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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Welcome to DDR4 For Dummies, 4th 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 Gen9/Gen10 servers. This book covers the advantages of DDR4 memory over DDR3 memory, new memory population rules, and selected reliability, accessibility, and serviceability (RAS) features for HPE Gen9/Gen10 servers with Intel Xeon four-way processors.

About This Book

This book comprises five 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 on HPE Gen9 servers with Intel Xeon v3/v4 central processing units (CPUs) (codename: Haswell/Broadwell) versus DDR4 used on HPE Gen10 servers with Intel Xeon CPUs (codename: Skylake). 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:

- Unbuffered dual in-line memory modules (UDIMMs) for price and reliability
- Registered DIMMs (RDIMMs) for price, reliability, and performance
- Load-reduced DIMMs (LRDIMMs) for performance and maximum memory capacity
- LRDIMMs three-dimensional stack (3DS) using Through-Silicon Via (TSV) for high-performance/watt and highest memory capacity
- Nonvolatile DIMMs (NVDIMMs) for workload optimized solutions that coexist with DDR4

You also discover how to identify DDR4 DIMMs and understand per-channel restrictions.
Part II: Memory RAS Technologies. Learn all about the most common DDR4 memory RAS features on HPE Gen9/Gen10 server platforms.


Part IV: Populating the HPE Gen9/Gen10 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 V: Ten Common Questions about DDR4. This part concludes the book with some common questions. These are the “there are no stupid questions” questions.

Terms Used in This Book

Before we get started, here are five 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 (that 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.

LRDIMM 3DS TSV, or load-reduced DIMM 3DS using TSV, is similar to the LRDIMM; the differences are within the package (wire-bonding versus TSV).
NVDIMM, or nonvolatile DIMM, is a new category of DIMM offered by Hewlett Packard Enterprise (HPE) starting with HPE Gen9 servers for workload optimized solutions.

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 information and benefits of DDR4.

This icon points out super-important information.

This icon alerts you to information that may damage your system. Proceed with caution!
In late 2014, a new generation of servers (HPE Gen9 servers) arrived with new CPUs (Intel Xeon v3), introducing the new Intel 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 were long!) DDR4 memory uses (as did its predecessors DDR3, DDR2, and DDR1) each of the two phases of the clock (rising and falling) to achieve the double data rate as compared to what is now known as single-data-rate SDRAM.

In early 2016, this generation of servers received an upgrade to next-generation Intel CPUs (Intel Xeon v4) named Broadwell, which took huge leaps forward in performance and power efficiency by shrinking the technology. Along with CPU improvements, HPE offered new DDR4 memory with higher capacity DIMMs and higher performance. Also for the first time, nonvolatile DIMMs (NVDIMMs) became available for HPE ProLiant and Synergy servers.
In mid-2017, HPE introduced its next generation of servers (HPE Gen10) with new CPUs (Intel Xeon Scalable processors [SP]) that used the new Intel microarchitecture named Skylake. Those systems have seen another increase in performance by using even higher speed DDR4 memory. In early 2019, this generation of servers received an upgrade to the next generation of Intel Xeon Scalable processors, named Cascade Lake. Cascade Lake delivers additional features, capabilities, performance, and frequency. It is also the first microarchitecture to support DIMM-form-factor HPE Persistent Memory. Figure 1-1 lists the maximum supported memory speeds since the DDR4 introduction on HPE Gen9/Gen10 servers.

<table>
<thead>
<tr>
<th>HPE ProLiant Gen9</th>
<th>HPE ProLiant Gen10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Release</strong></td>
<td><strong>Launch</strong></td>
</tr>
<tr>
<td><strong>Architecture</strong></td>
<td><strong>Haswell</strong></td>
</tr>
<tr>
<td><strong>Skylake</strong></td>
<td></td>
</tr>
<tr>
<td><strong>DIMMs</strong></td>
<td><strong>(Xeon v3)</strong></td>
</tr>
<tr>
<td><strong>Skylake</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Cascade Lake</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PCA-2133</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>PCA-2400</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>PCA-2666</strong></td>
<td>X</td>
</tr>
<tr>
<td><strong>PCA-2933</strong></td>
<td>X</td>
</tr>
</tbody>
</table>

**FIGURE 1-1:** DDR4 DIMM support in HPE Gen9/Gen10 servers.

Take a look at how DDR4 SDRAM DIMM is deconstructed:

- **DDR (Double Data Rate Memory):** It transfers twice the data per clock cycle (CK) versus non-DDR memory (now called *single data rate* [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 hit Aardvark before Zebra.
- **DIMM (Dual Inline Memory Module):** Specifications for 64-bit processors need 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 (V); later, DDR3L (L for low voltage) ran even lower at 1.35 V. DDR4 is available only at 1.2 V, 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. You want DDR4 over DDR3 for several reasons (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 of years (still around 14 nanoseconds [ns]), the bandwidth certainly did. DDR4 on Intel 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 Intel 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 1–2 gives you the supported DDR3 and DDR4 data rates.

![Figure 1-2: Supported DDR3/DDR4 data rates.](image)

At DDR4 launch, HPE Gen9 servers with Intel Xeon v3 CPUs (Haswell) supported data rates up to a maximum of 2133 mega transfers per second (MT/s). By upgrading to an Intel Xeon v4 CPU...
(Broadwell), in combination with the new higher speed grade DDR4 DIMMs, data rates increased up to the maximum of 2400 MT/s depending on the configuration. With the introduction of HPE Gen10 servers, memory speeds again increased by another speed bin to 2933 MT/s. (Note: In Cascade Lake, this is valid for all configurations.) That’s a 22 percent increase in speed.

Some refer to MT/s as megahertz (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 to “double the flavor,” which is what this DDR thing is all about. You can see the difference in Figure 1–3.

Low power

Running at the same speeds, the 1.2 V DDR4 supply cuts power consumption by up to 20 percent over DDR3 memory, which ran at 1.35 V. 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

With DDR3, DIMMs from 2 gigabytes (GB) up to 64GB were available on HPE ProLiant servers. For DDR4, the capacities shown in Figure 1–4 are available on HPE Gen9/Gen10 servers so far.

With larger SDRAM capacities like the HPE 128GB LRDIMM, you can run up to 3 terabytes (TB) of memory in an HPE ProLiant DL380 system with 24 DIMM slots, while HPE Persistent Memory provides capacities of up to 512GB per persistent memory kit.
PART I
Getting to Know DDR4

Runs cooler

DDR4's improved thermal characteristics enable each DIMM to run at lower temperatures than DDR3. DDR4 does its part to be neutral on climate change.

