TECHNISCHE UNIVERSITÄT DRESDEN
Center for Information Services and High Performance Computing (ZIH)

SPEC ACCEL

A Standard Application Suite for Measuring Hardware Accelerator Performance

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ZIH
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Who is 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

Benchmarks

- CPU
- Graphics/Workstations
- ACCEL/MPI/OMP
- Java Client/Server
- Mail Servers
- Network File System
- Power
- SIP
- SOA
- Virtualization
- Web Servers

- Results Search

- Submitting Results
  - CPU/Java/Power/SFS
  - SIP/Virtualization
  - ACCEL/MPI/OMP
  - SPECapc/SPECviewperf/SPECwpc

Tools

- SERT
- PTDaemon

The SPEC Consortium: Members and Associates

SPEC Members:

*Acer Inc. * Action S.A. * Advanced Micro Devices * Amazon Web Services, Inc. * Apple Inc. * ARM * ASUSTeK Computer Inc. * Avere Systems * Bull S.A. * Cisco Systems, Inc. * Dell, Inc. * E4 Computer Engineering SPA * EMC * Fujitsu * Gartner, Inc. * Hitachi Data Systems * Hitachi Ltd. * HP * Huawei Technologies Co. Ltd. * IBM * Intel * Lenovo * Microsoft * NEC - Japan * NetApp * NVIDIA * Oracle * Platform Computing Inc. * Primary Data * Principled Technologies * Qualcomm Technologies Inc. * Quanta Compute Inc. * Red Hat * Samsung * SAP AG * Seagate * SGI * Sugon * Super Micro Computer, Inc. * SUSE * Symantec Corporation * Twitter, Inc. * Unisys * Via Technologies * VMware * Voxeo Corporation **

SPEC Associates:

*Acadamia Sinica, Institute of Information Science * Austrian Energy Agency * Argonne National Laboratory * Charles University * Department of Veteran's Affairs - Corporate Data Center Operations * Dresden University of Technology ZIH * Indiana University * Institute for Information Industry Taiwan * JAIST * Karlsruhe Institute of Technology * Leibniz Rechenzentrum - Germany * MIT Lincoln Laboratory * National University of Singapore * Ohio State University * Pennsylvania State University * Purdue University * RWTH Aachen University * Technische Universität Darmstadt * 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 * Virginia Polytechnic Institute and State University **

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

SPEC ACCEL

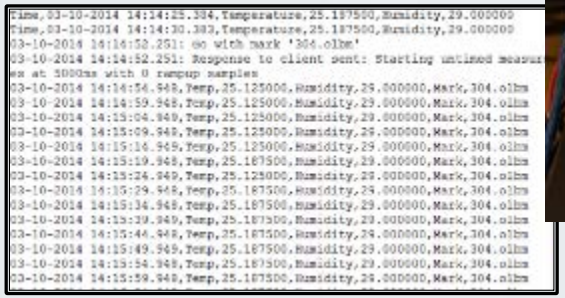
- SPEC Accel provides a comparative performance measure of
  - Hardware Accelerator devices (GPU, Co-processors, etc.)
  - Supporting software tool chains (Compilers, Drivers, etc.)
  - Host systems and accelerator interface (CPU, PCIe, etc.)
- Computationally-intensive parallel High Performance Computing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

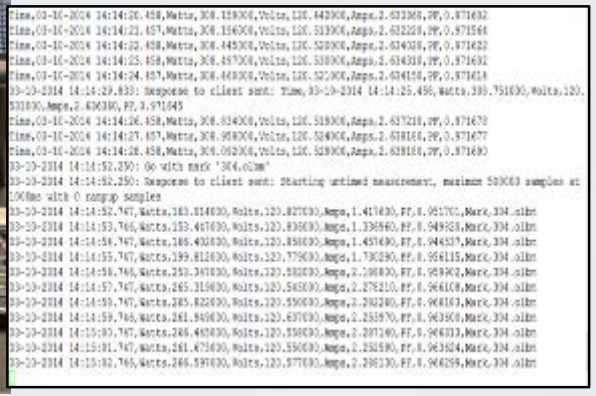
SPEC ACCEL Users

- Users looking for objective apples-to-apples comparison
- System vendors
- Accelerator vendors
- Software vendors
- Researchers

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





OpenCL Suite – Benchmarks Taken from Parboil

Benchmarks	Language	Application Domain
101.tpacf	C++	Astrophysics
103.stencil	C++	Thermodynamics
104.lbm	C++	Fluid Dynamics
110.fft	C	Signal processing
112.spmv	C++	Sparse Linear Algebra
114.mriq	C	Medicine
116.histo	C	Silicon Wafer Verification
117.bfs	C	Electronic Design Automation, Graph Traversals
118.cutcp	C	Molecular Dynamics

