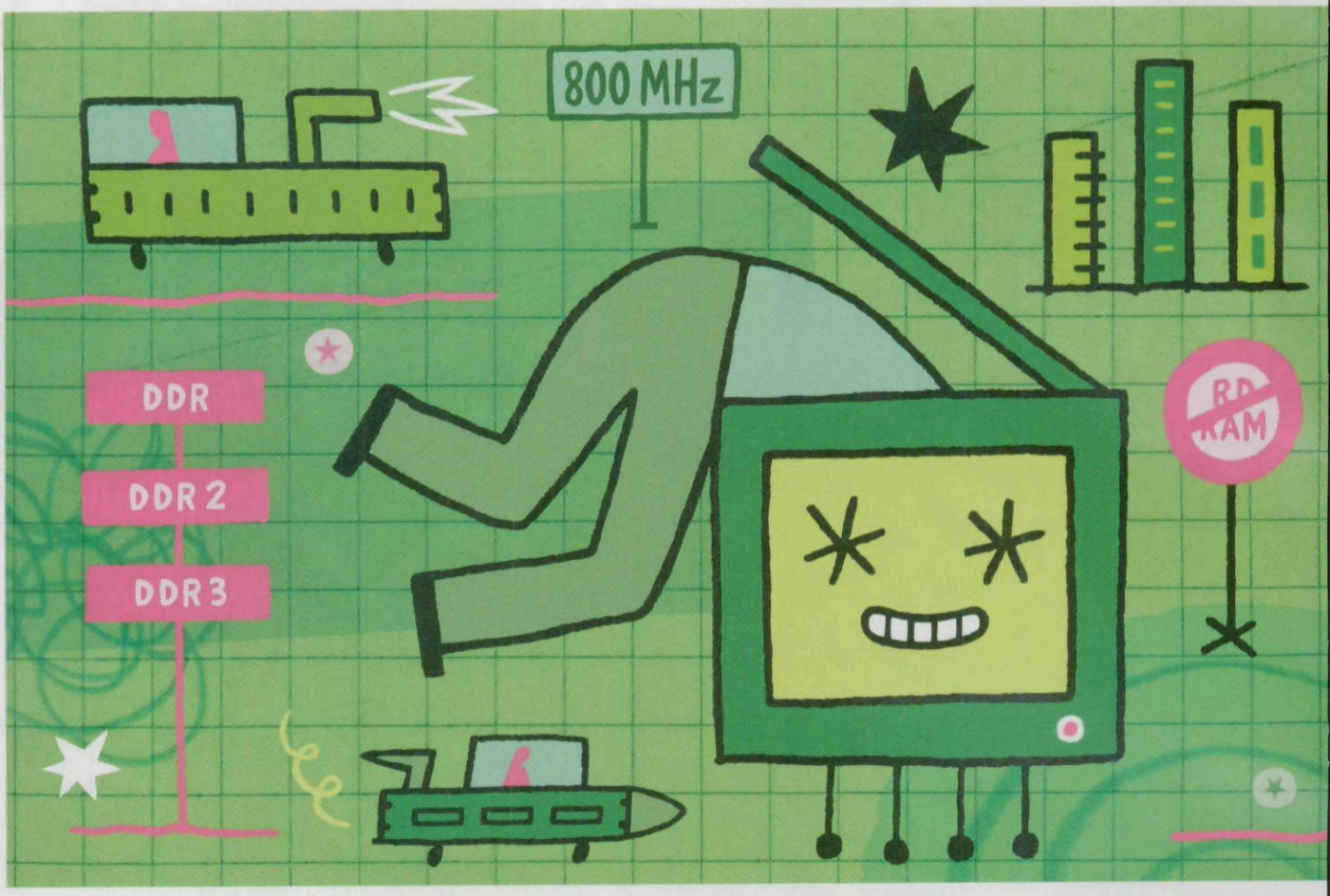


Refresh Your Memory

In this starter guide, we explain the new memory technology and tell you how to save big bucks.