Other DDR4 benefits

Additional DDR4 features worth mentioning include the following:

- Write cyclic redundancy check data bus gives you better error detection capability and reliability.
- Data bus inversion reduces the power consumption and improves signal integrity.
- Command/Address (CA) parity is a method to verify the integrity of CA transfers (used on UDIMMs only).

DD4R Memory Options at HPE

Just as with the previous release of Intel Xeon v4 CPUs in HPE Gen9, HPE DDR4 memory options for HPE Gen10 are available in both HPE SmartMemory and HPE Standard Memory.
HPE SmartMemory

HPE SmartMemory enables performance-tuned and high-efficiency features for enterprise customers without compromising performance. This memory

- Operates at higher speeds than industry standard in certain configurations (for HPE Gen9 only)
- Offers advanced error detection technology that pinpoints issues that may cause uncorrectable errors and unplanned downtime before they happen
- Integrates with the HPE Active Health System, which records critical memory errors, allowing administrators to make a faster diagnosis and avoid unexpected interruption of business operations

Figure 1–5 shows a comparison table on HPE SmartMemory kits offered with the introduction of Haswell (Intel Xeon v3), Broadwell (Intel Xeon v4), Skylake (Intel Xeon), and Cascade Lake (Intel Xeon).

Note: 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 customers looking for enhanced memory performance and features at an affordable price.
HPE Standard Memory offers the following:

- **HPE quality and reliability** is engineered into every HPE Standard Memory product, with only the best components selected.

- **Optimized compatibility** through authentication ensures that you’re using a genuine HPE product.

- **The error correcting code (ECC) RAS feature** protects businesses from data loss and unplanned system downtime.

- **Performance at industry-standard speeds** with the peace 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 1–6 shows a comparison of HPE Standard Memory offered with the introduction of HPE Gen9/Gen10 servers.

When selecting DDR4 HPE SmartMemory (see the preceding section) or HPE Standard Memory, options include the following capacities:

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

In HPE Gen9, the speed at which DIMMs usually run depends on the capability of the CPU, the DIMM type, and the number of DIMMs installed in a channel. Currently, standard data transfer rates on HPE Gen9 systems are shown here:

<table>
<thead>
<tr>
<th>Supported Data Rates (MT/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1600</td>
</tr>
<tr>
<td>1866</td>
</tr>
<tr>
<td>2133</td>
</tr>
<tr>
<td>2400</td>
</tr>
</tbody>
</table>
In HPE Gen10, due to the architecture change (maximum of two DIMMs per channel), the speed at which DIMMs run depends on the CPU and the DIMM. Standard data transfer rates on HPE ProLiant Gen10 systems (Cascade Lake) are shown here:

<table>
<thead>
<tr>
<th>Supported Data Rates (MT/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1600</td>
</tr>
</tbody>
</table>

**HPE SERVER MEMORY OPTIONS**

HPE DDR4 memory has several highlights:

- For HPE Gen9 servers, DDR4 memory was launched at 1.2 V and speeds of up to 2133 MT/s for Intel Xeon E3-12xx v5 series (1P servers), Intel Xeon E5-26xx v3 series (2P servers), and Intel Xeon E7-48xx v3 (4P servers). Memory sizes varied from 4GB/8GB to up to 64GB. DDR4 memory speeds increased up to 2400 MT/s with the launch of the Intel Xeon E5-26xx v4 series and Intel Xeon E7-48xx v4 series. Memory sizes varied from 8GB/16GB/32GB/64GB and up to 128GB.

- On HPE servers, HPE 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.

- For HPE Gen10 servers, DDR4 memory was launched at 1.2 V and speeds up to 2933 MT/s for most Intel Xeon CPUs. **Warning:** Some CPUs don't support the maximum speed of 2933 MT/s.

- All HPE servers support advanced ECC for better data integrity.

- For HPE ProLiant/Synergy Gen9 servers, the maximum capacity with 32GB RDIMMs is as high as 768GB for 2P servers (Intel Xeon E5-2600 v3/v4), 1.5TB for 4P servers (Intel Xeon E5-4600 v3/v4), and now 3TB for 4P servers (Intel Xeon E7-4800 v3/v4). In HPE Gen10, the maximum capacity with 32GB RDIMMs is 768GB for 2P servers and 1.5TB for 4P servers.

- Memory modules carry a one-year warranty or assume the longer warranty of the server in which they're installed.

- HPE DDR4 option kits contain a single DIMM module.
Additional rules apply for HPE ProLiant and Synergy servers. For details, see the sidebar “HPE server memory options.”

Choosing a DIMM Type

Back in DDR3-land, you had the choice among three different types of DIMMs (UDIMMs, RDIMMs, and LRDIMMs). The choices for DDR4 were narrowed down in HPE Gen9 with the launch of Intel 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 when it comes to performance and reliability. With the introduction of Intel Xeon v4 (Broadwell), UDIMMs were added back as HPE Standard Memory on HPE 10/100 Series rack and tower servers using desktop-class CPUs or compatible Intel Xeon processors.

DDR4 memory has three primary characteristics (there are more, but these are the main ones):

- **Capacity** is the total amount of storage on a single DIMM.
- **Rank** is a group of DRAM chips that are accessed simultaneously (via the chip select [CS] signal) to provide 72 bits of data (64 bits data + 8 bits ECC) to the system. The ranks used are 1R/2R/4R/8R (read single-rank, dual-rank, quad-rank, and octal-rank).
- **Organization** determines the number of data bits coming out of a single DRAM. In DDR4, you see x4 (pronounced *by four*) and x8 (by eight).

Figure 1–7 shows an example of a HPE 8GB DDR4 memory kit, using a DRAM density of 8 gigabit (Gb): HPE 8GB 1Rx8 PC4–2666V–R Kit (8 Gb x 8 DRAMs x 1 rank = 8GB).

Figure 1–8 is an example of an HPE 16GB memory kit: HPE 16GB 1Rx4 PC4–2666V–R Kit (8 Gb x 16 DRAMs x 1 Rank = 16GB).
As you may have observed, the HPE memory kits for both DIMMs are labeled PC4-2666V-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. DDR4 starts by default at a higher data rate, so currently the maximum operating data rate in Cascade Lake is DDR4-2933, which means 2933 MT/s.

**DIMM Data Rate:**
- **DDR3:** The memory bus of a DIMM is 64 bit wide (data portion without ECC), which at 1600 MT/s results in a DIMM data rate of 12.8GB/s (1600 megabits [Mb]/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:** In DDR4, things became simpler. The data rate for each DRAM is written as DDR4-2666. For the label on the DIMM, it’s practically the same — PC4-2666.

