3.7 Memory

3.7.1 DRAM video 4 minutes

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3.7.3 RAM facts
Random Access Memory (RAM) can be classified as one of two types:

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| --- | --- |
| Type | Description |
| Static RAM (SRAM) | SRAM stores data using four transistors for every bit of data. SRAM does not require constant power to maintain the contents of memory. * SRAM is more complex and less dense (e.g., lower storage capacity) than DRAM.
* SRAM is faster and requires less power than DRAM.
* Regular SRAM still requires periodic power to maintain the state of memory, but the rate of refresh is less than with DRAM. Non-volatile SRAM (nvSRAM) is able to maintain memory contents when the power is turned off.
* SRAM is typically used in cache memory, such as CPU cache, hard disk cache, and cache in networking devices.
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| Dynamic RAM (DRAM) | DRAM stores data using a single transistor for every bit of data (a 0 or a 1). To maintain the state of the transistor, DRAM must continually supply power to the transistor; when the power is turned off, the data is lost. * DRAM is simple to implement.
* DRAM can have a very high density (e.g., high storage capacity).
* Because of the simplicity, DRAM is relatively inexpensive.
* DRAM is used in the main system memory on a computer.
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All system memory used in personal computers is DRAM. Individual DRAM chips are packaged onto a board that contains circuitry for reading and writing to the memory. You should be aware of the following standards for DRAM:

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| Hardware | Standard | Description |
| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/ddr.jpg | DDR | DDR (Double-Data Rate Synchronous Dynamic RAM) is a variation of the original synchronous DRAM (SDRAM). * All variations of DDR are synchronized with the system clock and accept 64-bit words.
* DDR accepts a single command and two consecutive data sets per bus clock cycle.
* Operating at the same frequency, DDR has twice the bandwidth of SDRAM.
* DDR operates at 2.5 volts at bus frequencies between 100-200 MHz.

DDR memory has a single notch, slightly off center. DDR memory has 184 pins. |
| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/ddr2.jpg | DDR2 | DDR2 doubles the data transfer rate of DDR, for four times the bandwidth of SDRAM. * DDR2 accepts four consecutive 64-bit words per bus clock cycle.
* DDR2 includes a buffer between the data bus and the memory.
* DDR2 operates at 1.8 volts at bus frequencies between 200-533 MHz. The internal memory frequency is half that of the bus frequency (100-266 MHz).

DDR2 memory differs from DDR memory as follows:* The notch is slightly closer to the middle.
* It has 240 pins. While you don't need to count the pins, you should notice that the pins are smaller because they have to fit in the same space as the DDR memory.
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| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/ddr3.jpg | DDR3 | DDR3 doubles the data transfer rate of DDR2, for eight times the bandwidth of SDRAM (twice that of DDR2). * DDR3 accepts eight consecutive 64-bit words per bus clock cycle.
* DDR3 operates at 1.5 volts at bus frequencies between 400-1000 MHz. The internal memory frequency is one-fourth that of the bus frequency (100-266 MHz).

DDR3 memory has a single notch more left of center than the notch for DDR or DDR2. Like DDR2, DDR3 has 240 pins. |
| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/ddr4.png | DDR4 | DDR4 doubles the data transfer rate of DDR3 for ten times the bandwidth of SDRAM. * DDR4 accepts eight consecutive 64-bit words per bus clock cycle.
* DDR4 operates at 1.2 volts at bus frequencies between 1066-2133 MHz. The internal memory frequency is about one-tenth that of the bus frequency (100-266 MHz).
* DDR4 reduces the demand for power.
* DDR4 is not compatible with earlier types of random access memory (RAM) because of the different signaling voltages, physical interface, and other factors.
* DDR4 theoretically allows for DIMMs of up to 512 GB in capacity, compared to the DDR3's theoretical maximum of 128 GB per DIMM.

DDR4 memory has a single notch slightly right of center. DDR4 has 288 pins. |

DDR is no longer used in modern motherboards, although you might encounter DDR memory in older systems.

Memory comes in various form factors (or packages), with the form factor determining the number of pins and the size of the memory module. Generic form factor labels that you should be familiar with are:

|  |  |  |
| --- | --- | --- |
| Hardware | Form | Description |
| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/ddr.jpgDDR DIMM | DIMM | A DIMM (dual in-line memory module) has pins on both sides of the module, with each pin being unique. * DIMMs have a 64-bit data path that matches the system bus width.
* RDRAM and DDR/2/3/4 are packaged into DIMMs, with each specification having a unique number of pins and notch position.
* DDR4 allows for DIMMs of up to 512 GB in capacity.
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| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/144dimm.jpg144-pin SODIMMhttp://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/200dimm.jpg200-pin SODIMM | SODIMM | A SODIMM (small outline dual in-line memory module) is a smaller DIMM used in laptops. SODIMMs are much smaller than other memory, perfect for notebook computers. Notice the notch slightly off center in the 144-pin SODIMM. 144-pin SODIMMs are used by SDRAM, DDR, and DDR2 memory. On the 200-pin SODIMM, notice that the notch is farther off center than the 144-pin SODIMM. You might also be able to notice the higher pin density. 200-pin SODIMMs are used by DDR2 and DDR3 memory. |
| http://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/ram_types/unidimm.png | UniDIMM | UniDIMM (Universal DIMM) is a specification for DIMMs and is designed to carry DRAM chips. UniDIMMs can be populated with either DDR3 or DDR4 chips, but do not support any additional memory control logic. Because of this, the computer's memory controller must support both DDR3 and DDR4 memory standards. UniDIMM: * Is an upgrade to the current SODIMM standard
* Allows mobile platform users to use both DDR3 and DDR4
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3.7.5 Memory speed facts
Memory is rated based on its guaranteed stable operating frequency and bandwidth (the rate at which data can be read or written). Memory ratings help you to differentiate between slower and faster RAM. The following rating systems are used:

