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2nd HPE Special Edition

DDR4 FOR DUMMIES®

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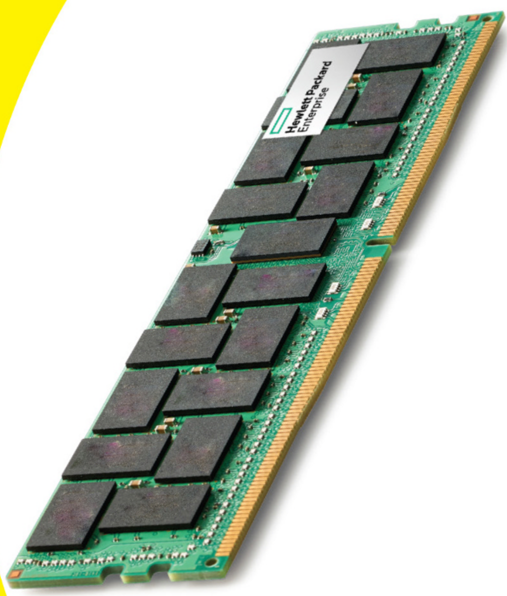

Learn to:

- Choose your preferred DIMM type
- Go to the HPE configuration tool online
- Avoid common mistakes

Hermann Wienchol
Marty McAfee

About HPE

HPE — a leader in IT innovation for more than 75 years — has the expertise and solutions you need to transform your business. HPE offers dozens of products, solutions, and options to build and support your server infrastructure. HPE server memory, however, is more than just an option — it's a critical component to meeting business resource constraints caused by operational costs, server virtualization, cloud computing, high-performance computing, and resource-intensive applications.

HPE leverages strong global alliances with top tier suppliers to obtain high quality server memory products. It tests server memory while it's still in development with suppliers and then tests again afterward to ensure that the HPE server memory you install in your server meets strict quality specifications.

HPE server memory provides the performance, reliability, efficiency, and security that enterprise or small and medium businesses like yours need to productively and confidently manage your expanding workloads. HPE also works with you to proactively manage the health of your server infrastructure.

All of this attention to superior quality ensures that HPE's memory solutions improve the functionality of your servers and data centers. And with sales and support sites in the United States, Europe, and Asia-Pacific, HPE supports you no matter where you are in the world.

More information about HPE (NYSE: HPE) is available at **www.hpe.com.**

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Table of Contents

Introduction

Welcome to *DDR4 For Dummies,* 2nd HPE Special Edition — a book with everything you need to know about Double Data Rate 4 (DDR4) memory, the latest generation high-speed memory for the HPE ProLiant Gen9 servers. This books helps you discover the memory population rules for HPE's Intel Xeon 4-way servers and the advantages of DDR4 over DDR3 memory.

About This Book

This book comprises four parts:

- **Part I: Getting to Know DDR4.** Find out what's new about DDR4 and how it compares to DDR3. (Hint: It's faster and also uses less power.) You learn about the differences between DDR4 used with Xeon v3 CPUs (codename: Haswell) versus DDR4 used with Xeon v4 CPUs (codename: Broadwell). You also read about HPE SmartMemory and HPE Standard Memory and, of course, the main types of DDR4 Memory that are used in HPE servers:

  - *UDIMMs* (**U**nbuffered **DIMM**s) for price and reliability
  - *RDIMMs* (**R**egistered **DIMM**s) for price, reliability, and performance
  - *LRDIMMs* (**L**oad-**R**educed **DIMM**s) for performance and maximum memory capacity
  - *LRDIMMs 3DS TSV* (**L**oad-**R**educed **DIMM**s **3-D**imensional **S**tack using **T**hrough **S**ilicon **V**ias) for high-performance/watt and highest memory capacity
  - *NVDIMMs* (**N**on**v**olatile **D**IMMs) for workload optimized solutions that coexist with DDR4 (covered in Part II)

  You also discover how to identify DDR4 DIMMs and understand per-channel restrictions.

- **Part II: Nonvolatile DIMMs for DDR4.** A new DIMM that comes with the performance of memory and the persistence of storage. Resilient technology for workload-optimized solutions.
- **Part III: Populating the Server.** There are guidelines for getting the best performance, and rules also exist about what works and what doesn't. You ought to follow these guidelines, and you can't break the rules.
- **Part IV: Ten Common Questions about DDR4.** This part finishes the book with some common questions. These are the "there are no stupid questions" akin to the cruise ship passenger who asks, "Does the crew sleep on the ship?"

Terms Used in This Book

Before we get started, here are three acronyms you see a lot in this book that describe the types of DDR4 memory.

DIMM stands for *Dual Inline Memory Module,* a module where the connectors, or gold fingers (not related to the 1960s James Bond movie), at the front of the module are electrically separated from the ones at the back in order to utilize a wider data bus (whereas a *SIMM,* or *Single Inline Memory Module,* has the same amount of connectors at the front and the back of the module, but electrically shorted).

RDIMM, or *Registered DIMM,* uses a register (which acts as a buffer) on the address/command bus in order to put less of an electrical load on the system's memory controller. It has nothing to do with filling out a registration or warranty card.

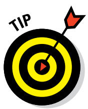
LRDIMM, or *Load-reduced DIMM,* is similar to an RDIMM, but in addition to the register, it also uses a buffer on the data-bus to reduce the electrical load on the system's memory controller. It's faster.

For more about the different types of DIMM, see Part I.

Icons Used in This Book

This book uses icons to alert you to geeky, useful, and important factoids.

This icon alerts you to extra information that helps you make sense of some of the more technical aspects in this book.



This icon points out helpful and useful information.

This icon points out super-important information.

This icon alerts you to information that may damage your system. Proceed with caution!

Part I

Getting to Know DDR4

In This Part

- Exploring DDR4 and HPE Smart/Standard Memory
- Choosing the right DIMM
- Understanding memory protection
- Identifying HPE DIMMs
- Seeing DIMMs per channel restrictions
- Taking a look at HPE part numbers

In late 2014, a new generation of servers (HPE ProLiant Gen9) arrived with new CPUs (Xeon v3), introducing Intel's new processor microarchitecture named Haswell. To maximize their performance, a new generation of memory, called DDR4, was introduced. Spelled out, DDR4 SDRAM is short for *double-data-rate fourth-generation, synchronous dynamic random access memory.* (And you thought the 34 characters of "supercalifragilisticexpialidocious" was long!) DDR4 memory uses (as its predecessors DDR3, DDR2, and DDR1 already did) each of the two phases of the clock (rising and falling) to achieve the double data rate compared to what is now known as single-data-rate SDRAM.

In early 2016, this generation of servers received an upgrade to Intel's next-generation CPUs (Xeon v4) named Broadwell, which takes huge leaps forward in performance and power efficiency through shrinking the technology. Along with the CPU improvements comes new DDR4 memory offering higher capacity DIMMs and higher performance. Also for the first time, Nonvolatile DIMMs (NVDIMMs) will be available on HPE ProLiant and Synergy Servers.

Take a look at how DDR4 SDRAM DIMM is deconstructed:

- **DDR (Double Data Rate Memory):** It transfers twice the data per clock cycle (CL) versus non-DDR memory (which is now called single data rate, or SDR).
- **4 (Fourth Version of DDR):** If you were trying to catch up, if this was the Super Bowl, it would be DDR IV.
- **S (Synchronous):** The memory accesses are synchronized with a memory clock.
- **D (Dynamic Memory):** Unlike flash memory in your camera or a solid state drive, this memory needs to be electrically refreshed every few milliseconds or, oops, no data.
- **RAM (Random Access Memory):** Every bit can be accessed equally as fast, unlike a tape drive or file cabinet where you get to Aardvark before Zebra.
- **DIMM (Dual Inline Memory Module):** Specs for 64-bit processors needed two matched 32-bit single inline memory modules (SIMMs) to fill the 64-bit data path; DIMMs have it all on one module.