» **CAS Latency (CL):** CL is the DRAM response time from issuing a READ command (column address command) to first data out on the memory bus. CL is usually counted in clock cycles even when it’s a fixed asynchronous timing. For example, a CL14 (pronounced CAS latency of 14) means the response of the DRAM is 14 clock cycles at a certain speed. In Figure 1-9, you see how this works out by issuing a read command to the DRAM with a CL14.

![FIGURE 1-9: Looking at CL.](image)

So, what happens when the speed increases? Well, because the CL is more or less a constant, you just have to count more clocks in the same amount of time, as you see in Figure 1-10.

![FIGURE 1-10: CL at different memory speeds.](image)

Of course, you can imagine that the faster the clock runs by keeping the CL (in clock cycles) constant, the actual response time decreases. For the CL, DDR3 used numbers such as PC3-12800R-13, where 13 was the CL.

In DDR4, you use letters starting at the letter P, which is CL15. From there you go on: R = CL16, T = CL17, U = CL18, V = 19, Y = 21, and so on. So, the label on a DDR4 DIMM tells you the following: PC4-2933Y-R is a DDR4 DIMM with a data rate of 2933 MT/s per data line and a CL of 21. What does the R stand for? Here we go . . . now it’s finally time to choose the DIMM type (yay!). On HPE ProLiant/Synergy servers, you can choose from the DIMM types shown in Figure 1-11.
UDIMM is the most cost-efficient memory. It is usually configured as part of cost-conscious servers (such as the HPE ML10 or DL20 servers) and is subject to certain limitations. It’s not ideal for the highest speeds due to high loadings on the command/address signals. It can only be configured with a maximum of two DIMMs per channel. Figure 1-12 shows an HPE 16GB 2Rx8 PC4-2666V-E UDIMM.

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

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 on the DIMM (this provides greater reliability at a slight cost in
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 one, two, and four ranks per DIMM support, which caused some problems in a three-slots-per-channel system (3 × 4 ranks per channel = 12 ranks) because there was a restriction of a maximum of eight ranks per channel.

In DDR4, you’re limited to one and two ranks per RDIMM, 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, 32GB, and 64GB. In a 24-slot server, you could have as much as 1.5TB of DDR4 memory when using 64GB RDIMMs. To get to higher memory capacities, the LRDIMM is the way to go.

**LRDIMM**

LRDIMM has additional data buffers on the DIMM between the memory controller and DRAM in order to reduce electrical loading on the data signals of the memory bus. Figure 1-14 shows a HPE 64GB 4Rx4 PC4-2666V-L 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 enables higher data rates on the memory channel and also higher DIMM capacities.
DDR4 offers a new concept known as chip-select encoding, which enables the system to address multiple ranks behind the LRDIMM buffer by encoding the chip-select, instead of using one chip-select per rank.

Being able 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 4GB was available, which leads to 16GB, 32GB, and 64GB LRDIMMs. In late 2018, 16Gb DRAM became available, enabling 64GB RDIMMs and 128GB two-high-stacked LRDIMMs.

**LRDIMM 3DS TSV**

With the introduction of 8GB DRAMs in 2016, you’ve seen the DIMM capacity go up to 128GB. In a 24-slot server, such as the HPE ProLiant DL360, you’re able to have up to 3TB of DDR4 memory installed. The 128GB LRDIMM is a new generation of DIMM that was introduced using advanced technology such as 3DS and TSV. The conventional stacking solution on low-capacity DIMMs (64GB and smaller) is usually through wire bonding, as shown in Figure 1–15.

The wire-bond package can hold up to four DRAM dies (quad die package [QDP]), which are connected over the redistribution layer 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 1–16 shows.

The high loading on the backside of the data buffer limits the DIMMs while running at high-speed operations. TSV was made available to mitigate that issue. See Figure 1–17.
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.

**FIGURE 1-15:** A conventional stack solution, using wire bonding.

**FIGURE 1-16:** A QDP.

**FIGURE 1-17:** A QDP using TSV.
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 1-18.

![Figure 1-18: A stack solution, using TSV on a memory module.](image)

Currently, standard LRDIMMs can’t be configured in conjunction with 3DS TSV LRDIMMs.

Different DIMM types can’t be mixed and matched. You need to decide the DIMM type that works best for your needs. Choose from UDIMM, RDIMM, LRDIMM, and LRDIMM 3DS TSV inside the same server. What happens if you mix those? No big deal, you won’t start an explosion. Although you won’t spoil any components, the server won’t boot. Take a look at the options in Figure 1-19 where we’ve captured all the options.

![Figure 1-19: An overview of choices in technology in HPE Gen9/Gen10 servers.](image)
NVDIMM-N (HPE Gen9)

A new category of DIMMs was introduced in HPE Gen9, called NVDIMM-N. This module is a hybrid combining regular DRAM with flash memory. During normal system operation, the NVDIMM-N behaves like a regular RDIMM (data can be written to and read from the DRAM through the multiplexers, or MUX for short). In the event that the system loses power or shuts down, the DRAM data content will be backed up into the flash memory. That way, once the system is up and running again, the information will be restored back to the DRAM, reducing the threat of data loss. NVDIMM-Ns are very similar to LRDIMMs. The data buffer devices become MUXs (functions as a switch); the register is an ASIC/register combination with an additional flash device.

Figure 1–20 shows the architecture of the HPE NVDIMM-N offered in HPE Gen9.

The restrictions and special population rules for NVDIMMs are discussed in more detail in Part III.

NVDIMM-N (HPE Gen10)

In HPE Gen10, HPE introduced an industry standard NVDIMM-N that has seen major architecture changes. Those have a very positive impact on performance because they enable the NVDIMM-N to run in conjunction with RDIMMs in one DIMM per channel (DPC) and 2DPC configurations at maximum speed of 2666 MT/s. In Figure 1–21, the external MUXs for the data on the DIMMs
aren’t present anymore. Instead, data is now switched internally in the DRAM, which significantly improves the signal integrity of the DIMM. Gen10 NVDIMM-Ns are only compatible with first-generation Intel Xeon Scalable processors.

More information about the new NVDIMM-N for HPE Gen10 servers can be found in Part III of this book.

