

Performance of Oracle Database 12c analytical workload on IBM Power Systems built with POWER9 processor technology

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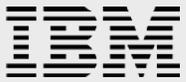
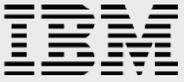


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Abstract

This paper provides educational comparative performance information for Oracle Database Release 12c Row and In-Memory access of data for analytical queries running on an IBM Power Systems™ S924 scale-out server with POWER9™ processors.

Executive Overview

The testing conducted with the Power® System S924 server and Oracle Database In-Memory for analytical queries demonstrated outstanding performance benefits with fewer cores. The analytical queries running on the Oracle Database with In-Memory feature enabled are 10x faster than those run with row type access only, while using one quarter the number of POWER9 cores. The improved performance results and the number of POWER9 cores required for producing those results with Oracle Database In-Memory reduces the cost of computing and licensing dramatically compared to the same results and higher number of cores required to execute with Row type access.

There is from 25X to 34X improvement seen in the turnaround time of analytical queries run on Oracle Database In-Memory by up to 8 concurrent users with 24 cores compared with the same workload run with row type access only.

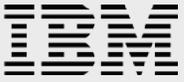
The outstanding performance of analytical queries with Oracle Database In-Memory was made possible by the performance of POWER9 processor threads that leverage Simultaneous Multi-Threading, enhanced cache hierarchy, and the lower latency and higher bandwidth of the memory subsystem.

Disclaimer: *The results shown in this document are for education purpose only. The results DO NOT represent the full potential performance capability of the Power S924 server, Oracle Database 12c, and IBM FlashSystem™ 840. The results were derived from the “out of the box” configuration, without any intense tuning on AIX®, Oracle Database 12c, or the SAN storage server. The performance results would vary on different POWER9 processor-based systems and for different types of applications with differing workload characteristics.*

Testing an IBM Power S924 server, Oracle Database 12c, and IBM FlashSystem 840

At the IBM lab, Oracle Database 12c Release 2 was verified on a Power S924 server with IBM FlashSystem 840 configured as follows:

IBM Power S924 Configuration	24 Cores 256 GB of System memory 4 PCIe2 16Gb 2-Port Fibre Channel Adapter PCIe2 4-port 1GbE Adapter 5899 Two PCI3 and eight SAS RAID Internal Adapter 6Gb
AIX Oracle Database logical partition (LPAR)	AIX 7.2 TL02 SP02
Virtual I/O server (VIOS)	VIOS 2.2.3.3



IBM FlashSystem 840	12 x 2 TB flash modules (RAID5 array [10 + 1 Parity + 1 Spare])
Oracle Database 12c	Oracle Database 12c version 12.2.0.1
Workload: Analytics Reporting Workload with simple, moderate and complex queries (Total 26 queries)	Single Instance Database Automatic Storage Management (ASM) Database created on IBM FlashSystem 840
	1TB raw data, Fact table with 9 Billion rows (726GB) SGA size 256GB, In-Memory size 200GB Up to 8 concurrent users

