each benchmark has its own reference machine
SPEC Benchmark Philosophy cont’d

• SPEC (HPG) benchmarks are full applications.
  – Including all the overhead of a real application

• SPEC harness ensures correctness of results.
  – To detect “overly aggressive optimization”
  – To guard against tampering

• Each benchmark suite has a set of run rules.
SPEC Benchmark Philosophy cont’d

• Hierarchy within benchmark suits
  – Benchmark suite i.e. SPEC ACCEL
  – Benchmark i.e. OpenACC
  – Dataset size i.e. Medium
  – Component i.e. 350.md
SPEC Benchmark Philosophy cont’d

- Benchmarks support “Base” and “Peak” configuration
  - These yield separate SPEC scores.
  - “Peak” runs allow for more freedom.

- Base runs
  - The same compiler switches for all components
  - The same parallelism
  - Only portability switches allowed
SPEC Power

• SPEC provides a standard methodology to measure and report power usage which can be incorporated into a SPEC benchmark.

• Normalizes the power usage across the full run of the suite
Benchmark Development Process

• Group effort, with lots of discussions
• Final decisions are by vote, even though we strive for consensus
• Technical and managerial parts
  – Find benchmark components and define run rules
• Using SPEC provided tools
  – SVN, harness, “common rules”
  – Websites, mailing lists, meeting venues
Result Submission Process

• Obtain and install the benchmark
• Perform a valid run
• Supply hardware and software description
• Submit result for review (and publication) to SPEC HPG
  – 2 week review process
  – (Define embargo period)

• Use the result as you would like
The Value of a Curated Result Repository

• Given appropriate hardware.... a published result should be reproducible just with the information available in the submission.
• Peer reviewed results are so much better than “everyone can upload a result”!
• The value of a benchmark suite lies in public results, their correctness and the ability to compare them.
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SPEC ACCEL

• SPEC Accel provides a comparative performance measure of
  – Hardware accelerator devices (GPU, Co-processors, etc.)
  – Supporting software tool chains (Compilers, Drivers, etc.)
  – Host systems and accelerator interface (CPU, PCIe, etc.)
• Computationally-intensive parallel HPC applications and mini-apps
• Portable across multiple accelerators
• Two distinct benchmarks
  – OpenACC v1.0
  – OpenCL v1.1
SPEC OMP2012

• Follow on to SPEC OMP2001
• 14 applications
• Scales up to 512 threads
• Support for power measurement
SPEC MPI2007

• Large and medium data set
• 13 applications
• Scales to 2048 MPI processes
• Power not supported
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SPEC USERS

• System vendors
• Accelerator vendors
• Software vendors
• Users looking for objective comparison
• Researchers
Vendors

• Marketing
• Drive benchmark development
  – To utilize state of the art hardware/software features
• Internal validation suite
  – Compiler
  – OMP / MPI runtime libraries
• Prepare for RFPs
Application Developers

• Include their application in the benchmark suite
• Compare hardware and software stack
  – Compilers
  – Parallel runtimes
  – Different versions of processors
  – Different interconnects
HPC Centers

• Include the benchmarks in the RFP process
• Use them for performance regression testing
  – Hardware
  – Software
• System configuration and tuning
• Power consumption
Researchers

• Scalability studies
• Novel implementations of parallel runtime libraries
• Detailed power consumption studies
• Comparison of parallel programming paradigms
Join and Contribute

• Submit results

• Full members vs. associate members

• Contribute benchmark components

• Help with benchmark suite development

• Test release candidates
Result Submissions by Benchmark

- OMP2001 (Large)
- OMP2001 (Medium)
- MPI2007 (Large)
- MPI2007 (Medium)
- OMP2012
- ACCEL OpenACC
- ACCEL OpenCL

Number of Submissions:
- 2001-2012
- 2007
- 2012
- 2014

Years:
- 2001
- 2007
- 2012
- 2014
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Use Cases (at IU)

