

the ultimate memory guide

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THE INTRO

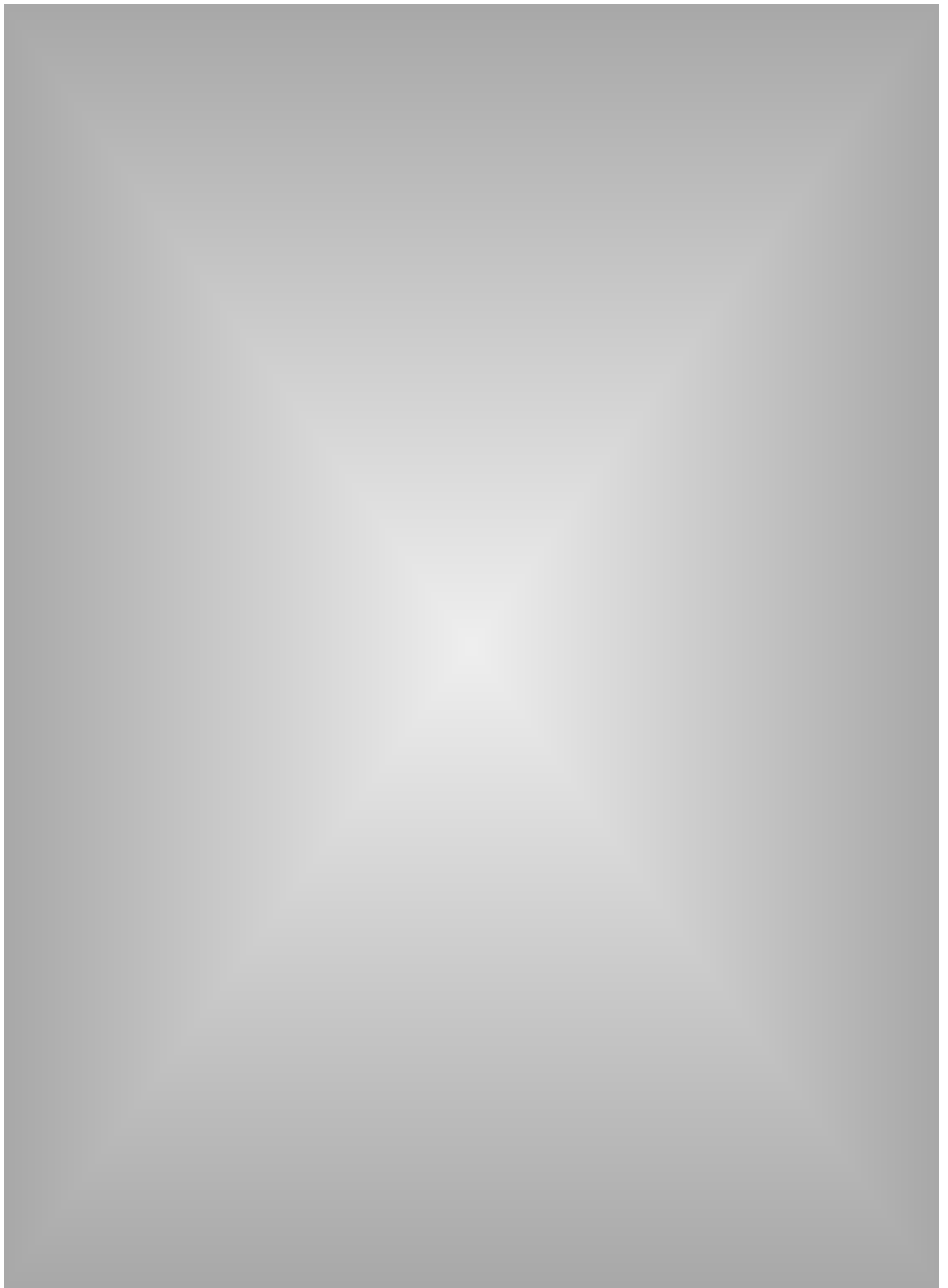
WHAT IS MEMORY?

THE DIFFERENCE BETWEEN MEMORY AND STORAGE

HOW MUCH MEMORY IS ENOUGH?

MEMORY RECOMMENDATION CHART

WHAT MEMORY LOOKS LIKE



the intro

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These days no matter how much memory your computer has it never seems quite enough. Not long ago, it was unheard of for a personal computer, or PC, to have more than 1 or 2 **megabytes** of memory. Today, you need at least 4 megabytes of memory just to boot up a system; using more than one application at a time requires at least 16 megabytes, and maximum performance today calls for 32-64 megabytes or more.

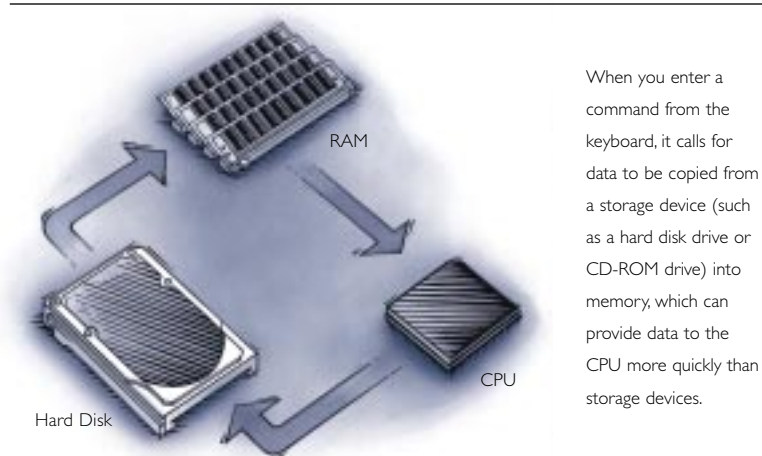
To get an idea of how much things have changed over the last decade, an excerpt from *Inside the IBM PC*, written by Peter Norton in 1983, describes the merits of IBM's new XT computer: "So IBM has equipped all XTs with what it considers to be the minimum gear for a serious personal computer. Now the 10-megabyte disk and the 128K [one eighth of a megabyte] of memory are naturals for a serious machine."

For some, the memory equation is simple: more is good; less is bad. However, for those who want to know more, this reference guide provides a general overview of what memory is and how it works.

what is memory?

People in the computer industry commonly use the term memory to refer to **Random Access Memory**, or **RAM**. A computer uses random access memory to hold temporary instructions and data needed to complete tasks. This enables the computer's **Central Processing Unit**, or **CPU**, to access instructions and data stored in memory very quickly.

A good example of this is when the CPU loads an application program—such as a word processor or page layout program—into memory, thereby allowing the application program to run as quickly as possible. In practical terms, this means you can get more work done with less time spent waiting for the computer to perform tasks.



This “putting things the CPU needs in a place where it can get at them more quickly” process is similar to placing various electronic files and documents you’re using on the computer into a single file folder or directory. By doing so, you keep them handy and avoid searching in several places every time you need those documents.

It's important to save frequently while working on a computer. The computer memory holds any changes you make to a document until you save the changes to a disk. If anything interrupts the computer's operation—such as a power outage or system error—any changes made, but not saved, are lost.

the difference between memory and storage

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People often confuse the terms **memory** and **storage**, especially when describing the amount they have of each. The term memory refers to the amount of RAM installed in the computer, whereas the term storage refers to the available amount of hard disk capacity.

To clarify this common mix-up, it helps to compare your computer to an office that contains a work table and a set of file cabinets.



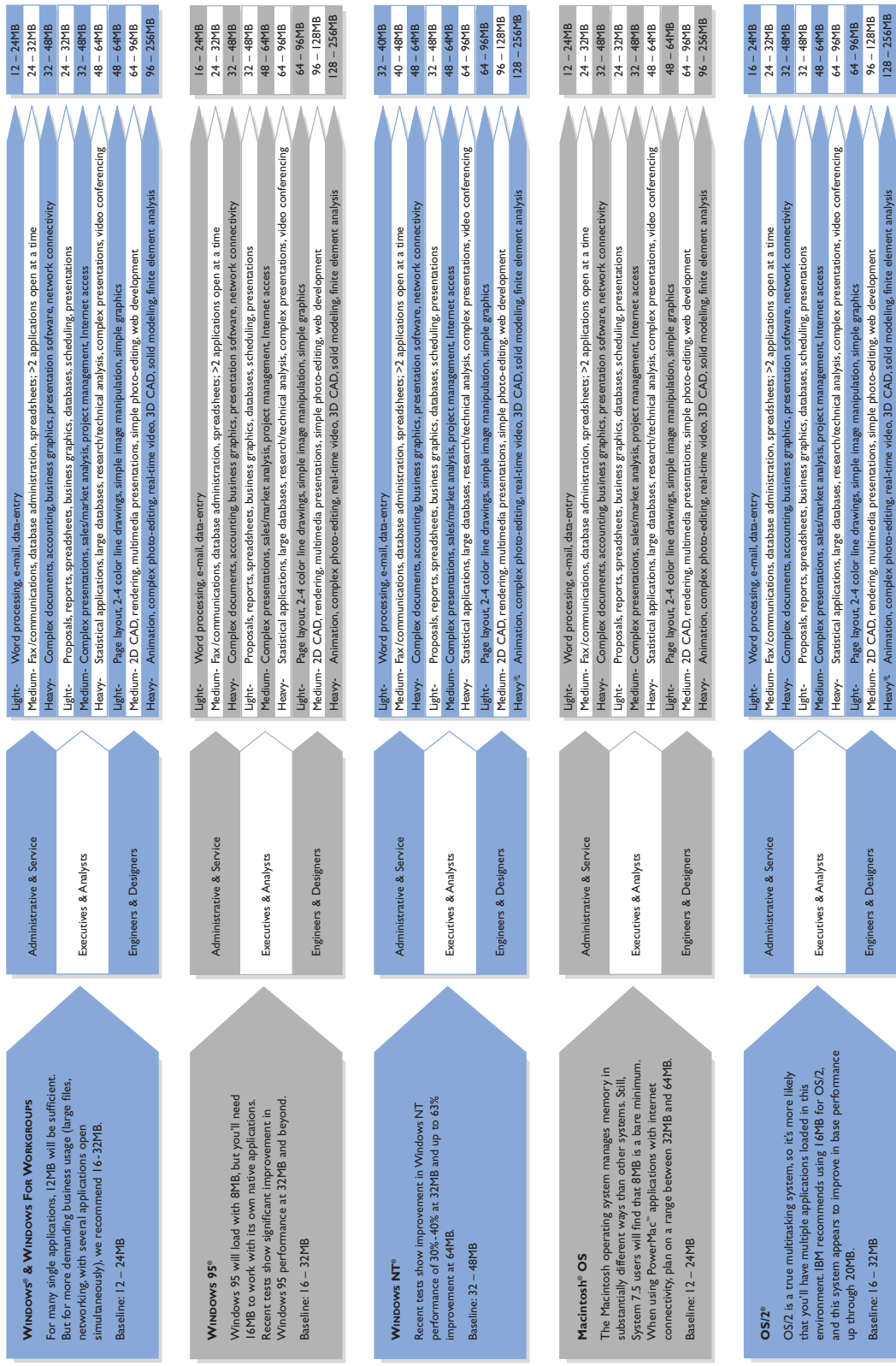
The file cabinets represent the computer's hard disk, which provides high-capacity storage. The work table represents memory, which offers quick and easy access to the files you're working on at the moment.

Another important difference between memory and storage is that the information stored on a hard disk remains intact even when the computer is turned off. However, any data held in memory is cleared when the computer is turned off. (It's like saying that any files left on the work table at closing time will be thrown away.)

how much memory is enough?

The right amount of memory varies according to the type of work you do and the type of software applications you're using. Today's word processing and spreadsheet work requires as little as 12 megabytes. However, systems equipped with 32 megabytes have become the low-end assumption by software and operating system developers. Systems used for graphic arts, publishing, and multimedia call for at least 64 megabytes of memory and it's common for such systems to have 128 megabytes or more.