Table 1. Tested Power S924 configuration

Oracle Database 12c Release 2 on IBM Power S924 experiences

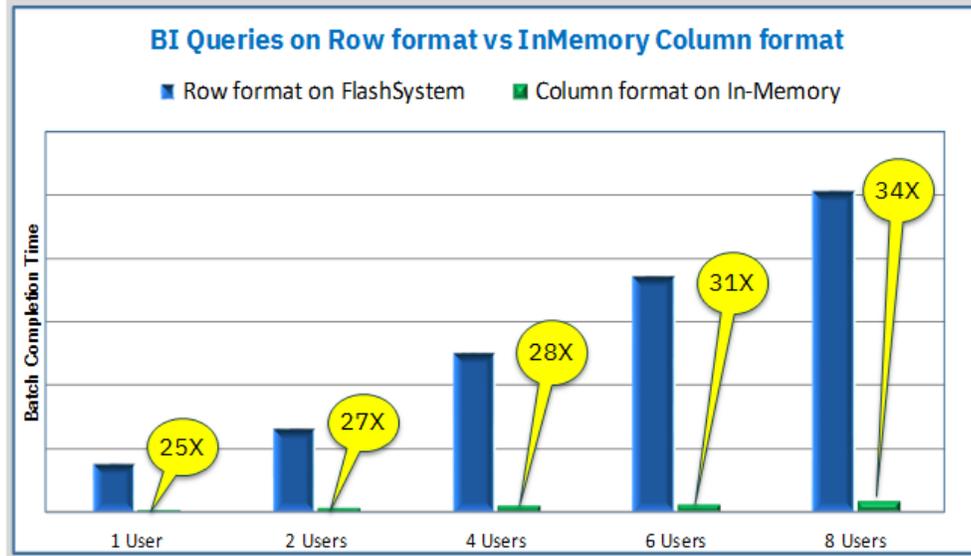
Oracle Database 12c Release 2 (version 12.2.0.1) was successfully installed on the Power S924 server and tested with a single instance Oracle Database. No specific patches of Oracle Database or AIX were required to complete this step with the POWER9 processors. Because Oracle Database certifications are done to the AIX operating system, the Oracle Database is fully certified for running on Power Systems servers with POWER9 processors. IBM's commitment to binary compatibility across all Power Systems servers allows customers to run with confidence on any of the new Power Systems servers built with POWER9 processor technology.

Analytical workload

One Terabyte of raw data representing Retail sales tracking called BIDAY was loaded into the Oracle Database. An IBM internally grown analytical workload was used to query the database with various numbers of concurrent users, up to eight users. The base line performance data was collected by running the workload on Row type tables. Then the same queries were executed with the fact table loaded into Oracle Database In-Memory.

In running this test, we present each concurrent execution of this script as an additional user. For two users two copies are run, with eight users there are eight copies run concurrently.

Oracle Database 12c Release 2 was tested on the Power S924 with SMT8 enabled for both Row and In-Memory testing scenarios. The result from the In-Memory queries showed an outstanding performance improvement ranging between 25X and 34X. The following chart shows a comparison of these test results derived from analytical queries that ran in both Row format and In-Memory column format.



Shorter bar is faster batch completion time

Figure 1. Analytical query performance with Row and In-Memory column format

Similarly, the following additional results were collected for the same queries run with 12 and six cores in the LPAR. Queries run with 12 cores on Oracle Database In-Memory showed an average of 20X speedup and 6 cores showed an average of 10X speedup compared with 24 cores used for Row type access.

Concurrent Users	24 core In-Memory	12 core In-Memory	6 core In-Memory
1 user	25X	19X	9X
2 users	27X	20X	11X
4 users	28X	19X	10X
6 users	31X	19X	10X
8 users	34X	20X	10X

Table 2. Performance improvement in speed up with Oracle Database In-Memory and Power Systems POWER9 cores

This tables shows that queries running In-Memory completed on average 10X faster compared to the Row format even when only one quarter the number of cores were used!

CPU utilization: The Analytical workload saturated nearly all the available CPU cycles of 24 cores for more than four users with In-Memory option enabled. The same workload running with one user on the Row format consumed nearly all CPU cycles with 24 cores. The following figure shows the CPU cycles used in the four user scenario with In-Memory and Row type query processing. The I/O read throughput for Row type access was measured up to 3.5 GB/s even though the maximum bandwidth between the LPAR and the Flash Storage was available up 6.4 GB/s.

In the Figure 2, the total amount of CPU capacity required to complete the four user case for In Memory and Row Format is compared.

In this chart the capacity required for Row format is bounded by the blue box, 24 cores for 100 percent of the time. The capacity required by In-Memory cases is shown by the yellow, gray and red boxes. For example, the yellow box requires only 1/40th the total capacity of the blue box. This means In-Memory is ten times faster using only 6 cores providing 40X of improved efficiency compared to Row type.

