Storage Performance, Price-Performance and Power: The Three Keys to Success

Walter E. Baker/ SPC Administrator and Auditor
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Agenda

- Storage performance, price-performance and power/energy consumption
- Storage Performance Council (SPC) Overview
- SPC Benchmark 1™ (SPC-1™) Overview
  - Storage Vendor Perspective
  - End-User/Customer Perspective
Storage Performance
Price-Performance
Power/Energy Consumption
Keys to a Successful Storage Product

- **Performance**, **price-performance** and **power/energy consumption** are three key factors:
  - Successful development of a storage product (**vendor perspective**).
  - Successful purchase or upgrade (**end-user/customer perspective**).
Performance – Vendor Perspective

- A “measure of success” during product development.
  
  *(Are performance targets maintained during the development cycle?)*

- A factor in internal product positioning.
  
  *(Where should the product be positioned and marketed within a product family?)*

- A key differentiator in competitive positioning.
  
  *(How should the product be positioned and marketed against competitors?)*
Performance – End-User Perspective

- Can the product deliver the I/O performance required for successful application performance.
  - **Volume/Quantity (throughput)**
    - I/O rate needed to support the required online transaction rate.
    - Data throughput needed to support batch processing requirements.
  - **Response/Residence Time**
    - I/O response time required for acceptable OLTP performance.
    - Data rate required for batch processing timing requirements.
Price-Performance

- **Vendor Perspective:**
  A key differentiator in competitive positioning. *(How should the product be positioned and marketed against competitors?)*

- **End-User/Customer Perspective:**
  What is the realistic cost, including support and maintenance, for a product that meets the performance and power/energy consumption requirements.
Power/Energy Consumption

- A relatively new factor that is gaining importance for consideration along with performance and price-performance.

- End users/customers are developing energy ‘budgets’ during data center planning to consider:
  - Increasing cost of finite energy sources: coal, petroleum products, etc.
  - Ecological impact of increasing energy use.
Storage Performance Council (SPC)

The SPC provides the means to accurately assess and compare storage performance, price-performance and power/energy consumption for both storage vendors and end-users/customers.
Storage Performance Council (SPC) Overview
Storage Performance Council (SPC)

- The SPC is a non-profit corporation founded in 1998 to accomplish the following:
  - Define, standardize and promote the first industry-standard storage performance benchmarks
  - Disseminate objective, verifiable storage performance data to developers and end-users/customers of computer systems
SPC Objectives

- Provide an incentive for storage performance improvements in the computer systems industry
- Enable end-users/customers to accurately compare storage products in a multi-vendor marketplace
- Establish a level “playing field” for storage vendors
- Publicize storage performance results
- Ensure accuracy and authenticity of those results
SPC Membership

ECC Corporation

EMC Corporation

HP

IBM
SPC Membership

KAIST
ORACLE
SK hynix memory solutions
TOSHIBA
Leading Innovation
LI
PENNSTATE
SOLIDFire
UC SANTA CRUZ
NEC
SAMSUNG
STEC
VIOIN MEMORY
NetApp
Go further, faster
Seagate
Symantec Corporation
Western Digital
NIMBUS DATA
sgi
THE GEORGE WASHINGTON UNIVERSITY
xio
HUAWEI
SPC Membership Consolidation

- Dell
- Compellent
- IBM
- Texas Memory Systems
- EMC Corporation
- XtremIO
- Oracle
- Sun Microsystems
- HP
- 3PAR
- Violin Memory
- GridIron
SPC Benchmarks

- SPC Benchmark 1™ (SPC-1™)
- SPC Benchmark 2™ (SPC-2™)
- SPC-1 and SPC-2 are the two “core” benchmarks of the SPC.
- From those “core” benchmarks:
  - Component-level benchmarks
  - Energy extensions to measure power consumption
SPC Benchmark 1 (SPC-1)

- SPC-1 consists of a single workload that demonstrates storage performance type of business critical applications.
- Those applications are characterized by predominately random I/O operations, requiring both queries as well as update operations.
- Examples of those types of applications include OLTP, database operations and mail server implementations.
SPC Benchmark 2 (SPC-2)

- SPC-2 consists of three distinct workloads to demonstrate the storage subsystem performance of business critical applications, which require large-scale, sequential movement of data.

- Those applications are characterized predominately large I/Os organized into one or more concurrent sequential patterns.
SPC Benchmark 2 (SPC-2)

- SPC-2 Workloads:
  - **Large File Processing (LFP):** Simple sequential processing of one or more large files (scientific computing, large-scale financial processing, etc.).
  - **Large Database Query (LDQ):** Scans or joins of large relational tables (data mining, business intelligence, etc.)
  - **Video on Demand (VOD):** Delivery of individualized video entertainment to a community of subscribers from a digital film library.
SPC Component Benchmarks

- There is a distinct need to provide objective and verifiable performance measurement and comparisons of individual storage components such as storage devices (HDDs/SSDs), HBAs/controllers, small storage subsystems, storage software, etc.