Why DDR4: Less Filling, Tastes Great

You'll be happy to know that DDR4 continues the pace of energy efficiency. DDR3 started running at 1.5 volts; later, DDR3L (L for low voltage) ran even lower at 1.35V. DDR4 is now available starting at 1.2 volts, which in terms of power consumed (watts), is good for significant improvement over DDR3, which had improved consumption advantage over DDR2, as DDR2 had over DDR1. Future DDR4 enhancements may drive power consumption even lower.

Speed also matters. DDR4 helps make servers faster and more powerful. There are several reasons why you want DDR4 over DDR3 (beyond the fact that DDR3 won't fit in DDR4 slots, and you'll break something trying to prove otherwise):

- **High performance:** Performance of memory is usually characterized through latency (internal delays) and bandwidth (the rate data is read from or written to RAM). Although the overall latency hasn't changed much over the last couple years (still around 14 nanoseconds, or ns), the bandwidth certainly did. DDR4 on Xeon v3 CPUs (Haswell) enables memory to run (at introduction) at a 15 percent higher data rate than the maximum data rate of DDR3. From there, upgrading to Xeon v4 CPUs (Broadwell) gives you another 13 percent increase in data rate, assuming you're using the DDR4 DIMMs with new speed grading along with it. Over the next couple of years, you'll see an increase in data rate on DDR4 over DDR3 of about 70 percent. Figure 1-1 gives you the supported DDR3 and DDR4 data rates.

DRAM type	*Supported data rates (MT/s)*									
	800	1066	1333	1600	1867	2133	2400	2666	2933	3200
DDR3	√	√	√	√	√					
DDR4 (Haswell)			√	√	√	√				
DDR4 (Broadwell)			√	√	√	√	√			
DDR4 (JEDEC)			√	√	√	√	√	√	√	√

Figure 1-1: The supported DDR3/DDR4 data rates.

At DDR4 launch, server with Xeon v3 CPUs (Haswell) supported data rates up to a maximum of 2133MT/s, upgrading to a Xeon v4 CPU (Broadwell) in combination with the new higher speed grade DDR4 DIMMs, data rates will increase up to the maximum of 2400MT/s, depending on the configuration.

Some refer to mega-transfers per second (MT/s) as MHz. For a 1066 MHz clock, the data transfer rate is 2133 MT/s, hence double data rate. The two were the same when you moved one piece of data for each tick of the clock, but now you get double that "double the flavor," which is what this DDR thing is all about. Here, MHz means *megahertz,* not megatransfers.

- **Low power:** Running at same speeds, the 1.2V DDR4 supply cuts power consumption by up to 20 percent over DDR3 memory, which ran at 1.35V. Eagle-eyed math wizards will notice that's an 11 percent drop in voltage, but let us explain: Other things are happening as well, and the power draw, expressed in watts, is down by about 20 percent.
- **High capacity:** In DDR3, DIMMs from 2GB up to 64GB were available; in DDR4, capacity starts at 4GB up to 64GB and higher. This means you're able to run up to 3TB of memory in a DL380Gen9 system with the release of the HPE 128GB DIMMs.
- **Runs cooler:** DDR4's improved thermal characteristics allow each DIMM to run at lower temperatures than DDR3. DDR4 does its part to be neutral on climate change.

Additional features worth mentioning include

- **Write Cyclic Redundancy Check Data Bus** gives you better error detection capability and reliability but won't be supported on server platforms because of ECC.
- **Data Bus Inversion** reduces the power consumption and improve signal integrity.
- **CA (Command/Address) Parity** is a method to verify the integrity of command/address transfers (used on UDIMMs only).

With the release of Xeon v4 CPUs, DDR4 memory options at HPE will split in two major categories.

HPE SmartMemory

HPE SmartMemory enables performance-tuned and high-efficiency features for enterprise customers without compromising performance. Some of those features are

- Operation at higher speeds than industry standards at certain configurations
- Advanced error detection technology that pinpoints issues that may cause uncorrectable errors and unplanned downtime — before they happen

- Integration with Active Health System, which records critical memory errors, allowing administrators to make a faster diagnosis, avoiding unexpected interruption of business operations

Figure 1-2 shows a comparison table on HPE SmartMemory Kits offered with the Introduction of Haswell (Xeon v3) and Broadwell (Xeon v4).

Type¤	PC4-2133 Kits (Xeon v3)¤	PC4-2400 Kits (Xeon v4)¤
RDIMM¤	4GB 1Rx8 PC4-2133P-R¤	¤
	¤	8GB 1Rx8 PC4-2400T-R¤
	8GB 1Rx4 PC4-2133P-R¤	8GB 1Rx4 PC4-2400T-R¤
	¤	16GB 1Rx4 PC4-2400T-R¤
	16GB 2Rx4 PC4-2133P-R¤	16GB 2Rx4 PC4-2400T-R¤
	32GB 2Rx4 PC4-2133R-15¤	32GB 2Rx4 PC4-2400T-R¤
LRDIMM¤	16GB 2Rx4 PC4-2133P-L¤	¤
	32GB 4Rx4 PC4-2133P-L¤	32GB 2Rx4 PC4-2400T-L¤
	64GB 4Rx4 PC4-2133P-L¤	64GB 4Rx4 PC4-2400T-L¤
	¤	128GB 8Rx4 PC4-2400T-L¤

Figure 1-2: HPE SmartMemory DIMMs with Xeon v3/v4.

HPE SmartMemory doesn’t include UDIMMs.

HPE Standard Memory

HPE Standard Memory (HPE 10/100 series rack and tower servers) offers a reliable solution for small and medium business (SMB) customers looking for enhanced memory performance and features at an affordable price. Some points about this type of memory include the following:

- **HPE quality and reliability** is engineered into every Standard Memory product with only the best components selected.
- **Optimized compatibility** through authentication ensures that you’re using a genuine HPE product.

- **Error Correcting Code (ECC) memory** protects businesses from data loss and unplanned system downtime.
- **Performs at industry-standard speeds** with piece of mind that comes with working with HPE.
- **Low acquisition cost** offers a solution for small businesses looking for the right performance and features at an affordable price.

Figure 1-3 shows a comparison of HPE Standard Memory offered with the introduction of Haswell (Xeon v3) and Broadwell (Xeon v4):

Type	PC4-2133 Kits (Xeon v3)	PC4-2400 Kits (Xeon v4)
UDIMM	4GB 1Rx8 PC4-2133P-E	
	8GB 2Rx8 PC4-2133P-E	
	8GB 1Rx8 PC4-2133P-E	
	16GB 2Rx8 PC4-2133P-E	
RDIMM	4GB 1Rx8 PC4-2133P-R	
		8GB 1Rx8 PC4-2400T-R

Figure 1-3: HPE Standard Memory DIMMs.

When selecting DDR4 *HPE SmartMemory* or *HPE Standard Memory,* options will include the following capacities for

- **UDIMMs:** 4GB/8GB/16GB
- **RDIMMs:** 4GB/8GB/16GB/32GB
- **LRDIMMs:** 16GB/32GB/64GB/128GB

The speed at which DIMMs usually run depends on the capability of the CPU and the DIMM, as well as the number of DIMMs installed in a channel. Currently valid data rates are 1333/1600/1866/2133/2400 MT/s. Additional rules apply for HPE ProLiant and Synergy servers. For details, see the sidebar "DDR4 for HPE."

