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**What is System Memory?**

Memory (referred to as RAM) is essentially the computer's workspace – the place where the computer temporarily stores data and programs. How well memory works is an important factor that influences the overall performance of your PC. Memory speed allows more data to be transferred in a given time for greater system response and performance in demanding applications and games.  
  
PC system memory is a means to temporarily store data and instructions for use by the central processing unit (CPU). System memory is typically referred to as RAM, which stands for Random Access Memory. Modern system memory can store different data in different areas, which can be accessed randomly for processing. Previous versions of system memory were accessed sequentially. To better understand this concept, compare finding a song on a cassette tape with finding a song on a CD.  
  
System memory is typically attached to the motherboard in the form of a chip or module called a DIMM (Dual Inline Memory Module), which is a circuit board that holds the memory chips and plugs into specific slots on the motherboard.  
  
**Supplemental Information: DRAM vs. SRAM**

There are also several subcategories of RAM. The type of RAM that most people work with is DRAM or Dynamic RAM, which means that the memory must continually be refreshed or recharged upwards several thousands of times a second. If it is not refreshed, the RAM will lose its stored content. The opposite of DRAM is SRAM or Static RAM, which does not have to be refreshed and is therefore faster than DRAM. SRAM is also much more expensive to manufacture, so is typically only found in small amounts as CPU cache.

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**How Memory Works in the Computer System**

All data and instructions are processed by the CPU. In order to load the data into its registers, the CPU must find the information from the different places where the data might be stored. The process follows a fast to slow hierarchy, meaning the CPU will look for the information in the place that can deliver the data quickest. Typically this means that the CPU first looks in its on-die cache – usually L1 and L2 cache – which are forms of SRAM. If the data is not in the cache, the CPU looks in the next fastest place, which is the RAM. If the information is not in the RAM, the CPU looks for it on the hard disk drive.  
  
As an example, you may notice that when you exit a program and load a different program that your computer may take a little longer to load the second program. That’s because none of the information the CPU is looking for is in the cache or the memory, so it has to call the hard drive. You may have also noticed that when you exit the second program and reload it later, the program comes up much quicker. That’s because the cache and memory are already holding information the CPU needs to load that program, since you used it last.

**System Memory Specifications and What to Look For**

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**Introduction**

Given a specified memory type, there are still tens or even hundreds of products from different manufacturers available. They are of course different, both in features and in price. Like many other computer products, some of these features may not be important to certain users depending on their applications and requirements, so it could be helpful to have some general understanding of the basic memory specifications to help you figure out which features really matter to you.

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**Capacity**

Generally speaking, the larger the capacity the more programs you will be able to run simultaneously (as long as your motherboard and operating system supports it). The capacity you need should depend on your requirements: For most home users, any more than 3GB of memory will not result in any performance gains – at least for now.

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**Speed**

Memory speed is a little bit complicated as there are two measurements: operating frequency (or more accurately, the transfer or data rate) and bandwidth. Bandwidth can be regarded as how much data the memory can transfer at any one time. To illustrate, imagine cars on a highway. If the highway has several lanes, traffic moves faster. If the highway only has one lane for both directions, traffic can move very slowly. Higher bandwidth means more lanes for your data traffic.  
  
SDRAM rated PC100 and PC133 work at 100MHz and 133MHz and provide 800MB/s and 1066MB/s bandwidth respectively. An easy way to determine bandwidth is to multiply the frequency of the RAM by how many bytes the memory can transfer in one clock cycle. SDRAM uses a 64-bit architecture. Eight bits equals one byte. Therefore, SDRAM transfers eight bytes per clock cycle. Multiply eight bytes by the RAM frequency and you get the bandwidth in megabytes.  
  
Ex. SDRAM rated PC133 works at 133MHz x 8 bytes ~ 800MB/s  
  
RDRAM utilizes the same rating system as SDRAM - a PC800 RDRAM operating at 800MHz, provides a bandwidth of 1600MB/s. The bandwidth isn’t calculated the same way, because RDRAM uses a 16-bit architecture, which yields two bytes instead of eight.  
  