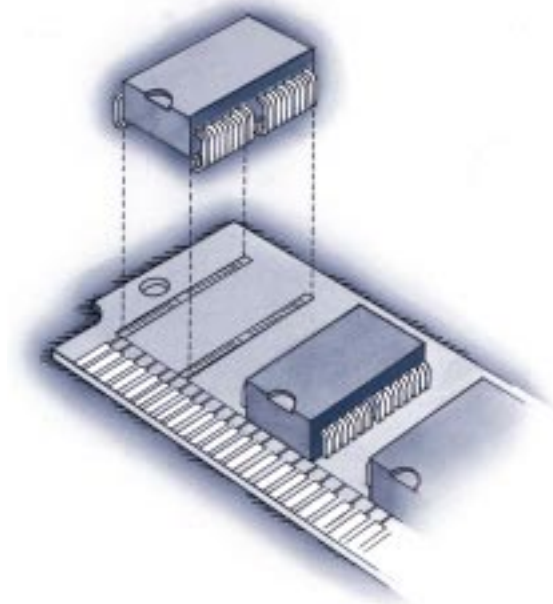
Perhaps you already know what it's like to work on a system that doesn't have quite enough memory. Things run a little more slowly at times, memory errors can occur more frequently, and sometimes you can't launch an application or a file without first closing or quitting another. On a system with sufficient memory, however, you can do multiple tasks at once—such as printing one document while working on another—and you can keep multiple applications open simultaneously.



* Please Note: These figures reflect work done in a typical PC environment. Higher-end workstation tasks may require up to 1GB. Naturally, a chart such as this evolves as memory needs and trends change. Over time, developers of software and operating systems will continue to add features and functionality to their products. This will continue to drive the demand for more memory. More complex character sets, like Kanji, may require more memory than the standard Roman based (english) character sets.

what memory looks like

The **Integrated Circuits**, or **ICs**, that make up your computer's memory configuration are referred to as **Dynamic Random Access Memory**, or **DRAM**. DRAM is by far the most common type of memory chip. The quality of DRAM chips used in a memory module is the most important component in determining the overall quality and reliability of the module.



How DRAM fits
on a SIMM

A common memory product is the **Single In-line Memory Module**, or **SIMM**. As you can see from the illustration, a typical SIMM consists of a number of DRAM chips on a small **Printed Circuit Board**, or **PCB**, which fits into a **SIMM socket** on a computer's **system board** (more on this later).

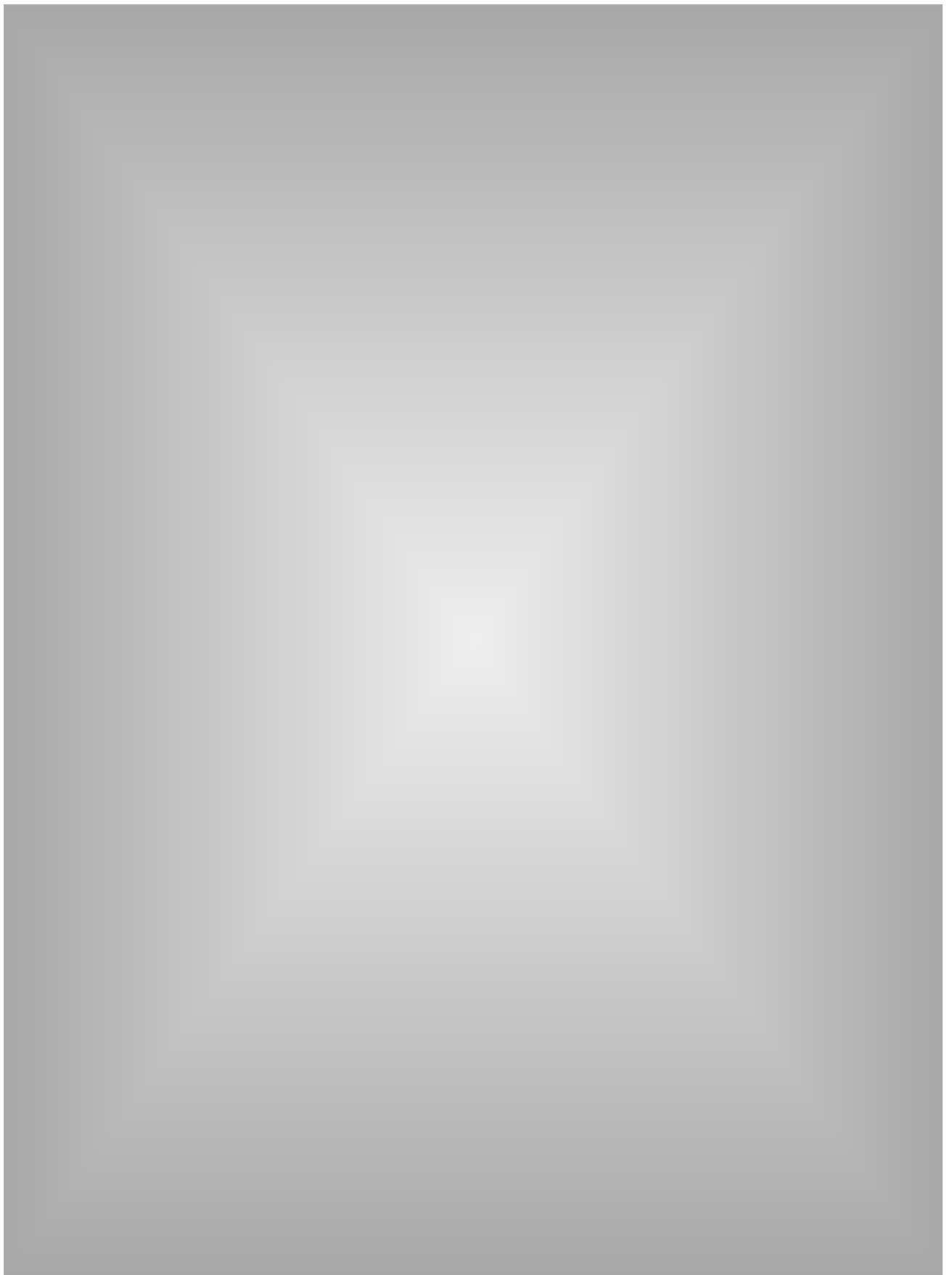
SIMMs come in a variety of forms, including 30- and 72-pin formats. These and other types of memory products are covered in greater detail in the “Bits and Bytes” section on page 23.

A CLOSER LOOK

WHERE MEMORY COMES FROM

WHERE MEMORY GOES IN THE COMPUTER

MEMORY BANKS AND BANK SCHEMAS

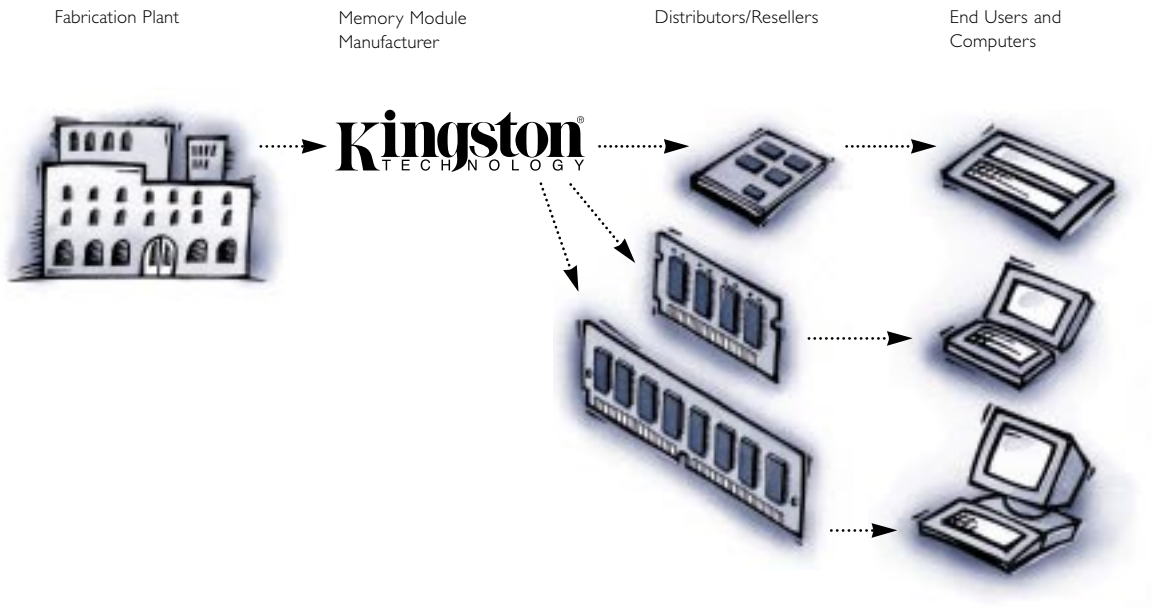


a closer look

In this section you'll find more information on where memory comes from and where it goes in the computer.

where memory comes from

As mentioned in the introduction, DRAM is the most common type of memory chip. These chips are produced in very large, highly specialized fabrication plants. From there, the chips go to memory module manufacturers (like Kingston) where they're used to make different memory products. These products find their way through various distribution channels to people who install them in computers.



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where memory goes in the computer

For memory modules to do their job, they must be in direct communication with the computer's CPU. It used to be that memory was always soldered directly onto the computer's system board (also known as **logic board** or **motherboard**). But as memory requirements increased, it became infeasible to solder all the memory chips onto the system board.

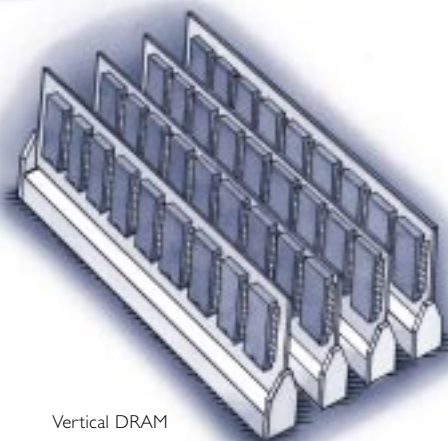
This is how SIMMs and SIMM sockets became popular. The SIMM format offers a flexible method of upgrading memory while using less space on the system board.

One of the key advantages of SIMM memory is the ability to pack large amounts of memory into a small area. Some 72-pin SIMMs contain 20 or more DRAM chips; four of these SIMMs would contain 80 or more DRAM chips. If those 80 chips were installed horizontally on the system board, they would consume 21 square inches of surface area. The same 80 DRAM chips contained on vertically-installed SIMMs consume just 9 square inches of surface area.



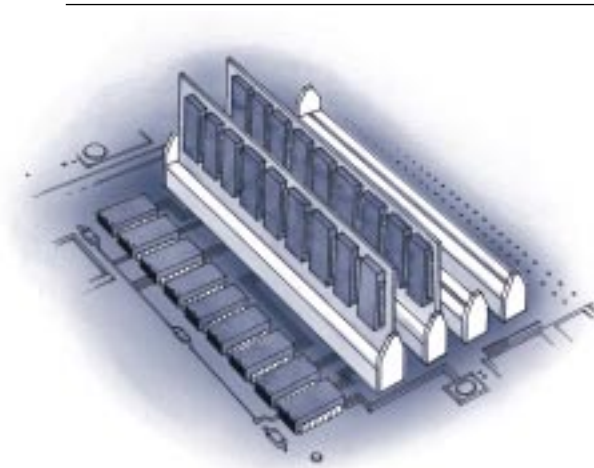
Horizontal DRAM

Horizontal DRAM configuration on a system board and vertical DRAM configuration in SIMMs.