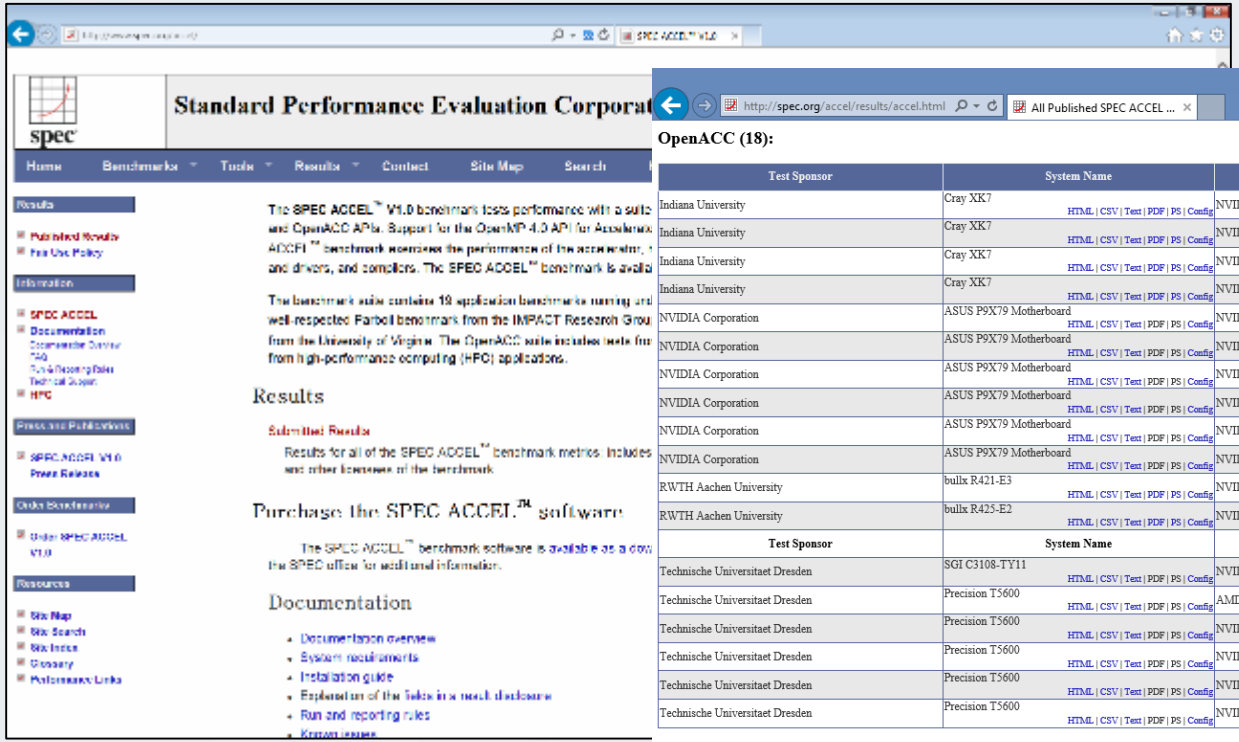
OpenCL Suite – Benchmarks Taken from Rodinia