**HPE Persistent Memory (HPE Gen10)**

HPE ProLiant, Synergy, and Apollo Gen10 servers that use second-generation Intel Xeon Scalable processors offer new HPE Persistent Memory in 128GB, 256GB, and 512GB modules featuring Intel Optane DC Persistent Memory; see Figure 1-22. The next step in the evolution of persistent memory, this technology approximates the speed of traditional volatile DRAM and combine it with the persistence of storage, ensuring ongoing data access for high-performance computing, big data analytics, and data transfer for large datasets even in the event of an interruption in power due to an unexpected power loss, system crash, or a normal system shutdown. Although new HPE Persistent Memory fits regular memory slots and pairs with DRAM, customers using it will see their maximum processor speeds drop to 2666 MT/s on two DIMM-per-channel configurations. Additionally, some reliability, accessibility, and serviceability (RAS) features will be disabled with the use of HPE Persistent Memory, which can affect performance.
The color coding in the memory slots for most HPE servers makes installing DDR4 memory very simple. In HPE Gen9, memory slots are coated white and black, and in some instances, blue. Because HPE Gen10 servers no longer support three slot-per-channel (3SPC) memory, slots are coated either white or black. White slots are the ones where you would install the first memory module on each channel. It may require a few instances to understand the memory slot installation procedures, but once you do it a few times, it’s pretty simple to follow.

By the way, when you’re handling DIMMs, remember to always wear an electrostatic discharge (ESD) strap (shown in Figure 1-23) or ground yourself properly (by touching the server chassis, for instance). Even small electrical discharges can potentially harm your DIMM. While you might not see the effect immediately, you may see a degradation in performance over time or even increasing system ECC errors.
Identifying HPE DIMMs

This section gives you a reference when dealing with product selector guides. HPE-certified memory will have these markings, from left to right:

- HPE indicates it is HPE-approved memory being sold through an HPE channel or directly from HPE.
- nGB is the capacity (n= 4, 8, 16, 32, 64, or 128GB).
- eR indicates the number of ranks (e=one, two, four, or eight 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, 2400 MT/s, or 2666 MT/s).
- P is the CL (P=15, R=16, T=17, U=18, V=19, none for NVDIMMs).
- R is the DIMM type (U=UDIMM, R=RDIMM, L=LRDIMM/ LRDIMM 3DS TSV, none for NVDIMMs).
Kit at the end indicates it is an HPE memory kit (and remember that with DDR4 there’s one module per kit, not two). This doesn't apply for NVDIMMs.

Module at the end indicates it is an HPE NVDIMM module.

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, CL of 15, and an HPE kit.

**DIMM-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. HPE Gen9 servers based on Intel Xeon v3/v4 processors include four memory channels. This changes with HPE Gen10 servers; each CPU now has six channels — a 50 percent increase.

Population rules for HPE Gen9 and HPE Gen10 servers are slightly different and must be followed or errors will occur. Some basic common rules are the following:

- Same DIMM type; UDIMM, RDIMM, LRDIMM, and LRDIMM 3DS TSV can’t be mixed in a system (meaning, you can’t populate one CPU with RDIMMs, and the other one with LRDIMMs).
- Same size is recommended for performance; however, it’s possible to mix capacities.
- Same speed; if different speeds are populated, the system will run at the lowest speed DIMM.
- Same technology (DDR4); DDR2 and DDR3 modules won’t physically fit 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 V.
HPE Part Numbers Matter
(Not Vendor Names)

When buying server memory through HPE, remember that DIMMs don’t have to be from the same vendor. HPE memory DIMMs, independent of manufacturer, follow the Joint Electron Device Engineering Council (JEDEC) Solid State Technology Association standards. All DIMMs sourced through HPE pass strenuous HPE memory qualification tests. Summing up, if the HPE part number is the same, the DIMMs are compatible.
Memory failures are some of the most frequent type of failures for servers besides storage failures. HPE Gen9/Gen10 servers provide an increasingly comprehensive suite of memory RAS features that can be split into three major categories:

- Error detection and correction
- Redundancy and resiliency
- Maintenance

In this part, you discover why memory protection is needed and learn some of the basic and advanced RAS features available on HPE Gen9/Gen10 servers.

Why Memory Protection Is Needed

One of the most critical aspects of data center maintenance is server uptime. We usually differentiate three major categories of errors — correctable, uncorrectable, and recoverable errors.
The determination of which errors are correctable or uncorrectable is dependent on the capability of the memory controller.

» Correctable errors are, by definition, errors that can be detected and corrected by the memory controller and don’t automatically result in server downtime. These errors are generally single bit. All Hewlett Packard Enterprise (HPE) servers are capable of detecting and correcting single-bit errors and with advanced ECC support, multi-bit errors. On HPE systems, the user is warned about a DIMM exceeding the correctable error threshold (maximum amount of correctable errors tolerated in a certain time window) either through LEDs on the front panel or system board (if available) or the HPE Integrated Management Log (IML).

» Uncorrectable errors are errors that can be detected but not corrected by the memory controller. Those are generally multi-bit memory errors. The error will be logged in the IML. Uncorrectable errors can typically be isolated down to a single DIMM. Uncorrectable errors will usually immediately result in a system crash or shutdown of the system.

» Recoverable errors are essentially uncorrectable memory errors, but they don’t cause the system to crash. By combining operating system (OS) support and advanced SKU processors (Intel Xeon Platinum and Gold processors), uncorrectable errors don’t have to result in a system crash. For error recovery details, consult your OS documentation.

Errors in DRAMs generally come in two different types:

» Hard errors typically indicate a problem with the DIMM itself. Although hard correctable memory errors are corrected by the system and won’t result in system downtime or data corruption, they still indicate a hardware problem. Hard errors will typically cause a DIMM to exceed the correctable error threshold on HPE servers. The user is warned when these errors occur.

» Soft errors don’t indicate any issues with the DIMM. They occur when the data and/or ECC bits on the DIMM are incorrect, but the error won’t continue to occur once the data and/or ECC bits on the DIMM have been corrected. Soft errors won’t typically cause a DIMM to exceed the correctable error threshold on HPE servers; therefore, no indication of a hardware issue is shown.
Any kind of error, if not handled correctly, can eventually cause a system shutdown. In early days of servers, basic ECC was sufficient to resolve most DRAM failures. However, today’s servers present a completely different challenge, and additional RAS features are necessary to maintain expected server stability and uptime.

By avoiding a critical failure, a system crash can be avoided. Failed memory devices are replaced as part of periodic service. Also, memory RAS technologies can detect a device on a DIMM that has had numerous soft errors and will recommend replacing it before it has a hard failure. So, listen to Hal and replace the component.

Memory RAS Technologies on HPE Servers

This section gives you an overview of the functionality of selected memory RAS technologies.