Vertical DRAM on SIMMs

Memory installed on a typical computer system board might look like this:



In this example, the system board has 4 megabytes of memory soldered onto the system board. It also has four SIMM sockets for memory expansion, two of which contain SIMMs.

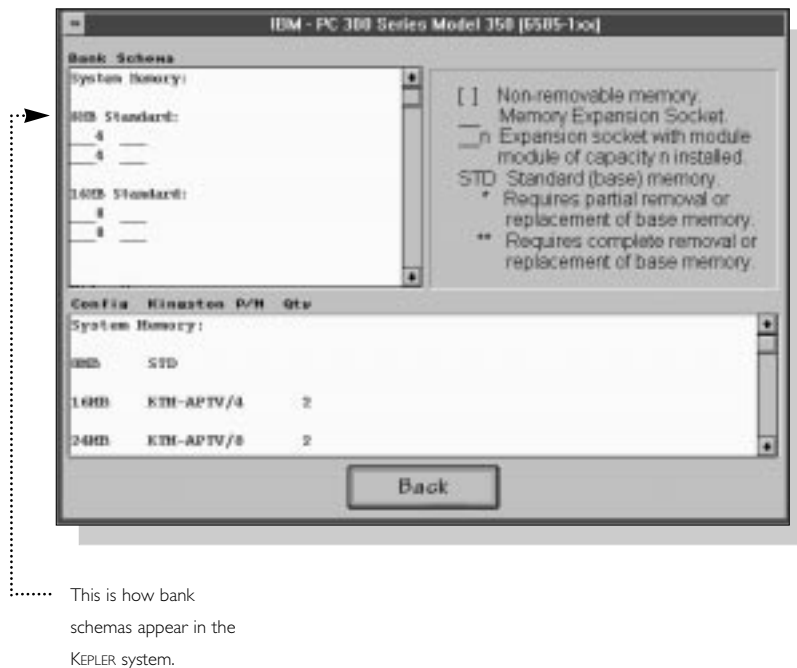
memory banks and bank schemas

Computers have memory arranged in what are called **memory banks**. The number of memory banks and their specific configurations vary from one computer to another because they're determined by the computer's CPU and how it receives information. The needs of the CPU determine the number of memory sockets required in a bank.

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While we can't look at every possible memory configuration, we can look at a system for depicting memory configuration requirements called the **bank schema**. A bank schema is a diagram of rows and columns that shows the number of memory sockets in a system. This visual display is a theoretical bank layout and not an actual system board layout; it is designed to help you quickly determine the configuration requirements when adding memory modules.

Kingston uses the bank schema system to help customers easily understand the configuration rules of various computer systems. The bank schema system appears in Kingston's product documentation, which includes the Kingston *Upgrade Manual* (a hard copy reference) and an electronic reference system called KEPLER™.



This is how bank schemas appear in the KEPLER system.

IBM MEMORY

PC 300 Series Model 350 (6585-1xx), Model 330 (6575-1xx)



SYSTEM MEMORY FEATURES: Standard Memory: 8MB or 16MB (removable) system memory
1MB (non-removable) video memory
Maximum Memory: 128MB system memory
2MB video memory
Expansion: 4 sockets (2 banks of 2) system memory
2 sockets (1 bank of 2) video memory


KINGSTON MEMORY PRODUCTS:

Product Description:	# pieces:	Kingston Part Number:	Mfr Part Number:
4MB Module	1	KTM-APT/4	92G7539
8MB Module	1	KTM-APT/8	92G7541
16MB Module	1	KTM-APT/16	92G7543
32MB Module	1	KTM-APT/32	92G7545
1MB Video Upgrade Kit	2	KTM7443/1	92G7443

COMMENTS: MODULES MUST BE ORDERED AND INSTALLED IN PAIRS

BANK SCHEMA: System Memory:

8MB Standard:  16MB Standard: 

Video Memory
[1MB]


MEMORY UPGRADE PATH(S):

8MB Standard:		48MB**		(2) KTM-APT/16		96MB**		(2) KTM-APT/32	
16MB	(2) KTM-APT/4			(2)	KTM-APT/8			(2)	KTM-APT/16
24MB	(2) KTM-APT/8	72MB	(2) KTM-APT/32	128MB**	(4) KTM-APT/32				
40MB	(2) KTM-APT/16	80MB**	(2) KTM-APT/8						

16MB Standard:		48MB		(2) KTM-APT/16		128MB**		(4) KTM-APT/32	
24MB	(2) KTM-APT/4	80MB	(2) KTM-APT/32						
32MB	(2) KTM-APT/8	96MB**	(2) KTM-APT/32						
			(2) KTM-APT/16						

Video Memory:

1MB		STD	
2MB	(1)	KTM7443/1	

** Requires replacement of all standard memory where indicated.

526 KINGSTON UPGRADE MANUAL 1998 EDITION

This is how bank schemas appear in the Kingston Upgrade Manual.

HOW MEMORY WORKS

BITS AND BYTES

CPU AND MEMORY REQUIREMENTS

30-PIN SIMMS

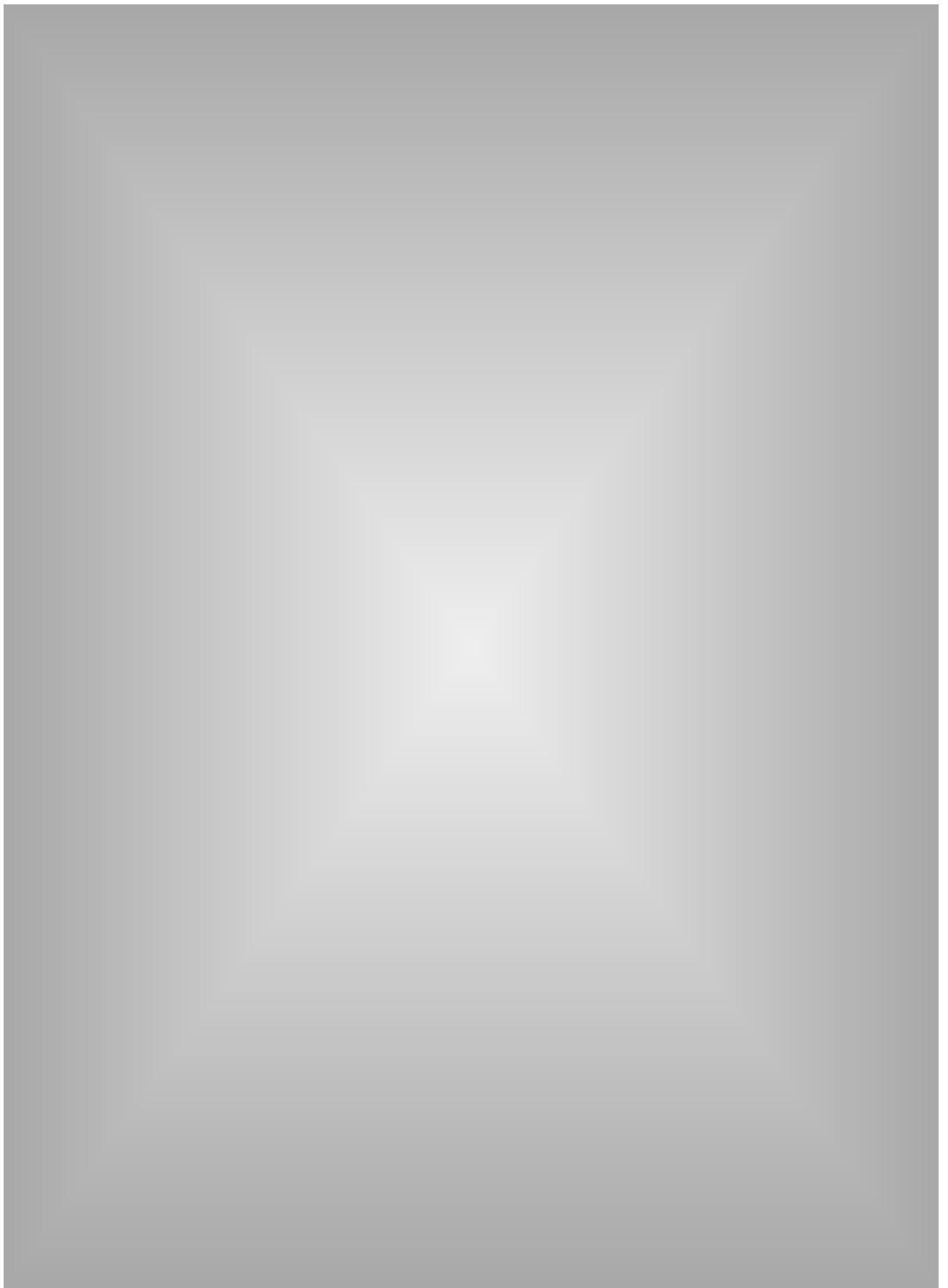
72-PIN SIMMS

CREDIT CARD MEMORY

DIMM MEMORY

SMALL OUTLINE DIMMS

MORE ABOUT PROPRIETARY MEMORY



how memory works

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Up to now, we've alluded to some of the technical attributes of memory and how it functions in a system. Now we're down to the technical aspect—the bits and the bytes. In this section we discuss the **binary** numbering system that forms the basis of computing and how memory modules are designed to work within the binary system.

bits and bytes

Your computer speaks a language made up of only two numerals: 0 and 1. This two-numeral form of communication is called machine language; the numerals combine to form binary numbers. Machine language uses binary numbers to form instructions for the chips and microprocessing devices that drive computing devices—such as computers, printers, hard disk drives, and so on.

You may have heard the terms **bit** (short for binary digit) and **byte**. A bit is the smallest unit used by your computer and can be either a 1 or a 0. A byte consists of 8 bits (more about bytes later). Because binary numbers consist of only 1's and 0's, binary number values appear different from the decimal values we use in everyday life. For example, in the decimal system when you see the number 1 followed by two 0's (100), you know it represents a value of one hundred. In binary, however, the same number combination—100—represents a value of four.

DECIMAL NUMBERS AND THEIR BINARY EQUIVALENTS

DECIMAL		▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼
tens		0	0	0	0	0	0	0	0	0	0	1	1	1	1
ones		0	1	2	3	4	5	6	7	8	9	0	1	2	3
BINARY		=	=	=	=	=	=	=	=	=	=	=	=	=	=
eights		0	0	0	0	0	0	0	0	1	1	1	1	1	1
fours		0	0	0	0	1	1	1	1	0	0	0	0	1	1
twos		0	0	1	1	0	0	1	1	0	0	1	1	0	0
ones		0	1	0	1	0	1	0	1	0	1	0	1	0	1

The process of counting in binary numbers isn't all that different from the decimal system. As you count in decimals, when you reach 9, the count resets to 0 and a 1 shifts into the tens column. When you count in binary, the process is very similar. However, because there are only two numerals, the resetting and shifting of digits happens more quickly.

Take a look at the table above. On the top are the decimal numbers 0 through 15; on the bottom are the binary equivalents.

Going back to how machine language uses 1's and 0's, remember that each digit in a binary number represents 1 bit. Machine language thinks of each bit as either "on" or "off." A bit with a value of 1 is considered "on," and a bit with a value of 0 is "off." Therefore, determining the value of a binary number is simply a matter of adding up the columns that are "turned on," in other words, wherever a 1 appears. (This "on/off" idea comes in handy later.)

In the decimal numbering system, each column (ones, tens, hundreds, and so on) has ten times the value of the previous column. In the binary numbering system, however, each column has a value twice that of the previous column (ones, twos, fours, eights, sixteens, and so on).