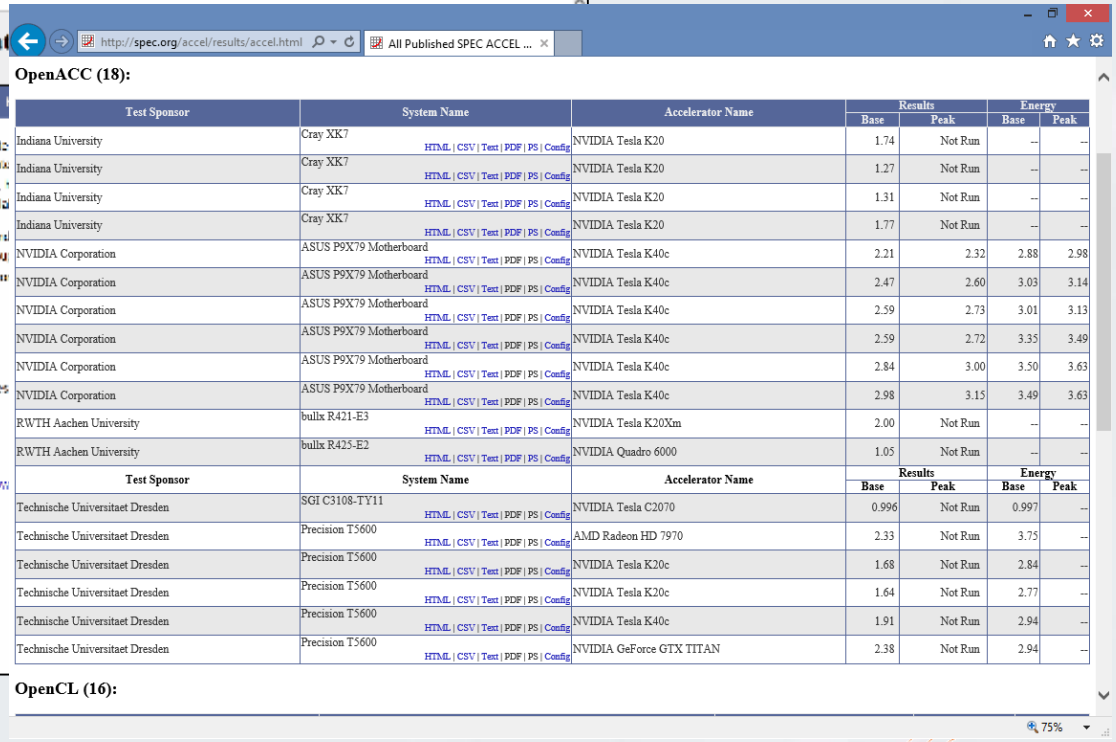
Benchmarks	Language	Application Domain
120.kmeans	C++	Dense Linear Algebra, Data Mining
121.lavamd	C	N-Body, Molecular Dynamics
122.cfd	C++	Unstructured Grid, Fluid Dynamics
123.nw	C++	Dynamic Programming, Bioinformatics
124.hotspot	C	Structured Grid, Physics Simulation
125.lud	C++	Dense Linear Algebra, Linear Algebra
126.ge	C++	Gaussian Elimination
127.srad	C	Structured Grid, Image Processing
128.heartwall	C	Structured Grid, Medical Imaging
140.bplustree	C	Graph Traversal, Search

OpenACC Suite

OpenACC Benchmarks	Language	Origin	Application Domain
303.ostencil	C	Parboil, University of Illinois	Thermodynamics
304.olbm	C	Parboil, University of Illinois, SPEC CPU2006	Computational Fluid Dynamics, Lattice Boltzmann
314.omriq	C	Rodinia, University of Virginia	Medicine
350.md	Fortran	Indiana University	Molecular Dynamics
351.palm	Fortran	Leibniz University of Hannover	Large-eddy simulation, atmospheric turbulence
352.ep	C	NAS Parallel Benchmarks (NPB)	Embarrassingly Parallel
353.clvrleaf	C, Fortran	Atomic Weapons Establishment (AWE)	Explicit Hydrodynamics
354.cg	C	NPB	Conjugate Gradient Solver
355.seismic	Fortran	GeoDynamics.org, University of Pau	Seismic Wave Modeling (PDE)
356.sp	Fortran	NPB	Scalar Penta-diagonal solver
357.csp	C	NPB	Scalar Penta-diagonal solver
359.miniGhost	C, Fortran	Sandia National Lab	Finite difference
360.ilbdc	Fortran	SPEC OMP2012	Fluid Mechanics
363.swim	Fortran	SPEC OMP2012	Weather
370.bt	C	NPB	Block Tridiagonal Solver for 3D PDE

Published Results





Test Sponsor	System Name	Accelerator Name	Results		Energy	
			Base	Peak	Base	Peak
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	1.74	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	1.27	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	1.31	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	1.77	Not Run	--	--
NVIDIA Corporation	ASUS P9X79 Motherboard HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	2.21	2.32	2.88	2.98
NVIDIA Corporation	ASUS P9X79 Motherboard HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	2.47	2.60	3.03	3.14
NVIDIA Corporation	ASUS P9X79 Motherboard HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	2.59	2.73	3.01	3.13
NVIDIA Corporation	ASUS P9X79 Motherboard HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	2.59	2.72	3.35	3.49
NVIDIA Corporation	ASUS P9X79 Motherboard HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	2.84	3.00	3.50	3.63
NVIDIA Corporation	ASUS P9X79 Motherboard HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	2.98	3.15	3.49	3.63
RWTH Aachen University	bullx R421-E3 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20Xm	2.00	Not Run	--	--
RWTH Aachen University	bullx R425-E2 HTML | CSV | Text | PDF | PS | Config	NVIDIA Quadro 6000	1.05	Not Run	--	--
Test Sponsor	**System Name**	**Accelerator Name**	**Results**		**Energy**	
			Base	**Peak**	**Base**	**Peak**
Technische Universitaet Dresden	SGI C3108-TY11 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla C2070	0.996	Not Run	0.997	--
Technische Universitaet Dresden	Precision T5600 HTML | CSV | Text | PDF | PS | Config	AMD Radeon HD 7970	2.33	Not Run	3.75	--
Technische Universitaet Dresden	Precision T5600 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20c	1.68	Not Run	2.84	--
Technische Universitaet Dresden	Precision T5600 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20c	1.64	Not Run	2.77	--
Technische Universitaet Dresden	Precision T5600 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K40c	1.91	Not Run	2.94	--
Technische Universitaet Dresden	Precision T5600 HTML | CSV | Text | PDF | PS | Config	NVIDIA GeForce GTX TITAN	2.38	Not Run	2.94	--

