ZES ZIMMER
Precision Power Measurement

ZES ZIMMER – THE EXPERTS IN PRECISION POWER ANALYSIS

LMG600 Series Application:

SPECpower Benchmark – Power Consumption and Energy Efficiency Measurement of Data Center Servers

v1.3

Industry power-performance benchmarking of data centers – Enabled by reliable power measurement

In today's energy-conscious world, optimizing power efficiency in data centers has become a key focus for IT infrastructure. As the demand for data processing grows, data centers are consuming more energy, making energy efficiency in server operations a critical factor in evaluating server performance in the modern tech landscape. As a result, the need to effectively measure and benchmark power consumption to optimize server energy efficiency is more pressing than ever.

Topics

- What is the SPECpower benchmark and PTDeamon?
- How do server performance and server power differ?
- How does a power analyzer facilitate the SPECpower benchmark?
- What are data center planning measures to consider?
- Which standards do server manufacturers need to comply with?
- What benchmark measurements will be performed and how?
- What are the results of the benchmark?

Challenges

For IT managers and data center operators:

- Best performance at low energy waste (performance-power-ratio)
- Appropriate capacity planning and resource management
- Low cost and space requirement of infrastructure
- Compliance with industry standards and regulations

For manufacturers of server-class computer equipment:

- High energy efficiency (operations-per-watt)
- Product differentiation and market competitiveness
- Low equipment size and noise
- Low product costs
- Compliance with industry standards and regulations

There are various measures that can be taken to improve the performance per watt of a data center infrastructure. The journey begins with the manufacturers of the individual components and ultimately extends to additional measures in their interaction and the operation of the data center.

Solutions

For IT managers and data center operators:

- Use of virtualization technologies and workload consolidation
- Use of highly optimized and energy efficient hardware
- Operation of energy management software solutions with power capping
- Use of renewable energy and waste heat utilization
- Strategic positioning of server racks and modular data center designs
- and more

For manufacturers of server-class computer equipment:

- Improved micro architecture (tasks-per-clock cycle)
- Dynamic voltage and frequency scaling (DVFS)
- Power gating and clock gating
- Fine-tuned thermal-efficient multicore designs
- Optimization of cache utilization
- and more

How can these measures be professionally supplied and verified in order to overcome the challenges?

To address above, the Standard Performance Evaluation Corporation (SPEC) has developed tools like the SPECpower benchmark, offering standardized methods to measure server power consumption for improved energy efficiency. The SPECpower benchmark with its interface PTDaemon (Power/Temperature Daemon or PTD) helps IT managers, data center operators and equipment manufacturers to make more informed decisions by understanding how a server performs under different loads in terms of power consumption along with other selection criteria.

This application note provides an overview of how power analyzers, specifically our LMG600 series[1], are used in SPECpower benchmarking, highlighting key features that ensure accurate and reliable power and energy measurements.

Learnings

Optimizing energy efficiency is crucial for data centers and server manufacturers. IT managers and data center operators focus on virtualization and energy-efficient hardware, while manufacturers of equipment and devices used here prioritize efficient designs and cost reduction. The SPECpower benchmark helps measure energy consumption and supports informed decisions for improved efficiency. In order to do so and to provide reliable and accurate benchmark results, precise power measurement with an appropriate measuring instrument, such as from our LMG600 power analyzer series, is an indispensable part of this.

The SPECpower benchmark - Setup and measurement

The SPECpower benchmark suite (first one released known as SPECpower_ssj2008) was basically developed to standardize the evaluation of server energy efficiency across various workloads. It simplifies comparisons by offering a structured methodology for measuring energy consumption and performance.

The according test bench setup consists of four main hardware components:

- Power analyzer approved by the SPECpower committee
- Temperature sensor
- SUT (System Under Test as workload)
- Corresponding controller

The most critically important part is the integration of precise power measurement tools, such as the ZES ZIMMER's LMG series power analyzers[2], which are officially supported and recognized by SPEC Power committee as approved instruments for accurate power measurement. Our power analyzer provides precisely-measured active power and energy data during server operations, enabling data center operators and associations to better understand their server's performance and energy use, ultimately helping them optimize the system's efficiency. The typical SPECpower test setup incorporating our LMG671 Power Analyzer is illustrated in Figure 1.

