Memory - DDR1, DDR2, and DDR3

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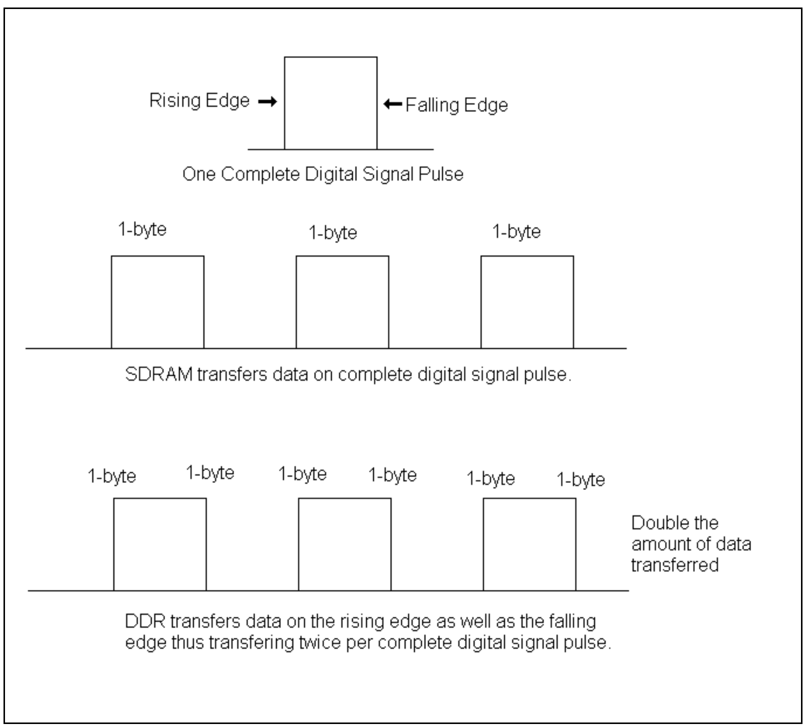
DDR1

Double Data Rate-SDRAM, or simply DDR1, was designed to replace SDRAM. DDR1 was originally referred to as DDR-SDRAM or simple DDR. When DDR2 was introduced, DDR became referred to as DDR1. Names of components constantly change as newer technologies are introduced, especially when the newer technology is based on a previous e one.

The principle applied in DDR is exactly as the name implies "double data rate". The DDR actually doubles the rate data is transferred by using both the rising and falling edges of a typical digital pulse. Earlier memory technology such as SDRAM transferred data after one complete digital pulse. DDR transfers data twice as fast by transferring data on both the rising and falling edges of the digital pulse. Look at figure below.



DDR Digital Pulse

As you can see in the drawing, DDR can transfer twice the amount of data per single digital pulse by using both the rising edge, and the falling edge of the digital signal. DDR can transfer twice the data as SDRAM.

DDR2

DDR2 is the next generation of memory developed after DDR. DDR2 increased the data transfer rate referred to as bandwidth by increasing the operational frequency to match the high FSB frequencies and by doubling the prefetch buffer data rate. There will be more about the memory prefetch buffer data rate later in this section.

DDR2 is a 240 pin DIMM design that operates at 1.8 volts. The lower voltage counters the heat effect of the higher frequency data transfer. DRR operates at 2.5 volts and is a 188 pin DIMM design. DDR2 uses a different motherboard socket than DDR, and is not compatible with motherboards designed for DDR. The DDR2 DIMM key will not align with DDR DIMM key. If the DDR2 is forced into the DDR socket, it will damage the socket and the memory will be exposed to a high voltage level. Also be aware the DDR is 188 pin DIMM design and DDR2 is a 240 pin DIMM design.

DDR3

DDR3 was the next generation memory introduced in the summer of 2007 as the natural successor to DDR2. DDR3 increased the pre-fetch buffer size to 8-bits an increased the operating frequency once again resulting in high data transfer rates than its predecessor DDR2. In addition, to the increased data transfer rate memory chip voltage level was lowered to 1.5 V to counter the heating effects of the high frequency. By now you can see the trend of memory to increase pre-fetch buffer size and chip operating frequency, and lowering the operational voltage level to counter heat.