A Single Result Explained

SPEC® ACCEL_ACC Result

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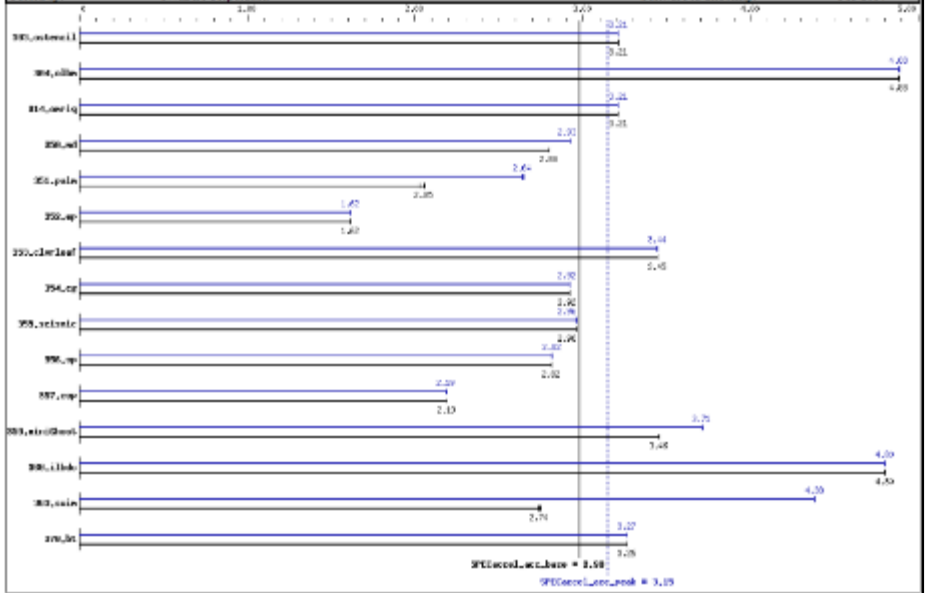
ASUS (Test Sponsor: NVIDIA Corporation)
NVIDIA Tesla K40c
ASUS P9X79 Motherboard

SPECaccel_acc_base =	2.98
SPECaccel_acc_energy_base =	3.49
SPECaccel_acc_peak =	3.15
SPECaccel_acc_energy_peak =	3.63

ACCEL license:	019	Test date:	Feb-2014
Test sponsor:	NVIDIA Corporation	Hardware Availability:	Nov-2013
Tested by:	NVIDIA Corporation	Software Availability:	Feb-2014



Hardware

CPU Name:	Intel Core i7-3930K
CPU Characteristics:	
CPU MHz:	3200
CPU MHz Maximum:	3800
FPU:	Integrated
CPU(s) enabled:	6 cores, 1 chip, 6 cores/chip, 2 threads/core
CPU(s) orderable:	1 chip
Primary Cache:	32 KB I + 32 KB D on chip per core
Secondary Cache:	256 KB I+D on chip per core

Accelerator

Accel Model Name:	Tesla K40c
Accel Vendor:	NVIDIA
Accel Name:	NVIDIA Tesla K40c
Type of Accel:	GPU
Accel Connection:	PCIe 3.0 16x
Does Accel Use ECC:	No
Accel Description:	GPU Boost set to maximum graphic clock frequency of 875 MHz. See notes below.
Accel Driver:	NVIDIA UNIX x86_64 Kernel Module 319.60

Power

Power Supply:	1200 W
Power Supply Details:	Thermaltake SMART M1200W
Max. Power (W):	398.64
Idle Power (W):	94.87
Min. Temperature (C):	26.56