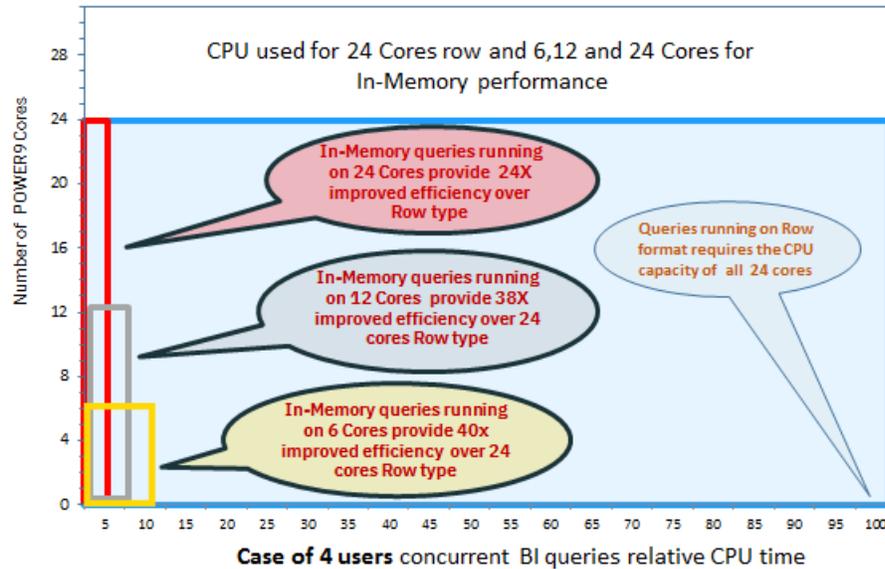


Figure 2. Total CPU capacity spent for Row and In-Memory queries executed by 4 concurrent users is shown by the area enclosed in the blue, yellow, gray and red boxes. The yellow box needs 1/40th the capacity of the blue box.

Results: The outstanding results of this testing demonstrate the benefit of POWER9 processors for Oracle Database In-Memory workloads. IBM Power Systems with POWER9 processors provide faster answers for the queries running on Oracle Database In-Memory with fewer CPUs. This helps to reduce the licensing cost dramatically and uses the Oracle Database and POWER9 licenses efficiently. The overall cost of running the queries in Row format is considerably reduced if the queries are run in Oracle Database In-Memory.

In our test, even when the number of CPU cores is reduced from 24 to 6 cores, the Oracle Database In-Memory scenario demonstrated a 10X improvement.

Strength of Power S924 for Oracle Database workloads

The IBM Power Systems Simultaneous Multi-Threading (SMT) capability enables concurrent execution of threads on the same core. Power System servers built with POWER9 processors support up to eight threads (SMT8) run on a single core. An AIX logical partition is set with SMT8 by default. Database software such as Oracle Database is capable of using multi-threading processor cores and can make use of the SMT8 configuration option to take full advantage of the available cores.

The SMT8 capability completes the long running database queries in a shorter time. A client can take full advantage of the combination of Power Systems built with POWER9 processors and Oracle Database In-Memory for complex database queries.



An AIX logical partition can also be set with SMT4. The decision on whether to keep the default SMT (SMT8) or tune it to SMT4 can be based on the nature of the application and characteristics of the workload being used in the LPAR. IBM highly recommends using SMT8 to take full advantage of the POWER9 cores.

Based on the testing of an Analytical type of workload running on Power Systems with POWER9 processors, we have demonstrated that the queries need fewer POWER9 cores with the Oracle Database In-Memory feature. Business Intelligence queries run faster in Oracle Database In-Memory than in the Row type format. With POWER9 processors you can optimize number of required cores without compromising the performance of these queries. The remaining available POWER9 cores in a Power Systems server can be utilized for other critical applications running on another LPAR in the same server.

Power System servers with POWER9 processors are flexible for scale up and scale down number of cores. The Oracle operational database and the Business Intelligence queries can run on different AIX logical partitions without affecting each other's performance by using PowerVM® Micro-partitioning technology.