The physical DDR3 is also designed with 240 pins, but the notched key is in a different position to prevent the insertion into a motherboard RAM socket designed for DDR2. DDR3 is both electrical and physically <u>incompatible</u> with previous versions of RAM.

In addition to high frequency and lower applied voltage level, the DDR3 has a memory reset option which DDR2 and DDR1 do not. The memory reset allows the memory to be cleared by a software reset action. Other memory types do not have this feature which means the memory state is uncertain after a system reboot. The memory reset feature insures that the memory will be clean or empty after a system reboot. This feature will result in a more stable memory system. DDR3 uses the same 240-pin design as DDR2, but the memory module key notch is at a different location.

Compare DDR Prefetch, Chip Voltage and Data Rates for Motherboard FSB.

	DDR1	DDR2	DDR3
Prefetch Buffer	2-bits	4-bits	8-bits
Voltage level	2.5 V	1.8 V	1.5 V
FSB Data Rates expressed as MHz	200,266,333,400	400, 533, 677,800	800,1066,1330,1600

Memory Module PC Classification	**Memory Chip Classification**	**Memory Module Bandwidth**
PC100	SDRAM	800 MB
PC133	SDRAM	1.1 GB
PC1600	DDR	1.6 GB
PC2100	DDR	2.1GB
PC2700	DDR	2.7GB
PC2-3200	DDR2-400	3.2GB
PC2-4200	DDR2-533	4.2 GB
PC2-5300	DDR2-667	5.3GB
PC2-6400	DDR2-800	6.4 GB
PC2-8500	DDR2-1066	8.5 GB
PC3-6400	DDR3-800	6.4 GB
PC3-8500	DDR3-1066	8.53 GB
PC3-10600	DDR3-1333	10.67 GB
PC3-12800	DDR3-1600	12.80 GB

Note: The chart is based on theoretical throughputs, and do not take in account the memory controller, BIOS, or chip set. For a motherboard designed with dual channel architecture, the memory module bandwidth is effectively doubled theoretically.

The memory Chip Classification correlates to the memory chip frequency design. For example, a DDR2-400 is designed to operate at 400 MHz.

The memory module PC classification correlates to the memory module frequency times 8. For example A DDR2-400 would be identified as a PC2-3200. The 3200 is equal to 8 times the 400 MHz.

The memory module band width is the theoretical amount of data that can be transferred expressed in the chart as Giga Bytes. This is the measurement of expected system performance. Also be aware that the expected performance can double when the motherboard memory transfer design is dual channel.

Note: You will see many video cards with a specification of GDDR3 as the main memory type mounted on the video card. Do not confuse this with DDR3; GDDR3 is only designed for video cards.

DDR Pre-fetch Memory Buffer

Memory chips can operate at extremely high frequencies inside the memory chip structure. The frequencies of the individual electronic logic transistors inside the chip operate at a much higher frequency than the outside connections such as the FBS or the HyperTransport bus. The transferring data is positioned into a buffer located on the chip and then awaits the proper time to transfer the data to the bus on the motherboard. The entire operating is referred to as the memory prefetch.

The term pre-fetch is followed by the lower case letter "n" and a number, which represents the number of data bits. For example, DDR1 has a pre-fetch 2n, which means it can store 2-bits of data in each pre-fetch buffer. DDR2 uses a prefetch 4n, or 4-bit buffer thus doubling the amount of data transfer from the buffer as compared to DDR1. DDR3 uses a prefect 8n which double the size of prefetch used in DDR2. The increased size of the pre-fetch buffer, and the increased memory bus operational frequency lets each generation of DDR increase the overall throughput.

The overall throughput of the various DDR RAM speeds is only a theoretical throughput, even though it is expressed as exact values such as 12.8 GB. The 12.8 GB is the theoretical data transfer rate, and does not account for other devices using the bus, or other activities using the CPU to process data. The theoretical speed is just a value used to compare the various DDR RAM types and classifications.

