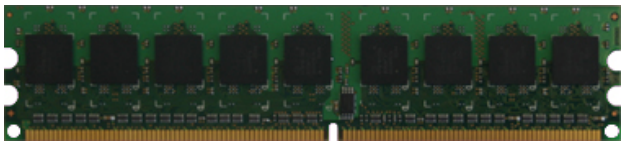
3.7.3 RAM Facts

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

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.
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.

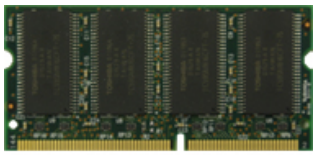
All system memory used in personal computers is DRAM. Individual DRAM chips are packaged onto a board that contains circuitry for reading and writing to the memory. You should be aware of the following standards for DRAM:

Hardware	Standard	Description
	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.
	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.
	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.
	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
 DDR 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.
 144-pin SODIMM  200-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.
	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