In general, the Oracle Database In-Memory option is best suited for analytical type of queries which mostly read data from memory and select few columns but many rows. The Row format might be the best fit for Online Transaction Processing (OLTP) type of workloads which are mostly doing update and insert operations with many columns and a few rows.

IBM Power Systems POWER9 S class servers

On March 20, 2018, IBM released Power Systems server models S924, S922 and S914 with POWER9 processors with different sized chassis and numbers of sockets. They are 2U and 4U models with one or two Single Chip Module (SCM) sockets, up to 24 cores, and up to 1 TB to 4 TB of DDL4 memory. The systems support IBM AIX, IBM i, and Linux® operating systems. IBM Power Systems 2U and 4U scale-out servers provide up to 12 cores per SCM. Each core is capable of running up to eight simultaneous multithreads (SMT) to meet the requirements of resource-hungry applications. These Scale-Out servers are designed to run commercial, cognitive, and database workloads.

The new Power Systems servers are built with IBM POWER9 processor technology, on-chip transactional memory, eight simultaneous multithreads (SMT8), Open Coherent Accelerator Processor Interface (OpenCAPI), Hot-plug PCIe Gen4 and Gen3 I/O slots, NVIDIA NVLink and enhanced reliability, availability, and serviceability (RAS) features packed together to provide efficient consolidation of workloads through virtualization and a reliable environment for business applications.

The Power Systems servers with POWER9 technology can run in three different power and performance mode setups. They are Static Power Saver mode, Dynamic Performance mode and Maximum Performance mode. All modes can be disabled to make the system run with a fixed nominal frequency.

New Power Systems S class servers are ideal platforms for In-Memory and data-centric applications. They are optimized for big data and analytics while still delivering the capacity needed for current workloads such as online transaction processing (OLTP). These 1 and 2 socket servers provide the ideal foundation for scale-out and cloud environments, while the 24 cores and up to 192 simultaneous multithreads deliver sufficient scalable capacity to meet the demands of many single-system workloads.

The new Power Systems servers are designed to be housed in a 19-inch rack and managed by the Hardware Management Console (HMC) or Virtual HMC (vHMC).

The following table shows the list of new POWER9 processor-based Scale-Out servers. The letter “S” stands for Scale-Out.

New Power Systems server	Number of sockets, cores, and speed	Memory (Max)	OS support	Server image
Power S924	<u>2 sockets, each with:</u> 8-cores x 3.8 to 4.0 GHz 10-cores x 3.5 to 3.9 GHz 12-cores x 3.4 to 3.9 GHz	4TB DDR4	AIX IBM i Linux	
Power S922	<u>2 sockets, each with:</u> 4-cores x 2.8 to 3.8 GHz 8-cores x 3.4 to 3.9 GHz 10-cores x 2.9 to 3.8 GHz	4TB DDR4	AIX IBM i Linux	
Power S914	<u>1 socket :</u> 4-cores x 2.3 to 3.8 GHz 6-cores x 2.3 to 3.8 GHz 8-cores x 2.8 to 3.8 GHz	1TB DDR4	AIX IBM i Linux	

Table 3. New Power Systems server Scale-Out models

For full specifications of the new IBM Power Systems servers, refer to the following link:

For **Power S924** – Refer [IBM Power Systems S924 Announcement letter](#)

For **Power S922** – Refer [IBM Power Systems S922 Announcement letter](#)

For **Power S914** – Refer [IBM Power Systems S914 Announcement letter](#)

For full specifications of the new IBM Power Systems servers, refer to the following link:

[IBM Power Systems .](#)

IBM FlashSystem

IBM FlashSystem 840 was used for evaluating the performance of Oracle Database queries on the Power System S924. It is an enterprise data storage system that stores data on flash memory chip modules. The FlashSystem 840 is based on a custom hardware architecture which incorporates Field-Programmable Gate Arrays (FPGAs) that replace traditional server-based array controllers. The FlashSystem unit includes flash modules, external storage area network interfaces, and FPGA logic which spread data throughout the system.

