HOW MUCH MEMORY IS ON A MODULE?

Bits and Bytes

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Up to now, we've discussed some of the technical attributes of memory and how memory functions in a system. What's left are the technical details – the "bits and bytes," as they say. This section covers the **binary numbering system**, which forms the basis of computing, and calculation of a memory module's capacity.

BITS AND BYTES

Computers speak in a "code" called **machine language**, which uses only two numerals: 0 and 1. Different combinations of 0s and 1s form what are called **binary numbers**. These binary numbers form instructions for the chips and microprocessors that drive computing devices – such as computers, printers, hard disk drives and so on.

You may have heard the terms "bit" and "byte." Both of these are units of information that are important to computing. The term **bit** is short for "binary digit." As the name suggests, a bit represents a single digit in a binary number; a bit is the smallest unit of information used in computing and can have a value of either 1 or a 0. A **byte** consists of 8 bits. Almost all specifications of your computer's capabilities are represented in bytes. For example, memory capacity, data-transfer rates and data-storage capacity are all measured in bytes or multiples thereof (such as kilobytes, megabytes, or gigabytes).

This discussion of bits and bytes becomes very relevant when it comes to computing devices and components working together. Here, we'll address specifically how bits and bytes form the basis of measuring memory component performance and interaction with other devices like the CPU.

CPU AND MEMORY REQUIREMENTS

A computer's CPU (central processing unit) processes data in 8-bit chunks. Those chunks, as we learned in the previous section, are commonly referred to as bytes. Because a byte is the fundamental unit of processing, the CPU's processing power is often described in terms of the maximum number of bytes it can process at any given time. For example, Pentium and PowerPC microprocessors currently use 64-bit data paths, which means they can simultaneously process 64 bits, or 8 bytes, at a time.

Each transaction between the CPU and memory is called a **bus cycle**. The number of data bits a CPU can transfer during a single bus cycle affects a computer's performance and dictates what type of memory the computer requires. Most desktop computers today use 168-pin DIMMs, which support 64-bit data paths. Earlier 72-pin SIMMs were designed to support a 32-bit data path. When used in configurations that supported a 64-bit data path, they had to be installed in pairs with each pair of modules making up a memory bank. The CPU communicated with the bank of memory as one logical unit.

Interestingly, RIMM modules, which are newer than DIMMs, use smaller 16-bit data paths; however they transmit information very rapidly, sending several packets of data at a time. RIMM modules use pipelining technology to send four 16-bit packets at a time to a 64-bit CPU, so information still gets processed in 64-bit chunks.

CALCULATING THE CAPACITY OF A MODULE

Memory holds the information that the CPU needs to process. The capacity of memory chips and modules are described in **megabits** (millions of bits) and **megabytes** (millions of bytes). When trying to figure out how much memory you have on a module, there are two important things to remember:

A module consists of a group of chips. If you add together the capacities of all the chips on the module, you get the total capacity of the module. Exceptions to this rule are:

- If some of the capacity is being used for another function, such as error checking.
- If some of the capacity is not being used, for example some chips may have extra rows to be used as back-ups. (This isn't common.)

While chip capacity is usually expressed in megabits, module capacity is expressed in megabytes. This can get confusing, especially since many people unknowingly use the word "bit" when they mean "byte" and vice versa. To help make it clear, we'll adopt the following standards in this book:

> When we talk about the amount of memory on a module, we'll use the term "module capacity"; when we are referring to chips, we'll use the term "chip density". Module capacity will be measured in megabytes (MB) with both letters capital, and chip density will be measured in megabits (Mbit), and we'll spell out the word "bit" in small letters.

COMPONENT	CAPACITY EXPRESSION	CAPACITY UNITS	EXAMPLE
Chips	Chip Density	Mbit (megabits)	64Mbit
Memory Modules	Module Capacity	MB (megabytes)	64MB

Chip Density

Each memory chip is a matrix of tiny cells. Each cell holds one bit of information. Memory chips are often described by how much information they can hold. We call this chip density. You may have encountered examples of chip densities, such as "64Mbit SDRAM" or "8M by 8". A 64Mbit chip has 64 million cells and is capable of holding 64 million bits of data. The expression "8M by 8" describes one kind of 64Mbit chip in more detail.