- SPC-1 and SPC-2 provide that type of performance measurement and comparison, but are used for large, complex storage configurations.
SPC Component Benchmarks

- **SPC Benchmark 1C™ (SPC-1C™)**
  - SPC-1C is based on the SPC-1 benchmark specification and will utilize the single SPC-1 workload.

- **SPC Benchmark 2C™ (SPC-2C™)**
  - SPC-2C is based on the SPC-2 benchmark specification and will utilize the three SPC-2 workloads.
SPC Component Benchmarks

- SPC-1C and SPC-2C provide performance measurement and comparison for storage components such as:
  - Storage devices (*HDDs and SSDs*)
  - HBAs/controllers
  - Small storage subsystems (*single enclosure*)
  - Processors used in the above components
  - Storage software such as Logical Volume Managers
SPC Energy Extensions

- SPC Benchmark 1/Energy™ (SPC-1/E™)
- SPC Benchmark 2/Energy™ (SPC-2/E™)
- SPC Benchmark 1C/Energy™ (SPC-1C/E™)
- SPC Benchmark 2C/Energy™ (SPC-2C/E™)

Each SPC benchmark includes an optional energy extension, which includes energy use measurement and reporting.
SPC Benchmark 1™ (SPC-1™) Overview
SPC Benchmark 1 (SPC-1)

- SPC-1 read and write requests are directed at storage configured into three elements, Application Storage Units (ASUs), comprised of three or more LUNs.
  - **ASU-1**: The *Data Store* for incoming data.
  - **ASU-2**: The *User Store* to hold data processed by the application system.
  - **ASU-3**: The log that contains data for the purpose of protecting the integrity of the data maintained in the *Data* and *User Stores*.
SPC Benchmark 1 (SPC-1)

- **ASU-1 (Data Store):**
  - Contains 45% of the configured storage capacity.
  - Target of 59.6% of the SPC-1 I/O requests.
  - The I/O requests are generated by four parallel streams:
    - Read and writes randomly distributed over the entire address space.
    - Highly localized read and writes to specific areas.
    - Some sequential reads
SPC Benchmark 1 (SPC-1)

- **ASU-2 (User Store):**
  - Contains 45% of the configured storage capacity.
  - Target of 12.3% of the SPC-1 I/O requests.
  - The I/O requests are generated by three parallel streams:
    - Read and writes randomly distributed over the entire address space.
    - Highly localized read and writes to specific areas. *(less than ASU-1)*
    - Some sequential reads.
SPC Benchmark 1 (SPC-1)

- **ASU-3 (Log, Sequential):**
  - Contains 10% of the configured storage capacity.
  - Target of 28.1% of the SPC-1 I/O requests.
  - One sequential write stream.
SPC Benchmark 1 (SPC-1)

I/O Stream Generator

ASU-1 Streams
S-1 → S-2 → S-3 → S-4

ASU-2 Streams
S-1 → S-2 → S-3

ASU-3 Stream
S-1

I/O Command Generator

I/O Requests

ASU-1

ASU-2

ASU-3
SPC Benchmark 1 (SPC-1)

- **Business Scaling Unit (BSU):**
  - Represents the aggregate I/O generated by an application user of ~50 I/Os per BSU.
  - The SPC-1 offered load is specified by BSUs.
    - The offered load is the amount of ‘work’ presented to the storage configuration.
    - Specifying 2,000 BSUs would create an offered load of 100,000 SPC-1 IOPS distributed over the seven ASU streams to be processed by the storage configuration.
Storage Vendor Perspective
SPC-1 Performance

- Every member company that has used SPC-1 has “discovered” opportunities to improve product performance.
- SPC-1 measurements have become a “measure of success” during product development.
SPC-1 Performance

- Many member companies have incorporated SPC-1 measurements into the product development cycle.
  - Provides a basis for performance targets.
  - Used in regular regression testing to assess performance improvement or degradation.