The latest IBM Flash System Storage servers when this paper was written are the IBM FlashSystem 9100 and IBM FlashSystem V9000. For more information about IBM FlashSystem storage servers, go to: ibm.com/it-infrastructure/storage/flash.

IBM FlashSystem 840 storage is designed to provide extreme performance and large flash storage capacity with reliability, availability, and serviceability (RAS) features. The FlashSystem 840 supports several protocols, including Fibre Channel (FC), Fibre Channel over Ethernet (FCoE), and Infiniband interfaces to connect with high performance host servers and Storage Area Networks (SAN).



Figure 3 IBM FlashSystem 840

The FlashSystem 840 supports a maximum of twelve 4 TB flash modules, which provide a maximum raw capacity of 48 TB (RAID 0). The flash modules available are either 2 TB or 4 TB in capacity. For our lab test with the IBM Power System S824 and Oracle Database 12c, 12 of the 2 TB modules were used.

The FlashSystem 840 supports both RAID 0 and RAID 5 configurations. The RAID 5 array with twelve 2 TB flash modules gives 20 TB of usable storage space and with 4 TB flash modules give 40 TB of usable space.

The number of LUNs that you create on FlashSystem 840 can affect the overall performance in AIX. It is recommended to carve out 32 LUNs and present them to Oracle ASM. If fewer volumes are needed by an application in AIX, use AIX Logical Volume Manager (LVM) to create fewer logical volumes on 32 LUNs and present the logical volumes to the application.

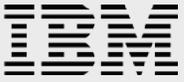
The FlashSystem 840 16 Gb/s FC ports do not support direct connection to client hosts. A SAN switch must be placed between the FlashSystem 840 and any 16 GB/s-attached client host. If arbitrated loop is required by the client host, connect at 8 GB/s FC to the FlashSystem 840.

The configuration and total quantity of host connection ports on IBM FlashSystem 840 include:

- Up to 16 ports of 8Gb FC or 8 ports of 16Gb FC (can also operate at 8Gb and 4Gb)
- Up to 16 ports of 10Gb FCoE
- Up to 16 ports of 10Gbps iSCSI
- 8 ports of InfiniBand QDR 40Gb

A FlashSystem 840 supports only a 512-byte sector size. The AIX operating system supports the 512-byte sector size.

For more technical information about IBM FlashSystem 840 and best practices, refer to the “Document Resources” section of this document.



IBM AIX and Linux support

IBM AIX is an open standards-based UNIX® operating system. AIX, in combination with IBM's virtualization offerings, provide new levels of flexibility and performance to allow you to consolidate workloads on fewer servers, which can increase efficiency and conserve energy. AIX delivers high levels of security, integration, flexibility, scalability and reliability that are essential for meeting the demands of today's information technology environments. AIX operates on IBM systems based on IBM Power Architecture® technology. For more information about AIX, refer to the following web page:

ibm.com/systems/power/software/aix/

Oracle product support for IBM Power Systems servers is based on AIX operating system support. Oracle does not directly certify IBM server hardware with their software, they certify a specific level of AIX.

For fully leveraging new features and capabilities of the new Power Systems servers, the following AIX, Linux, and virtualization software versions are supported.

IBM AIX and Virtual I/O Server (VIOS)	AIX 7.2 TL02 SP02, or later
	PowerVM VIOS 2.2.6.21, or later

Table 4. Supported AIX and virtualization software

IBM also provides support for earlier technology levels or service packs for AIX 7.2, 7.1 and 6.1 for the POWER9 family of servers. When running on these or lower TL levels not all of the new features and capabilities will be available.

IBM AIX and Virtual I/O server (VIOS)	Partition with all virtual resources via VIOS : Minimum : <ul style="list-style-type: none"> • AIX 7.1 TL3 SP01 or later
	Other partitions : Minimum : <ul style="list-style-type: none"> • AIX 7.2 TL0, TL1 (P8 Compatibility Mode) • AIX 7.1 TL4, TL5 (P8 Compatibility Mode)
	Partition with all virtual resources via VIOS : Minimum : <ul style="list-style-type: none"> • AIX 6.1 TL09 SP01 or later

Table 4 Supported earlier versions

The following versions of Linux are supported with the new POWER9 servers.