DDR4 for HPE

HPE memory has several highlights:

- DDR4 memory was launched at 1.2 volts and speeds up to 2133 MT/s for Intel Xeon E3-1200 v5 series (1P servers), Xeon E5-2600 v3 series (2P servers) and Intel Xeon E7-4800 v3 (4P servers). Memory sizes varied from 4GB/8GB over 16GB/32GB up to 64GB. DDR4 Memory speeds are increasing up to 2400 MT/s with the launch of Intel Xeon E5-2600 v4 series and Xeon E7-4800 v4 series. Memory sizes vary from 8GB/16GB/32GB/64GB and up to 128GB.
- On HPE servers, ProLiant Gen9 platforms with Intel processors support DDR4 UDIMMs, RDIMMs, and LRDIMMs, but *not* mixed in the same unit. HPE Synergy servers only support RDIMMs and LRDIMMs.
- All HPE servers support advanced ECC for better data integrity.
- For HPE servers, maximum capacity with 32GB RDIMMs is as high as 768GB for 2P servers (E5-2600 v3/v4), 1.5 TB for 4P servers (E5-4600 v3/v4), and now 3TB for 4P servers (E7-4800 v3/v4).
- Memory modules carry a one-year warranty or assume the longer warranty of the server they're installed inside.

HP DDR4 option kits contain a single DIMM module.

Choosing a DIMM Type

Back in DDR3-land, you had the choice among three different types of DIMMs (UDIMMs, RDIMMs, LRDIMMs). The choices for DDR4 were narrowed down with the launch of Xeon v3 (Haswell) to two types, RDIMMs and LRDIMMs. The main reason UDIMMs were left out this time is that at higher DDR4 speeds you won't get any advantage over RDIMMs anymore when it comes to performance and reliability. With the introduction of Broadwell (Xeon v4), UDIMMs are coming back as HPE Standard Memory on HPE 10/100 Series rack and tower servers.

DDR4 memory is categorized by capacity, rank, and organization:

- **Capacity** is the total amount of storage on a single DIMM.
- **Rank** is a group of DRAM chips that are accessed simultaneously (via the CS or chip select signal) to provide 72 bits of data (64 bits data + 8 Bits ECC) to the system. Used are 1R/2R/4R/8R.
- **Organization** determines the number of data bits coming out of a single DRAM. In DDR4 you will see x4 (pronounced "by four") and x8.

Figures 1-4 is an example of an HPE 4GB DDR4 memory kit, using the same DRAM density of 4 Gbit: HPE 4GB 1Rx8 PC4-2400P-R Kit (4Gb x 1 x 8 = 4 GByte).

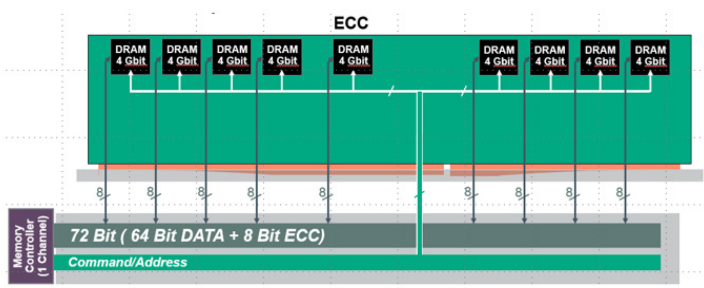


Figure 1-4: An HPE 4GB DDR4 memory kit.

Figure 1-5 is an example if an HPE 8GB memory kit: HPE 8GB 2Rx8 PC4-2133P-R Kit (4Gb x 2 x 8 = 8 GByte).

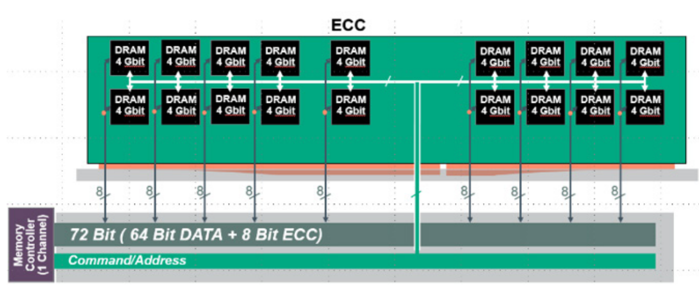


Figure 1-5: An HPE 8GB DDR4 memory kit.

As you probably notice, the HPE memory kits for both DIMMs are labeled “PC4-2133P-R Kit.” This is slightly different from what you were probably used to in DDR3, which was “PC3-12800R-13 Kit.”

Here are the differences:

- **DRAM Data Rate:** This is the operating data rate for each bit on the DRAM. For example, DDR3-1600 has a data rate of 1600 MT/s (Mega Transfers per second). DDR4 starts by default at a higher data rate, so the maximum operating data rate is DDR4-2133, which means 2133 MT/s.
- **DDR3 DIMM Data Rate:** The memory bus of a DIMM is 64 bit wide, which results in a DIMM Data Rate of 12.8 GB/s (1600 Mbit/s * 64 bit/8 bits per Byte). The data rate for the whole DIMM is then labeled “PC3-12800.” Now you can easily derive all other speed-bins in DDR3, such as DDR3-1333 is PC3-10600.
- **DDR4 DIMM Data Rate:** In DDR4 things become simpler, and the data rate for each DRAM is written “DDR4-2133.” For the label on the DIMM, it’s practically the same — “PC4-2133.”
- **CAS latency:** It’s the DRAM response time from the column address command (READ) to 1st data out on the memory bus. CAS latency is usually counted in CL even when it’s a fixed asynchronous timing, so for example, a CL13 (pronounced “CAS latency of 13”) means the response of the DRAM is 13 CL at a certain speed. In Figure 1-6, you see how this works out by issuing a read command (RD) to the DRAM with a CL13.

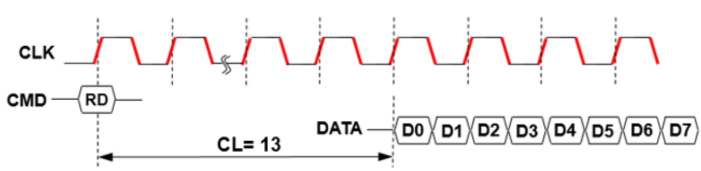


Figure 1-6: CL is the time (number of clocks) from an issued read command to first data out.

So, what happens when the speed increases? Well, because the CAS latency is a constant, you just have to count more clocks in the same amount of time, as you see in Figure 1-7.

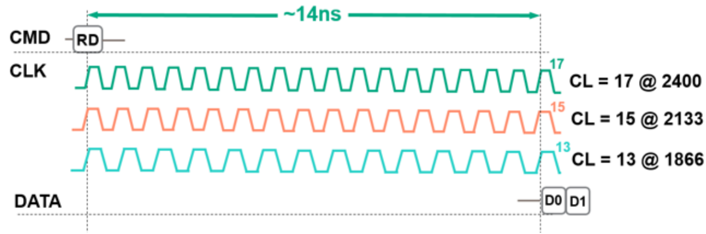


Figure 1-7: CL is the time from an issued column address command (RD) to first data out.

Of course, you can imagine that the faster the clock runs by keeping the CL constant, the actual response time decreases. For the CAS latency, DDR3 used numbers such as PC3-12800R-13, where 13 was the CAS latency. In DDR4, you use letters starting at the letter P, which is CL15. From there you go on: R = CL16, T = CL17, U = CL18, and so on. So, the label on a DDR4 DIMM tells you the following:

PC4-2133P-R is a DDR4 DIMM with a data rate of 2133 MT/s per data line and a CAS latency of 15. What does the R stand for? Here we go . . . now it's finally time to choose the DIMM type (Yay!!). You can choose from three different types — UDIMM (E), RDIMM (R), or LRDIMM (L).