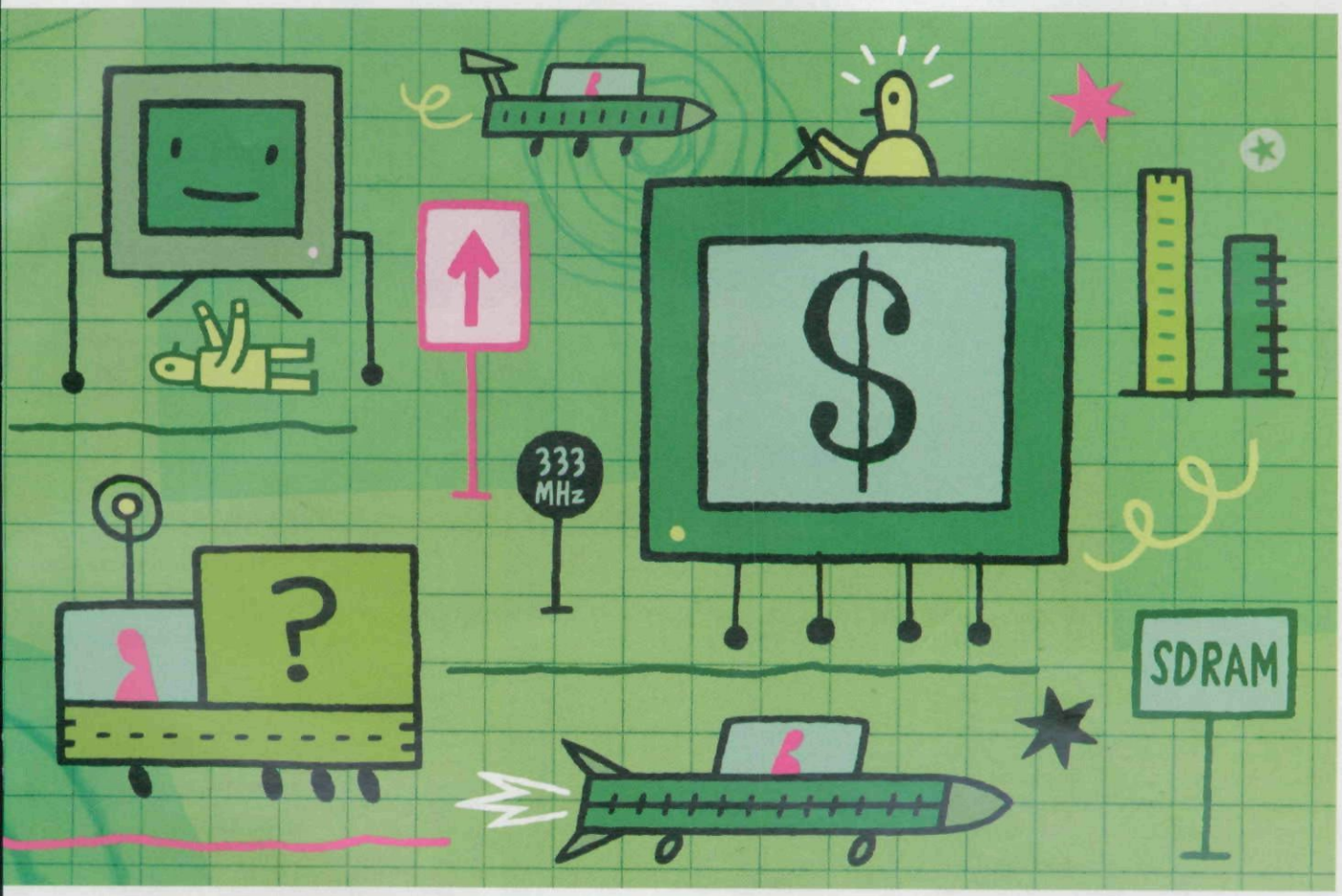
BY LOYD CASE

HOW MUCH MEMORY does Vista really need? What about Windows XP? And what the heck does DDR mean? How much money will a memory upgrade cost, and where do you buy it? We'll answer these questions and more, briefing you on the essentials of PC memory technology and saving you a great deal of money and hassle. Whether you're building a new system from scratch or upgrading, you'll find PC Magazine Labs–tested advice you won't get anywhere else.