Linux	<ul style="list-style-type: none"> • RedHat RHEL 7.4 LE (P8 Compatibility Mode) • SuSE SLES 11 SP4 (P8 Compatibility Mode) • SuSE SLES 12 SP3 • Ubuntu 16.04.4 LTS (P8 Compatibility Mode)
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Table 5. Supported Linux versions



Starting with Oracle Database 11g Release 2 (11.2.0.4), Oracle Database **Instant Client** is supported on Linux on Power (32-Bit) and (64-Bit). Customers currently using the Oracle Database Instant Client 10g Release 2 can upgrade to the 11g Release 2 version by simply replacing the 10g Release 2 libraries with the newer 11g Release 2 version. The Instant Client version of the Oracle Database is also supported on the 12c version of the database. With Oracle Database 12c Release 1, support for little-endian was introduced for the Instant Client running on Linux on Power and with 12c Release 2 support is for little-endian only.

Refer to the *Instant Client Releases Section of My Oracle Support* (see resources) note “*Release Schedule of Current Database Releases (Doc ID 742060.1)*” for the latest status.

Recommended code levels

There are two tools to help determine the recommended code levels among AIX and Power Systems related components.

- The Fix Level Recommendation Tool (FLRT) can determine the recommended code levels among a mixture of AIX, HMC, server firmware, VIOS, IBM General Parallel File System (IBM GPFS) and IBM PowerHA®. The FLRT web page is: <http://www14.software.ibm.com/webapp/set2/flrt/home>. Note, the FLRT recommendation provides a minimum acceptable level of compatibility.
- The IBM POWER® code matrix indicates the recommended code levels for the HMC and server firmware. The POWER code matrix web page is: <http://www14.software.ibm.com/webapp/set2/sas/f/power5cm/home.html>. Note that the POWER code matrix recommendations can provide the maximum stable code combinations.

Service strategy

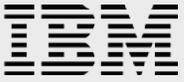
To review the latest *IBM AIX Operating System Service Strategy Details and Best Practices* document, refer to the website: <http://www14.software.ibm.com/webapp/set2/sas/f/best/home.html>.

C and C++ compilers

The XL C/C++ compiler family includes several versions of standards-based, high performance C and C++ compilers with advanced optimizing and debugging features. They provide you the ability to optimize and tune applications for optimal execution on systems using all types of IBM POWER processors. The compiler family supports IBM Power Systems servers capable of running IBM AIX 7.2, AIX 7.1, and AIX 6.1.

XL C/C++ V13.1 fully supports the IBM Power Systems servers. Applications compiled with earlier supported compiler versions are able to run on the new IBM Power Systems servers with POWER9 processors, but the XL C/C++ V13.1 compiler can be used to optimize and tune the application further for Power Systems servers.

C++ applications might have dependency on C++ runtime; and the XL C/C++ runtime environment is installed during the installation of base AIX. To download the latest runtime environment, go to the XL C/C++ web page at: <https://www-01.ibm.com/support/docview.wss?uid=swg21110831>.



If the XL C/C++ Enterprise Edition for AIX compiler is installed, confirm that the latest updates are applied by visiting the product support link "[Latest updates for supported IBM C and C++ compilers](#)", then download and apply the appropriate compiler updates.

IBM XL C/C++ for Linux, V13.1.6 supports application development on Power Systems servers with POWER9 processors that run the little-endian Linux distributions.

A single XL C/C++, V13.1.1 offering contains two C/C++ compilers that support:

- Big-endian Linux distributions and IBM Power Systems servers configured for big-endian mode.
- Little-endian Linux distributions and IBM Power Systems servers configured for little-endian mode.