**Error correction code**

Error correction code (ECC) is the fundamental form of memory protection for HPE servers. Parity, as in parity error (you occasionally get parity errors on a desktop personal computer), tells you something went wrong, and the wrong can’t be made right (sorry!). ECC is based on advanced mathematics, and there’s a fancy formula to tell you how many redundant data bits you need \((\log_2(N) + 1\text{, where } N \text{ is the number of data bits})\). Or, this simple explanation — to protect 64 bits of data, you need eight 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**

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 Olympic Games. Advanced ECC uses the same number of redundant bits as ECC, but uses them differently. Instead of correcting each 64-bit word by itself, advanced ECC takes multiple 64-bit data words and combines them together to create a larger word with a larger number of redundant bits. By using the
combined redundant bits across the larger word, it’s able to detect and correct up to four data bits.

With advanced ECC, you can protect against the loss of a single DRAM device. The data bus is divided into groups of four bits each, and any group can have all four bits in error as long as the other groups are okay. It’s able to detect any combination of errors that span two groups; it could be a two-bit error or an eight-bit error as long as it stays within the two groups. If four-bit-wide DRAMs are used, then one DRAM represents one group on the bus.

**Online spare with advanced ECC support**

Online sparing provides protection against persistent DRAM failure. It tracks an excessive number of correctable errors and copies the contents of an unhealthy rank to an available spare rank in advance of multi-bit or persistent single-bit failures that may result in future uncorrectable faults. It doesn’t identify or disable individual failed DRAMs, but it instead disables the DIMM rank.

Because a DIMM rank is needed to perform sparing, this technique reduces the total amount of available memory by the amount of memory used for sparing. Sparing can only handle one failure per channel. Ranks within DIMMs that are likely to receive a fatal/uncorrectable memory errors are automatically removed from operation, resulting in less system downtime. DIMM sparing and rank sparing aren’t compatible with mirroring.

**Memory scrubbing (patrol and demand)**

*Maintenance scrubbing* is a standard memory RAS feature designed to prevent soft errors from accumulating in memory and eventually becoming an uncorrected error. It does this by proactively writing correct data back to memory every time an error is detected.

In today’s systems, scrubbing comprises two types: patrol scrubbing and demand scrubbing. Both do the same thing. Once an error is found, they correct it in memory. The big difference between the two is how the error is found. Patrol scrubbing is a proactive search for errors and is done in the background. The background scan runs by stealing idle cycles on the bus and will typically scan...
through all memory once every 24 to 48 hours. Demand scrubbing, on the other hand, occurs only when memory is actually read by the OS or the application.

**Memory mirror mode — full-channel mirroring**

Memory mirroring provides protection against uncorrectable memory errors that would otherwise result in system failure. In this mode, the system maintains two copies of all data. If an uncorrectable memory error occurs, the system automatically retrieves the good data from the mirrored (redundant) copy. The system continues to operate normally without any user intervention.

By providing added redundancy in the memory sub-system, memory mirroring provides the greatest protection against memory failure not corrected, for example, by ECC or other RAS features. The performance impact for implementing memory mirroring is very small. There is no READ or WRITE performance impact in low memory traffic, but there can be a small performance loss while WRITING during heavy bus utilization.

Because memory mirroring consumes 50 percent of the system memory capacity, it’s merited for server workloads that must receive the highest level of protection from memory device failures.

Consider memory mirroring for workloads that can’t have downtime and can’t risk waiting until scheduled downtime to replace degraded memory modules.

The implementation of full-channel mirroring varies between HPE Gen9 and Gen10 servers due to their different architectures.

**HPE Gen9 server**

On the HPE Gen9 server, full-channel mirroring is supported between two equally populated channels on one memory controller. For example, on a 3SPC system like the HPE DL360 Gen9 server, only one side has to be equally populated, as shown in Figure 2–1.
The same rule applies on a 2SPC system such as the HPE BL460c Gen9 server blade. You have to equally populate two channels on one memory controller, as shown in Figure 2-2.

**FIGURE 2-1:** Full-channel mirroring on an HPE DL360 Gen9 server.

**FIGURE 2-2:** Full-channel mirroring on an HPE BL460c Gen9 server blade.

**HPE Gen10 server**

With the introduction of six memory channels in HPE Gen10 processors, the rules for full channel mirroring changed slightly. Now we differentiate between two methods:
**Two-channel mirroring** will mirror between two of the three channels on each side of the CPU (channels 2 and 3 or 5 and 6), as shown in Figure 2-3.

**Three-channel mirroring** will mirror memory across all three memory channels on each side of the CPU, as shown in Figure 2-4.
Full memory mirroring is done on one integrated memory controller (IMC). It is not done across both IMCs, so the IMCs mirror independently from each other.

**New RAS Features on HPE Gen10 Servers**

On HPE Gen10 servers, two new RAS features were introduced.

**HPE Fast Fault Tolerance**

HPE Fast Fault Tolerance is a new HPE memory RAS feature first introduced in HPE Gen10 servers with Intel Xeon. Those servers configured with HPE SmartMemory and HPE Fast Fault Tolerance offer an extra layer of protection against planned server downtime and server crashes. HPE Fast Fault Tolerance, the result of a joint Intel and HPE collaboration, is an enhanced version of the RAS feature adaptive double device data correction (ADDDC). HPE Fast Fault Tolerance has more spare regions (a part of the memory allocated only for replacing bad memory areas) and more options to map out bad sections of memory. This results in significantly better memory reliability and availability than what the rest of the industry can provide using ADDDC only.

**Memory mirror mode — partial mirror**

Partial memory mirroring is a different form of mirroring. The loading rules are the same as those for standard mirrored memory, but unlike full mirrored memory, partial memory mirroring allows the user to assign a smaller amount of the system memory to be mirrored. This feature is supported with advanced CPU SKUs (Intel Xeon Platinum and Gold processors). Partial memory mirroring can be configured by the customer and supports different modes:

- **OS configured:** In this mode, the BIOS is set up to place the system into partial memory mirror mode from the operating system.
- **First 4 gigabytes (GB) of memory:** In this mode, the first 4GB of memory is reserved for memory mirroring.
Ten percent of memory above 4GB: In this mode, 10 percent of the memory above 4GB is reserved for memory mirroring.

Twenty percent of memory above 4GB: In this mode, 20 percent of the memory above 4GB is reserved for memory mirroring.

All the memory reserved for mirroring is marked with an attribute in the memory map. For partial memory mirroring support, consult OS documentation for more details. Because partial memory mirroring uses less memory, the cost of implementation can be significantly lower than full memory mirroring.