Unbuffered DIMM (UDIMM)

Unbuffered dual in-line memory module (UDIMM) is the most cost efficient memory. It's usually used in cost conscious servers (such as the HPE ML10 or DL20) and is subject to certain limitations. It's not ideal for highest speeds due to high loadings on the command/address signals and you can only populate a maximum of 2 DIMMs per channel. Figure 1-8 shows a 8GB 2Rx8 PC4-2133P-E UDIMM: HPE 8GB 2Rx8 PC4-2133P-E Kit (4Gb x 2 x 8 = 8 GByte).

The address bits are connected to all 18 DRAMs on the DIMM. This means that each address bit sees 18 loads (max can be 36 for a 16GB UDIMM), which causes a degradation in signal integrity. To get around this "high load" situation, another type of DIMM is available, called RDIMM.

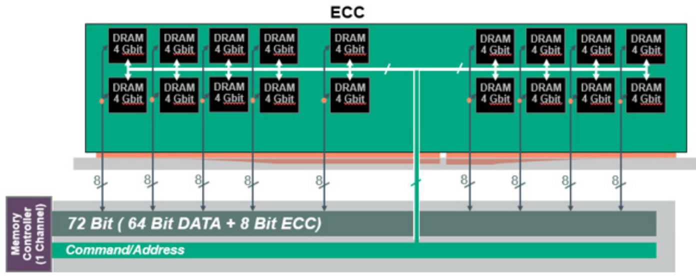


Figure 1-8: Unbuffered DIMM (UDIMM).

Registered DIMM (RDIMM)

Registered dual in-line memory module (RDIMM) puts less electrical loading on the command/address signals due to the register, which acts as a buffer on the DIMM between the memory controller and the DRAMs.

The register captures the command/address signals from the memory controller and retransmits them to the DRAMs locally (this provides greater reliability at a slight cost in performance of one CL to affected signals). As a result, the system sees only one load per address line instead of 9, 18, or 36. Figure 1-9 shows an RDIMM.

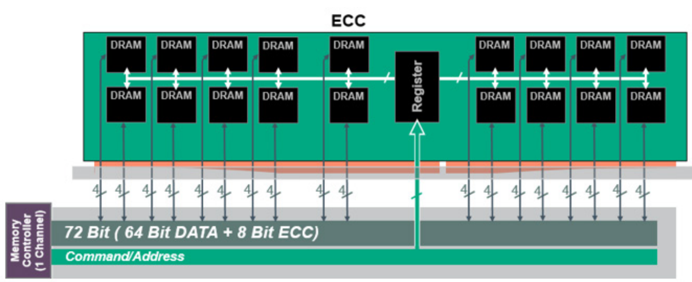


Figure 1-9: An example of an RDIMM.

The data still flows in parallel as 72 bits (64 bit data + 8 bit ECC) across the data portion of the memory bus, which becomes the limitation due to the electrical loading when populating more DIMMs in a channel. In DDR3, RDIMMs allowed for 1, 2, and 4 Ranks/DIMM support, which caused some problems in a 3-SPC system (3 times 4 Ranks per channel = 12 Ranks) because there was a restriction of maximum 8 Ranks per channel.

In DDR4 you're limited to 1 and 2 Ranks/DIMM, so this restriction isn't there anymore. RDIMMs can be used in all HPE ProLiant and Synergy Servers. They come in capacities of 4GB, 8GB, 16GB, and 32GB (with the release of Xeon v4 CPUs). In a 24-slot server, you could have as much as 768GB of DDR4 memory when using 32GB RDIMMs. To get to higher memory capacities, you need to look for another type of DIMM, the load-reduced DIMM (LRDIMM).

Load-reduced DIMM (LRDIMM)

LRDIMM has additional data buffers (DB) on the DIMM between the memory controller and DRAM in order to reduce electrical loading on the data signals of the memory bus. Figure 1-10 shows an LRDIMM.

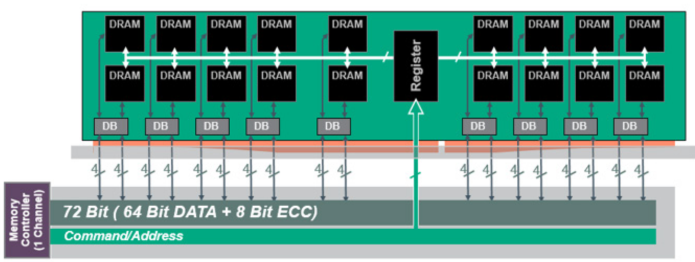


Figure 1-10: An LRDIMM.

The limitation of the RDIMM (having a high electrical load on the data signals when having more ranks or populating more DIMMs per channel) is now gone. This allows now for higher data rates on the memory channel and also higher capacities on the DIMMs.

TECHNICAL STUFF

In DDR4, a new concept known as chip-select-encoding is introduced. This allows the system to address multiple Ranks behind the LRDIMM buffer by encoding the chip-select instead of using one chip-select per rank.

With the advantage to run high-capacity LRDIMMs in the system at a higher bandwidth, the memory buffer adds additional latency to the data signals. LRDIMMs come in different capacities. At DDR4 launch, only a DRAM density of 4 Gbit was available, which leads to 16GB, 32GB, and 64GB LRDIMMs. With the introduction of 8GB DRAMs in 2016, you see the capacity going up to 128GB per DIMM. In a 24-slot server, such as the HPE DL360 Gen9, you could have as much as 3TB of DDR4 memory when using 128GB LRDIMMs.

LRDIMM 3DS TSV

With the 128GB LRDIMM, a new generation of DIMMs gets introduced by using advanced technology such as **3D S**tacking (3DS) and **T**hrough **S**ilicon **V**ias (TSV). The conventional stacking solution on low-capacity DIMMs (<64GB) usually uses wire-bonding, as shown in Figure 1-11.

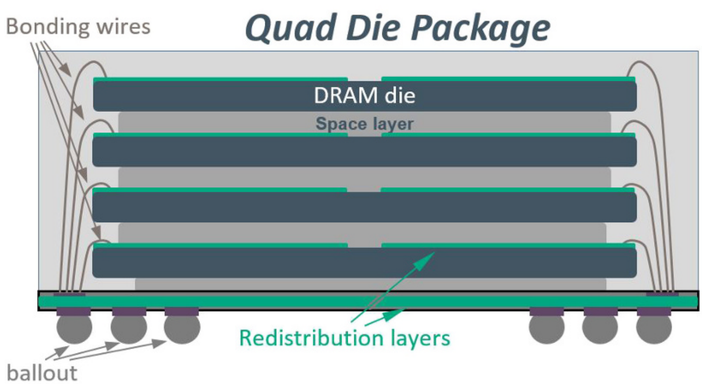


Figure 1-11: A conventional stack solution, using wire-bonding.

The wire-bond package can hold up to 4 DRAM dies (QDP, or Quad-Die-Package), which are connected over the RDL via bonding wires to the substrate (it almost looks like a small can of Pringles chips). All DRAM dies are identical and connected in parallel, as Figure 1-12 shows.

The high loading on the backside of the data buffer limits the DIMMs in running at high-speed operations. To get around this problem, TSV was introduced. See Figure 1-13.

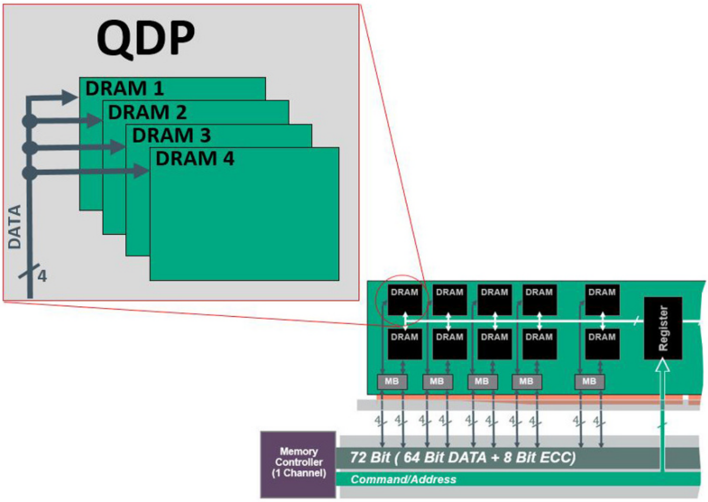


Figure 1-12: A QDP.