**DECIMAL AND BINARY
NUMBER COMPARISON**

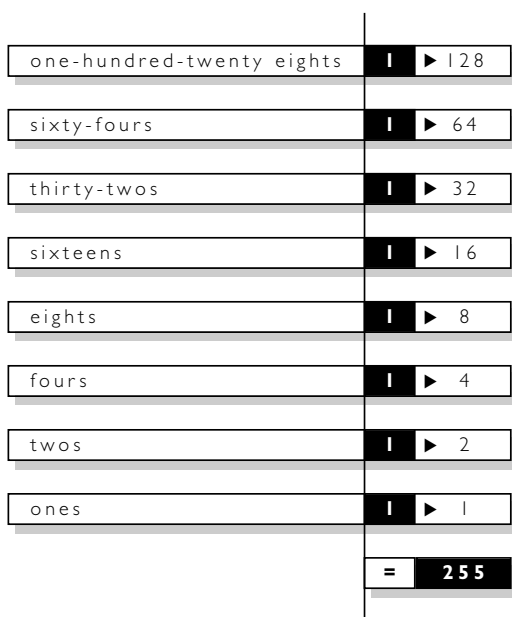
DECIMAL		
hundreds	1	▶ 100
tens	1	▶ 10
ones	1	▶ 1
	=	111
BINARY		
fours	1	▶ 4
twos	1	▶ 2
ones	1	▶ 1
	=	7

This example compares the same number combination (111) in each of the two systems. In the decimal numbering system, the number 111 represents the addition of 100+10+1. In binary, 111 represents a binary value of 7 because it's the result of adding 4+2+1.

Because your computer understands binary values consisting of 1's and 0's, a binary value exists for every possible keyboard character. The most widely accepted standardized system for numbering keyboard characters is called the **ASCII** system. (ASCII is pronounced "askee" and stands for **American Standard Code for Information Interchange**.)

EIGHT BINARY DIGITS

It takes up to 256 different binary number combinations (0 through 255) to describe every possible keystroke you might enter from your keyboard. Representing the decimal numbers 0 through 255 requires eight binary digits. As you can see here, the highest number value (255) is that in which all eight columns are “turned on,” or contain the numeral 1.



We mentioned earlier that 8 bits—represented by 8 binary digits—together are referred to as a byte. 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** or megabytes). The following table summarizes how to refer to quantities of bits and bytes.

**TERMS FOR MULTIPLE
BITS AND BYTES**

When calculating multiple bits and bytes, something potentially confusing is how the letter K (kilo) is used to express quantities of bytes or bits. Outside the computer environment, a kilo represents 1,000 units. However, in computer science, the kilo prefix represents exactly 1,024 units, or 2^{10} .

bit	▶	a single 0 or 1
kilobit (Kb)	▶	1 bit \times 1,024 (1,024 bits)
megabit (Mb)	▶	1 bit \times 1,024 ² (1,048,576 bits)
gigabit (Gb)	▶	1 bit \times 1,024 ³ (1,073,741,824 bits)
byte	▶	8 bits
kilobyte (KB)	▶	1 byte \times 1,024 (1,024 bytes)
megabyte (MB)	▶	1 byte \times 1,024 ² (1,048,576 bytes)
gigabyte (GB)	▶	1 byte \times 1,024 ³ (1,073,741,824 bytes)

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 by the maximum number of bytes it can process at any given time. For example, the most powerful Pentium and PowerPC microprocessors currently are 64-bit CPUs, 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 use either 72- or 30-pin SIMMs. A 30-pin SIMM supports 8 data bits; a 72-pin SIMM supports 32 data bits.

30-pin SIMMs

Let's look at the example of a CPU that supports 32 data bits. If the computer's system board has 30-pin SIMM sockets, each of which supports 8 data bits, you'll need four 30-pin SIMMs to supply 32 bits. This is a common configuration for systems that use 30-pin SIMMs. The memory configuration on such a system is typically divided into two memory banks—bank zero and bank one. Each memory bank consists of four 30-pin SIMM sockets. The CPU addresses memory one bank at a time.

note: With most computer models, mixing different-capacity SIMMs within the same bank prevents the computer from accurately detecting the amount of available memory. This causes one of two things to occur:

- 1) The computer will not boot up.
- 2) The computer will boot up but will not recognize or use some of the memory in the bank. For example, if a bank had three 1-megabyte SIMMs and one 4-megabyte SIMM, it would recognize them all as 1-megabyte SIMMs.

credit card memory

“Credit card memory” is designed for use in notebook computers. Because of its compact form factor, credit card memory is ideal for applications where space is limited. (Credit card memory got its name because the form factor is the approximate size of a credit card.)

Credit Card Memory



On the surface, there are few similarities between credit card memory and the SIMM-style memory described earlier. However, inside are the same familiar components used in the construction of SIMMs.

note: Although their appearances are similar, a credit card memory module is not to be confused with a **PC Card (PCMCIA: Personal Computer Memory Card International Association)**. Credit card memory uses a non-PC Card slot on the computer and is designed only to provide memory expansion. Kingston, however, does offer products that conform to the PC Card standard, which is designed for attaching input/output devices to laptop and portable computers.

DIMM memory

Dual In-line Memory Modules, or **DIMMs**, closely resemble SIMM-type memory. Like SIMMs, most DIMMs install vertically into expansion sockets. The principal difference between the two is that on a SIMM, opposing pins on either side of the board are “tied together” to form one electrical contact; on a DIMM, opposing pins remain electrically isolated to form two separate contacts.

DIMMs are often used in computer configurations that support a 64-bit or wider memory bus. In many cases, these computer configurations are based on powerful 64-bit processors like Intel’s Pentium or IBM’s PowerPC processors.

For example, Kingston’s KTM40P/8 DIMM module used in IBM’s PowerPC 40P RISC 6000 computer is a 168-pin DIMM.

small outline DIMMs

Another type of memory commonly used in both notebook and laptop computers is called **Small Outline DIMM**, or **SO DIMM**. A small outline DIMM is like a 72-pin SIMM in a reduced-size package, but with some important technical differences. The small outline DIMM and the SIMM shown opposite both have 72 pins. However, it’s the way the pins are arranged that differentiates these two types of memory.



SO DIMM

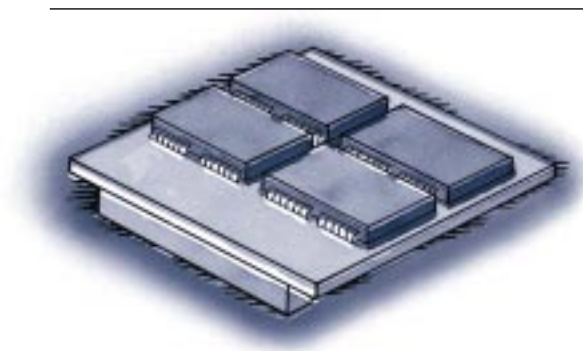
72-pin SIMM

168-pin DIMM

The three examples illustrate the differences among SIMM, DIMM, and SO DIMM products. The full-size, 168-pin DIMM supports 64-bit transfers without being twice the size of the 72-pin SIMM which supports only 32-bit transfers. The SO DIMM also supports 32-bit transfers and was designed for use in notebook computers.

more about proprietary memory

By definition, **proprietary memory** is memory designed specifically for a particular manufacturer or computer model. For example, the KCN-IB150/16 proprietary module is used in Canon® INNOVA notebook computers.



The form factor for the KCN-IB150/16 memory upgrade is extremely small, which allows it to be installed in areas where very little space is available.

The KCN-IB150/16 is only one in many examples of proprietary memory. Kingston manufactures several other proprietary modules, including many credit card and DIMM components. As mentioned earlier, the term proprietary does not apply to a particular type of memory, it simply means the memory upgrade is applicable to only one type of computer. Keep in mind that a memory module doesn't require a unique appearance to be proprietary. Kingston also sells proprietary versions of SIMMs, DIMMs, and SO DIMMs. In fact, the DIMM memory example highlighted in the "DIMM memory" section is a proprietary memory module.

MEMORY DATA INTEGRITY CHECKING

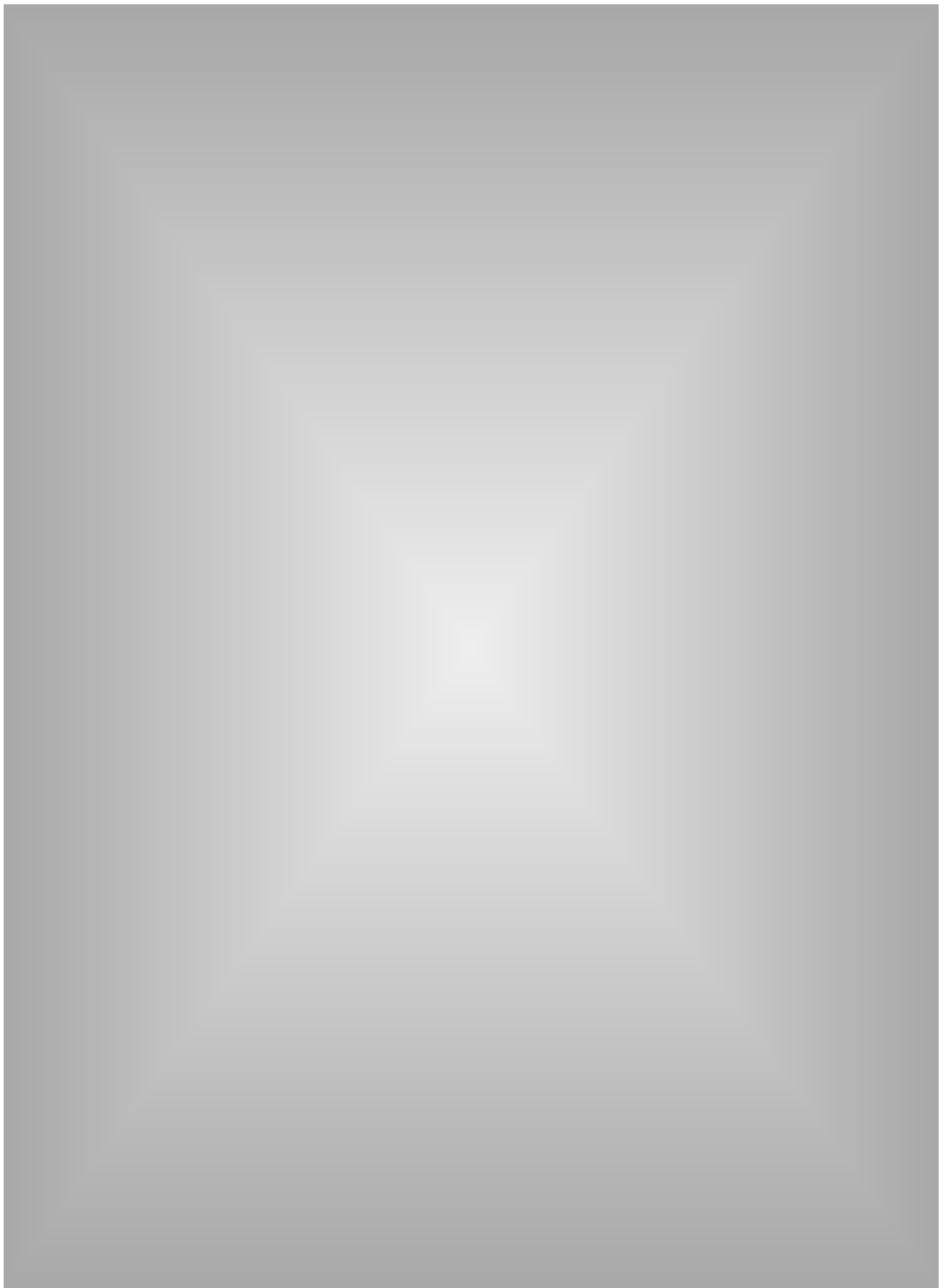
A WORD ABOUT THE MEMORY CONTROLLER

PARITY

AN ADVISORY ABOUT “FAKE PARITY”

ECC

**WHAT KIND OF SIMMs ARE USED IN
ECC CONFIGURATIONS?**



memory data integrity checking

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One aspect of memory design involves ensuring the integrity of data stored in memory. Currently, there are two primary methods to ensure the integrity of data stored in memory:

- **Parity** has been the most common method used to date. This process adds 1 additional bit to every 8 bits (1 byte) of data.
- **Error Correction Code (ECC)** is a more comprehensive method of data-integrity checking that can detect and correct single-bit errors.