For more info on RAS features, visit www.hpe.com/docs/memory-ras-feature.
Nonvolatile DIMMs for DDR4

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

NVDIMM Type N

The NVDIMM type N (NVDIMM-N) was the first NVDIMM introduced on HPE ProLiant Gen9 server platforms in 2016. It combines DRAM and NAND flash onto a single DIMM module and runs like a regular RDIMM in the system during normal operation. There is no direct access to the NAND flash from the CPU. Figure 3-1 shows a simple representation of an NVDIMM-N.

In the event of a power loss, such as unplanned outage or shutdown, the memory content is saved into the flash. The advantage is that the device can be used as a nonvolatile storage device on the high-speed memory bus.
An NVDIMM-N has the following characteristics:

- Capacity (in the tens of gigabytes [GB])
- Performance (read latency tens of nanoseconds)
- Endurance and reliability of DRAM

Application-specific benchmark tests have shown performance improvements of up to four times by simply using NVDIMMs in a HPE server system. The architecture of the NVDIMM-N released by Hewlett Packard Enterprise (HPE) for Gen9 platforms is shown in Figure 3–2. It has some physical similarities to an LRDIMM, but some minor differences also exist.

Rather than a data buffer found on an LRDIMM, an NVDIMM-N features a data MUX in its place. During normal operation, data can be written to and read from the DRAM through the data MUX. In the event of an unplanned power outage or a shutdown, the HPE Smart Storage Battery kicks in to provide power for a limited amount of time. That is what enables the on-DIMM application-specific integrated circuit (ASIC) to save all DRAM data into the flash memory. After power is restored, data in the DRAM is recovered completely to the initial state before the power outage.
The NVDIMM architecture for HPE Gen10 changed substantially. In order to be able to run at the highest data rate (2666 MT/s), the data MUXs on the DIMM had to be removed to enhance the timing and the quality of the data signals (SI or signal integrity) within a memory channel. The functionality of those data MUXs were placed right onto the DRAM die so they were no longer visible to the memory controller of the CPU. Figure 3–3 shows the new architecture of the HPE NVDIMM-N in HPE Gen10.

**FIGURE 3-3:** NVDIMM-N architecture for HPE Gen10 servers (HPE 16GB NVDIMM 1Rx4 DDR4-2666 Kit).

### NVDIMM-N POPULATION RULES FOR HPE GEN9 AND HPE GEN 10

To install one or more NVDIMM-Ns in a system, some requirements have to be met in order to make all this work. As an excerpt from the official HPE Gen9 and HPE Gen10 population rules for NVDIMM-Ns, NVDIMM-Ns follow these general memory population rules and guidance.

**For HPE Gen9**

- Can be mixed with RDIMMs only (no mixing with LRDIMMs and UDIMMs).
- When installing NVDIMM-Ns on the same memory channel as RDIMMs, populate the RDIMMs first/farthest from the CPU, then populate the NVDIMM-Ns last/closer to the CPU.
- There must be a minimum of one RDIMM installed in any DIMM slot in the first CPU socket.

(continued)
NVDIMM Type F

NVDIMM type F (NVDIMM-F) is another type of NVDIMM that was defined with the NVDIMM-N but was never supported on HPE servers. Figure 3-4 shows a simple representation of an NVDIMM-F.

For HPE Gen10

- Can be mixed with RDIMMs only (no mixing with LRDIMMs and UDIMMs).
- When installing NVDIMM-Ns on the same memory channel as RDIMMs, populate the RDIMMs first/farthest from the CPU, then populate the NVDIMM-N's last/closer to the CPU.
- There must be a minimum of one RDIMM installed in any DIMM slot in the first CPU socket.
- The maximum number of NVDIMM-Ns in a 2+2+2 server, such as the HPE DL360, HPE DL380, or HPE ML350, is 12.
- The maximum number of NVDIMM-Ns in a 2+1+1 server, such as the HPE BL460c or HPE BL660c, is two.
All DRAMs sitting on the module have been removed from the layout; instead, an ASIC with a RAM buffer is in its place, and 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 type of DIMM has the following characteristics:

- Capacity (100s GB to ones 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 3-5, will most likely be released in the Gen10/Gen11 timeframe on HPE servers. It will rely on high-speed nonvolatile memory technology.

![Figure 3-5: A NVDIMM-P module.](image)

Before supporting NVDIMM-P memory, a new memory technology needs to be developed, along with a new memory bus protocol, which are yet to be defined. The CPU is designed to communicate directly with the NVM (nonvolatile memory), which can take a few forms:

- **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.
- **Spin-transfer-torque magnetoresistive RAM (STT-MRAM)**, 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.
Phase change memory (PCM), 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.

Clearly, a number of NVM technologies are being investigated for this application. Some of the specification requirements for the NVDIMM-P are

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

NVDIMM-P can support both transfer types — byte addressable (load/store) and block accesses from the host.

**NVDIMM-N/-F/-P Commonalities**

The boot/restore sequence is what all three NVDIMM types have in common. Figure 3−6 illustrates this.

**FIGURE 3-6:** A common NVDIMM boot/restore sequence.
In addition, the software interaction between NVDIMM hardware and the OS is also common among all three NVDIMM types. Figure 3-7 shows the hierarchical structure of the interaction.

**FIGURE 3-7:** Common NVDIMM implementation between hardware and OS.
This part is dedicated to the specific instructions that help end-users install DDR4 memory in HPE Gen9 and Gen10 servers. We go over the nitty-gritty details on populating memory slots. The set of guidelines may seem overwhelming at first — there’s a lot of nitty and a lot of gritty. But stick with us!

Mandatory rules apply to HPE Gen9 and Gen10 systems that you need to follow to enable the server to run. Other rules are designed for performance optimization. For instance, more DIMMs per channel can actually reduce the system bandwidth due to high loads on the memory channel. This can be seen in Figure 4-1, which lists the maximum memory speeds for different configurations of HPE Gen9/Gen10 servers.

Those differences in speed between HPE Gen9 over Gen10 systems are mainly caused by the architecture and the internal components of the new HPE Gen10 Intel Xeon processor.
When DDR4 was first introduced on HPE Gen9 servers in 2014, the new architecture appeared to be very similar to the architecture of previous generations. Each Xeon-EP processor offered four memory channels and a maximum of 3SPC memory. A two-socket system like the HPE DL360 Gen9 server was able to support up to 24 DIMMs (two CPUs × four channels × three DIMMs), a four-socket system, such as the HPE DL560 Gen9 server, could host up to 48 DIMMs (four CPUs × four channels × three DIMMs).

Figure 4-2 shows a single processor on a 3SPC system with its four memory channels and the corresponding color-coded DIMM slots.