XL C/C++ V13.1.6 supports Ubuntu 16.04.4 for POWER9 processors, and SUSE Linux Enterprise Server 12 for Power Systems servers includes exploitation of the little-endian architecture on the POWER9 processor.

For more information on XL C/C++ compiler version for POWER9 based servers, refer to:

ibm.com/support/docview.wss?uid=swg27007322

Oracle Database and IBM Power Systems

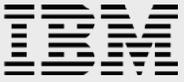
Oracle Database 12c Release 2 is the latest version (at the time of this publication) in a nearly two decade long series of releases of the database on the AIX operating system. Oracle Database 12c includes many new features over its previous database versions. The letter "c" in "12c" stands for "cloud". Oracle Database 12c provides a multitenant architecture that simplifies the process of consolidating databases into a private cloud model. Oracle Database 12c allows each database plugged into the multitenant architecture to have the look and feel of a standard database to the applications. Oracle Real Application Clusters (RAC) is an option of Oracle Database that allows a database to be installed across multiple servers (RAC nodes). Oracle RAC uses the shared disk method of clustering databases. Oracle RAC processes running in each node access the same data residing on shared data disk storage.

Refer to the following two white papers for the latest certifications and support information for Oracle Database 12c Release 1 and Oracle Database 11g Release 2 on AIX and IBM Power Systems servers.

- For Oracle Database 11g, *Oracle Database 11g R2 and Oracle RAC 11g R2 on IBM AIX: Tips and Considerations*:
ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP101176
- For Oracle Database 12c, *Oracle Database 12c R1 and Oracle RAC 12c R1 on IBM AIX: Tips and Considerations*:
ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP102425

The following table shows the versions of Oracle Database supported on the new IBM Power Systems servers built with POWER9 processor technology.

Oracle Database	Oracle Database 18c
	Oracle Database 12c Release 2.
	Oracle Database 12c Release 1.
	Oracle Database 11g Release 2.



	Oracle Database 10g Release 2 (Note - Oracle Database 10g Release 2 is supported on AIX 6.1 only. So, it can run in the <i>IBM POWER7® compatibility mode</i> on the new IBM Power Systems servers.)
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Table 6. Supported Oracle Database versions

Tuning tips

The same AIX OS tuning tips are applicable for both Oracle Database 12c Releases and Oracle Database 11g Release 2. For a list of resources that can be useful when tuning an Oracle Database on IBM Power Systems servers, refer to the “Resources” section at the end of this paper.

Oracle Database licensing on IBM Power Systems

Oracle’s licensing policies can be found at Oracle’s “Oracle Global Pricing and Licensing” website at: <https://www.oracle.com/corporate/pricing/index.html>

Generally speaking, Oracle’s licensing policy applies equally to any hardware platform with a few exceptions. For the purpose of this white paper, the Core Factor table is a critical document since Oracle applies different core factors to different hardware platforms in order to calculate the price of its software per core. In some cases Oracle software can be licensed by number of users instead of licensing per core. The Oracle core factor table is available at:

<http://www.oracle.com/us/corporate/contracts/processor-core-factor-table-070634.pdf>.

The new Power Systems Scale-Out servers with POWER9 technology are all configured with one or two sockets, where each socket is populated with an SCM. A two-socket servers can be configured with up to 24 cores.

Three versions of the Oracle Database are available for use on IBM Power Systems servers:

- **Oracle Database Standard Edition** is only applicable on the servers with Oracle Database 11g Release 2 based on current Oracle product support. It allows use on up to four sockets.
- **Oracle Database Standard Edition 2** is supported on servers or clusters of servers with up to two sockets. Because Oracle defines each chip as a socket for the purposes of licensing, the Power S914, S922 and S924 servers are eligible to run with Oracle Database Standard Edition 2. To be eligible, a server cannot have more than two sockets at any time. When using the Oracle RAC capability of Oracle Database Standard Edition 2, the number of sockets in the entire cluster must be no more than two.
- **Oracle Database Enterprise Edition** is licensed by the number of physical cores available in the logical partitions that the Oracle Database is running in, when virtualization is being used. This is because Oracle accepts Dynamic Logical Partitions (DLPAR) as hard partitioning and charges for the maximum number of physical cores that the Oracle Database is capped to run on. Any Power Systems server can run Oracle Database Enterprise Edition.