[1] https://www.spec.org/power/docs/SPECpower-Device_List.html
[2] https://www.zes.com/en/Products/Precision-Power-Analyzers

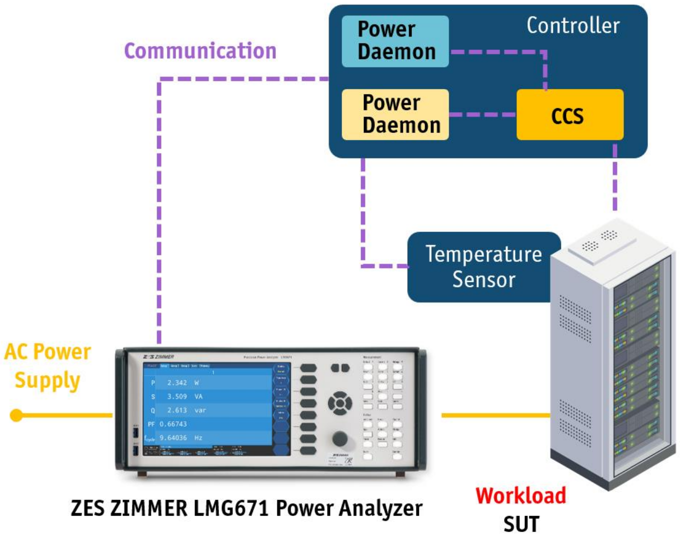

Figure 1: Integration of LMG671 Power Analyzer to SPECpower benchmark test environment

During benchmarking, each device is managed by a dedicated instance of SPEC's PTDaemon. The software handles communication with the connected power analyzer and sensors, allowing the system under test (SUT) to focus solely on running workload tasks. By offloading power measurement to PTDaemon, the SUT is not overburdened, ensuring both accurate energy consumption readings and reliable performance data.

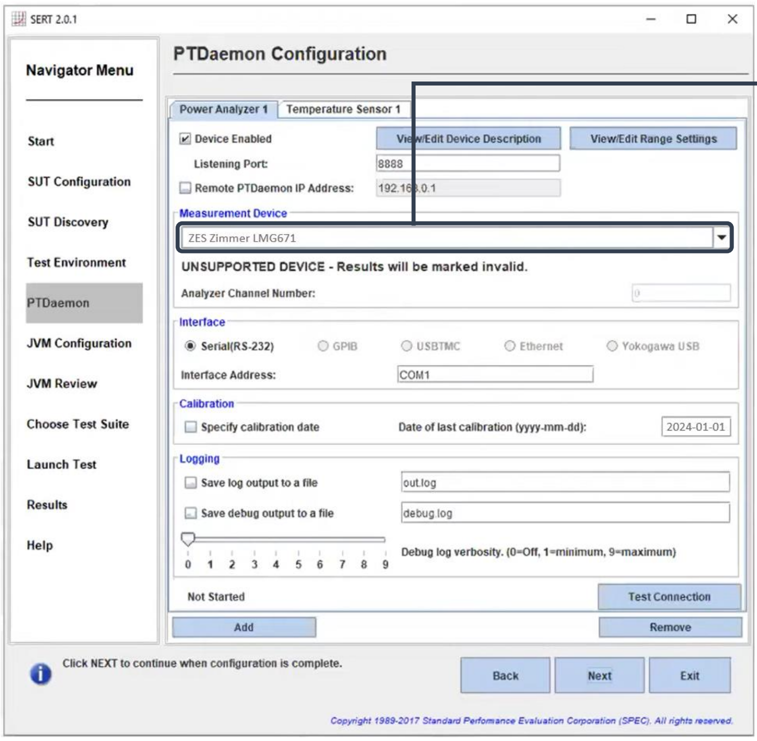

Figure 2: Screenshot of SERT 2.0.1 Suite's PTDaemon setup wizard

In the SERT Suite's PTDaemon Configuration, several accepted and tested ZES ZIMMER LMG Series Power Analyzers can be selected:

Model	Windows x86	Linux x86
LMG95	Serial	Serial
LMG450	Serial	Serial
LMG500	Serial	Serial
LMG610	Ethernet, Serial	Ethernet, Serial
LMG611	Ethernet, Serial	Ethernet, Serial
LMG641	Ethernet, Serial	Ethernet, Serial
LMG671	Ethernet, Serial	Ethernet, Serial

Table 1: ZES ZIMMER Power Analyzers accepted and tested for SPECpower benchmarking in SERT suite

The LMG671 communicates with and exchanges data to PTDaemon over TCP using a proprietary protocol or Serial (RS-232), which enables precise control and data collection. SPECpower's approach measures energy efficiency at different load levels to evaluate server performance under various conditions, from full capacity to idle.

