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HP Special Edition

# DDR4 FOR DUMMIES®

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## Learn to:

- Choose your preferred DIMM type
- Get to the HP configuration tool online
- Avoid common mistakes

Bill Howard
Hermann Wienchol
Lidia Warnes

# About HP

HP is the leader for driving new technology to volume. HP, one of the world's largest technology companies, simplifies the technology experience for consumers and businesses with a portfolio that spans printing, personal computing, software, services, and IT infrastructure. More information about HP (NYSE: HPQ) is available at **www.hp.com**.

**Infrastructure matters.** It's the foundation for all the information and applications of your business. Server memory is one of the most critical components — even the slightest defect can result in downtime that could shut down your business. HP server memory can increase and improve the functionality of your servers and data centers.

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**Project Editor:** Carrie A. Johnson

**Acquisitions Editor:** Katie Mohr

**Editorial Manager:** Rev Mengle

**Business Development Representative:** Karen Hattan

**Production Coordinator:** Melissa Cossell

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# Introduction

Welcome to *DDR4 For Dummies,* HP 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 HP ProLiant Gen9 servers. You discover the memory population rules for HP's Intel Xeon 4-way servers and the advantages of DDR4 over DDR3 memory.

## About This Book

This book comprises three parts:

- **Part I: Getting to Know DDR4.** You find out what's new about DDR4 and how it compares to DDR3. (Hint: It's faster. It uses less power.) You learn about the two main types of DDR4 Memory that are used in HP servers:

  R-DIMMs (**R**egistered **DIMM**s) for price and performance

  LR-DIMMs (**L**oad-**R**educed **DIMM**s) for performance and maximum memory capacity.

  You'll also learn how to identify DDR4 DIMMs and understand per-channel restrictions.

- **Part II: 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 III: 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 (abbreviations) you'll 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).

*R-DIMM,* 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.

*LR-DIMM,* or *Load-Reduced DIMM,* is similar to an R-DIMM, 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 two 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!

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# Part I

# Getting to Know DDR4

***In This Part***

- Exploring DDR4
- Choosing between R-DIMMs and LR-DIMMs
- Looking at installation
- Understanding memory protection
- Identifying HP DIMMs
- Seeing DIMMs per channel restrictions
- Taking a look at HP part numbers

A new generation of servers arrived in 2014 with new CPUs (Xeon v3). To maximize their performance, a new version 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 memory. DDR4 is capable of supporting higher bandwidths than DDR3 already at introduction.


Take a look at how DDR4 SDRAM DIMM is deconstructed:

- **DDR (Double Data Rate Memory):** It transfers twice the data per clock cycle 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 with 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 13ns, or nanoseconds), the bandwidth certainly did. DDR4 enables memory to run

(at introduction) at a 15 percent higher data rate than the maximum data rate of DDR3, which will increase up to 70 percent over the next couple of years.

In Figure 1-1, you can see the DDR4 versus DDR3 data rate (in MT/s).

| *DRAM type* | *Supported DATA Rates* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DDR3 | 800 | 1066 | 1333 | 1600 | 1867 | ----- | ----- | ----- | ----- |
| DDR4 | ---- | ---- | 1333 | 1600 | 1867 | 2133 | 2400 | 2667 | 3200 |

**Figure 1-1:** DDR4 versus DDR3 data rates (in MT/s).

Server support at DDR4 launch runs up to 2133MT/s (depending on configuration). Some refer to MT/s (mega-transfers per second) as MHz. For a 1066MHz clock the data transfer rate is 2133MT/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, 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 128GB DIMMs.
- **Runs cooler:** DDR4's improved thermal characteristics allow each DIMM to run at lower temperatures then DDR3. DDR4 does its part to be neutral on climate change.

Additional features worth mentioning include

- **Write Data Cycle Cyclical Redundancy Check** gives you better error detection capability and reliability but won't be supported on server platforms because of ECC.
- **Data Bus Inversion** will reduce the power consumption and improve signal integrity.
- **CA (Command/Address) Parity** is a method to verify the integrity of command/address transfers (expected to be used eventually when U-DIMMs, or unregistered [unbuffered] DIMMs become available).