Due to price competition, it is becoming more common among personal computer manufacturers not to use data integrity checking. They are eliminating the need for more expensive parity memory, for example, to lower the price of their computers. (This trend is complemented by the increased quality of memory components available from certain manufacturers and, as a result, the relative infrequency of memory errors.)

a word about the memory controller

The **memory controller** is an essential component in any computer. Simply stated, its function is to oversee the movement of data into and out of memory. The memory controller determines what type of data integrity checking, if any, is supported. With methods such as parity and ECC, the memory controller plays an active role in the process.

The decision about data-integrity checking must be made when you purchase your computer. If the computer is to play a critical role—as a server, for example—then a computer with an ECC-capable memory controller is an appropriate choice. Most computers designed for use as high-end servers are designed to support ECC. Most desktop computers designed for use in business and government are designed to support parity. Most low-cost computers designed for use at home or in small businesses are designed for nonparity memory.

parity

When parity is in use on a computer system, one parity bit is stored in DRAM along with every 8 bits (1 byte) of data. The two types of parity protocol—**odd parity** and **even parity**—function in similar ways. This table shows how odd parity and even parity work. The processes are identical but with opposite attributes.

	ODD PARITY	EVEN PARITY
step 1	<p>The parity bit will be forced to 1 (or turned “on”) if its corresponding byte of data contains an even number of 1’s.</p> <p>If the byte contains an odd number of 1’s, the parity bit is forced to 0 (or turned “off”).</p>	<p>The parity bit is forced to 1 if its corresponding byte of data contains an odd number of 1’s.</p> <p>The parity bit is forced to 0 if the byte contains an even number of 1’s.</p>
step 2	The parity bit and the corresponding 8 bits of data are written to DRAM.	(Same as for odd parity)
step 3	<p>Just before the data is sent to the CPU, it is intercepted by the parity circuit.</p> <p>If the parity circuit sees an odd number of 1’s, the data is considered valid. The parity bit is stripped from the data and the 8 data bits are passed on to the CPU.</p> <p>If the parity circuit detects an even number of 1’s, the data is considered invalid and a parity error is generated.</p>	<p>(Same as for odd parity)</p> <p>Data is considered valid if the parity circuit detects an even number of 1’s.</p> <p>Data is invalid if the parity circuit detects an odd number of 1’s.</p>

The parity method does have its limitations. For example, a parity circuit can detect an error, but cannot perform any correction. This is because the circuit can't determine which of the 8 data bits are invalid. Furthermore, if multiple bits are invalid, the parity circuit will not detect the problem if the data matches the odd or even parity condition that the parity circuit is checking for. For example, if a valid 0 becomes an invalid 1 and a valid 1 becomes an invalid 0, the two defective bits cancel each other out and the parity circuit misses the resulting errors. Fortunately, the chances of this happening are extremely remote. **39**

an advisory about “fake parity”

With normal parity, when 8 bits of data are written to DRAM, a corresponding parity bit is written at the same time. The value of the parity bit (either a 1 or 0) is determined at the time the byte is written to DRAM, based on an odd or even quantity of 1's. Some manufacturers use a less expensive “fake parity” chip. This chip simply generates a 1 or a 0 at the time the data is being sent to the CPU in order to accommodate the memory controller. (For example, if the computer uses odd parity, the fake parity chip will generate a 1 when a byte of data containing an even number of 1's is sent to the CPU. If the byte contains an odd number of 1's, the fake parity chip will generate a 0.) The issue here is that the fake parity chip sends an “OK” signal no matter what. This way, it “fools” a computer that's expecting the parity bit into thinking that parity checking is actually taking place when it is not. Fake parity cannot detect an invalid data bit.

ECC

Error Correction Code is used primarily in high-end PCs and file servers. The important difference between ECC and parity is that ECC is capable of detecting and correcting 1-bit errors. With ECC, 1-bit error correction usually takes place without the user even knowing an error has occurred. Depending on the type of memory controller your computer uses, ECC can also detect rare 2-, 3-, or 4-bit memory errors. However, while ECC can detect these multiple-bit errors, it can only correct single-bit errors. In the case of a multiple-bit error, the ECC circuit reports a parity error.

Using a special algorithm (mathematical sequence) and working in conjunction with the memory controller, the ECC circuit appends ECC bits to the data bits and together they are stored in memory. When data is requested from memory, the memory controller decodes the ECC bits and determines if one or more of the data bits are corrupted. If there's a single-bit error, the ECC circuit corrects the bit. As mentioned, in the rare case of a multiple-bit error, the ECC circuit reports a parity error.

what kind of SIMMs are used in ECC configurations? 41

If you see a 72-pin SIMM with a $\times 39$ or $\times 40$ width specification, you can be reasonably certain that the SIMM is designed exclusively for ECC. However, some high-end PCs and many file servers use pairs of $\times 36$ SIMMs for ECC error checking. Two $\times 36$ SIMMs supply a total of 72 bits; 64 bits are used for data and 8 bits are used for ECC. This can be confusing because when these same $\times 36$ modules are used in other configurations, they are simply parity modules. This reinforces the point that whether or not a system performs parity or ECC error checking depends more on the memory controller than it does on the memory module. The memory module provides the bits, but it is the memory controller that decides how they will be used. Generally, in order to use ECC memory, your computer must include a memory controller designed to take advantage of ECC technology.

There is a new technology called **ECC on SIMM**, or **EOS**, that offers ECC capability on systems designed for parity. So far, this technology has been rather expensive. In addition, its application may remain limited simply because most people who want ECC decide so before purchasing a computer and therefore can get ECC support in the computer more affordably than on EOS modules.

MORE ABOUT MEMORY TECHNOLOGIES

SIMM MODULE IDENTIFICATION

REFRESH

3.3-VOLT VERSUS 5-VOLT

COMPOSITE VERSUS NONCOMPOSITE

EDO MEMORY

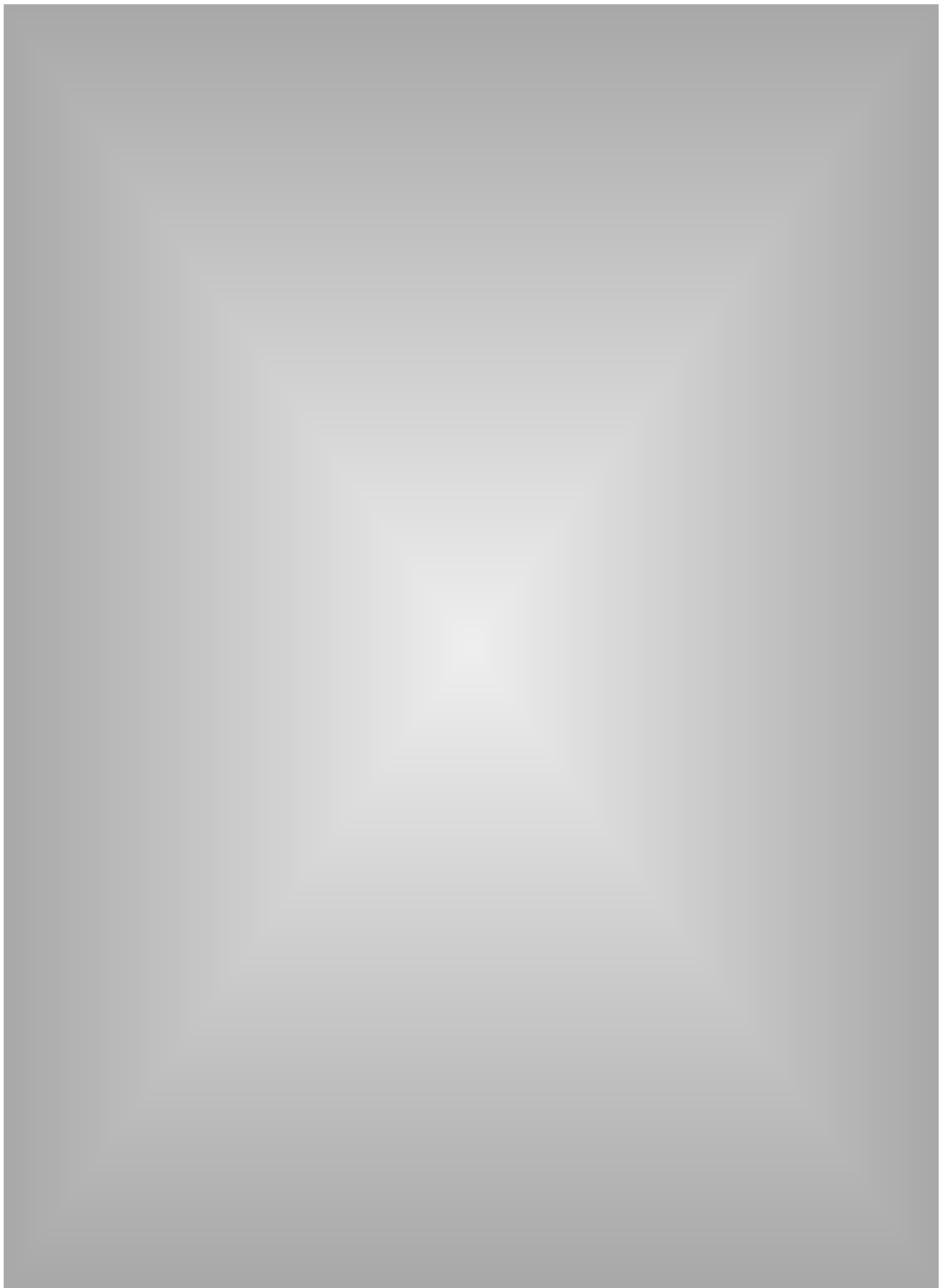
SYNCHRONOUS DRAM

DDR OR SDRAM II

RDRAM (RAMBUS DRAM)

SLDRAM (SYNCLINK DRAM)

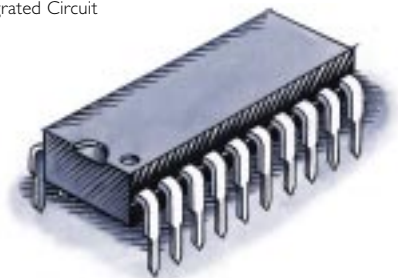
CACHE MEMORY



more about memory technologies

DRAM chips come primarily in three forms: **DIP (Dual In-line Package)**, **SOJ (Small Outline J-lead)**, and **TSOP (Thin, Small Outline Package)**. Each is designed for specific types of applications.

DIP Integrated Circuit



The DIP-style DRAM package was extremely popular when it was common for memory to be installed directly on the computer's system board. DIPs are through-hole components, which means they install in holes extending into the surface of the printed circuit board. DIPs can be soldered in place or installed in sockets.

SOJ DRAM Package



SOJ and TSOP packages are surface-mount components—that is, they mount directly onto the surface of the printed circuit board. TSOP and SOJ gained status with the advent of the SIMM. Of the two, the SOJ package is by far the most popular.

TSOP DRAM Package



SIMM module identification

SIMMs, just like the DRAM chips that comprise them, are specified in terms of depth and width, which indicate the SIMM's capacity and whether or not it supports parity. Here are some examples of popular 30- and 72-pin SIMMs. Note that the parity SIMMs are distinguished by the "x9" or "x36" format specification.

Note that the parity SIMMs are distinguished by the "x9" or "x36" format specifications. This is because parity memory adds a parity bit to every 8 bits of data. So, 30-pin SIMMs provide 8 data bits per cycle, plus a parity bit, which equals 9 bits; 72-pin SIMMs provide 32 data bits per cycle, plus 4 parity bits, which equals 36 bits.