Dual Channel

Dual channel requires a two data transfer paths, a memory controller or chip set that coordinates the data transfer between the two memory channels. A dual channel application basically double the throughput of memory data transfer throughput allow twice as much data to flow as would a single channel of memory. To implement dual channel you must install DRAM as a pair.

The pair does not necessarily need to match, but it is highly recommended that they match for best performance. When the pair does not match then the memory module with the least amount of memory will be matched by the other memory module. For example a 512 Mb memory module, and a 1 GB memory module, paired in a dual channel arrangement will result in the same effect as two 512 MB not 1 GB pair. Also be aware that the worst latency will apply to both modules as a pair.

When installing pairs of memory in dual channel architecture, the size, speed and latency should be matched, otherwise unexpected and intermitted problems could occur.

Latency

To understand latency, you must first understand how computers located and transfer data stored in memory locations. The RAM can be thought of as a matrix of storage bins, each bin containing a bit of information in a binary format. The each individual location corresponds to a specific column and row identification.

Reading or writing to a memory location takes time. The time required to complete a memory read or write operation is measured in clock signals. A clock signal is when the voltage level switches between high and low. There are two main measurements and several minor measurements of read write access. The first is RAS.

Row Address Selection (**RAS**) is a term that describe the time it takes to start a memory read or write the row location in the memory matrix. RAS is the first step of a memory access operation followed next by CAS.

Column Address Select (**CAS**) is a term used to describe the time it takes to access the exact column location in the memory matrix after RAS. There is a minimum amount of time the CAS must remain active to complete the read operation. For example, a (CAS 3) means that there will be three clock signals required before the CAS can complete the read of the memory location.

CAS is considered by most experts as the most important number when expressing latency. You will find that in most cases, CAS is the primary way latency measure is described. In other words, when a publication such as a computer parts catalog or technical article appears, and it states that the latency is 5, they are generally basing the latency measure on the CAS.

Other latency measures are used when memory latency is expressed as a series of number. For example it may be expressed as 3-3-3-5. Such factors as tCL, tRCD, tRP, and tRAS are used to express latency.

Look at the chart below to see what each number and term represents in the exact same sequence as provided. Below is a typically a CL-tRCD-tRP-tRAS latency sequence.

Term	Description
tCL	This is equal to CAS or Column access strobe.
tRCD	The amount of delay between the RAS and CAS.
tRP	How long it takes to pre-charge the RAS.
tRAS	The delay to pre-charge the RAS

Now you can see why most articles simply use the CAS value. These other latency terms require a more in-depth understanding of digital electronics otherwise they are very cryptic to the average reader.

In general, the lower the number used to describe the latency the better the performance. There is an exception to this general rule, must compare latency between similar DDR technologies for a fair comparison. As frequencies rise, memory latency goes up. For example, DDR has latencies in the range of 1.5 to 3, DDR2 has latency range from 2 to 5, and DDR3 has latency from 7 to 11. While DDR3 has the largest latency number, it provides much better system performance when compared to the DDR2 or DDR3, with a much lower latency value. If you double the memory frequency you will double the latency.

Note: Be aware that most computers will develop memory errors if the latency of the memory modules paired do not have matching latency. This is an import consideration for memory upgrades or replacements.