When selecting DDR4 memory, options will include

- R-DIMMs (higher performance, lower latency) modules: 4GB/8GB/16GB data rates: 1333/1600/1867/2133 MT/s
- LR-DIMMs (higher bandwidth, higher capacity) modules: 16GB/32GB/64GB data rates: 1333/1600/1867/2133 MT/s

- DIMM speed depends on CPU capability, DIMM capability and number of DIMMs installed.
- ECC (error-correcting code)

Additional rules apply for HP servers. For details, see the sidebar "DDR4 for HP."

## DDR4 for HP

A few things make HP memory stand out:

- DDR4 memory was launched at 1.2 volts for Intel Xeon E5-2600 v3 series (2P servers) and Intel Xeon E7-4800 v3 (4P servers). Memory sizes are 4GB/8GB/16GB/32GB and 64GB.
- On HP servers, ProLiant Gen9 platforms with Intel processors support DDR4 R-DIMMs and LR-DIMMs but *not* mixed in the same unit.
- All HP servers support Advanced ECC for better data integrity.
- For HP servers, maximum capacity with 16GB R-DIMMs is as high as 384GB for 2P servers and now 1.5TB for 4P servers.
- Memory modules carry a one-year warranty or assume the longer warranty of the server they're inside.

HP DDR4 option kits contain a single DIMM module.

# Choosing a DIMM Type

Back in DDR3-land you had the choice among 3 different types of DIMMs (U-DIMMs, R-DIMMs, LR-DIMMs), the choices in DDR4 are narrowed down to two, R-DIMMs and LR-DIMMs. The main reason U-DIMMs are left out this time is that at higher DDR4 speeds you won't get any advantage over R-DIMMs anymore when it comes to performance and reliability.


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.

Figure 1-2 is an example of an HP 4GB and 8GB DDR4 memory kit using the same DRAM density of 4 Gbit.

As you probably notice, the HP memory kits for both DIMMs are labeled "PC4-2133P-R Kit." This is slightly different from what you were probably used to in DDR3.

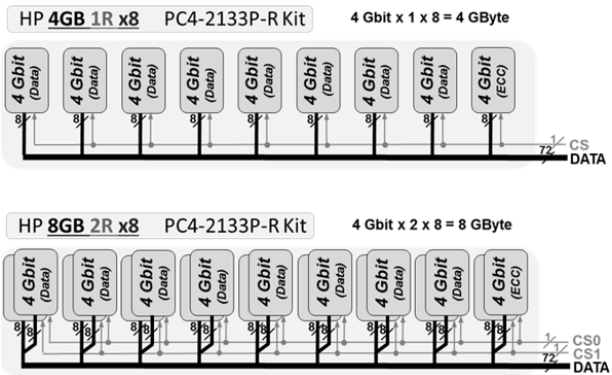


**Figure 1-2:** An HP 4GB and an 8GB DDR4 memory kit.


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).
- **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 than 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:** The DRAM response time from column address command to 1st data out on the memory bus. CAS latency is counted in clock cycles, so for example, a CL13 (pronounced "CAS latency of 13") means the response of the DRAM is 13 clock cycles. In Figure 1-3, you see how this works out by issuing a read command (RD) to the DRAM with a CL13.

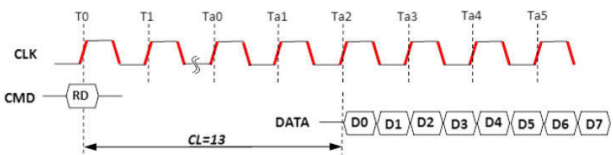


**Figure 1-3:** An issued read command (RD) to the DRAM with a CL13.

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: Q = CL16, R = CL17, and so on. So, the label on a DDR4 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 . . . it's finally the type of DIMM you can choose from, either R-DIMM (R) or LR-DIMM (L).