At each stage, power consumption data is collected, providing detailed insights into how a server's efficiency changes with different workloads. The work done on the SUT is called a worklet, and several worklets can be grouped into a workload. Suites like SPEC Server Efficiency Rating Tool (SERT) group multiple worklets into workloads. 10 stages of the benchmark reduce the target load from 100% to 0% (idle) to take account of energy consumption under idle power. The sequence of target load levels decreases from 100% to 0% in increments of 10%, as shown in Figure 3.

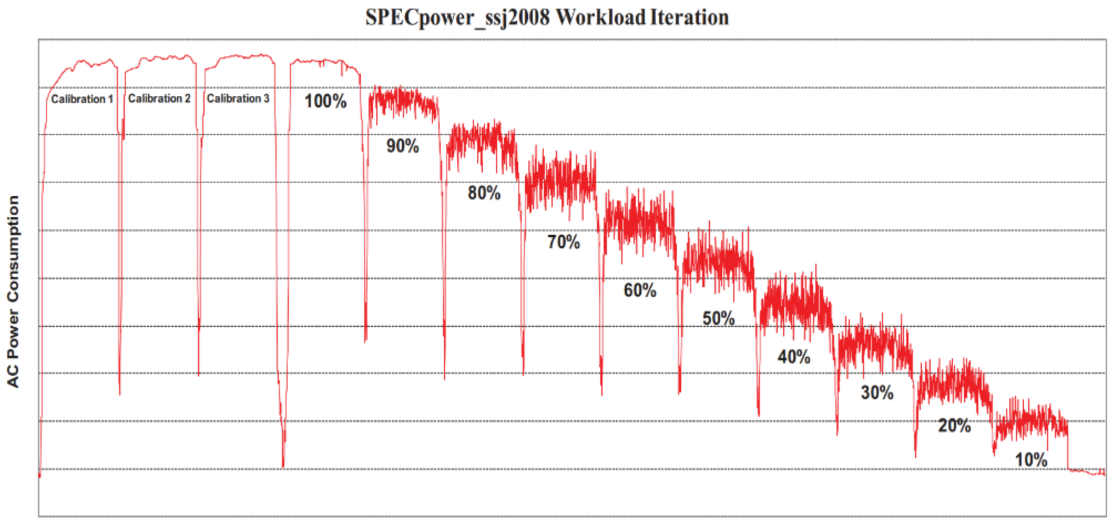

Figure 3: Load Levels, (Su, et al., 2022)

Measuring the points in decreasing order limits the change in load to 10% at each level, resulting in a more stable power measurement. Using increasing order would have resulted in a jump from 100% to 10% moving from the final calibration interval to the first target load and another jump from 100% to active idle at the end of the run.

Learnings

The SPECpower benchmark standardizes server energy efficiency evaluation across workloads using a structured method. The setup includes a power analyzer, temperature sensor, system under test (SUT), and controller. Accurate power measurement is key, with tools like ZES ZIMMER's LMG series power analyzers providing precise measuring data. PTDaemon manages communication with power analyzers, ensuring accurate readings while the SUT handles workloads. The server's power consumption is measured at different load levels to determine its varying efficiency.

Workload dispatching, result collection, and test execution are managed by the Chauffeur framework located in the SUT, where the workload is executed. The communication between the controller and host occurs via a network interface for synchronization and data collection. The PTDaemon client API Java module which can be integrated into benchmarks for simplified communication between PTDaemon and the benchmark code.

On the controller, the director component communicates with the host running on the SUT. Each logical CPU is assigned a client by the host, bound to the CPU via an affinity provider. The workload runs sequentially on the clients, with parallelism achieved by running multiple clients or using multi-threading. The power analyzer measures total SUT power consumption, while temperature sensors ensure consistent environmental conditions, reducing inaccuracies from temperature fluctuations.