Ex. RDRAM rated PC800 works at 800MHz x 2 bytes = 1600MB/s  
  
Things are different when it comes to DDR, DDR2 and DDR3 memory. Initially, DDR used the same rating system as SDRAM, e.g. PC266. This has now been changed to DDR266 instead, which still means the memory works at 266MHz, providing 2100MB/s bandwidth, which is where the PC2100 designation comes from. DDR400 memory, by the same rule, is called PC3200 for its 3200MB/s bandwidth. The same rule applies to DDR2 and DDR3 memory, for example, the DDR2 533 is also called PC2 4200 or PC2 4300 but 'PC2' is used here to refer to DDR2 instead. DDR3 1066 can be called PC3 8500. 'PC3' here also refers to DDR3.  
  
The bandwidth we refer to here is for single channel scenarios. Dual channels are becoming industry standard for motherboards. When memory is used in dual channel mode, the bandwidth doubles - for instance, dual channel DDR2 800 provides 12800MB/s bandwidth as opposed to 6400MB/s for single channel DDR2 800.

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**CAS Latency/Timing**

DRAM stores data in a matrix of columns and rows just like a spreadsheet. If you need to find information in a particular cell, you look for the correct column and then the row. DRAM works the same way. It finds the information by sending signals to the memory in the forms of a Column Address Strobe (CAS) and a Row Address Strobe (RAS).  
  
CAS Latency (or CL), it is the amount of time it takes between a CAS signal assertion and the initial transfer of the data stream. The CAS Latency is measured in clock cycles. For example, a CAS Latency of 2 or CL2 means the data is available 2 clock cycles after the CAS signal prompting. As with any latency parameters in the computer domain, a smaller CAS Latency value means better performance.  
  
There are other memory latency parameters as well, such as tRCD (Row-to-Column Delay), tRP (RAS Precharge) and tRAS (minimum bank cycle time), these parameters affect memory performance as well, but generally not as much as CAS Latency. We often call all these latency parameters "timing" as well, and a "loose timing" means high latency parameters, in contrast to "tight timing".

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**Multi-Channel Kits**

There are many memory modules shipped in the form of multi-channel kits – these are essentially multiple identical memory modules in one package, one for each channel. This type of product is designed for motherboards/systems that support multi-channel mode, with two 64-bit wide channels to provide double the bandwidth of single-channel memory systems. Identical memory modules are preferred for multi-channel usage because this symmetric architecture causes less compatibility problems and delivers the highest performance. A dual channel kit product marked as "1GB (512MB x 2)" means it contains two identical 512MB memory modules.

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**Heatspreaders**

Almost all manufacturers add heatspreaders to their high-end memory products for better cooling. The amount of surface area exposed to air is what really matters when you are trying to dissipate heat, and that is where the heatspreader comes into play – it simply spreads heat over a larger surface area than the memory chips, thus providing more efficient dissipation. This really makes sense for high-end products since cooling is always vital in high performance rigs.

**Understanding System Memory Types**

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**Introduction**

There are many different types of memory products available, and they aren't all compatible with each other or provide the same features, such as dual channel mode, registers and error checking. System memory support depends on your motherboard, therefore it is vital that you determine the memory type and speed support of your motherboard (or processor) before choosing the memory product to purchase. Newegg offers hundreds of RAM products and the following information will help you make an educated purchase for your personal computer.

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**SDRAM**

Synchronous Dynamic Random Access Memory: SDRAM has a synchronous interface. It waits for a clock pulse before transferring data and is therefore synchronous with the computer system and processor. To illustrate, imagine a clock face with a minute hand. Every time the minute hand makes a complete revolution will be called a clock cycle. In that clock cycle – for example, at the 30-second mark – a clock pulse triggers the CPU, the computer system and the RAM to process information. In reality, clock cycles are much faster than 60 seconds. This design greatly improves performance over asynchronous DRAM. SDRAM, by itself, is not as popular as it once was, however, current RAM, like DDR3, build off of the SDRAM architecture.