## Registered DIMM (R-DIMM)

*Registered dual in-line memory module* (R-DIMM) puts less electrical loading on the command/address signals due to the register on the DIMM between the memory controller and the DRAMs. The big difference is that LR-DIMM buffers Command/Address bus + data bus, R-DIMM only Command/address bus.

The register captures the command/address signals from the memory controller and retransmits them to the DRAMs locally (provides greater reliability at a slight cost in performance of one clock cycle to affected signals). As a result, the system sees only one load per address line instead of 9, 18, or 36. Figure 1-4 shows an R-DIMM in a 2 SPC (slots per channel) system like the HP Proliant BL460 Gen9 populated with 1 DPC (DIMM per channel).

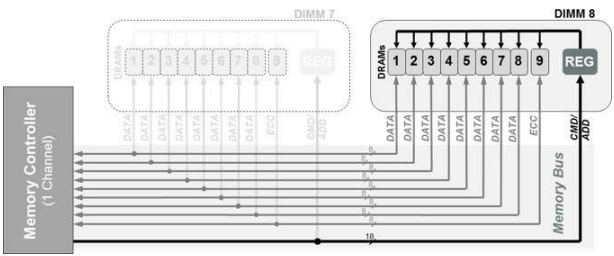


**Figure 1-4:** An R-DIMM in a 2 SPC (slots per channel) system.

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, R-DIMMs allowed for 1, 2, and 4 Ranks/DIMM support, which caused some problems in a 3SPC 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. R-DIMMs can be used in all HP Servers. Capacities are 4GB, 8GB, 16GB, and 32GB (when available). In a 24-slot server, you could have as much as 384GB of DDR4 memory installed by using 16 GB R-DIMMs. To get higher memory capacities, you need to look for another type of DIMM — the load-reduced DIMM.

## Load-reduced DIMM (LR-DIMM)

*LR-DIMM,* or load-reduced DIMM, adds 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 1-5 shows an LR-DIMM in a 2SPC system in a 1DPC configuration.

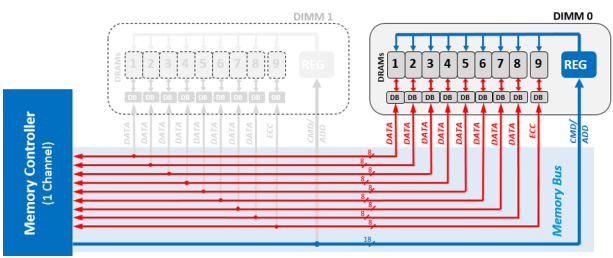


**Figure 1-5:** An LR-DIMM in a 2SPC system in a 1DPC configuration.

The limitation of the R-DIMM (having a lot of electrical loading 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.


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

With the advantage to run high capacity LR-DIMMs in the system at a higher bandwidth, the memory buffer ads additional latency to the data signals. LR-DIMMs come in different capacities. With the current available DRAM density of 4 Gbit, you'll see 16GB, 32GB, and 64GB LR-DIMMs. Later, with the release of 8 Gbit DRAMs, you see capacity going up to 128GB per DIMM. In a 24-slot server, you could have as much as 1.5 TB of DDR4 memory installed using 64 GB LR-DIMMs. With the introduction of the 128 GB LR-DIMM it will even go up to 3 TB.


By the way, you have to choose one DIMM type. You can't mix and match R-DIMM and LR-DIMM 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**

| | *R-DIMMs* | *LR-DIMMs* |
|---|---|---|
| Capacities | 4GB, 8GB, 16GB, (32GB) | 16GB, 32GB, 64GB, (128GB) |
| Maximum DIMMs per channel | 3 dual rank | 3 "any" rank |
| Address error detection | Yes | No |
| Lower cost | Yes | No (due to add, buffer, and stacking technology) |
| Ranks/DIMM support | 1, 2, 4 | 2, 4, 8 |
| DRAM support | ×4, ×8 | ×4, ×8 |
| Maximum server capacity (GB) | 384 (24 slots) 1500 (96 slots) | 1500 (24 slots) 6000 (96 slots) |

# Installation

Installing DDR4 memory is physically easy, especially because the slots are color-coded on most HP 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.
- **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.