The benchmark's operation phases

The test sequences of the benchmark process include three main operation phases, also illustrated in Figure 4:

- Warm-up: During the warm-up phase (W), no power data is recorded to allow the system to stabilize and avoid the transient effects.
- Calibration: The calibration (Cal. n, with n = calibration iteration) determines the maximum throughput of the system by generating transactions at maximum rate
- Measurement: The measurement phase captures the actual performance (workload as number of operations per second – "ssj_ops") power measurement data

Each phase includes intervals, with intermediate measurement periods, pre- and post-measurement (PR, PO), to stabilize power and performance metrics.

The default measurement is carried out at different levels of the calibrated workload (i.e. 100%, 75%, ..., 25%) and is kept at a duration of 120 seconds, though it can be adjusted based on the workload. During this time, power and temperature data are collected every second, and transaction rates are calculated using calibration results and target load levels.

There is a delay between the load level specified as sleep (S) phase that eases post run visual analysis.

Throughout the test, the LMG671 Power Analyzer continuously measures and logs the power consumption, offering a detailed view of energy usage. However, for the official benchmark reports, the average power consumption during the measurement period is used. All these intervals are long enough to provide sufficient settle time for consistent power and performance measurements. Eventually, this provides a meaningful performance-watt curve depending on the load.

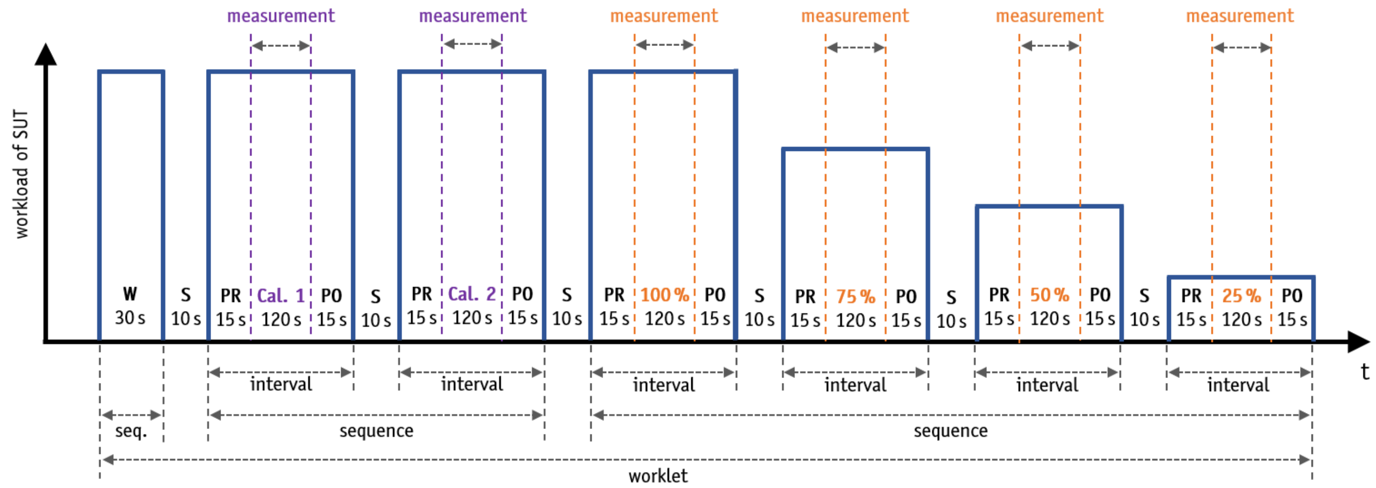

Figure 4: Example of SPECpower benchmark's power measurement phases and intervals

As the output of the overall worklet, the average performance to power ratio is calculated, reflecting the final benchmark's result. The calculation includes the single performance to power ratios. Example results are listed in Table 2. The calculations are executed as:

$$\text{performance to power ratio}_{\,i} = \frac{\text{ssj\_ops}_i}{\text{average active power}} \qquad \text{i = target load interval}$$

$$\text{performance to power ratio}_{\,\text{total}} = \frac{\sum \text{ssj\_ops}_i}{\sum \text{average active power}}$$