- Audited SPC-1 Result upon product release to provide external “proof point” for competitive positioning.
SPC-1 Performance

- Detailed performance data available:
  - Throughput in IOPS
  - Average response time in milliseconds (ms)
  - Data rate in MB per second

- Performance data reported for various levels:
  - All ASUs (overall performance)
  - By individual ASU
  - By reads and writes
SPC-1 Performance

Response Time / Throughput Curve

100%, 95%, 90%, 80%, 50% and 10% of the maximum specified BSU level

8,012 BSUs, 400,600 SPC-1 IOPS maximum
SPC-1 Performance – SPC-1 IOPS

8,012 BSUs specified

400,587.11 SPC-1 IOPS reported

I/Os per Second

<table>
<thead>
<tr>
<th></th>
<th>All ASUs</th>
<th>ASU1</th>
<th>ASU2</th>
<th>ASU3</th>
<th>Reads</th>
<th>Writes</th>
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SPC-1 Performance – Response Time

8,012 BSUs specified

0.75 ms average response time reported

### Average Response Time (ms)

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<th>All ASUs</th>
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<th>ASU2</th>
<th>ASU3</th>
<th>Reads</th>
<th>Writes</th>
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<td><strong>Average</strong></td>
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<td>0.84</td>
<td>0.74</td>
<td>0.82</td>
<td>0.71</td>
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SPC-1 Performance – Data Rate

8,012 BSUs specified
3,287.55 MBPS reported

<table>
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<tr>
<th>MBytes per Second</th>
<th>All ASUs</th>
<th>ASU1</th>
<th>ASU2</th>
<th>ASU3</th>
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<th>Writes</th>
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<td>2,191.89</td>
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</tbody>
</table>
Example of identifying response time as a area for investigation and possible performance improvement.

- Variability of reported response time for each ASU
- Particularly log file (ASU-3, red line) performance, which could be the source of ASU-1 (Data Store) and ASU-2 (User Store) variability.
SPC-1 Performance – Response Time

![Graph 1: Average Response Time Distribution (Ramp_100 @8012 BSUs)]

![Graph 2: Average Response Time Distribution (Ramp_100 @3900 BSUs)]
SPC-1 Performance

- **Internal product positioning:** Internal SPC-1 measurements will provide the performance data necessary to accurately position and market a storage product within a family of products.

- **External competitive positioning:** Audited SPC-1 Results, available on the SPC website, will provide “proof points” for positioning and marketing a storage vendor’s products in competitive situations.
SPC-1/E Energy/Power Consumption

- SPC-1/E includes energy/power consumption measurements with each SPC-1 Test Run.
- Energy/power consumption measurements are synchronized with the performance measurements to provide a comprehensive, unified view of the storage product.
- SPC-1/E includes an Idle Test to provide a complete range of reporting.
SPC-1/E Energy/Power Consumption

- The SPC-1/E Idle Test consists of three Test Runs.
  - **Conditioning:** Ten minutes at 100% performance load.
  - **Idle:** A minimum of one Idle period of at least 30 minutes with no performance load.
  - **Recovery:** Ten minutes at 10% performance load to prepare the system for the SPC-1 Test Runs.
SPC-1/E Energy/Power Consumption

- Storage vendor uses:
  - Assess a product’s energy use at idle and under various performance loads.
  - Determine the impact of product improvements for energy efficiency such as multiple idle states.
  - Provide another factor for competitive positioning.
SPC-1/E – Idle Test

Identified unexpected ‘spike’ in power consumption immediately after the **Condition** Test Run (*no workload but ~490 watts consumed*). Determined it was system ‘housekeeping’ tasks that started when the system was idle.

<table>
<thead>
<tr>
<th>Execution Component</th>
<th>Load Level</th>
<th>SPC-1 IOPS™</th>
<th>Power (W)</th>
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</thead>
<tbody>
<tr>
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<td>Idle (Idle-L)</td>
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<td>Idle - Recovery (Recovery)</td>
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![Power/Performance Profile - Idle](image)
### SPC-1/E – Various Performance Loads

<table>
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<th>Execution Component</th>
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<th>Power (W)</th>
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</thead>
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<td>Ramp10 (10%)</td>
<td>10%</td>
<td>19,512.06</td>
<td>216.98</td>
</tr>
</tbody>
</table>

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**Power/Performance Profile - Ramp**

- **100%**: 382.82 W; 195,021.70 IOPS
- **95%**: 379.58 W; 185,250.57 IOPS
- **90%**: 379.00 W; 175,489.82 IOPS
- **80%**: 370.51 W; 156,026.23 IOPS
- **50%**: 351.56 W; 97,504.04 IOPS
- **10%**: 326.98 W; 19,512.06 IOPS
End-User/Customer Perspective
SPC-1 – End User/Customers

- SPC-1 Results provide accurate, reliable performance, price-performance and energy/power consumption data for product comparisons in purchase evaluations.

- That same data can also be used to prepare detailed capacity plans, including an energy budget for the storage portion of a data center.
SPC-1 – End User/Customers

- Additional end user/customer perspectives provided in the “SPC Benchmarks – An Aid to Evaluate Storage Products” presentation that is part of the Enterprise Storage track.

- SPC Results (all SPC benchmarks): [http://www.storageperformance.org/results](http://www.storageperformance.org/results)
Thank you

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