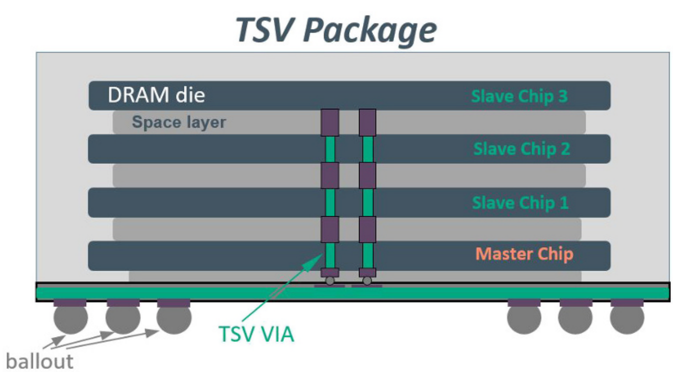


Figure 1-13: A stack solution that uses TSV.

Instead of connecting the pins by using bonding wires, an etching technique (a chemical process) is used to connect through the silicon DRAM die connecting the Master Chip with the Slave Chips. The Master Chip is the only interface on the stack that communicates with the memory controller over the Data Buffer on an LRDIMM. This is shown in Figure 1-14.

At this time, there's no support in mixing those 3DS TSV LRDIMMs with regular LRDIMMs.

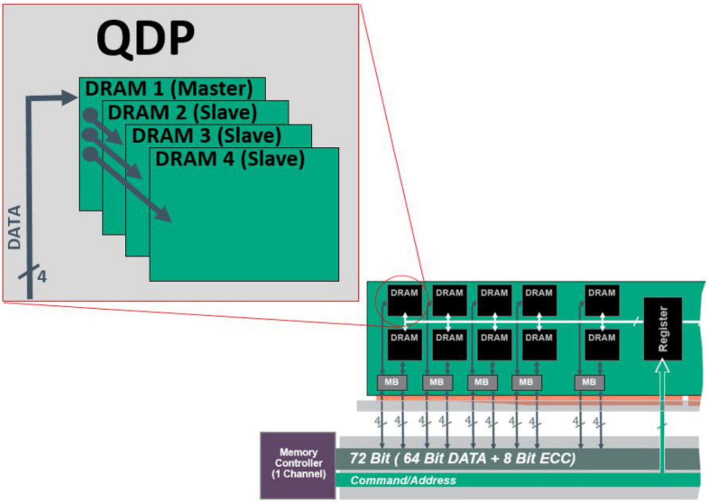


Figure 1-14: A stack solution, using TSV on a memory module.

By the way, you have to choose one DIMM type. You can't mix and match RDIMMs and LRDIMMs inside the same server. What happens if you mix? The server won't boot. Nothing gets damaged (except egos).

Take a look at the options in Table 1-1.

Table 1-1 Choices in Memory Technology

	UDIMMs	*RDIMMs*	*LRDIMMs*
PC4-2133P capacities	4GB 8GB 16GB	4GB 8GB 16GB 32GB	32GB 64GB
PC4-2400T capacities	8GB	8GB 16GB 32GB	32GB 64GB 128GB
Maximum DIMMs per channel	1 dual rank	3 dual rank	3 "any" rank
Address error detection	Yes	Yes	Yes

(continued)

Table 1-1 *(continued)*

	UDIMMs	*RDIMMs*	*LRDIMMs*
Lower cost	Yes	Yes	No (due to additional components and stacking technology)
Ranks/DIMM support	1, 2	1, 2	2, 4, 8
DRAM support	x8	x4, x8	x4
Maximum server capacity (GB)	64 (4 slots)	768 (24 slots) 3072 (96 slots)	3072 (24 slots) 12288 (96 slots)

Installation

Installing DDR4 memory is physically easy, especially because the slots are color-coded on most HPE servers. Memory slots are colored white and black and sometimes blue; the white slots are where you install the first memory module on each channel. It does take a bit of advance work but not a lot.

Memory Protection

ProLiant Gen9 servers offer several levels of memory protection, similar to previous generations (see Table 1-2):

- **ECC,** or error-correction code, is the fundamental form of ProLiant memory protection. *Parity,* as in parity error (you very occasionally get parity errors on a desktop PC), tells you something went wrong, as in wrong and it can't be made unwrong, so sorry. ECC is based on advanced mathematics, and there's a fancy formula to tell you how much you need (log2(N)+1, where N is the number of data bits) or this simple explanation: To protect 64 bits of data, you need 8 redundant bits. How good is it? ECC memory can detect and correct single-bit errors (the vast majority), can detect double-bit errors, and might detect (sorry, no guarantee) errors greater than double-bit.

Table 1-2 Advanced Memory Protection

	Basic ECC Technology	*HPE Advanced ECC Technology*
Device failure protection	No	Yes
Industry-standard DIMMs	Yes	Yes
Hot plug	No	No
Failed DIMM — replacement	Offline	Offline
Memory expansion	Offline	Offline
Additional memory expense	0%	0%

- **Advanced ECC (multiple-bit error detection)** is ECC on steroids, except in this case steroids are good and won't get you tossed out of the Olympics. Advanced ECC requires 16 redundant bits to protect a 128-bit word. It's able to detect and correct up to 4 data bits. With Advanced ECC, you can protect against the loss of a single DRAM device. The data bus is divided into groups of 4 bits each, and any group can have all 4 bits in error so long as the other groups are okay. It's able to detect 2-bit errors occurring in different groups. If 4-bit-wide DRAMs are used, then one DRAM represents one group on the bus.
- **Mirrored memory protection** is just like a mirrored hard disk drive. You have twice as much as you need. Half is configured as system memory, and half is mirrored memory. Data is written to both places. Reads are from the system memory unless — you've probably guessed this — there's an uncorrectable system error.

Identifying HPE DIMMs

This section helps you read the fine print on product selector guides. HPE certified memory will have these markings, from left to right:

- **HPE** indicates it's HPE-approved memory being sold through an HPE channel or direct from HPE.
- **nGB** is the capacity (n= 4, 8, 16, 32, 64, or 128GB).

- **eR** indicates the number of ranks (e=1, 2, 4, or 8 Ranks).
- **xf** is the data width (f=4 or 8 bit).
- **PC4** is the memory type, PC4 being DDR4.
- **wwww** is the module bandwidth (2133 MT/s).
- **P** is the CAS latency (P=15, R=16, T=17, U=18).
- **R** is the DIMM type (U=UDIMM, R=RDIMM, L=LRDIMM).
- **Kit** at the end indicates it's an HPE kit (and remember that with DDR4 there's one module per kit, not two).

For example, 726718-B21 HPE 8GB 1Rx4 PC4-2133P-R Kit indicates an HPE DIMM with an 8GB capacity, single rank, a data width of 4, memory type of DDR4 with a data rate of 2133*8 MT/s, CAS latency of 15, and an HPE kit.

DIMMs per Channel Restrictions

A *memory channel* refers to DIMM slots tied to the same wires on the CPU. Multiple memory channels allow for faster operation, theoretically allowing memory operations to be up to four times as fast. Dual channel architecture with 64-bit systems provides a 128-bit data path. Memory is installed in banks, and you have to follow a couple of rules to optimize performance. With the HPE Intel E5-2600v3 and E7-4800v3 series ProLiant Gen9 servers, there are four channels from each processor.

WARNING!