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**RDRAM**

Rambus Dynamic Random Access Memory is a type of synchronous DRAM created by the Rambus Corporation. RDRAM features an architecture designed to achieve high bandwidth, it is used in the Sony PlayStation 2, early Pentium 4 desktop systems and other applications. The XDR DRAM, RDRAM's successor, is used in IBM's Cell processor and Sony PlayStation 3. RDRAM is also mainly used for capacity expansion of old desktop systems and often come in the form of 184-pin RIMMs (Rambus Inline Memory Modules).

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**DDR SDRAM**

Double Data Rate SDRAM sends and receives data twice as often as common SDRAM. This is achieved by transferring data on both the rising edge and the falling edge of a clock cycle. To continue the illustration from earlier, instead of the clock pulse only triggering at the 30-second mark, it also triggers at the 60-second mark, effectively doubling the processes. DDR memory is replaced by DDR2 memory. DDR memory modules usually take the form of 184-pin DIMMs.

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**DDR2 SDRAM**

Second generation DDR memory provides greater performance with a larger bandwidth, which allows more information to be processed. DDR2 replaces DDR in the desktop DRAM market. DDR2 memory modules are 240-pin DIMMs. It also features a host of new technologies that you can read about in the DDR section of this guide.

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**DDR3 SDRAM**

Third generation DDR memory leaps greatly forward in data transfer rate and power management. DDR3 provides even higher bandwidth than DDR2. You can read about DDR3 in the DDR section of this guide.

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**Other Considerations**

**Unbuffered Memory vs. Registered Memory**  
  
This topic will be discussed in greater detail later in this guide. For now, here’s some basic information: Almost all system memory in PCs today is unbuffered memory. With increasing system memory, stability and performance deterioration is inevitable since the memory controller has to address each memory chip on all modules directly. To solve this problem, systems with more RAM use registered memory instead, which contains registers as buffers to temporarily hold data for one clock cycle before it is transferred. This increases the reliability of high-speed data access to high density memory but sacrifices some performance. Registered memory modules are typically used only in servers and other mission-critical systems where it is extremely important that data is properly handled. Motherboard support is necessary as well.   
  
**ECC Memory**  
  
ECC stands for Error Checking and Correction. Occasionally, the data held by memory becomes corrupted. ECC utilized by memory modules uses single bit error correction, which is capable of detecting and correcting single-bit errors. With error correction, as far as your processes are concerned, the error never happened. ECC will also detect two-bit and some multiple bit errors, but is unable to correct them. This feature needs a motherboard's support, and is usually applied in workstation and server products. You can read more about this topic in the ECC Memory section of this guide.

**Understanding DDR Memory**

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**DDR Basics**

Short for "Double Data Rate", DDR technology doubles the bandwidth of SDRAM under optimal conditions. This is to say that twice as much data can be transferred between the memory and system during the same amount of time. This is because DDR SDRAM sends and receives data twice as often as common SDRAM.  
  
Remember that SDRAM transfers data on every clock cycle (to be specific, on the rising edge of every clock cycle). DDR, on the other hand, transfers data on both the rising edge (clock signal bounces from LOW to HIGH) and the falling edge (clock signal bounces from HIGH to LOW) of a clock cycle. Therefore, two bits (per data line) are transferred every clock cycle. In order to do this, two bits are accessed from the memory array (where data is actually stored) for each data line on every clock cycle, this process is called the "2-bit prefetch".  
  
A DDR200 module provides a data bandwidth of 1.6GB/s - we also call this PC1600 memory. Likewise, DDR400 is also called PC3200 memory, because it provides 3.2GB/s bandwidth. You can double the bandwidth by using same-speed memory modules in dual channel mode if your system supports it: dual channel DDR400 is capable of delivering 6.4GB/s bandwidth.