**Table 1-2 Advanced Memory Protection**

| | *Basic ECC Technology* | *HP 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% |

# Identifying HP DIMMs

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

- **HP** indicates it's HP-approved memory being sold through an HP channel or direct from HP.
- **nGB** indicates the capacity (n= 1, 2, 4, 8, 16, 32 or 64 GB).
- **eR** indicates the number of ranks (e=1, 2 or 4 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, Q=16, R=17).
- **R** is the DIMM type (R=R-DIMM, L=LR-DIMM).
- **Kit** at the end indicates it's an HP kit (and remember that with DDR4 there's one module per kit, not two).

For example, 726718-B21 HP 8GB 1Rx4 PC4-2133P-R Kit indicates an HP DIMM with a 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 HP 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 HP Intel E5-2600v3 and E7-4800v3 series ProLiant Gen9 servers, there are four channels from each processor.

Population rules must be followed or errors will occur. That is:

- Same DIMM type; R-DIMM and LR-DIMM can't be mixed in a system (meaning, you can't populate one CPU with R-DIMMs, the other one with LR-DIMMs)
- 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 II.

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# HP Part Number Matters (Not Vendor Name)

When buying memory through HP, remember that DIMMs don't have to be from the same vendor. DIMMs are JEDEC standard. All DIMMs sourced through HP pass HP memory qualification tests.

In brief: If the HP part number is the same, the DIMMs are compatible.

# Part II

# Populating the Server

***In This Part***

- Knowing 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 may 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 R-DIMMs (registered DIMMs) or LR-DIMMs (load-reduced DIMMs) 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 processor 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 years, but always check online for the best and latest.

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

# Population Rules — HP DDR4 ML, DL, and SL Servers

These are the key rules to follow when populating memory slots on ProLiant Intel–based G9 servers. This is not the complete list. Still, it covers most HP ProLiant servers. Population rules for each of the HP Proliant servers can also be found in the HP QuickSpecs at `http://www.hp.com/go/memory`. Also see Figure 2-1.

| DIMM Type | R-DIMM | | | | | LR-DIMM | |
|---|---|---|---|---|---|---|---|
| DIMM Rank | Single Rank | | Dual Rank | | | Quad Rank | |
| DIMM Capacity | 4 GB | 8 GB | 8 GB | 16 GB | 32 GB | 32 GB | 64 GB |
| DRAM Organization | x8 | x4 | x8 | x4 | x4 | x4 | x4 |
| DIMM Native Speed (MT/s) | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 |
| | | | | | | | |
| Maximum Capacity that can be achieved using these DIMMs | | | | | | | |
| 16 slot servers (GB) | 64 | 128 | 128 | 256 | 512 | 512 | 1024 |
| 24 slot servers (GB) | 96 | 192 | 192 | 384 | 768 | 768 | 1536 |
| | | | | | | | |
| Operating speed as a function of DIMM population (MT/s) | | | | | | | |
| 2 slots per channel, 1 DIMM loaded | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 |
| 2 slots per channel, 2 DIMMs loaded | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 |
| 3 slots per channel, 1 DIMM loaded | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 | 2133 |
| 3 slots per channel, 2 DIMMs loaded | 2133 | 1866 | 1866 | 1866 | 1866 | 2133 | 2133 |
| 3 slots per channel, 3 DIMMs loaded | 2133 | 1600 | 1600 | 1600 | 1600 | 1866 | 1866 |
| Notes | | | | | | | |
| LR-DIMMs will operate 1 speed bin faster than R-DIMMs in 3 slot per channel servers. | | | | | | | |

**Figure 2-1:** Memory options for HP DDR4.

For the Proliant Intel-based G9 servers, the chipset supports a maximum of 4 DDR4 channels per CPU socket. Following the Intel documentation naming convention, these channels are numbered from 0 through 3.