Besides 3SPC systems, Hewlett Packard Enterprise (HPE) also offers 2SPC systems in Gen9 such as the HPE BL460c Gen9 server (two-socket blade server) or HPE BL660c Gen9 server (four-socket blade server). The major difference is that due to the smaller footprint of those systems, only eight DIMMs per CPU will fit.
Figure 4-3 shows a single processor on a 2SPC system with its four memory channels and the corresponding color-coded DIMM slots.

In HPE Gen10, things changed drastically. First, the 3SPC systems are removed and the channel count on a single CPU increases from four channels to six channels (which, by the way, gives you by default a 50 percent increase in bandwidth already). In a 2SPC
system with six channels per CPU, each CPU will still support 12 DIMM slots. If you look at a HPE DL360 Gen10 server, it will look very similar to the HPE DL360 Gen9 server in the memory subsystem region.

Figure 4–4 shows a single processor on a 2SPC system with its six memory channels and the corresponding color-coded DIMM slots.

![FIGURE 4-4: The 2SPC system architecture in HPE Gen10 showing one CPU.](image)

Now you’re probably curious how the architecture looks on a blade server like the HPE BL460c Gen10 server, where you have eight DIMM slots and six memory channels. Well, it’s kind of a hybrid architecture, where the two channels closest to the CPU support two DIMMs, while all other channels support one DIMM. Figure 4–5 shows an example for the hybrid architecture in HPE Gen10. The second DIMM slots on channels one and four are usually used when you need NVDIMMs.

Now that we have covered the architecture, the rest of this part gives you a look at how to populate those systems with memory.
Basic Memory Population Rules

There are a lot of rules on how to populate a server; some of them are rather basic that are necessary to boot the system correctly. Others are more for performance improvements. Those rules are different on HPE Gen9 and Gen10 servers.

Let’s start with the basic rules:

Populate the DIMMS in color order:

- Always populate the white DIMM slot first, or the system won’t boot.
- Populate the black DIMM slots.
- At the end of the process, populate the blue DIMM slots (only available in HPE Gen9 systems with 3SPC).

Never mix 3DS TSV LRDIMMs with standard LRDIMMs, RDIMMs or UDIMMs; the system will simply not boot.

Current NVDIMMs offered by HPE can only be mixed with RDIMMs.
Never install DIMMs if a corresponding CPU isn’t installed. If in a two-socket system there’s only one CPU, only half the DIMM slots are functional. This is really obvious when you’re referencing the guidelines (less so when you’re staring at all those available memory slots in front of you).

Start populating the heaviest load DIMMs (octal-rank) to the lightest load (single-rank) within a channel. The heaviest load (DIMM with the most ranks) within a channel should be positioned the farthest away from the CPU.

Mixing DIMM speeds is allowed, but understand that all DIMMs will run at the slowest of the speed ratings.

To optimize for performance beyond the basic rules, keep reading for the specific rules for HPE Gen9 and Gen10.

Understanding the HPE Gen9-Specific Population Rules

For its Gen9 servers, HPE recommends populating the DIMMs in alphabetical order. Following alphabetical order ensures the best DIMM distribution in the system and server performance maximization. Observing these guidelines ensures that the DIMMs are spread between the processors installed in the system and the available memory channels, maximizing the use of memory bandwidth resources. In addition, following our recommendations when populating memory ensures that the available memory bandwidth resources are used and the memory interleaving is optimized.

Figure 4-6 shows the color and loading scheme for the DIMMs in a typical HPE Gen9 system with 3SPC.

For a quick guide on how to populate your slots for a 24-DIMM slot server (for example, HPE DL380 Gen9 server), check out Figure 4-7. Install DIMMs in alphabetical order. Look at the population order row. Start installing A first (which is slot 12), then B (slot 9), C, and so on down the alphabet. The rules are similar for CPU1 and CPU2.
For the 16-DIMM slot server (for example, HPE BL460c Gen9 server), a similar table is available, shown in Figure 4-8.

**TIP**

You can maximize the performance in the following ways:

» Divide equally or balance the memory capacity among installed processors.
Configure with the same type and capacity DIMMs to optimize the interleaving scheme.

Populate all memory channels to leverage the total bandwidth available in the memory subsystem.

Looking at the HPE Gen10-Specific Population Rules

For its Gen10 servers, HPE recommends slightly different population rules than in HPE Gen9 (see the preceding section) to maximize performance. This is mostly due to the new architecture of the Xeon-SP processor. In Gen10, HPE differentiates the systems by the number of DIMM slots on one side of the CPU.

Figure 4-9 shows a 2+2+2 system such as the HPE DL360 Gen10 server.

An HPE BL460c Gen10 server with eight DIMM slots per CPU is considered a 2+1+1 system, as shown in Figure 4-10.

For a given number of DIMMs per CPU, populate those DIMMs in the corresponding numbered memory slot(s) on that row within the chart, as illustrated in Figure 4-11.
As shown in Figure 4-11, memory should be installed as indicated based on the total number of DIMMs being installed per CPU. For example, if two DIMMs are being installed per CPU, they should be located in white memory slots 8 and 10. If six DIMMs are being used per CPU, they should be installed in memory slots 1, 3, 5, 8, 10, and 12.
Unbalanced configurations are noted with an asterisk and aren’t recommended because memory performance will be inconsistent or degraded compared to a balanced configuration.

If you’ve been reading along, you may be curious how to populate a 16-DIMM slot server, such as the HPE BL460c Gen10 server. Well, you’re in luck! Figure 4-12 shows how.

Unbalanced configurations are noted with an asterisk in Figure 4-12 and aren’t recommended.

### Figure 4-12: The DIMM population order for HPE ProLiant Gen10 systems (16 slots).

<table>
<thead>
<tr>
<th>DIMMRs</th>
<th>Population Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 DIMM</td>
<td>3</td>
</tr>
<tr>
<td>2 DIMMs</td>
<td>2 3</td>
</tr>
<tr>
<td>3 DIMMs</td>
<td>1 2 3</td>
</tr>
<tr>
<td>4 DIMMs</td>
<td>2 3 6 7</td>
</tr>
<tr>
<td>5 DIMMs*</td>
<td>1 2 3 6 7</td>
</tr>
<tr>
<td>6 DIMMs</td>
<td>1 2 3 6 7 8</td>
</tr>
<tr>
<td>7 DIMMs*</td>
<td>1 2 3 6 7 8</td>
</tr>
<tr>
<td>8 DIMMs</td>
<td>1 2 3 4 5 6 7 8</td>
</tr>
</tbody>
</table>

* Unbalanced, not recommended

The principles are the same as for the 24-DIMM slot server. If two DIMMs are being installed, they should be located in white memory slots 2 and 3. If six DIMMs are being used, they should be installed in memory slots 1, 2, 3, 6, 7, and 8.