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**DDR2 Introduction**

As 2nd generation DDR, the most important improvement found in DDR2 memory is its transfer data rate or bandwidth. As in the case with DDR SDRAM vs. SDRAM, the bandwidth of DDR2 memory can double that of DDR.  
  
The DDR standard stops at DDR400 (of course, there are lots of DDR500 and even DDR600 products on market, but these are for overclockers), which provides 3.2GB/s bandwidth (single channel). The DDR2 standard starts from DDR2 400 and goes all the way up to DDR2 800 or even higher. DDR2 800 or PC2 6400 can provide 6.4GB/s bandwidth (single channel), twice as much as DDR400. Dual channel DDR2 800 will offer an unparalleled 12.8GB/s bandwidth, which is a huge leap from the 6.4GB/s bandwidth of dual channel DDR400 memory.  
  
Since DDR already transfers data on both the rising and falling edges of a clock cycle, how does DDR2 double the bandwidth yet again? The answer lies in the I/O buffer frequency, which is doubled with DDR2. The memory controller in our systems only deal with the I/O buffer on the memory chip. To double the data from the memory array to the I/O buffer, DDR2 utilizes a "4-bit prefetch" as opposed to the "2-bit prefetch" with DDR. This means that 4 bits of data are moved from the memory array to the I/O buffer per data line each core clock cycle.  
  
The core clock cycle here refers to the cycle time of the memory array, and the frequency of the memory array is half that of the I/O buffer and 1/4 of the data rates. Take DDR2 800 for example: it has an 800MHz data rate, the I/O buffer works at 400MHz, and the core frequency of the memory array is only 200MHz. The core frequency remains the same as DDR400. However, the DDR400 I/O buffer operates at 200MHz. The time of "a core cycle" is therefore the same whether it is DDR400 or DDR2 800.  
  
DDR2 chips may look different than DDR as well, because most DDR chips use the TSOP-II (Thin Small-Outline Package) form factor while DDR2 utilizes the FBGA (Fine Ball Grid Array) form factor, which is smaller in size than TSOP-II. FBGA chips also feature less electrical noise than TSOP-II, thus resulting in improved signal integrity at high operating frequencies. Besides the enhanced bandwidth, DDR2 also uses less power than DDR by operating on 1.8V - a 28% reduction compared to DDR (2.5V). DDR2 has power saving features such as smaller page sizes and an active power down mode too. These power consumption advantages make DDR2 memory especially suitable for use in notebook computers.  
  
**Supplemental Information: ODT, OCD and Other Memory Technology**

DDR-supporting motherboard typically have several resistors around the memory slots that are called termination resistors, which are used to eliminate excessive signal noise. These resistors are missing on motherboards utilizing DDR2 memory modules, since the termination resistors are built into each of the memory chips on the module, which is far closer to the source of the noise. This feature is called ODT or On-Die Termination, and it can reduce interference within the chip, thus guaranteeing the stability and reliability of DDR2 memory when working under high frequencies.

There are other features such as Posted CAS and Additive Latency, which work together to prevent data collisions and utilize the data bus more efficiently; and the Off-Chip Driver calibration (OCD), which increases signal integrity and system timing margin as well.

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**DDR3 Introduction**

Third generation DDR memory leaps greatly forward in data transfer rate and power management. DDR3 provides even higher bandwidth than DDR2 due to the 8-bit prefetch buffer (4-bit prefetch of DDR2, and 2-bit of DDR). The advanced fabrication technology allows lower operating currents and voltages (1.5V, compared to 1.8V of DDR2) and thus enhances thermal performance. Cooler operating temperatures make DDR3 the best choice for mobile operations. DDR3 memory modules take the form of 240-pin DIMMs, and are not compatible with DDR2 memory slots.