• Comparing performance and energy
• Comparing performance of hypervisors
• Comparing HPC systems at a site
• Compare compiler performance over time
• Compare performance of different compilers
• Scalability study for different interconnects
• System setup questions like to use HT or not, which OS to use
• Compare accelerator performance
SPEC ACCEL OpenCL
Different Hardware

SPEC Score

AMD Radeon R9 290
AMD Radeon HD 7970
Intel Xeon E5620
Intel Xeon E5-2697 v3
NVIDIA GeForce GTX 680
NVIDIA Tesla C2070
NVIDIA Tesla K20
NVIDIA Tesla K20c
NVIDIA Tesla K20Xm
NVIDIA Tesla K40c
NVIDIA Tesla K40m
NVIDIA GeForce GTX TITAN
SPEC ACCEL OpenACC
Different Hardware

Scores

<table>
<thead>
<tr>
<th></th>
<th>AMD Radeon HD 7970</th>
<th>FirePro s9150</th>
<th>NVIDIA Quadro 6000</th>
<th>NVIDIA Tesla C2070</th>
<th>NVIDIA Tesla K20</th>
<th>NVIDIA Tesla K20c</th>
<th>NVIDIA Tesla K20Xm</th>
<th>NVIDIA Tesla K40c</th>
<th>NVIDIA GeForce GTX TITAN</th>
</tr>
</thead>
</table>

- Scores range from 0.5 to 3.5.
- FirePro s9150 has the highest score among the listed hardware.
- NVIDIA Tesla K40c and NVIDIA GeForce GTX TITAN have the second highest scores.
- NVIDIA Tesla C2070 has the lowest score.
SPEC ACCEL OpenACC
IU Cray XK7 (NVIDIA Tesla K20)
SPEC MPI2007 Medium
Cray XE6 (AMD Opteron 6380)

- Packing Nodes
- Using only "proper" FPU Cores per Node

SPEC Score

Core counts

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<tr>
<th>Core counts</th>
<th>SPEC Score</th>
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<tbody>
<tr>
<td>16</td>
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<tr>
<td>32</td>
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<td>64</td>
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<td>256</td>
<td>8</td>
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<tr>
<td>512</td>
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</table>
SPEC MPI2007 Medium
IBM iDataPlex (Intel Xeon L5420)

SPEC Score

Core counts

32  64  128  256  512

Windows MS_MPI-1.0.6  Linux Intel_MPI-3.1  Linux OpenMPI-1.3.1
SPEC MPI2007 Medium
Available HPC Systems at IU

![Bar chart](image)

- Cray XE6
- HP DL580
- IBM iDataPlex
SPEC OMP2001 Medium
Native vs. Hypervisors

SPEC Score

Native | KVM | XEN | VirtualBox

0 | 5000 | 10000 | 15000 | 20000 | 25000 | 30000 | 35000 | 40000 | 45000

RESEARCH TECHNOLOGIES
PERVASIVE TECHNOLOGY INSTITUTE
SPEC OMP2012
Performance and Energy (Dell PE 2970)

Virtual Machine vs Native

- KVM
- Native

SPEC Score

Performance Score

Energy Score
SPEC OMP2012
Performance and Energy

Systems/Environments

- Dell PowerEdge 2970 (KVM)
- Dell PowerEdge 2970
- HP Proliant DL580 G7

Performance Score
Energy Score
SPEC OMP2012
Available HPC Systems at IU

<table>
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<tr>
<th>System</th>
<th>SPEC Score</th>
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<td>Cray XE6</td>
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<tr>
<td>HP DL580</td>
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<tr>
<td>IBM NeXtScale nx360</td>
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SPEC OMP2012
IBM NeXtScale nx360 (Xeon E5-2650 v2)

SPEC Score

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<th>hyperthreading</th>
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<tr>
<td>SPEC Score</td>
<td>4.87</td>
<td>5.05</td>
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Live Demo!
Thank you!

Questions?