For servers with 24 memory slots, there are three DIMM slots for each memory channel; 24 total slots (two CPU servers). For servers with 16 memory slots, there are two DIMM slots for each memory channel; 16 total slots

(two CPU servers). For servers with 12 memory slots, there are three DIMMs slots for each memory channel; 12 total slots (one CPU server).

The following bullets describe the memory subsystem and the population rules.

- Memory Channels 1 and 3 comprise the three DIMMs closest to the processor. Memory Channel 0 and 2 comprise the three DIMMs farthest from the processor.
- Populate the white DIMM slots first.
- Don't mix LR-DIMMs with R-DIMMs.
- Don't install DIMMs if there's no corresponding processor 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.
- You can have up to twelve ranks installed per channel.
- You can install three quad-rank DIMMs per channel.
- To maximize performance
  - Balance the memory capacity among installed processors.
  - Use the same type and same capacity DIMMs to optimize the interleaving scheme.
  - Populate all the memory channels to make use of all the bandwidth available in the memory subsystem.

- Populate DIMMs from heaviest load (quad-rank) to lightest load (single-rank) within a channel. The heaviest load (DIMM with most ranks) within a channel goes farthest from the chipset.

*Memory mirroring* is the mechanism by which the memory is mirrored, creating two identical copies of the data in the main and target copy. 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 0 is exactly duplicated on the memory channel 1 and similarly channel 2 is duplicated on channel 3. The DIMM configuration on the mirrored channels should be identical. Note that only half of the memory capacity of both memory channels is available. The scope of the mirroring is limited to within a processor socket.

Mixing DIMM speeds is allowed, but DIMMs will run at the slower of the two speed ratings.

# DIMM Socket Color Coding

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


In dim light, black looks a lot like blue. Your work area should be well lit. If necessary, supplement room light with a flashlight or your phone's flashlight utility.

Figure 2-2 shows the color and loading scheme for the DIMMs in HP's DDR4 systems.

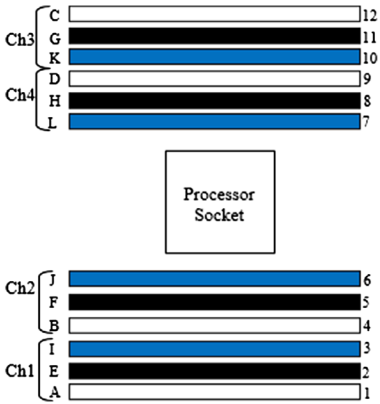


**Figure 2-2:** DIMM Socket Color Scheme.

# Populating Alphabetically

HP 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 2-3. Install DIMMs in alphabetical order. Look at the Population Order column. You'd 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 | | |
|---|---|---|---|---|
| | CPU1 - Present | | CPU2 – Not Present | |
| Channel 1 | 1 | A (1st) | | |
| | 2 | E (5th) | | |
| Channel 2 | 3 | B (2nd) | | |
| | 4 | F (6th) | | |
| Channel 3 | 5 | C (3rd) | | |
| | 6 | G (7th) | | |
| Channel 4 | 7 | D (4th) | | |
| | 8 | F (8th) | | |
| | CPU1 - Present | | CPU2 – Present | |
| Channel 1 | 1 | A (1st) | 1 | A (2nd) |
| | 2 | E (9th) | 2 | E(10th) |
| Channel 2 | 3 | B (3rd) | 3 | B (4th) |
| | 4 | F(11th) | 4 | F (12th) |
| Channel 3 | 5 | C (5th) | 5 | C (6th) |
| | 6 | G (13th) | 6 | G (14th) |
| Channel 4 | 7 | D (7th) | 7 | D (8th) |
| | 8 | H (15th) | 8 | H (16th) |

**Figure 2-3:** 16 DIMM Slots CPU1 and CPU2.

For a quick guide on how to populate your slots for a 24 DIMM slot server, check Figure 2-4. Install DIMMs in alphabetical order. Look at the Population Order column. You'd 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 HP DDR4 online configuration tool: `http://www.hp.com/go/memory`.

| Channel | CPU1 - Present | | CPU2 – Not Present | |
|---|---|---|---|---|
| | Slot # | Population Order | Slot # | Population Order |
| 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 2-4:** 24 DIMM Slots for CPU1 and CPU2.