Power Analyzer

Power Analyzer:	Power Analyzer
Hardware Vendor:	Xitron Technologies, Inc.
Model:	2801
Serial Number:	28011109005
Input Connection:	RS232 via USB-adapter
Metrology Institute:	NIST
Calibration By:	Micro Precision Calibration, Inc.
Calibration Label:	220081222038459
Calibration Date:	02.20.2014
PTDaemon Version:	1.6.2 (372e138a; 2013-12-04)
Setup Description:	connected to the single power supply that powers the system
Current Ranges Used:	2.0A
Voltage Range Used:	135V

Temperature Meter

Temperature Meter:	Temperature Meter
Hardware Vendor:	Digi
Model:	DigiWATCHPORT_H
Serial Number:	WS34682143
Input Connection:	USB
PTDaemon Version:	1.6.2 (372e138a; 2013-12-04)
Setup Description:	Position 5mm above intake fan

Base Results Table

Benchmark	Seconds	Ratio	Energy (kJ)	Maximum Power	Average Power	Energy Ratio	Seconds	Ratio	Energy (kJ)	Maximum Power	Average Power	Energy Ratio	Seconds	Ratio	Energy (kJ)	Maximum Power	Average Power	Energy Ratio
303.ostencil	45.8	3.17	16.8	384	367	3.15	45.7	3.17	16.6	374	364	3.18	**45.8**	**3.17**	**16.8**	**375**	**366**	**3.16**
304.olbm	194	2.35	56.1	296	290	2.78	194	2.35	56.3	298	291	2.77	**194**	**2.35**	**56.1**	**299**	**290**	**2.78**
314.omriq	354	2.70	131	375	369	2.92	**354**	**2.70**	**131**	**375**	**371**	**2.91**	354	2.70	132	376	372	2.90
350.md	90.6	2.78	31.6	354	349	2.97	90.7	2.78	31.7	367	349	2.97	**90.7**	**2.78**	**31.6**	**363**	**349**	**2.97**
351.palm	**184**	**2.01**	**42.0**	**238**	**228**	**2.54**	189	1.96	43.1	237	228	2.48	184	2.01	42.0	241	228	2.55
352.ep	330	1.60	83.8	275	254	1.96	**330**	**1.61**	**83.9**	**256**	**254**	**1.96**	330	1.61	83.5	255	253	1.97
353.clvrleaf	145	3.07	46.0	322	317	3.42	145	3.07	45.9	322	317	3.43	**145**	**3.07**	**45.8**	**325**	**316**	**3.44**
354.cg	**144**	**2.84**	**41.5**	**328**	**289**	**3.37**	144	2.84	41.5	328	289	3.37	144	2.84	41.4	326	288	3.38
355.seismic	**133**	**2.79**	**38.2**	**298**	**288**	**3.38**	133	2.79	38.1	298	287	3.39	133	2.79	38.1	297	287	3.39
356.sp	118	2.35	33.9	292	288	2.74	**118**	**2.35**	**33.8**	**291**	**288**	**2.74**	118	2.35	33.8	291	287	2.74
357.csp	143	1.89	39.3	286	275	2.24	143	1.89	39.1	285	274	2.25	**143**	**1.89**	**39.2**	**288**	**275**	**2.25**
359.miniGhost	**132**	**2.80**	**37.0**	**304**	**281**	**3.21**	132	2.80	36.8	304	280	3.23	132	2.80	36.8	302	280	3.23
360.ilbdc	**97.3**	**3.77**	**29.7**	**315**	**305**	**4.37**	97.3	3.77	29.6	314	305	4.38	97.4	3.77	29.7	314	305	4.38
363.swim	88.7	2.59	23.5	266	265	3.23	88.4	2.60	23.4	265	264	3.25	**88.4**	**2.60**	**23.4**	**265**	**264**	**3.25**
370.bt	**75.7**	**2.95**	**21.3**	**284**	**281**	**3.56**	75.7	2.95	21.1	281	279	3.58	75.7	2.95	21.1	282	279	3.58

Results appear in the order in which they were run. Bold underlined text indicates a median measurement.