In the memory industry, DRAM chip densities are often described by their cell organization. The first number in the expression indicates the depth of the chip (in locations) and the second number indicates the width of the chip (in bits). If you multiply the depth by the width, you get the density of the chip. Here are some examples:

Current Available Chip Technology

	CHIP DEPTH IN MILLIONS OF LOCATIONS	CHIP WIDTH IN BITS	CHIP DENSITY = DEPTH X WIDTH
16Mbit Chips			
4Mx4	4	4	16
1Mx16	1	16	16
2Mx8	2	8	16
16Mx1	16	1	16
64Mbit Chips			
4Mx16	4	16	64
8Mx8	8	8	64
16Mx4	16	4	64
128Mbit Chips			
8Mx16	8	16	128
16Mx8	16	8	128
32Mx4	32	4	128
256Mbit Chips			
16Mx16	16	16	256
32Mx8	32	8	256
64Mx4	64	4	256

MODULE CAPACITY

It's easy to calculate the capacity of a memory module if you know the capacities of the chips on it. If there are eight 64Mbit chips, it's a 512Mbit module. However, because the capacity of a module is described in megabytes, not megabits, you have to convert bits to bytes. To do this, divide the number of bits by 8. In the case of the 512Mbit module:

$$\frac{\text{512Mbits}}{\text{8 bits per byte}} = \text{64MB}$$

You may hear standard memory modules in the industry being described as: "4Mx32" (that is, "4 Meg by 32"), or "16Mx64" ("16 Meg by 64"). In these cases, you can calculate the capacity of the module exactly as if it were a chip:

4Mx32 is 128Mbits.

$$\frac{\text{128Mbits}}{\text{8 bits per byte}} = \text{16MB module}$$

16Mx64 is 1024Mbits.

$$\frac{\text{1024Mbits}}{\text{8 bits per byte}} = \text{128MB module}$$

Here are some additional examples:

STANDARD MODULE TYPES

	STANDARD	MODULE DEPTH IN LOCATIONS	MODULE WIDTH IN DATA BITS	CAPACITY IN MBITS = DEPTH X WIDTH	CAPACITY IN MB = MBITS/8
72-Pin	1Mx32	1	32	32	4
	2Mx32	2	32	64	8
	4Mx32	4	32	128	16
	8Mx32	8	32	256	32
	16Mx32	16	32	512	64
	32Mx32	32	32	1024	128
168-Pin	8Mx64	8	64	512	64
	16Mx64	16	64	1024	128
	32Mx64	32	64	2048	256
	64Mx64	64	64	4096	512
	128Mx64	128	64	8192	1024

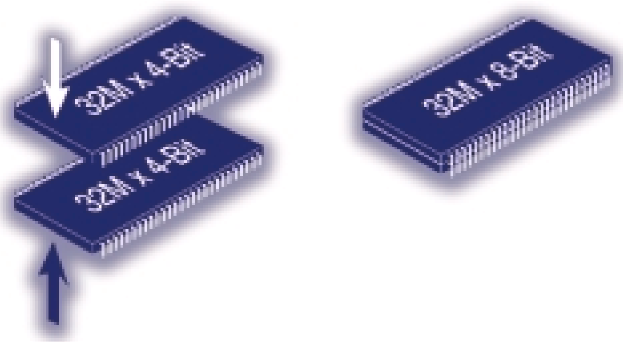
As we mentioned earlier, there's only room for a certain number of chips on a PCB. Based on an industry standard 168-pin DIMM, the largest capacity module manufacturers can make using 64Mbit chips is 128MB; with 128Mbit chips, the largest module possible is 256MB; and with 256Mbit chips, the largest module possible is 512MB.

STACKING

Many large servers and workstations require higher capacity modules in order to reach system memory capacities of several gigabytes or more. There are two ways to increase the capacity of a module. Manufacturers can stack chips on top of one another, or they can stack boards.

Chip Stacking

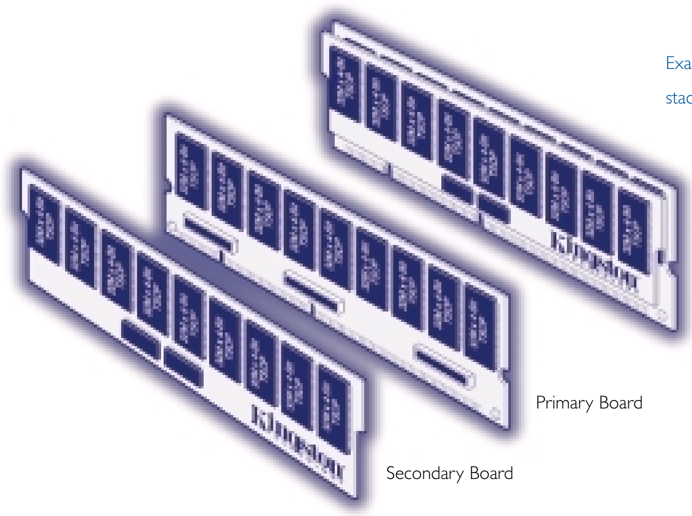
With chip stacking, two chips are stacked together and occupy the space that one chip would normally take up. In some cases, the stacking is done internally at the chip manufacturing plant and can actually appear to be one chip. In other cases the chips are stacked externally. The example below shows two externally stacked chips.



Example of externally stacked chips.

Board Stacking

As you might expect, board stacking involves putting two memory module printed circuit boards (PCBs) together. With board stacking, a secondary board mounts onto the primary board, which fits into the memory socket on the system motherboard.



Example of a stacked module.