IBM and IBM Business Partners can contact the IBM Oracle International Competency Center (ibmoracle@us.ibm.com) for help with evaluating the number of cores available in an LPAR.



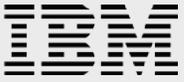
The document at the following link shows Oracle's partitioning policies:

<http://www.oracle.com/us/corporate/pricing/partitioning-070609.pdf>

Oracle core factors are applied to licenses of Oracle Database Enterprise Edition. To calculate the number of EE licenses required the core factor is applied to the total number of cores Oracle will run on and the factored value is used to calculate the number of licenses required. Oracle uses the core factor, to adjust for the performance of the processor, with more powerful processors having a higher core factor. However, this determination is exclusively the responsibility of Oracle Corporation and a client planning to install Oracle software on any hardware platform needs to discuss licensing terms and conditions with their Oracle representative.

Summary

This paper gathers a set of performance results from performance evaluation studies with a Power S924 server with POWER9 processors with analytical workloads running on Oracle Database 12c Release 2 and AIX 7.2. This paper compares the performance of analytical queries running with both Row type access and in an Oracle Database with the In-Memory feature enabled and concludes that Power Systems servers with POWER9 processors and Oracle Database In-Memory are the best combination to provide outstanding results. The performance numbers shown in the charts are for education purpose only. Additionally, a set of technical topics were included in this document that help understanding the support of AIX versions, Oracle Database versions, and IBM virtualization software versions and licensing for the new IBM Power Systems servers built with POWER9 processor technology.

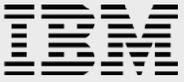


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Wayne Martin is the IBM Systems and Technology Group Technology Solutions Manager responsible for the technology relationship between IBM and the developers of Oracle Corporation Database and Fusion Middleware for all IBM server brands. His responsibilities include driving mutual understanding between IBM and Oracle on technology innovations that can generate benefits for mutual customers, managing the process of getting that technology implemented in products, and insuring that availability of the products to customers is timely. Wayne has held a variety of technical and management roles at IBM that have focused on driving enhancements of ISV software that uses IBM mainframe, workstation, and scalable parallel products. He can be reached at wmartin@us.ibm.com.



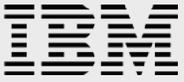
Document Resources

The following references are useful when tuning an Oracle Database environment. The same tuning of AIX for Oracle Database 11g Release 2 applies to Oracle Database 12c Release 1.

- IBM AIX “From Strength to Strength – A summary of upgrade benefits for each release of AIX”
<https://www-07.ibm.com/servers/tw/aix/PSO03004USEN.pdf>
- Tuning IBM AIX 5.3 and AIX 6.1 for Oracle Database (whitepaper)
<http://public.dhe.ibm.com/partnerworld/pub/whitepaper/162b6.pdf>
- Oracle RAC on IBM AIX best practices in memory tuning and configuring for system stability
http://www-01.ibm.com/support/docview.wss?mhq=wp101513&mhsrc=ibmsearch_a&uid=tss1wp101513
- Implementing IBM FlashSystem 840
<http://www.redbooks.ibm.com/abstracts/sg248189.html>
- IBM Power Systems, AIX and Oracle Database performance considerations
[ibm.com/support/techdocs/atsmastr.nsf/WebIndex/WP102171](http://www.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/WP102171)

These are some supplemental tuning resources.

- Diagnosing Oracle Database Performance on AIX Using IBM NMON and Oracle Statspack Reports (white paper):
<https://www-01.ibm.com/support/docview.wss?uid=tss1wp101720>
- My Oracle Support (userid and password are required to sign in)
<https://support.oracle.com/>



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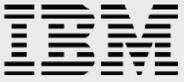
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