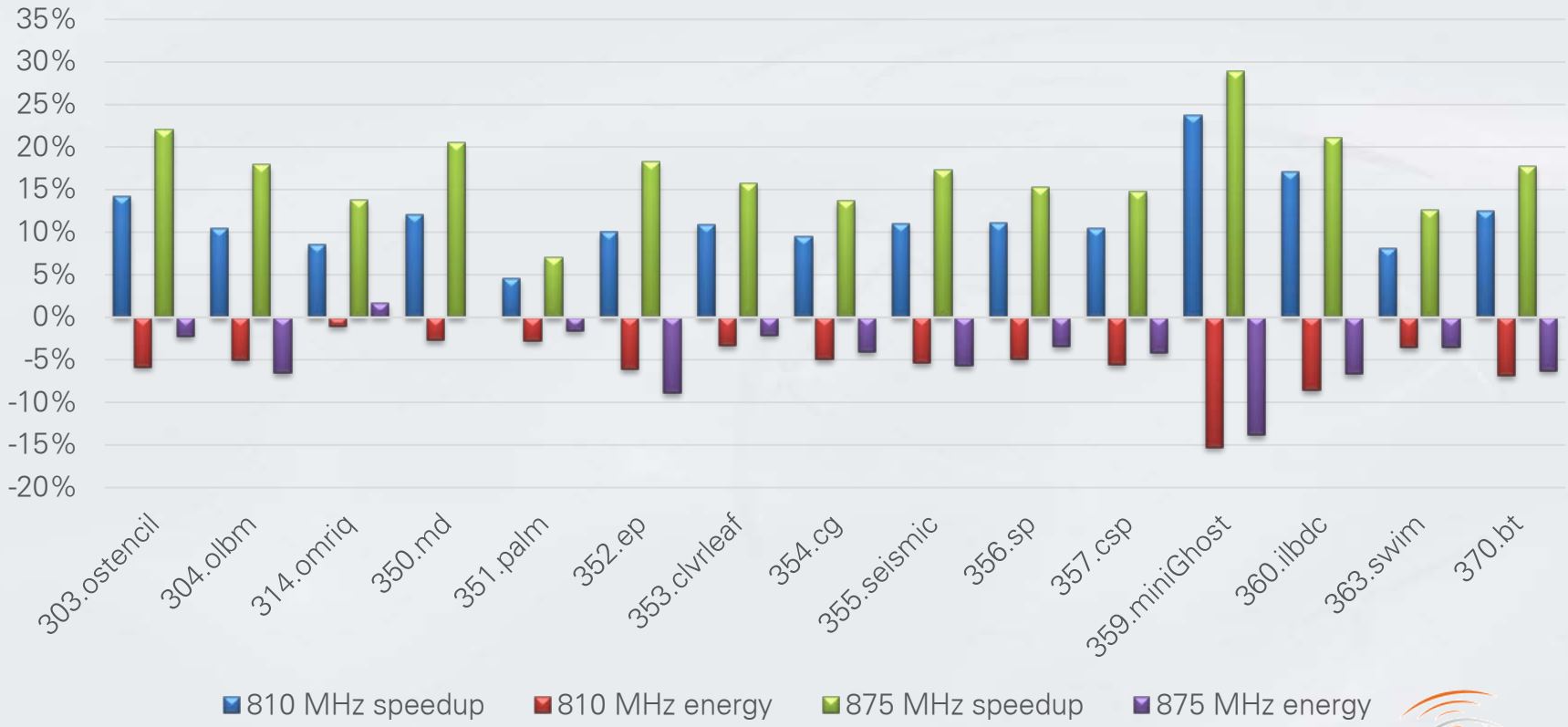
Peak Results Table

Benchmark	Seconds	Ratio	Energy (kJ)	Maximum Power	Average Power	Energy Ratio	Seconds	Ratio	Energy (kJ)	Maximum Power	Average Power	Energy Ratio	Seconds	Ratio	Energy (kJ)	Maximum Power	Average Power	Energy Ratio
303.ostencil	45.7	3.17	16.8	373	366	3.16	45.7	3.17	16.8	373	368	3.15	**45.7**	**3.17**	**16.7**	**374**	**364**	**3.18**
304.olbm	**194**	**2.35**	**56.2**	**303**	**290**	**2.78**	194	2.35	56.0	295	289	2.79	194	2.35	56.0	295	289	2.79
314.omriq	354	2.70	131	375	370	2.92	354	2.70	131	399	371	2.92	**354**	**2.70**	**131**	**391**	**370**	**2.92**
350.md	86.7	2.91	31.0	364	358	3.03	86.7	2.91	31.1	365	359	3.02	**86.7**	**2.91**	**31.0**	**363**	**358**	**3.03**
351.palm	145	2.54	34.7	256	238	3.09	**145**	**2.55**	**34.6**	**251**	**239**	**3.09**	145	2.55	34.5	251	238	3.10
352.ep	**330**	**1.60**	**83.6**	**255**	**253**	**1.97**	330	1.61	83.8	272	254	1.96	330	1.60	83.9	273	254	1.96
353.clvrleaf	145	3.07	45.9	322	316	3.43	**145**	**3.07**	**45.6**	**322**	**315**	**3.45**	145	3.07	45.7	321	315	3.45
354.cg	144	2.84	41.5	328	288	3.38	144	2.84	41.5	339	289	3.38	**144**	**2.84**	**41.7**	**328**	**290**	**3.36**
355.seismic	133	2.79	38.1	297	287	3.39	133	2.79	38.2	297	288	3.38	**133**	**2.79**	**38.2**	**304**	**288**	**3.38**
356.sp	**118**	**2.35**	**33.7**	**291**	**287**	**2.75**	118	2.35	33.8	291	288	2.74	118	2.35	33.7	292	287	2.75
357.csp	143	1.89	39.2	278	274	2.25	143	1.89	39.1	278	274	2.25	**143**	**1.89**	**39.2**	**278**	**275**	**2.24**
359.miniGhost	**121**	**3.04**	**35.1**	**336**	**289**	**3.39**	121	3.04	35.1	339	289	3.39	121	3.04	35.2	333	290	3.38
360.ilbdc	97.3	3.77	29.6	312	304	4.40	**97.3**	**3.77**	**29.6**	**326**	**304**	**4.40**	97.3	3.77	29.6	312	305	4.38
363.swim	**57.2**	**4.02**	**17.2**	**302**	**300**	**4.42**	57.2	4.02	17.1	300	298	4.45	57.3	4.02	17.1	300	299	4.43
370.bt	75.7	2.95	21.2	283	280	3.56	**75.7**	**2.95**	**21.2**	**283**	**280**	**3.56**	75.8	2.94	21.5	291	283	3.52