For more detailed information about how to populate HPE ProLiant Gen10 servers, visit [www.hpe.com/docs/memory-rules](http://www.hpe.com/docs/memory-rules).
The Part of Tens is a *For Dummies* tradition, so we didn’t want to skip it. In this part, we list ten of your most pressing questions about DDR4 and give you our answers.

### What Is DDR4 Memory and What’s the Big Deal?

Double data rate 4 (DDR4) is a form of SDRAM (synchronous dynamic random access memory). Breaking down the term looks like this:

- **“Double”** means data is sampled twice per clock cycle — double the data fun.
- **“Data rate”** means the speed at which data is transferred between the processor and the memory measured in MT/s.
- The “4” stands for the fourth iteration of DDR memory, which brings outstanding improvements. It’s faster and uses less power while delivering higher capacity than previous generations.
The current maximum data transfer rate is 2666 MT/s and is already 40 percent faster than DDR3 (which maxed out at 1866 MT/s), and you get all this at a lower power consumption. By using DDR4, HPE Gen9 and Gen10 servers get unprecedented new total memory capacity with high-capacity registered DIMMs (RDIMMs) and load-reduced DIMMS (LRDIMMs) options.

And what’s the big deal? The main benefits of DDR4 memory are its lower power and higher data transfer rates — delivering better performance at a lower cost of ownership.

How Many Kinds of DDR4 Memory Are There?

Hewlett Packer Enterprise (HPE) servers use three main types of DDR4 DIMMs:

- **Unbuffered DIMMs (UDIMMs),** which are offered as HPE Standard Memory only, come in densities of 4GB, 8GB, and 16GB. They operate at speeds of up to 2666 MT/s and are the lowest cost and lowest power DDR4 DIMMs.

- **RDIMMs** are offered as HPE Standard Memory in densities of 4GB, 8GB, and 16GB, or as HPE SmartMemory in densities of 4GB, 8GB, 16GB, and 32GB. They operate at speeds of up to 2666 MT/s and are lower cost and lower power DDR4 DIMMs.

- **LRDIMMs** are offered as HPE SmartMemory only and come in densities of 16GB, 32GB, 64GB, and 128GB. They run at speeds of up to 2666 MT/s. **Note:** In HPE Gen9, LRDIMMs run at higher speeds than RDIMMs in certain configurations.

The larger capacity LRDIMMs and the recent addition of NVDIMMs are also preferred for systems that run online transaction processing (OLTP) or in-memory database applications. They’re ideal for providing a place to store large amounts of data and improving the system’s overall performance by limiting the amount of time data has to be fetched from the significantly slower hard-disk drive or solid-state drive.
Do I Choose UDIMM, RDIMM, or LRDIMM for Price? For Performance?

The workload or your specific plans for usage of your server will be the key driver in selecting the right memory type. Here are our tips:

» UDIMMs are the ideal choice for lowest power and minimal cost. UDIMMs are always built from x8 DRAM devices.

» RDIMMs consume less power and are lower in cost. The majority of RDIMMs are also built using x4 DRAM devices, but some can be x8. Choose x4 RDIMMs for the best reliability, such as advanced ECC or double device data correction+1 features, depending on system and chipset support. This choice helps minimize system downtime by protecting you from memory errors.

» LRDIMMs are the best way to go if high capacity is a key concern. You get up to 3TB in a qualified 24-slot HPE server and enhanced server performance. LRDIMMs are always built using 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 no data buffers) and RDIMMs (no data buffers) are built with fewer devices and will therefore consume less power than the LRDIMMs (which are fully loaded). So the overall memory subsystem power will be lowest when using UDIMMs. For bandwidth-intensive benchmarks for which overall performance isn’t a function of total memory capacity, RDIMMs will provide the best performance per watt. For OLTP benchmarks such as TPC-C (Transaction Processing Performance Council-Type C), where performance is a function of total memory, LRDIMMs will provide the best TPC-C.
Which DIMMs Work in Which HPE ProLiant and Synergy Servers?

All UDIMMs, RDIMMs, and LRDIMMs covered in this book are compatible with HPE ProLiant and Synergy servers. However, you will need to define your strategy and choose one option; you can’t mix and match. For more information on HPE memory product offerings, visit www.hpe.com/info/memory.

How Else Could I Mess Things Up?

You can’t mix UDIMMs, RDIMMs, and LRDIMMs in the same system. In addition, you can’t use older memory technology (DDR2 or DDR3) in HPE ProLiant and Synergy Gen9 and Gen10 platform servers. Older technology DIMMs don’t fit because they’re keyed to prevent insertion in a DDR4 slot.

Does a DDR3 DIMM Fit in a DDR4 Server?

No. It just won’t fit (different pin configuration, different notch location). If you force it in, you’ll destroy either the memory module or socket. If you get it in somehow without major damage, the contacts still won’t line up and you’ll create a short. It. Will. Not. Work.

Will DDR4 SDRAM 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. If a DDR4 DIMM is forced inside the slot, 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, the purchase of a DDR4 server is required.
Is There a DDR5?

Good question! The Joint Electron Device Engineering Council (JEDEC), which creates global open standards for the microelectronics industry, is working on the definition of future memory devices. With DDR4 being the current standard, the next generation of memory is on the horizon. The wizards at JEDEC are behind the curtain diligently working on DDR5. We’re looking at a possible 2020 release, assuming the vision is relatively viable, and there are no major obstacles in the journey to DDR5.

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.

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 don’t get scrapped but, instead, get resold to other original equipment manufacturers and third-party module manufacturers.

HPE Memory is tested, tuned, and optimized for HPE ProLiant- and HPE Synergy-branded servers. This ensures utmost reliability and reduces memory errors due to board level signal integrity issues. HPE stands behind the memory it recommends and sells. HPE DDR4 Memory carries the warranty of the server for up to three years. Memory is one part of the hardware cost, and hardware cost is one part of the total cost of running the server during its lifetime.

For more information on HPE Server Memory or other HPE Server Options, please visit www.hpe.com/info/serveroptions.
Everything you need to know about DDR4

DDR4 is a type of memory that conserves energy and moves data fast. This 4th 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.

Inside...

- DDR4 demystified
- How to populate your server
- How memory is protected
- How many DIMMs you can load per channel
- Population rules for different servers
- Why you should buy HPE memory

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