* For all DDR memory (DDR, DDR2, and DDR3), a new designation was introduced to identify that twice the data was being transferred with each bus clock cycle.
	+ The number following the DDR-, DDR2-, and DDR3- prefixes is the data transfer rate (twice the bus frequency).
	+ For example, DDR-400 matches a bus frequency of 200 MHz; DDR2-800 has a bus frequency of 400 MHz; and DDR3-1600 has a bus frequency of 800 MHz.
* For DDR past 150 MHz (and for all DDR2 and DDR3 memory), the PC- designation was changed to identify the *bandwidth* instead of a number derived from the bus frequency.
	+ The bandwidth is 16 times the bus frequency, or 8 times the DDR- designation.
	+ For example, DDR-400 has a bandwidth of 3200 MBs (PC-3200); DDR2-800 has a bandwidth of 6400 MBs (PC-6400); and DDR3-1600 has a bandwidth of 12800 MBs (PC-12800).
	+ For a brief time, the double-frequency designation used the PC- prefix for early DDR modules. For example, PC-200 used with DDR indicates a bus frequency of 100 MHz, not a bandwidth of 100 MBs (PC-200 is equivalent to DDR-200 which is equivalent to PC-1600).

When listing the frequency, the frequency value usually indicates the bus speed, not the internal frequency (DDR designation) used by the memory.

The following table lists the various memory speed designations for the most common memory types:

|  |  |  |
| --- | --- | --- |
| Memory Type | Bus Speed | Designations |
| DDR | 100 MHz | PC-200 or PC-1600 or DDR-200 |
| 133 MHz | PC-266 or PC-2100 or DDR-266 |
| 166 MHz | PC-2700 or DDR-333 |
| 200 MHz | PC-3200 or DDR-400 |
| DDR2 | 200 MHz | PC2-3200 or DDR2-400 |
| 266 MHz | PC2-4200/4300 or DDR2-533 |
| 333 MHz | PC2-5300/5400 or DDR2-667 |
| 400 MHz | PC2-6400 or DDR2-800 |
| 533 MHz | PC2-8500/8600 or DDR2-1066 |
| DDR3 | 400 MHz | PC3-6400 or DDR3-800 |
| 533 MHz | PC3-8500 or DDR3-1066 |
| 667 MHz | PC3-10600/10666 or DDR3-1333 |
| 800 MHz | PC3-12800 or DDR3-1600 |
| 900 MHz | PC3-14400 or DDR3-1800 |
| 1000 MHz | PC3-16000 or DDR3-2000 |
| DDR4 | 800 MHz | PC4-12800 or DDR4-1600 |
| 933 MHz | PC4-14900 or DDR4-1866 |
| 1066 MHz | PC4-17000 or DDR4-2233 |
| 1200 MHz | PC4-19200 or DDR4-2400 |
| 1333 MHz | PC4-21300 or DDR4-2666 |
| 1600 MHz | PC4-25600 or DDR4-3200 |

When comparing the speed of memory modules, be aware of the following:

* The most useful way to compare most DDR modules will be to compare the amount of data that can be transferred per second (bandwidth), as indicated by the PC- designations. For example, PC-3200 will always indicate a "faster" memory module than one with a PC-2700 rating.
* PC- numbers up to PC-266 identify the frequency (or double the frequency), not the bandwidth. For example, a PC-266 module has a greater bandwidth than a PC-1600 module (PC-266 = PC-2100).
* Comparing DDR- numbers can also give you an idea of the relative bandwidth. For example, DDR-600 can transfer more data than a DDR2-400 module.
* The bandwidth identifies a theoretical maximum that the memory can transfer in a given time period, and is directly related to the front size bus frequency.
* If you can derive the bus frequency, you can also get a relative idea of the amount of data a module can handle.
	+ When comparing DDR modules, the frequency is relative to the bandwidth. For example, a DDR2 module operating on a 533 MHz bus is faster than a DDR3 module on a 400 MHz bus.
* Other memory characteristics besides the frequency could affect the effective bandwidth or actual speed of the memory module.

Another method for increasing memory bandwidth is by providing multiple channels within the memory controller.

* Dual-channel systems use two memory controllers, while triple-channel systems use three memory controllers. Quadruple-channel (quad-channel) systems use four memory controllers. Each memory controller can communicate with one or more memory modules at the same time.
* To operate in dual-channel mode, install memory in pairs; to operate in triple-channel mode, install memory in sets of three. To operate in quad-channel mode, install memory in sets of four
* Dual-channel systems theoretically double the bandwidth. However, in practice, only a 5–15% increase is gained.
* Dual-channel, triple-channel, and quad-channel support is mainly a function of the motherboard (e.g., the memory controller), not the memory itself. DDR, DDR2, DDR3, and DDR4 can all work in dual-channel systems (depending on the memory supported by the motherboard); both a triple-channel and a quad-channel system use DDR3 and DDR4.