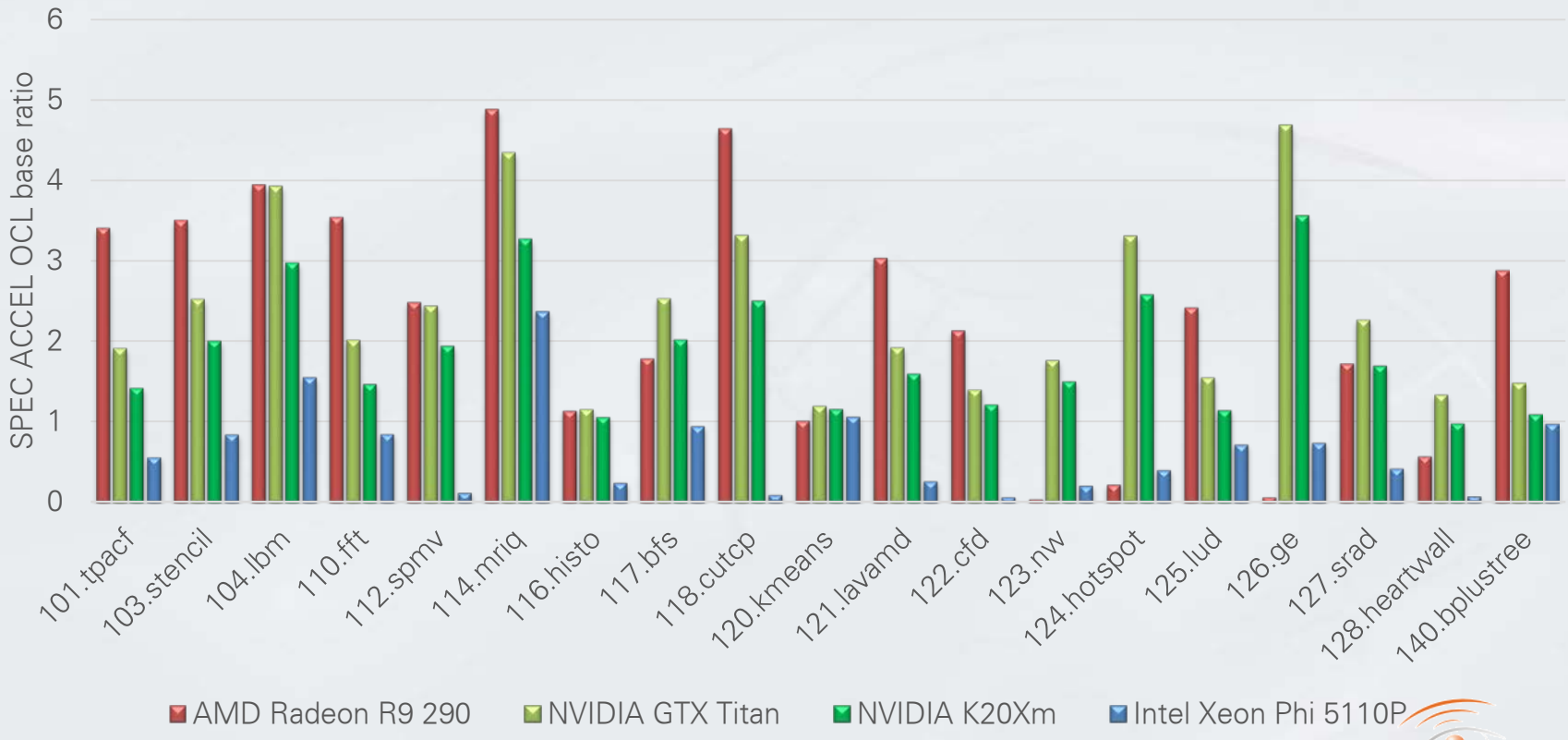
Results appear in the order in which they were run. Bold underlined text indicates a median measurement.