Population rules must be followed or errors will occur. Those rules are as follows:

- Same DIMM type; UDIMM, RDIMM, LRDIMM, and 3DS TSV LRDIMM can't be mixed in a system (meaning, you can't populate one CPU with RDIMMs, the other one with LRDIMMs)
- Same size is recommended for performance; however, it's possible to mix capacities
- Same speed

- Same technology (DDR4); DDR2 and DDR3 modules won't fit, physically, in a DDR4 socket due to the location of the notch of the DIMM and also of the outer edges being slightly beveled

Channel rules and restrictions are covered in more detail in Part III.

HPE Part Number Matters (Not Vendor Name)

When buying memory through HPE, remember that DIMMs don't have to be from the same vendor. DIMMs are JEDEC standard. All DIMMs sourced through HPE pass HPE memory qualification tests. In brief: If the HPE part number is the same, the DIMMs are compatible.

Part II

Nonvolatile DIMMs for DDR4

In This Part

- Discovering the NVDIMM-N
- Looking at the NVDIMM-F
- Understanding the NVDIMM-P

In this part, you discover the different types of nonvolatile DIMMs (NVDIMMs) and the advantages of using NVDIMM in your HPE server. NVDIMM is new to the industry, and the future is so bright with possibilities that you gotta wear shades.

NVDIMM Type N

NVDIMM type N (NVDIMM-N) combines DRAM and NAND Flash onto a single DIMM module and is the first one to be released by HPE on Gen9 server platforms. During normal operation, the DIMM runs like a regular RDIMM, and there's no direct access to the Flash. In case of a power loss (outage or shutdown), memory content is saved into the flash. This can be an advantage because the device can be used as a nonvolatile storage device on the high-speed memory bus.

NVDIMM-N has the following characteristics:

- Capacity (in the 10s GB)
- Performance (read latency 10s ns)
- Endurance and reliability of DRAM

Application-specific benchmark tests have shown performance improvements up to 4x by simply using NVDIMMs in an HPE server system. The NVDIMM-N module, shown in Figure 2-1, is similar looking to an LRDIMM, but there are some minor differences.

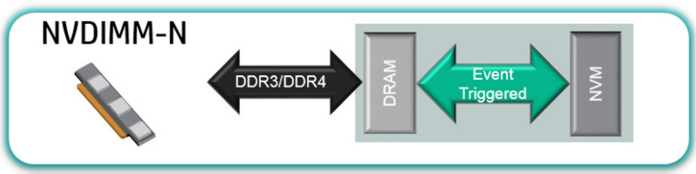


Figure 2-1: The NVDIMM-N module.

Instead of the data buffer found on an LRDIMM, you have **MU**ltiple**X**ers (short, MUX, functions as a switch) there instead. During normal operation, data can be written to and read from the DRAM through the MUX. In case of a power outage or a shutdown, the HPE MegaCell kicks in to provide power for a limited amount of time. This enables the On-DIMM ASIC (Application Specific Integrated Circuit) to save all DRAM data into the Flash memory. Once the power comes back, data in the DRAM gets restored completely to the state it was left before.

REMEMBER

The following requirements have to be met in order to make this all work:

- A maximum of 2 NVDIMMs can be populated in a 2-SPC (slots per channel) system.
- Slots per channel, like BL460c Gen9 or 16 NVDIMMs on a 3-SPC platform such as DL360 Gen9.
- HPE MegaCell (Smart Storage Battery) provides backup power to HPE NVDIMM-Ns (no SuperCaps required).

NVDIMM Type F

NVDIMM type F (NVDIMM-F) is the second type of NVDIMM that most likely will be introduced on HPE's Gen10 server platform. See Figure 2-2 for a configuration.

Figure 2-2: The NVDIMM-F module.

There's no DRAM sitting on the module anymore; instead, there's an ASIC with a RAM buffer that acts as a cache interfacing the high-speed memory bus (load/store) on one side with the low speed bus (block write) to the NAND flash on the other. This DIMM has the following characteristics:

- Capacity (100s GB to 1s TB)
- Performance (read latency 10,000 to 100,000 ns)
- Endurance and reliability of NAND Flash

NVDIMM Type P

NVDIMM type P (NVDIMM-P), shown in Figure 2-3, is further out in the future because it's relying on high-speed nonvolatile memory technology.

Figure 2-3: A NVDIMM-P module.

It not only requires a new memory technology, but also it needs a new memory bus protocol that still has to be defined. The CPU will communicate directly with the NVM (nonvolatile memory), which can be

- **Memristor,** an electrical component that limits or regulates the flow of electrical current in a circuit and remembers the amount of charge that has previously flowed through it
- **STT-MRAM (spin-transfer-torque magnetoresistive RAM),** which describes the effect in which the orientation of a magnetic layer in a magnetic tunnel junction or spin valve can be modified by using a spin-polarized current
- **PCM (phase change memory),** which uses a semiconductor alloy that can be changed rapidly between an ordered, crystalline phase having lower electrical resistance to a disordered, amorphous phase with much higher electrical resistance

Of course, there are many more NVM technologies out there that can't be listed here. The expected characteristics on the NVDIMM-P are

- Capacity somewhere in between DRAM and Flash memory
- Performance greater than Flash, less than DRAM
- Endurance and reliability greater than Flash, less than DRAM

NVDIMM-P will support both transfer types, byte addressable (Load/Store), and block accesses from the host.

NVDIMM population rules and guidelines

NVDIMMs follow general memory population rules and guidance:

- Can be mixed with RDIMMs only. No mixing with LRDIMM or UDIMM.
- When installing NVDIMM(s) on the same memory channel as RDIMM(s), populate the RDIMM(s) first/farthest from the processor, then populate the NVDIMM(s) last/closer to the processor.
- When NVDIMMs exist in the system, there must be a minimum of one RDIMM installed in any DIMM slot in the first CPU socket.
- One processor may have more than 8 NVDIMMs, but the total number of NVDIMMs among the two processors may not exceed 16 in a 3 SPC system. Balanced memory configuration between the two processors and between memory channels is still recommended to maximize performance.

The HPE Smart Storage Battery provides the battery backup source for NVDIMMs. NVDIMMs can only be installed in servers supporting the HPE Smart Storage Battery.

Part III

Populating the Server

In This Part

- Knowing the rules to follow (and why)
- Populating in the proper order

In this part, we go over the nitty-gritty about populating the memory slots. The rules seem overwhelming at first. There is a lot of nitty and a lot of gritty. Some rules you have to follow to make sure the server runs. Others you want to follow to optimize performance. The rules vary depending on whether you're installing UDIMMs, RDIMMs, or LRDIMMs and how many memory slots your server has. Some are pretty obvious, at least in hindsight, such as, don't install memory connected to the second CPU if you've only got one CPU installed in your server.

What follows here is wisdom likely to survive the ages, or at least the next couple of years, but always check online for the best and latest.

For more information and the latest information on configuring your HPE server with DDR4 memory, go to `www.hpe.com/info/memory`.

Population Rules for HPE DDR4 ML, DL, XL, and BL Servers

These are the key rules to follow when populating memory slots on HPE Intel-based Gen9 servers. This isn't the complete list. Still, it covers most of the HPE servers. Population rules for each of the HPE servers can also be found in the HPE QuickSpecs at `www.hpe.com/info/memory`.

Figures 3-1 and 3-2 show the maximum speeds for HPE Xeon v3 and Xeon v4 systems.