# Part III

# Ten Common Questions about DDR4

***In This Part***

- Figuring out what DDR4 is
- Deciding between R-DIMM and LR-DIMM
- Knowing what mistakes to avoid

The Part of Tens is a *For Dummies* tradition and has outlived Letterman's Top Ten lists. 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* meaning that the memory is volatile and it forgets what's stored when you pull the power plug, unlike ROM or Flash or other forms of non-volatile memory. The *double* part means data is transmitted twice per clock cycle.

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

This is the fourth iteration of double data rate memory, and it is faster, lower power and 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 two main types of DDR4 DIMMs:

- Registered DIMMs (R-DIMMs) come in densities of 4GB to 32GB, operate at speeds of up to 2133MT/s and are the lower cost and lower power DDR4 DIMMs.
- Load-reduced DIMMS (LR-DIMMs) come in densities of 32 GB and 64GB and are the performance DIMMs operating one speed bin higher than the R-DIMMs in 2 and 3 DIMM per channel configurations.

The larger capacity LR-DIMMs are also preferred for systems that run OLTP 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).

Other DDR4 DIMM types which are not frequently used in servers are

- U-DIMMs, unbuffered DIMMs (low capacity, low speed, low cost)
- So-DIMMs, small outline DIMMS, mainly used in workstations and PCs

## Do I Want R-DIMM, LR-DIMM for Price? For Performance?

LR-DIMMs are your choice for capacity (up to 1.5TB in a qualified 24-slot Intel server) and performance. R-DIMMs are your choice for lower power and lower cost.

LR-DIMMs are always built with x4 DRAM devices. The majority of the R-DIMMS are also built with x4 DRAM devices. Choose x4 DIMMs for best reliability capability support 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.

## Is LR-DIMM or R-DIMM Greener?

The good news is that DDR4 DIMMs use significantly less power than DDR3 DIMMs of the same capacity and speed. Among DDR4 types, the R-DIMMs are built with fewer DRAM devices and will consume less power than

the LR-DIMMs, so the overall memory subsystem power will be lowest when using R-DIMMs. For bandwidth intensive benchmarks for which the overall performance isn't a function of the total memory capacity, the R-DIMM will provide the best performance per watt. For benchmarks like TPC-C where the overall performance is a function of the total memory installed in the server, the LR-DIMMs will provide best TPC-C.

## Which Works in Which HP ProLiant G9 Server?

All R-DIMMs and LR-DIMMs covered in this book work with the Proliant G9 servers. But choose one; you can't mix 'n' match. For product offerings, visit `www.hp.com`.

## Is There DDR4 Memory for HP AMD Servers?

HP 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 LR-DIMMs and R-DIMMs on the same machine. And you can't use older technology memory (DDR2 or DDR3) in ProLiant G9 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 wouldn't line up and you'd create a short. Will left-over 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?

You had to ask! JEDEC (Joint Electron Device Engineering Council), which is creating the 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 just coming to market, the next generation of memory standards is far on the horizon. Our crystal ball can't tell us if we are looking at DDR5 or another future memory technology yet — stay tuned.


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 4 to 5 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 HP?

It's possible to find DDR4 RAM from sources other than HP. Being the largest buyer of DRAM on the planet, HP has the ability to choose and qualify only the highest-quality DRAM. The memory HP rejects doesn't get scrapped but, instead, gets resold to other OEMs and

third party module manufacturers. HP Memory is tested, tuned, and optimized on HP ProLiant-branded servers, not just test equipment. This ensures utmost reliability and reduces memory errors related to board level signal integrity issues. HP stands behind the memory it recommends and sells. HP 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.


For more information on HP Qualified Server Memory or other HP Qualified Options visit `www.hp.com/go/hpqo`.

# Notes

# Notes

# Notes

# An updated version with everything you need to know about DDR4

DDR4 is a type of memory that conserves energy and moves fast. This updated version of the book 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 HP memory**

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