If you know what you're doing, now is a great time to buy more memory because prices have never been lower. If you don't know what you're doing, though, you could end up spending a bundle on memory you really don't need. (More on pricing later in this story.) Let's get started with a refresher on memory basics.

DDR and Other Inscrutable Acronyms

Any computer that you bought in 2001 or later uses a type of dynamic random access memory (DRAM) known as dou-



ble data rate, commonly referred to as DDR. It simply refers to memory in which two data items are transmitted with each clock signal. It replaced single data rate SDRAM. (The S stands for synchronous.) DDR memory is also synchronous, and you may sometimes see DDR memory referred to as DDR SDRAM.

DDR also replaced RDRAM, so called because Rambus Corp. developed the standard. Rambus memory offered substantially higher memory bandwidth than SDRAM. However, RDRAM was always more expensive than SDRAM, and DDR's lower cost and equivalent throughput eventually canceled out any performance advantages RDRAM offered.

In 2003, a new generation of DDR memory, DDR2, appeared with Intel Pentium 4 processors. Because AMD Athlon 64 CPUs had integrated memory controllers, DDR2 support didn't appear in AMD processors until the launch of a new lineup in 2006 that used the AM2 socket.

DDR2 differs from DDR in that the bus carrying the data runs twice as fast as the actual memory clock. For example, older DDR memory that is clocked at 200 MHz clocks the I/O bus at 200 MHz and can transfer data at 3.2 gigabytes per second. Why? Well, the clock speed determines the speed of the I/O bus; that's why it's called synchronous DRAM. The calculation for determining transfer rate (3.2 GB in this case) is:

(bus clock × data rate × data width of memory module) ÷ 8

Meanwhile, DDR2 memory that runs at the same 200 MHz runs the I/O bus at 400 MHz. Each I/O bus clock cycle still carries two items of data, but the increased bus clock effectively doubles the maximum throughput to 6.4 GBps.

The various flavors of DDR2 are confusing because JEDEC, the standards group for the semiconductor industry, has issued variations of the specification. For example, some high-performance memory is rated at specs beyond the official JEDEC rating.

To hit those high specs, computer users need to go into the BIOS to increase voltage beyond the standard 1.8V. Increase the voltage and you increase the throughput. We've seen people buy DDR2 memory that manufacturers say can run at up to 1,066 MHz and be surprised that it runs only at DDR-667 speeds because memory is shipped at officially rated speeds. (The numbers following the hyphen represent the bandwidth in megahertz.) For example, DDR-400 has a maximum bandwidth of 3.2 GBps, which is also 3,200 MBps. So you'll see DDR-400 also called PC3200.

In PC Magazine Labs, we've seen DDR2 max out at DDR2-800 speeds at the rated 1.8V, but an effort is in the works to create a JEDEC standard for DDR2-1066. Micron has just announced that it's manufacturing DDR2-1066 chips that can run at 1.8V.

The memory manufacturers need to be sure that even high-end memory will run at standard voltages and speeds, because they don't know what motherboard will be the end destination. Not all motherboards can support higher clock rates or voltages.

DDR3: The New Kid on the Block

DDR3 memory delivers potentially greater throughput than DDR2 with less power but at the expense of higher latencies. (Latency is the delay that occurs during memory accesses. See the sidebar "A Shortcut to Understanding Memory Timings," page 71, for more on this impor-

Illustrations by Aaron Leighton

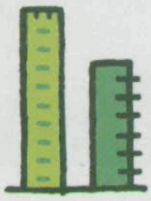
KEYED FOR YOUR PROTECTION The top module is a Corsair DDR2 module; the bottom one, a DDR3. Note the different locations of the key notch in each edge connector.

tant spec.) If that sounds like a sales pitch for DDR3, you're absolutely right. Take a quick look at the table at the bottom of this page for the main differences between DDR, DDR2, and DDR3.

What makes DDR3 special is the added throughput gained by quad-loading each clock cycle. The actual efficiency may be less, but the overall throughput compared with DDR2 is higher. And the lower voltage means less power draw—important in mobile systems.