Type	Ranks Per DIMM and Data Width	DIMM Capacity (GB)		Speed (MT/s); Voltage (V); Slot Per Channel (SPC) and DIMM Per Channel (DPC)				
				2 Slots Per Channel		3 Slots Per Channel		
				1DPC	2DPC	1DPC	2DPC	3DPC
		4 GB	8 GB	1.2 V	1.2 V	1.2 V	1.2 V	1.2 V
RDIMM	1Rx8	4 GB	8 GB	2133	2133	2133	2133	1600
RDIMM	1Rx4	8 GB	16 GB	2133	2133	2133	2133	1600
RDIMM	2Rx4	16 GB	32 GB	2133	2133	2133	2133	1600
LRDIMM	2Rx4		32 GB	2133	2133	2133	2133	1866
LRDIMM	4Rx4		64 GB	2133	2133	2133	2133	1866
LRDIMM	8Rx4		128 GB	2133	2133	2133	2133	1866

Figure 3-1: Max speeds on Xeon v3 by configuration.

Type	Ranks Per DIMM and Data Width	DIMM Capacity (GB)		Speed (MT/s); Voltage (V); Slot Per Channel (SPC) and DIMM Per Channel (DPC)				
				2 Slots Per Channel		3 Slots Per Channel		
				1DPC	2DPC	1DPC	2DPC	3DPC
		4 GB	8 GB	1.2 V	1.2 V	1.2 V	1.2 V	1.2 V
RDIMM	SRx8	4 GB	8 GB	2400	2133	2400	2400	1866
RDIMM	SRx4	8 GB	16 GB	2400	2133	2400	2400	1866
RDIMM	DRx4	16 GB	32 GB	2400	2133	2400	2400	1866
LRDIMM	DRx4		32 GB	2400	2400	2400	2400	2400
LRDIMM	QRx4		64 GB	2400	2400	2400	2400	2400
LRDIMM	8Rx4		128 GB	2400	2400	2400	2400	2400

Figure 3-2: Max speeds on Xeon v4 by configuration.

For the HPE Intel-based Gen9 servers, the chipset supports a maximum of four DDR4 channels per CPU socket. Following the Intel documentation naming convention, these channels are numbered from 1 through 4. The HPE Intel-based Gen9 servers are

- **HPE ProLiant DL380 Gen9,** with 24 memory slots, there are three DIMM slots for each memory channel; 24 total slots (two CPU servers).
- **HPE ProLiant BL460c Gen9,** with 16 memory slots, there are two DIMM slots for each memory channel; 16 total slots (two CPU servers).

The following points describe the memory subsystem and the population rules:

- **Memory channels 2 and 4 comprise the three DIMMs closest to the processor.** Memory channels 1 and 3 comprise the two DIMMs farthest from the processor.
- **Populate the white DIMM slots first.**
- **Don't mix 3DS TSV LRDIMMs with regular LRDIMMs, RDIMMs, or UDIMMs.**
- **Don't install DIMMs if there's no corresponding CPU installed.** If there's only one CPU in a two-CPU system, only half the DIMM slots are available. This one is so obvious when you're reading advice, less so when you have all those available memory slots staring you in the face.
- **Maximize performance by**
    - Balancing the memory capacity among installed processors
    - Using the same type and same capacity DIMMs to optimize the interleaving scheme
    - Populating all the memory channels to make use of all the bandwidth available in the memory subsystem

- **Populate DIMMs from heaviest load (octal-rank) to lightest load (single-rank) within a channel.** The heaviest load (DIMM with most ranks) within a channel goes farthest from the CPU.
- **Memory mirroring is a mechanism where two identical copies of data are stored in memory.** If the DIMMs were polished chrome and the mirrored channels faced each other, you could almost see to infinity. When mirroring is enabled, the memory image on the memory channel 1 is exactly duplicated on memory channel 2 and similarly channel 3 is duplicated on channel 4. The DIMM configuration on the mirrored channels should be identical. Note that only half of the memory capacity is available to the system. The scope of memory mirroring applies to each processor socket.
- **Mixing DIMM speeds is allowed, but DIMMs will run at the slower of the speed ratings.**

DIMM Socket Color Coding

In addition to the DIMM numbering scheme, a DDR channel has unique colors per DIMM socket. The first DIMM is populated in the white socket, and the second DIMM is populated in the black socket. If a third DIMM is present on that channel, that DIMM is in the blue socket.

TIP

In dim light, black looks a lot like blue. Your work area should be well lit. If necessary, supplement room light with a flashlight, your phone's flashlight utility, or a candle — just avoid dripping wax into the sockets.

Figure 3-3 shows the color and loading scheme for the DIMMs in a typical HPE Gen9 system.

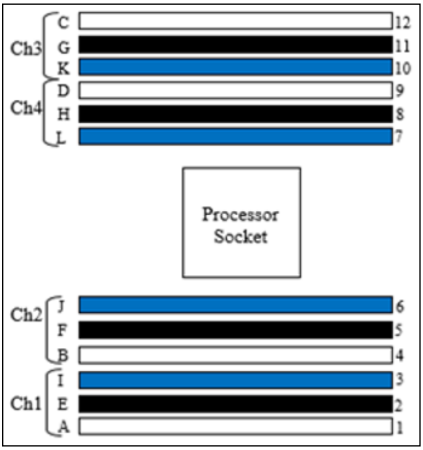


Figure 3-3: The HPE DIMM socket color scheme.

Populating Alphabetically

HPE recommends populating the DIMMs in alphabetical order to ensure best DIMM distribution in the system and to maximize server performance. This method ensures that the DIMMs are spread between the processors installed in the system and the available DDR channels, maximizing the use of memory bandwidth resources. Populating memory using this rule ensures that the available memory bandwidth resources are utilized and the memory interleaving is optimized.

For a quick guide on how to populate your slots for a 16-DIMM slot server, check Figure 3-4. Install DIMMs in alphabetical order. Look at the Population Order column. You install into the A slot first, installing into slot 2, then place B into slot 4, and so on down the alphabet. The rules are the same for CPU1 and CPU2.

Channel	Slot #	Population Order	Slot #	Population Order
	CPU1 - Present		**CPU2 – Not Present**	
1	1	A (1st)		
	2	E (5th)		
2	3	B (2nd)		
	4	F (6th)		
3	5	C (3rd)		
	6	G (7th)		
4	7	D (4th)		
	8	F (8th)		
	CPU1 - Present		**CPU2 – Present**	
1	1	A (1st)	1	A (2nd)
	2	E (9th)	2	E(10th)
2	3	B (3rd)	3	B (4th)
	4	F(11th)	4	F (12th)
3	5	C (5th)	5	C (6th)
	6	G (13th)	6	G (14th)
4	7	D (7th)	7	D (8th)
	8	H (15th)	8	H (16th)

Figure 3-4: 16-DIMM Slots CPU1 and CPU2.

For a quick guide on how to populate your slots for a 24-DIMM slot server, check Figure 3-5. Install DIMMs in alphabetical order. Look at the Population Order column. You install into the A slot first, installing into slot 3, then place B into slot 6, and so on down the alphabet. The rules are the same for CPU1 and CPU2.

Much more information is available via the HPE DDR4 online configuration tool: `www.hpe.com/info/DDR4memoryconfig`.

Channel	Slot #	Population Order	Slot #	Population Order
	CPU1 - Present		CPU2 – Not Present	
Channel 1	1	A (1st)		
	2	E (5th)		
	3	I (9th)		
Channel 2	4	B (2nd)		
	5	F (6th)		
	6	J (10th)		
Channel 3	7	C (3rd)		
	8	G (7th)		
	9	K (11th)		
Channel 4	10	D (4th)		
	11	H (8th)		
	12	L (12th)		
	CPU1 - Present		CPU2 – Present	
Channel 1	1	A (1st)	1	A (2nd)
	2	E (9th)	2	E(10th)
	3	I (17th)	3	I (18th)
Channel 2	4	B (3rd)	4	B (4th)
	5	F(11th)	5	F (12th)
	6	J (19th)	6	J (20th)
Channel 3	7	C (5th)	7	C (6th)
	8	G (13th)	8	G (14th)
	9	K (21st)	9	K (22nd)
Channel 4	10	D (7th)	10	D (8th)
	11	H (15th)	11	H (16th)
	12	L (23rd)	12	L (24th)

Figure 3-5: 24-DIMM slots CPU1 and CPU2.