SIMM TYPE	SIMM FORMAT	SIMM CAPACITY
30-pin	256K x 8	256K
	1M x 8	1MB
	4M x 8	4MB
	256K x 9 (parity)	256K
	1M x 9 (parity)	1MB
	4M x 9 (parity)	4MB
72-pin	256K X 32	1MB
	1M X 32	4MB
	2M X 32	8MB
	4M X 32	16MB
	8M X 32	32MB
	256K X 36 (parity)	1MB
	1M X 36 (parity)	4MB
	2M X 36 (parity)	8MB
	4M X 36 (parity)	16MB
	8M X 36 (parity)	32MB

refresh

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A memory module is made up of electrical cells. The **refresh** process recharges these cells, which are arranged on the chip in rows. The **refresh rate** refers to the number of rows that must be refreshed.

Two common refresh rates are 2K and 4K. The 2K components are capable of refreshing more cells at a time and they complete the process faster; therefore, 2K components use more power than 4K components.

Other specially-designed DRAM components feature **self refresh** technology, which enables the components to refresh on their own— independent of the CPU or external refresh circuitry. Self refresh technology, which is built into the DRAM chip itself, reduces power consumption dramatically. It is commonly used in notebook computers.

3.3-volt versus 5-volt

Computer memory components operate at either 3.3 volts or 5 volts. Until recently, 5 volts was the industry standard. Making integrated circuits, or ICs, faster requires a reduced cell geometry, that is, a reduction in the size of the basic “building blocks.” As components become smaller and smaller, the cell size and memory circuitry also become smaller and more sensitive. As a result, these components cannot withstand the stress of operating at 5 volts. Also, 3.3-volt components can operate faster and use less power.

composite versus noncomposite modules

The terms **composite** and **noncomposite** refer to the number of chips used on a given module. The term noncomposite describes memory modules that use fewer chips. For a module to work with fewer chips, those chips must be higher in density to provide the same total capacity. This table summarizes the primary differences between composite and noncomposite modules.

NONCOMPOSITE MODULES	COMPOSITE MODULES
Newer 16-Mbit technology Achieves memory capacity with fewer chips	Older 4-Mbit technology Requires more chips to achieve capacity

EDO memory

Extended Data Out, or **EDO** memory, is one of a series of recent innovations in DRAM chip technology. On computer systems designed to support it, EDO memory allows a CPU to access memory 10 to 20 percent faster than comparable **fast-page mode** chips.

synchronous DRAM

Synchronous DRAM (SDRAM) uses a clock to synchronize signal input and output on a memory chip. The clock is coordinated with the CPU clock so the timing of the memory chips and the timing of the CPU are in “synch.” Synchronous DRAM saves time in executing commands and transmitting data, thereby increasing the overall performance of the computer. SDRAM memory allows the CPU to access memory approximately 25 percent faster than EDO memory.

DDR or SDRAM II

Double-data rate SDRAM is a faster version of SDRAM that is able to read data on both the rising and the falling edge of the system clock, thus doubling the data rate of the memory chip. In music, this would be similar to playing a note on both the upbeat and the downbeat.

RDRAM® (Rambus™ DRAM)

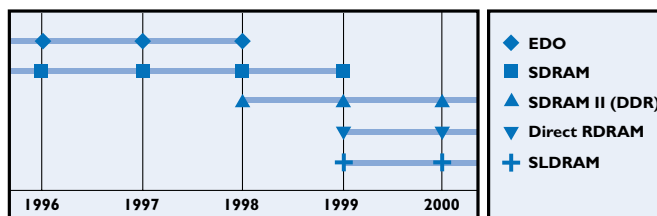
RDRAM is a unique design developed by a company called Rambus, Inc. RDRAM is extremely fast and uses a narrow, high-bandwidth “channel” to transmit data at speeds about ten times faster than standard DRAM. Rambus technology is expected to be used as main PC memory starting in about 1999.

SLDRAM (Synclink DRAM)

SLDRAM is the major competing technology to RDRAM. Backed by a consortium of chip manufacturers, Synclink extends the Synchronous DRAM four-bank architecture to 16 banks and incorporates a new system interface and control logic to increase performance.

The graph below is an approximate time-line regarding the emergence of memory technologies used for main memory in personal computers.

SDRAM and beyond...



Source: Toshiba, Intel, and Rambus

cache memory

Cache memory is a special high-speed memory designed to accelerate processing of memory instructions by the CPU. The CPU can access instructions and data located in cache memory much faster than instructions and data in main memory. For example, on a typical 100-megahertz system board, it takes the CPU as much as 180 **nanoseconds** to obtain information from main memory, compared to just 45 nanoseconds from cache memory. Therefore, the more instructions and data the CPU can access directly from cache memory, the faster the computer can run.

Types of cache memory include primary cache (also known as Level 1 [L1] cache) and secondary cache (also known as Level 2 [L2] cache). Cache can also be referred to as internal or external. Internal cache is built into the computer's CPU, and external cache is located outside the CPU.

Primary cache is the cache located closest to the CPU. Usually, primary cache is internal to the CPU, and secondary cache is external. Some early-model personal computers have CPU chips that don't contain internal cache. In these cases the external cache, if present, would actually be the primary (L1) cache.

Earlier we used the analogy of a room with a work table and a set of file cabinets to understand the relationship between main memory and a computer's hard disk. If memory is like the work table that holds the files you're working on making them easy to reach, cache memory is like a bulletin board that holds the papers you refer to most often. When you need the information on the bulletin board you simply glance up and there it is.



Cache memory is like a bulletin board that makes the work at the memory "work table" go even faster.

Memory is like a work table that makes immediate work easily accessible.

You can also think of cache memory as a worker's tool belt that holds the tools and parts needed most often. In this analogy, main memory is similar to a portable tool box and the hard disk is like a large utility truck or a workshop.

The "brain" of a cache memory system is called the cache memory controller. When a cache memory controller retrieves an instruction from main memory, it also takes back the next several instructions to cache. This occurs because there is a high likelihood that the adjacent instructions will also be needed. This increases the chance that the CPU will find the instruction it needs in cache memory, thereby enabling the computer to run faster.

THE MEMORY MARKET

DRAM MANUFACTURERS

HOW MEMORY IS SOLD

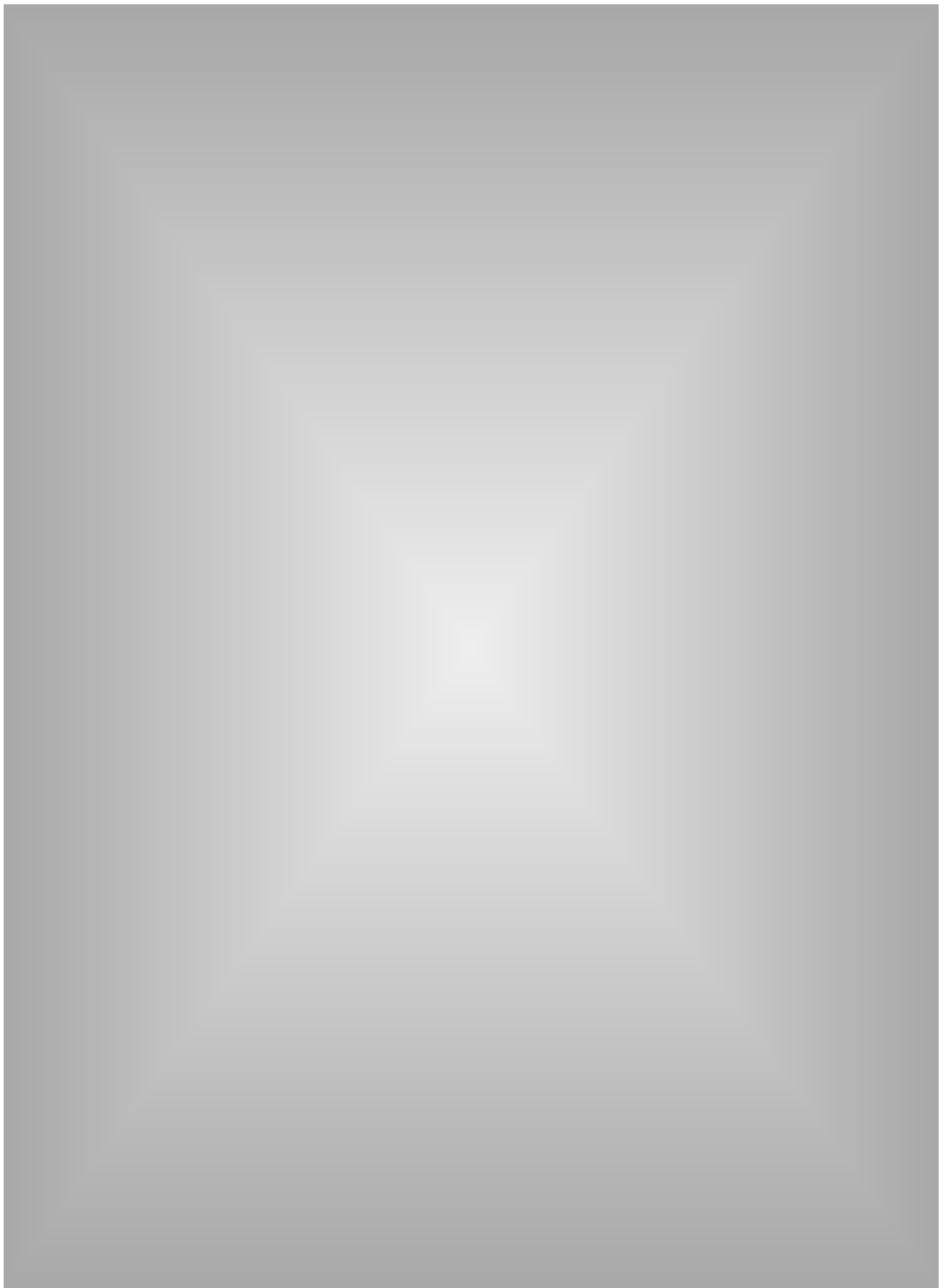
THE BROKER MARKET

THE GRAY MARKET

WHAT DRIVES DEMAND FOR MEMORY

CHOOSING HIGH-QUALITY MEMORY

DRAM MANUFACTURERS AND SAMPLE PART NUMBERS



the memory market

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While the majority of this guide talks about how memory functions, this section is dedicated to describing aspects of the memory business.

DRAM manufacturers

As mentioned, the most important components of a memory module are its memory chips. The quality of the DRAM chips used determines the overall reliability of the module.

The large manufacturing plants required to build DRAM chips cost a great deal of money—over \$2 billion for a typical plant—and can take up to two years to build. Making the decision to build a DRAM manufacturing facility requires careful consideration. To justify such a decision, a company must be able to predict the demand for the product two years in advance and sell the DRAM for a sufficient period of time and at a high enough price to cover the investment and make a profit.

Add to this the factor of evolving technologies: computer technology advances at such a rapid pace that by the time a company has built a plant to produce a particular DRAM chip, the technology and the demand for that chip may be outdated. Also, if there's a surplus of chips on the market and prices decline, a company may not be able to cover the cost of building the manufacturing facility—let alone make a profit.