Experiment 1: Impact of ECC (Using result #21 and #22, NVIDIA K40c, base)

Experiment 2: Impact of Clock Boost (result #13, #13, and #14, K40c, base)



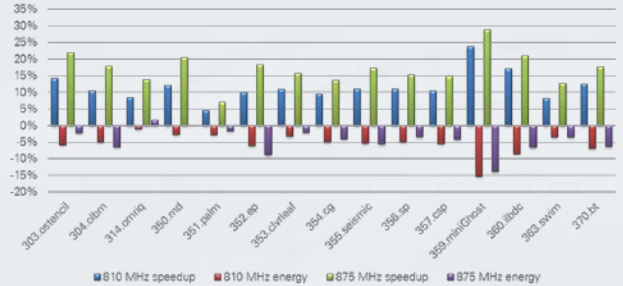
Experiment 3: Apples, Oranges, and other Fruit (using results #28-32, base)

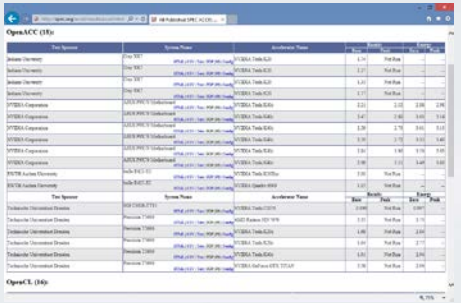


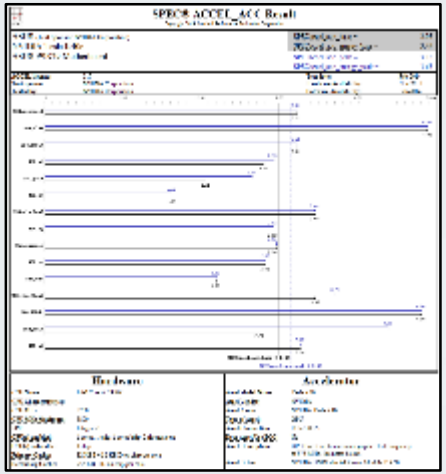
SPEC ACCEL Future Directions

- OpenMP 4.0 target directives
- OpenACC 2.0
- OpenCL 2.0
- Multiple Accelerators

Questions?







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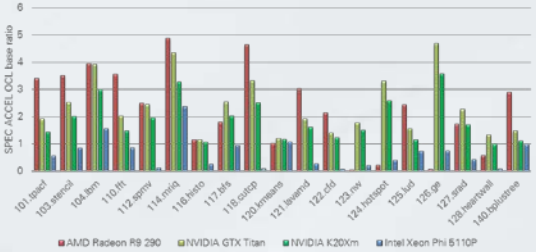
OpenACC Benchmarks	Language	Origin	Application Domain
303.ostencil	C	Parboil, University of Illinois	Thermodynamics
304.olbm	C	Parboil, University of Illinois, SPEC CPU2006	Computational Fluid Dynamics, Lattice Boltzmann
314.omriq	C	Rodinia, University of Virginia	Medicine
350.md	Fortran	Indiana University	Molecular Dynamics
351.palm	Fortran	Leibniz University of Hannover	Large-eddy simulation, atmospheric turbulence
352.ep	C	NAS Parallel Benchmarks (NPB)	Embarrassingly Parallel
353.clvrleaf	C, Fortran	Atomic Weapons Establishment (AWE)	Explicit Hydrodynamics
354.cg	C	NPB	Conjugate Gradient Solver
355.seismic	Fortran	GeoDynamics.org, University of Pau	Seismic Wave Modeling (PDE)
356.sp	Fortran	NPB	Scalar Penta-diagonal solver
357.csp	C	NPB	Scalar Penta-diagonal solver
359.miniGhost	C, Fortran	Sandia National Lab	Finite difference
360.ilbdc	Fortran	SPEC OMP2012	Fluid Mechanics
363.swim	Fortran	SPEC OMP2012	Weather
370.bt	C	NPB	Block Tridiagonal Solver for 3D PDE



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