SPD

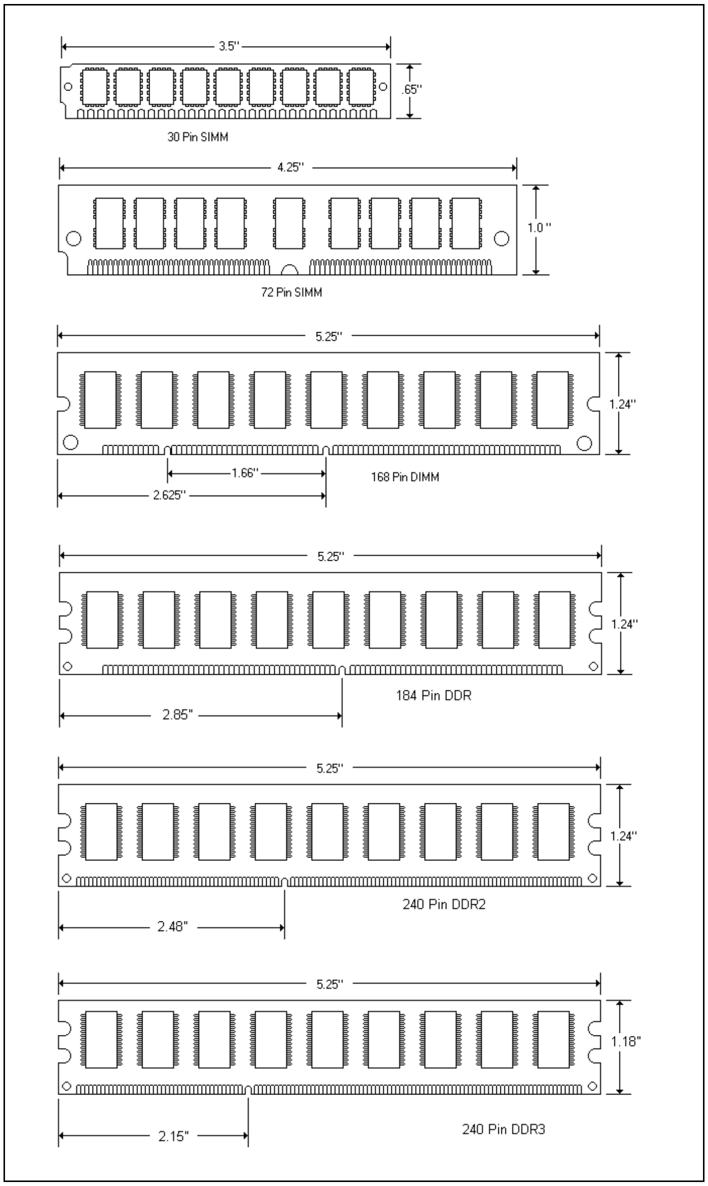
Serial presence detect (SPD) is a technology used to identify the type of RAM installed on a computer. It involves the presence of an extra chip on the memory module used to contain technical information about the RAM module. The information provided by SPD is used by the BIOS to automatically configure the BIOS RAM settings to match the installed RAM. You can still change the RAM settings manually in the BIOS, but this is not advised. RAM access clock speed is commonly performed by PC enthusiasts who wish to increase the performance of their computer.

This group of enthusiast is referred to as overclockers because they overclock the computer system forcing it to perform at higher frequencies. They not only over-clock the RAM performance but also the CPU. When you manually over ride the automatic SPD detection and configuration in BIOS, you run the risk of overheating the memory chips and causing a system failure or lockup. After failing to tweak the speed of the

RAM, the computer BIOS must be reset thus allowing the SPD to automatically reconfigure the BIOS RAM configuration correctly.

Memory Key Notch Alignment

Look at the various memory module physical designs in the drawing below. Pay particular attention to DDR1, DDR2, and DDR3 memory module key notch alignment located along the bottom edge of the memory module pins. The key or notch is used to match the proper memory module to the motherboard RAM memory socket. Insertion of the wrong memory module into the motherboard RAM socket will result in damage to the RAM socket. Do not force the memory module into the socket. It should fit snuggly, but experience only a little physical resistance. You can check the motherboard documentation for the correct memory type that is compatible with the motherboard and motherboard chip set. You cannot upgrade DDR1 to DDR2 or DDR2 to DDR3. They are not compatible physically or electrically. DDR is 2.5 Volts, DDR2 is 1.8 and DDR3 is 1.5 Volt. Be aware that some manufacturers may use a slightly different voltage level for their memory module.



DIMM key notch alignments.