Performance			Power	Performance to Power Ratio
Target Load	Measured Load	ssj_ops	Average Active Power [W]	
100%	99.8%	1,855,713	196	9,485
90%	90.0%	1,672,373	162	10,324
80%	90.0%	1,482,832	142	10,414
70%	70.1%	1,303,849	129	10,080
...	...	...	...	...
20%	20.1%	373,154	72.3	5,159
10%	10.1%	187,092	61.0	3,067
	Active Idle	0	36.0	0
			$\sum ssj_{ops}$ / $\sum power$	8,550

Table 2: Example of the SPECpower_ssj2008 result sheet

As one can see, upon the single performance to power ratio, the efficiency of the SUT increases from idle to 100% target load, achieving its best ratio value respectively efficiency at 80% of workload. Hence, one can state:

The more ssj_ops the SUT produce per one watt of power is produced, the higher the SPECpower_ssj2008 score and so the efficiency of the SUT!

Learnings

The SPECpower benchmark standardizes server energy efficiency evaluation across workloads using a structured method. The setup includes a power analyzer, temperature sensor, system under test (SUT), and controller. Accurate power measurement is key, with tools like ZES ZIMMER's LMG series power analyzers providing precise measuring data.

PTDaemon manages communication with power analyzers, ensuring accurate readings while the SUT handles workloads. The server's power consumption is measured at different load levels to determine its varying efficiency. Per target load, determined performance (number of operations)-to-power-ratio are averaged as a final score, that indicates the SUT's efficiency.

Knowledge

The EN 303 470 standard is designed for server manufacturers, testing bodies, and regulatory agencies, and is also valuable for data center operators, IT buyers, and consultants. This standard helps ensure that products on the EU market comply with eco-design requirements as specified in Regulation (EU) 2019/424. The measurement precision provided by LMG671 in the SPECpower benchmark supports the goals of EN 303 470, helping organizations make informed decisions based on reliable, measurable energy efficiency data.

Conclusion

In conclusion, the integration the ZES ZIMMER LMG600 Series Power Analyzers, as above the LMG671, into the SPECpower benchmarking framework provides a top-tier solution for evaluating server energy efficiency with precision. Eventually users can achieve an extremely important result bringing light into the dark at which load the SUT is achieving its best efficiency (performance to power ratio) in order to for instance ensure operating under mostly highly-efficient loads.

With advanced features like real-time data logging and flexible communication interfaces, it ensures accurate measurements, making it a crucial tool for data centers and server manufacturers focused on optimizing energy use. By using the LMG600 series, organizations can not only meet the energy efficiency standards, such as EN 303 470, but also advance broader sustainability goals. This leads to better server performance, lower energy consumption, and an eco-friendlier IT infrastructure – The key to complying with regulations and boosting long-term efficiency.

Recommended Products

ZES ZIMMER LMG600 Series Power Analyzers

LMG671

1 to 7 power channels

LMG641

1 to 4 power channels

LMG611

Single-phase table-top

Application and power analyzer features

- True RMS measurements:
  Accurate power measurement under various load conditions ensuring the power changes in computer servers are recorded correctly.
- World-class measurement accuracy:
  Best accuracy of 0.015% of reading, meeting the SPEC's accuracy requirements.
- High-speed data logging:
  Possibility to record and log the power data every second via communication interface to avoid forged results.
- Multi-spectrum measurement:
  Supports measurement and analysis of multiple power frequency spectra (wideband, narrowband, fundamental frequency) per channel simultaneously.
- Compliance with PTDaemon:
  Seamlessly integrates with SPECpower’s control software, ensuring reliable benchmarking with latest SPEC PTDaemon version supported.
- Flexible communication interfaces:
  For easy integration into PTDaemon, LAN (Gigabit-Ethernet) and serial (RS-232) communication are supported to connect the benchmark’s controller system and the LMG power analyzer.

References

J. von Kistowski, K.-D. Lange, J. A. Arnold, S. Sharma, J. Pais, and H. Block, "Measuring and Benchmarking Power Consumption and Energy Efficiency," in *ICPE '18: ACM/SPEC International Conference on Performance Engineering Companion*, Berlin, Germany, Apr. 2018, pp. 9. doi: 10.1145/3185768.3185775.

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