Because of the heavy investment and risk involved in manufacturing DRAM chips, DRAM manufacturers tend to be large, established companies. Many of these companies are government-subsidized or rely on partnerships with other large companies (such as Hitachi®, Toshiba®, Samsung® and so on) to generate the required capital.

how memory is sold

Once the manufacturing facilities are built, DRAM manufacturers must make and sell extremely large quantities of chips in order for the investment to pay off. Eighty percent of DRAM production is sold to companies that buy in quantities of 5,000 to 120,000 units based on long-term contracts. The duration of the contracts can range from three months to one year, during which time the quantity purchased and the price are guaranteed. This system protects the chip manufacturers from fluctuations in the DRAM market and ensures steady profits. DRAM manufacturers tend to limit their contract-based DRAM sales to well-established companies with whom they have developed long-term relationships. Companies sell the remaining 20 percent of their chips—those not tied to contracts—to smaller companies through a distribution channel. Again, this is to protect the DRAM manufacturers from fluctuations in pricing and to ensure economies of scale.

the broker market

In many cases, a company that buys chips on contract ends up with more than it needs. When this occurs, the company sells the excess inventory to memory brokers who buy and sell memory the same way a stock broker buys and sells stock. Brokers typically have sales channels in numerous countries, will buy from whoever gives them the lowest price, and sell to whoever pays the highest price. Because the memory market fluctuates daily, memory components may pass through the hands of several brokers before they end up in a computer.

the gray market

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The gray market is similar to the broker market; in fact, the terms are often used interchangeably. The primary distinguishing attribute of the gray market is that the seller is not authorized by the original manufacturer. For example, if you buy Kingston memory from someone who is not an authorized Kingston reseller, you are buying on the gray market. In such a case, you can be sure the memory has changed hands at least once since it was sold by the last authorized member of the distribution channel.

what drives demand for memory

As you can see, the memory market is governed by classic supply-and-demand economics. The factors that create demand for memory include:

- The development of high-performance software applications and operating systems such as Windows® NT and OS/2®
- Increased need for memory in a variety of consumer products such as video games, automobiles, and cellular phones
- Increased capabilities in film, multimedia, and video conferencing software packages
- An increase in both the number of personal computers sold and their standard memory configurations
 - In 1996, worldwide PC shipments grew roughly 19 percent to 70 million units; forecasts for the year 2000 predict almost 120 million systems shipped worldwide
 - Previously, standard configurations ranged from 1 to 4 megabytes of memory; currently, most new systems come standard with 16 or 32 megabytes and require upgrading to 64MB to utilize new software applications

- The migration to Microsoft® Windows® 95 and NT
 - Studies at the time of release show that Windows 95 will require at least 16-32 megabytes of memory to utilize the full functionality of the system
 - With NT sales on the rise, Microsoft estimates that within the next 12 months, 10 to 15 percent of new systems will ship with this Operating System
 - Microsoft also estimates that within the next 12 months, 70 to 80 percent of new systems will ship with Windows 95
 - As 32 bit Operating Systems and applications become prominent, 32 to 64MBs of base memory will emerge as a minimum starting point for PC memory requirements

As mentioned in the beginning of this guide, developers of software applications and operating systems will continue to drive the need for memory. Ultimately, developers themselves are driven by the needs and expectations of the market. As computer technologies evolve rapidly, people's expectations of what computers can do continue to escalate dramatically. Developers must respond to these changing needs and expectations with additional features and functionality in their software applications and operating systems. So far, enhanced features and functionality in software have always required additional memory. All indications suggest that this trend will continue.

choosing high-quality memory




When the demand for DRAM is higher than the available supply, some companies cannot secure enough allocation to fill all of their memory requirements. When supply of chips is higher than demand, excess product is "dumped" onto the gray market. This causes people to turn to the gray market to get "a good deal". Because there is no way of knowing how many times memory purchased from these markets has changed hands, it's difficult to ascertain its quality and reliability.

Here are two suggestions on evaluating memory at the time of purchase:

First, inspect the chips on the module to see if they come from one of the major manufacturers. The following table indicates some of the major DRAM manufacturers along with samples of the part numbers and markings they use to date their memory components.

Second, inspect the date codes imprinted on the memory module's DRAM chips. Most manufacturers have a way of marking their chips with the manufacturing date. For example, a Toshiba DRAM chip manufactured in the 9th week of 1997 has a date code of 9709. Chips that are more than two years old have probably changed hands several times before getting to you.

DRAM manufacturers and sample part numbers

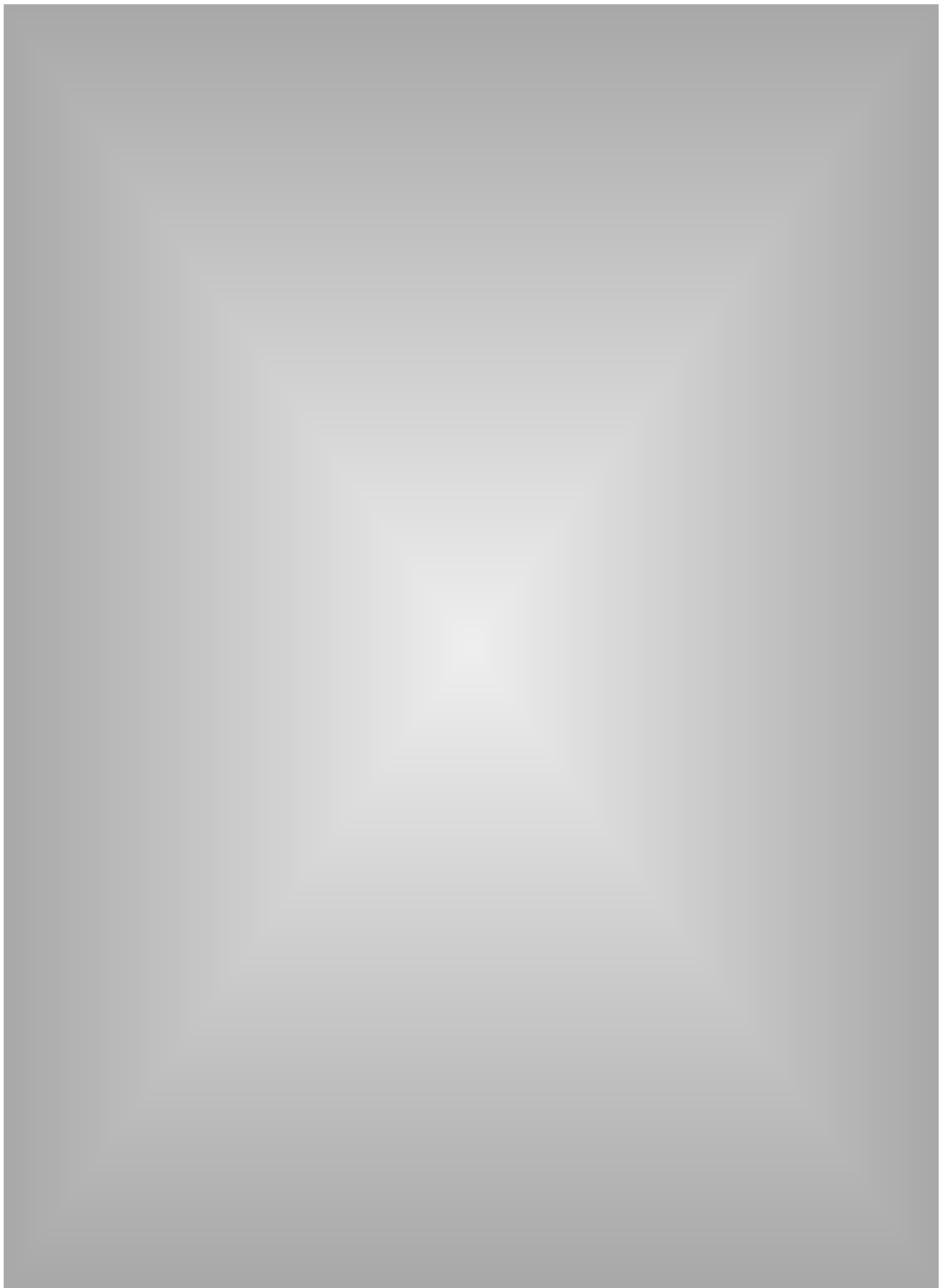
MANUFACTURER	SAMPLE DRAM PART NUMBER
Fujitsu	MB 814400-80L E 9445 T14
Hitachi	KOREA A107  9516 FFF HM5116100AS7
Micron	9512 C USA MT4C4007JDJ -6
Mitsubishi	 M5M44100AJ 222SB29-7
Motorola	MCMSL4800AJ70  TQQKX9236
NEC	NEC JAPAN D4216160G5 -70-7JF 9436LY200
Samsung	SEC KOREA 522Y KM44C4100AK-6
Toshiba	TOSHIBA TCS14100AFTL- 70 JAPAN 9409HCK

MORE ABOUT KINGSTON

PURPOSE

CORE VALUES

HOW TO REACH KINGSTON





purpose

The Kingston spirit reflects an individual commitment, based on teamwork and loyalty, to reach a standard of exceptional quality, reliability, and service in providing system enhancements to our customers worldwide.

core values

Respect for one another in our culturally diverse environment

Loyalty to our long-term partnerships

Flexibility and adaptability in responding to our customers' needs

Investing in our employees to continuously improve our most valuable resource

Having fun working in the company of friends

how to reach Kingston

There are many ways to reach us at Kingston:

internet

With its graphical interface, Kingston's World Wide Web site is the most visually exciting and user-friendly of our sources. With a few clicks of the mouse you can obtain upgrade information, product white papers and other technical information, support files, press releases and reviews, helpful hints, information about current events, as well as information on new Kingston products released within the last 30 days.

The address is **www.kingston.com**

phone

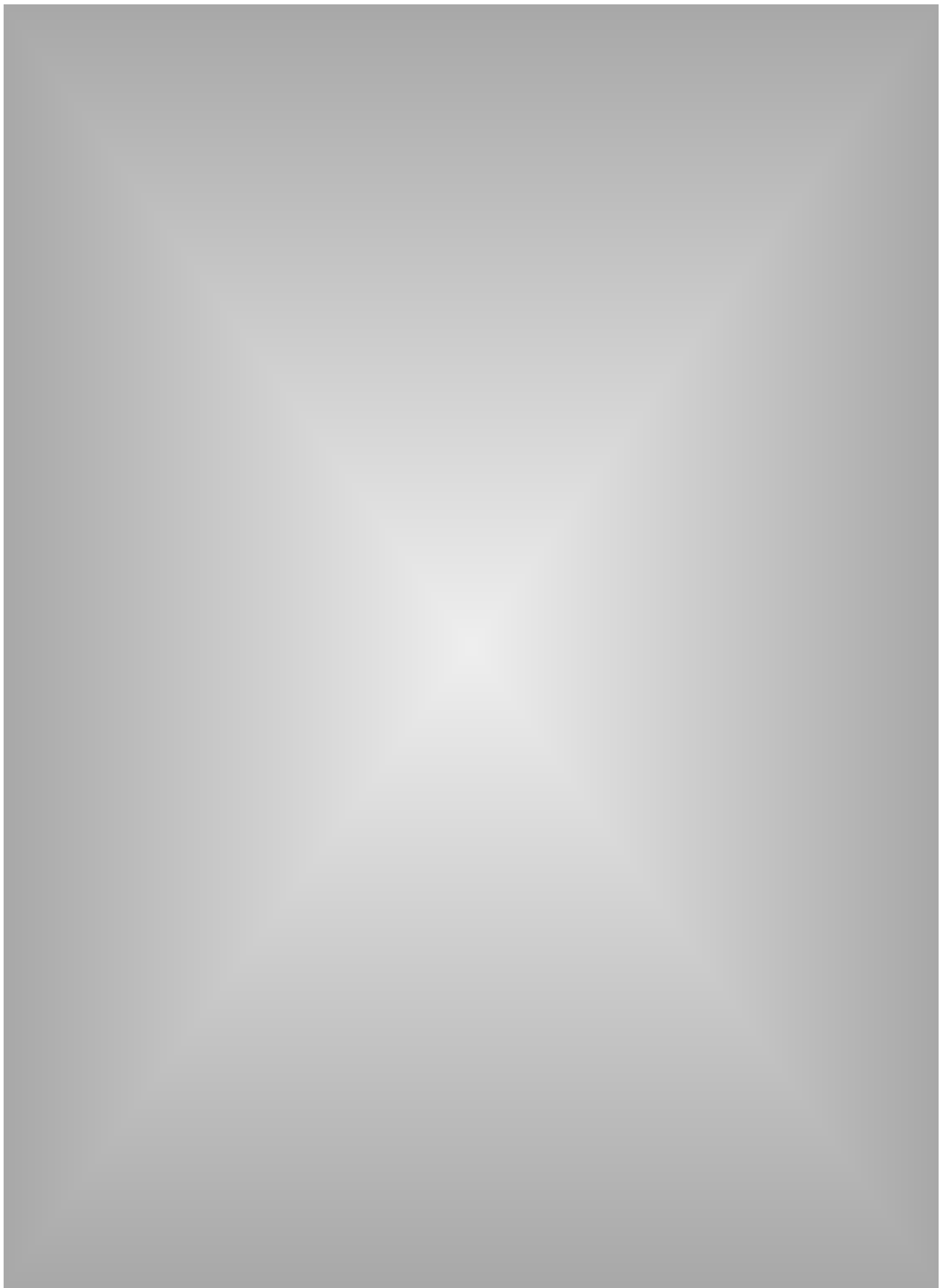
65

For specific product information, sales and marketing information, or answers to common technical questions, you can call our Customer Service team on 01932 738888.

fax

Alternatively you can fax us on 01932 738811 with your request for more information.