Part IV

Ten Common Questions about DDR4

In This Part

- Figuring out what DDR4 is
- Deciding between UDIMM, RDIMM, and LRDIMM
- Knowing what mistakes to avoid

The Part of Tens is a *For Dummies* tradition. In this part, we answer some of your most pressing questions. All the wisdom you need, in a nutshell.

What Is DDR4 Memory?

Double data rate (DDR) is a form of SDRAM (synchronous *dynamic* random access memory). *Dynamic* means that the memory is volatile and it forgets what's stored when you pull the power plug, unlike ROM, Flash, NVDIMM, or other forms of nonvolatile memory. The *double* part means data is sampled twice per clock cycle.

What Does the 4 Stand For? And What's the Big Deal?

This is the fourth iteration of DDR memory, and it is faster, uses less power, and provides higher capacity than the previous generations. Before there was DDR3, there was DDR2, which was preceded by DDR, now in hindsight called DDR1.

The main benefits of DDR4 memory are its lower power and higher data transfer rates — it provides better performance at a lower cost of ownership.

How Many Kinds of DDR4 Memory Are There?

For server use, there are three main types of DDR4 DIMMs:

- Unbuffered DIMMs (UDIMMs) come in densities of 4GB to 16GB, operate at speeds of up to 2400 MT/s, and are the lowest cost and lowest power DDR4 DIMMs.
- Registered DIMMs (RDIMMs) come in densities of 4GB to 32GB, operate at speeds of up to 2400 MT/s, and are the lower cost and lower power DDR4 DIMMs.
- Load-reduced DIMMS (LRDIMMs) come in densities of 16GB, 32GB, 64GB, and 128GB and run at higher speeds than RDIMMs for certain configurations.

The larger capacity LRDIMMs and now NVDIMMs are also preferred for systems that run OLTP (**O**n **L**ine **T**ransaction **P**rocessing) or in memory database applications, providing a place to store large amounts of data and improving the system overall performance by limiting the amount of time data has to be fetched from the significantly slower HDD (hard disk drive) or SSD (solid state drive).

Do I Want UDIMM, RDIMM, or LRDIMM for Price? For Performance?

TIP

UDIMMs are your choice for lowest power and lowest cost. UDIMMs are always built with x8 DRAM devices. RDIMMs are your choice for lower power and lower cost. The majority of the RDIMMs are also built with x4 DRAM devices, but some can be x8. Choose x4 RDIMMs for the best reliability, such as Advanced ECC or DDDC+1, depending on system and chipset support. This will minimize the system downtime by protecting you from memory errors.

LRDIMMs are your choice for capacity (up to 3TB in a qualified 24-slot HPE server) and performance. LRDIMMs are always built with x4 DRAM devices.

Which Is Greener: UDIMM, RDIMM, or LRDIMM?

The good news is that all DDR4 DIMMs use significantly less power than DDR3 DIMMs of the same type, capacity, and speed. Among DDR4 types, the UDIMMs (no register and data buffers) and RDIMMs (no data buffers) are built with fewer devices and will therefore consume less power than the LRDIMMs (they're fully loaded). The overall memory subsystem power will be lowest when using UDIMMs. For bandwidth-intensive benchmarks for which the overall performance isn't a function of the total memory capacity, the RDIMM will provide the best performance per watt. For benchmarks as TPC-C, where the overall performance is a function of the total memory installed in the server, the LRDIMMs will provide the best TPC-C (an online transaction processing benchmark of the Transaction Processing Performance Council).

Which Works in Which HPE ProLiant and Synergy Servers?

All UDIMMs, RDIMMs, and LRDIMMs covered in this book work with the ProLiant and Synergy servers. But choose one; you can't mix 'n' match. For product offerings, visit `www.hpe.com/info/memory`.

Is There DDR4 Memory for HPE AMD Servers?

HPE ProLiant servers with AMD processors will offer systems using DDR4 memory. Stay tuned.

How Else Could I Mess Up?

You can't mix and match UDIMMs, RDIMMs, and LRDIMMs in the same system. Also you can't use older technology memory (DDR2 or DDR3) in ProLiant and Synergy Gen9 platform servers. Older technology DIMMs don't fit because they are keyed to be prevented from being inserted in a DDR4 slot.

Does a DDR3 DIMM Fit in a DDR4 Server?

No. It won't fit (different pin configuration, different notch location). If you push it in, you'd destroy the memory module or socket. If you make it fit without damage, the contacts won't line up, and you'll create a short. Will leftover DDR3 work in a DDR4 server? No, and for the same reasons. It. Will. Not. Go.

Will DDR4 RAM Speed Up My Old DDR3 Server?

The DDR4 DIMM has a completely different pinout and key location compared to a DDR3 DIMM. For this reason, it will not fit in a DDR3 connector, and if forced, it will damage the server either by creating shorts or by causing mechanical damage.

To take advantage of the DDR4 lower power and better performance, you need to purchase a DDR4 server.

What about DDR4 PCs?

Let me guess: You've got a gamer in the family. The short answer is yes; there will be a new generation of higher-end CPUs, motherboards, and PCs that will support DDR4 memory for workstations and, of course, gaming fanatics. There will be some performance improvement. As with servers, you can't just drop DDR4 memory modules into an existing PC running DDR3 memory.

Is There a DDR5?

Good question! JEDEC (Joint Electron Device Engineering Council), which creates global open standards for the microelectronics industry, is working on the definition of the memory devices to be used in the future. Since DDR4 is in the market, the next generation of memory standards is on the horizon. Our crystal ball can't tell us what DDR5 will be at this time, so stay tuned.

TECHNICAL STUFF

If you're one for trend lines (past performance is no predictor of future performance, as the brokerage ads say), each iteration of DDR memory was four to five years apart, so a fifth point on the plot would be toward the end of this decade. That's a long time from now. Computer years are like dog years.

Why Should I Buy DDR4 Memory from HPE?

It's possible to find DDR4 memory from sources other than HPE. Being the largest buyer of server DRAM on the planet, and for that matter, the visible universe, HPE has the ability to choose and qualify only the highest-quality DRAM. The memory HPE rejects doesn't get scrapped but, instead, gets resold to other original equipment manufacturers (OEMs) and third-party module manufacturers. HPE Memory is tested, tuned, and optimized on HPE ProLiant- and HPE Synergy-branded servers, not just test equipment. This ensures utmost reliability and reduces memory errors related to board level signal integrity issues. HPE stands behind the memory it recommends and sells. HPE DDR4 memory carries the warranty of the server, up to three years. If there's a performance issue, you don't suffer from multiple-vendor finger pointing. Memory is just one part of the hardware cost, and hardware cost is just one part of the total cost of running the server over its useful lifetime.

TIP

For more information on HPE Server Memory or other HPE Server Options, visit `www.hpe.com/info/serveroptions`.

An updated version with everything you need to know about DDR4

DDR4 is a type of memory that conserves energy and moves data fast. This updated version of *DDR4 For Dummies* contains everything you ever wanted to know about DDR4 (or double data rate 4) memory. This is a new generation of higher speed memory for a new generation of faster, more powerful servers.

- ***DDR4 demystified* — *understand why DDR4 is the new memory type for lightning-fast servers***
- ***Populate your server* — *load memory on your servers the right way and optimize performance***
- ***Questions answered* — *get your DDR4 memory questions answered with this book***

Open the book and find:

- **The difference between DDR4 and DDR3**
- **How memory is protected**
- **How many DIMMs you can load per channel**
- **Helpful lists of population rules for different types of servers**
- **Why you should buy HPE memory**

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