THE GLOSSARY



ASCII (*American Standard Code for Information Interchange*)—A method of encoding text as binary values. The ASCII system requires nearly 256 combinations of 8-bit binary numbers to support every possible keystroke from the keyboard. **69**

bandwidth The capacity to move data on an electronic line such as a bus or a channel. In short, the amount of data moved relative to a specific time frame. It is expressed in bits, bytes, or Hertz (cycles) per second.

bank schema A method of diagramming memory configurations. The bank schema system consists of rows and columns that represent memory sockets on a system: rows indicate independent sockets and columns represent banks of sockets.

binary A method of encoding numbers as a series of bits. The binary number system, also referred to as base 2, uses combinations of only two digits—1 and 0.

bit The smallest unit of information a computer processes. A bit can have a value of either 1 or 0.

bus The central communication avenue in a PC's system board. It normally consists of a set of parallel wires or signal traces that connect the CPU, the memory, all input/output devices, and peripherals.

bus cycle A single transaction between system memory and the CPU.

byte A unit of information made up of 8 bits. The byte is the fundamental unit of computer processing; almost all aspects of a computer's performance and specifications are measured in bytes or multiples thereof (such as kilobytes or megabytes).

cache memory Also known as cache RAM; a small, high-speed memory device located between the CPU and the system DRAM. Cache is designed to supply the processor with the most frequently requested instructions and data. Cache memory can be three to five times faster than system DRAM.

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composite A term created by Apple® Computer, Inc. that describes a memory module that uses older 4-Mbit technology. For a given capacity, a composite module will have more chips than a noncomposite module.

CPU (*Central Processing Unit*)—The chip in a computer that has primary responsibility for interpreting commands and running programs. The CPU is the most vital component of a computer system.

credit card memory A type of memory typically used in laptop and notebook computers. Credit card memory features a small form factor and is named for its similarity to the size of credit card.

DDR (*Double Data Rate*) or **SDRAM II**—The next generation of the current SDRAM. DDR finds its foundations on the same design core of SDRAM, yet adds advances to enhance its speed capabilities. As a result, DDR allows data to be read on both the rising and the falling edge of the clock, delivering twice the bandwidth of standard SDRAMs. DDR essentially doubles the memory speed from SDRAMs without increasing the clock frequency.

DIMM (*Dual In-line Memory Module*)—A printed circuit board with gold or tin/lead contacts and memory devices. A DIMM is similar to a SIMM, but with this primary difference: unlike the metal leads on either side of a SIMM, which are “tied together” electrically, the leads on either side of a DIMM are electrically independent.

DIP (*Dual In-line Package*)—A form of DRAM component packaging. DIPs can be installed either in sockets or permanently soldered into holes extending into the surface of the printed circuit board. The DIP package was extremely popular when it was common for memory to be installed directly on a computer’s motherboard.

DRAM (*Dynamic Random Access Memory*)—The most common form of system memory packaging. DRAM can hold a charge (that is, data) for only a short period of time. Therefore, to retain the data it must be refreshed periodically. If the cell is not refreshed, the data is lost.

ECC (*Error Correction Code*)—An electronic method of checking the integrity of data stored in DRAM. ECC is a more elaborate error-detection method than parity; it can detect multiple-bit errors and can locate and fix single-bit errors. ECC usually uses three additional bits per byte of data (compared to one additional bit for parity). **71**

EDO (*Extended Data Out*)—A form of DRAM technology that shortens the read cycle between memory and CPU. On computer systems designed to support it, EDO memory allows a CPU to access memory 10 to 20 percent faster than comparable fast-page mode chips.

EOS (*ECC on SIMM*)—A data-integrity checking technology designed by IBM that features ECC data-integrity checking built onto a SIMM.

even parity A type of data integrity checking where the parity bit checks for an even number of 1's.

fast-page mode A common DRAM data-access scheme. Accessing DRAM is similar to finding information in a book. First, you turn to a particular page, then you select information from the page. Fast-page mode enables the CPU to access new data in half the normal access time, as long as it is on the same page as the previous request.

gigabit Approximately 1 billion bits: $1 \text{ bit} \times 1,024^3$ (that is, 1,073,741,824 bits).

gigabyte Approximately 1 billion bytes: $1 \text{ byte} \times 1024^3$ (that is, 1,073,741,824 bytes).

IC (*Integrated Circuit*)—An electronic circuit—consisting of components and connectors—contained on a semiconductor chip. Usually packaged in a plastic or ceramic case with external connector pins.

JEDEC (*Joint Electronic Devices Engineering Council*)—An international body of Semiconductor manufacturers that sets integrated circuit standards.

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kilobit Approximately one thousand bits: $1 \text{ bit} \times 2^{10}$ (that is, 1,024 bits).

kilobyte Approximately one thousand bytes: $1 \text{ byte} \times 2^{10}$ (that is, 1,024 bytes).

logic board (*see motherboard*)

megabit Approximately one million bits: $1 \text{ bit} \times 1,024^2$ (that is, 1,048,576 bits).

megabyte Approximately one million bytes: $1 \text{ byte} \times 1,024^2$ (that is, 1,048,576 bytes).

memory The term commonly used to refer to a computer system's random access memory (see also RAM). The term memory has also been used to refer to all types of electronic data storage (see storage). A computer system's memory is crucial to its operation; without memory, a computer could not read programs or retain data. Memory stores data electronically in memory cells contained in chips. The two most common types of memory chips are DRAM and SRAM.

memory bank A logical unit of memory in a computer, the size of which is determined by the computer's CPU. For example, a 32-bit CPU calls for memory banks that provide 32 bits of information at a time.

memory controller The interface between system memory and the central processing unit. The memory controller consists of special circuitry—usually a microprocessor—within a computer system that interprets requests from the central processing unit in order to locate data locations, or addresses, in memory.

motherboard Also known as logic board, main board, or system board; your computer's main electronics board, which in most cases either contains all CPU, memory, and I/O functions, or has expansion slots that support them.

nanosecond (*ns*)—One billionth of a second. Memory data access times are measured in nanoseconds. For example, memory access times for typical 30- and 72-pin SIMM modules range from 60 to 100 nanoseconds.

noncomposite A term created by Apple Computer, Inc. that describes a memory module which uses 16-Mbit technology. For a given capacity, a noncomposite module will have fewer chips than a composite module. **73**

odd parity A type of data integrity checking where the parity bit checks for an odd number of 1's.

parity A method of data integrity checking that adds a single bit to each byte of data. The parity bit is responsible for checking for errors in the other 8 bits.

PC 100 In roughly the middle of 1998, Intel will introduce the BX chip set to their motherboard designs. One element in this new architecture will include an increase in the PC main memory bus speed (Host bus) from 66 to 100 MHz, called PC 100. To match the 100MHz bus speed, 100MHz SDRAM modules will be the required memory technology for this new chip set.

PCB (*Printed Circuit Board*)—A component made up of layers of copper and fiberglass; the surface of a PCB features a pattern of copper lines, or “traces,” that provide electrical connections for chips and other components that mount on the surface of the PCB. Examples: motherboard, SIMM, credit card memory, and so on.

PC Card (*PCMCIA: Personal Computer Memory Card International Association*)—A standard that allows interchangeability of various computing components on the same connector. The PCMCIA standard is designed to support input/ output devices, including memory, fax/modem, SCSI, and networking products.

proprietary memory Memory that is custom-designed for a specific computer .

RAM (*Random Access Memory*)—A configuration of memory cells that hold data for processing by a computer's central processing unit, or CPU; (see also memory). The term random derives from the fact that the CPU can retrieve data from any individual location, or address, within RAM.

RDRAM Rambus DRAM technology is a system-wide, chip-to-chip interface design that allows data to pass through a simplified bus. Rambus uses a unique RSL (Rambus Signaling Logic) technology. Rambus is available in two flavors: RDRAM and Concurrent RDRAM. RDRAM is currently in production with Concurrent RDRAM production scheduled for late 1997. The third line extension, Direct RDRAM, is in development stages and scheduled for production in 1999. In late 1996, Rambus agreed to a development and license contract with Intel that will lead to Intel's PC chip sets supporting Rambus memory starting in 1999.

refresh An electrical process used to maintain data stored in DRAM. The process of refreshing electrical cells on a DRAM component is similar to that of recharging batteries. Different DRAM components call for different refresh methods.

refresh rate A specification determined by the number of rows on a DRAM component that must be refreshed. Two common refresh rates are 2K and 4K.

self refresh A memory technology that enables DRAM to refresh on its own— independent of the CPU or external refresh circuitry. This technology is built into the DRAM chip itself and reduces power consumption dramatically. It is commonly used in notebook and laptop computers.

SIMM (*Single In-line Memory Module*)—A printed circuit board with gold or tin/lead contacts and memory devices. A SIMM plugs into a computer's memory expansion socket. SIMMs offer two main advantages: ease of installation and minimal consumption of horizontal surface area. A vertically mounted SIMM requires only a fraction of the space required by horizontally mounted DRAM. A SIMM may have as few as 30 or as many as 200 pins. On a SIMM, the metal leads on either side of the board are electrically "tied together."

SIMM socket A component mounted on the system board, or motherboard, designed to hold a single SIMM.

SO DIMM (*Small Outline Dual In-line Memory Module*)—An enhanced version of a standard DIMM. The small outline DIMM is about half the length of a typical 72-pin SIMM. **75**

SOJ (*Small Outline J-lead*)—A common form of surface-mount DRAM packaging. It is a rectangular package with J-shaped leads on the two long sides of the device.

storage A medium designed to hold data, such as a hard disk or CD-ROM.

SDRAM (*Synchronous DRAM*)—A DRAM technology that uses a clock to synchronize signal input and output on a memory chip. The clock is coordinated with the CPU clock so the timing of the memory chips and the timing of the CPU are “in synch.” Synchronous DRAM saves time in executing commands and transmitting data, thereby increasing the overall performance of the computer. SDRAM allows the CPU to access memory approximately 25 percent faster than EDO memory.

SLDRAM (Synlink) SLDRAM is a “joint effort” DRAM that may be the closest speed competitor with Rambus. Development is coordinated through a consortium of twelve DRAM manufactures and system companies. SLDRAM is an enhanced and faster line extension of SDRAM architecture that extends the current four-bank design to 16 banks. SLDRAM is currently in the development stage and is scheduled for production in 1999.

system board (*see motherboard*)

TSOP (*Thin Small Outline Package*)—A type of DRAM package that uses gull-wing shaped leads on both sides. TSOP DRAM mounts directly on the surface of the printed circuit board. The advantage of the TSOP package is that it is one-third the thickness of an SOJ package. TSOP components are commonly used in small outline DIMM and credit card memory applications.