Don't stress about putting DDR memory in a DDR2 or DDR3 slot by mistake. That's not going to happen because memory modules are keyed with notches where the circuit board connects to the memory slot. (See the photos above.) Different types of memory have these notches in different places. For step-by-step instructions on installing memory, see *go.pcmag.com/memoryinstall.*

You'll need to get DDR3 modules if you buy one of the new DDR3-enabled motherboards with the Intel P35 or G33 chipsets. (You can buy P35-based motherboards supporting either DDR2 or DDR3.) And if you buy a new system with DDR3 inside and plan on upgrading, you'll need DDR3 modules. DDR3 suppliers are listed at *www.intel.com/technology/memory/ddr/valid/ddr3_dram_results.htm.*



AMD will stick with DDR2 for its Athlon 64 and upcoming Phenom line of processors. The company plans to integrate a DDR3 memory controller into its CPUs in 2008.

Free-Falling Prices

Now that we've covered some of the basics of memory technology, let's explore the state of the market and help you decide what to buy. The vast majority of memory sold today is DDR2, which has never been cheaper. Meanwhile, DDR3 currently costs a whopping three times that of DDR2. Toward the end of last year, memory manufacturers were drooling at the thought of vast numbers of people upgrading to Vista and buying more memory. Vista offers a smoother experience with at least a gigabyte of memory; two are even better. Lo and behold, neither the system makers nor Vista early adopters have rushed to add more memory, so inventories have increased and prices have sunk.

Prices are rock-bottom also because of the slow adoption of 64-bit operating systems. Sales of 32-bit Vista are far outstripping sales of the 64-bit version, which is hobbled by compatibility issues. We expect those issues to be resolved over the next year or so. For now, it's still a 32-bit world, which runs quite nicely on DDR2 memory. (We'll get into even more pricing details later on in this story.)

What's in *Your* System?

Before leaping into a memory upgrade, you need to know exactly what type of memory is in your system. You could always pop open the hood of your computer and yank out a module to take a look. But that takes time, and you'd have to button your PC back up again and then open it up one more time when you upgrade.

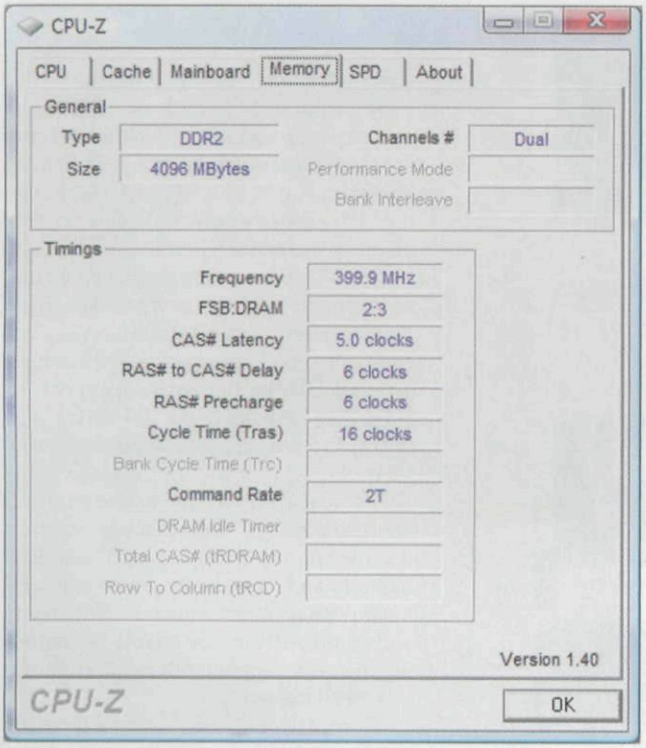
So we suggest you run the latest version of a handy utility called CPU-Z, available free at *www.cpuid.org.* When CPU-Z runs, a window with a set of tabs appears along the top. Click on the Memory tab and you'll find everything you need to know about your system memory. (See the screenshot on the opposite page, at left.)

For even more details, click on the tab labeled SPD, which stands for *serial presence detect.* This is a small chip on the

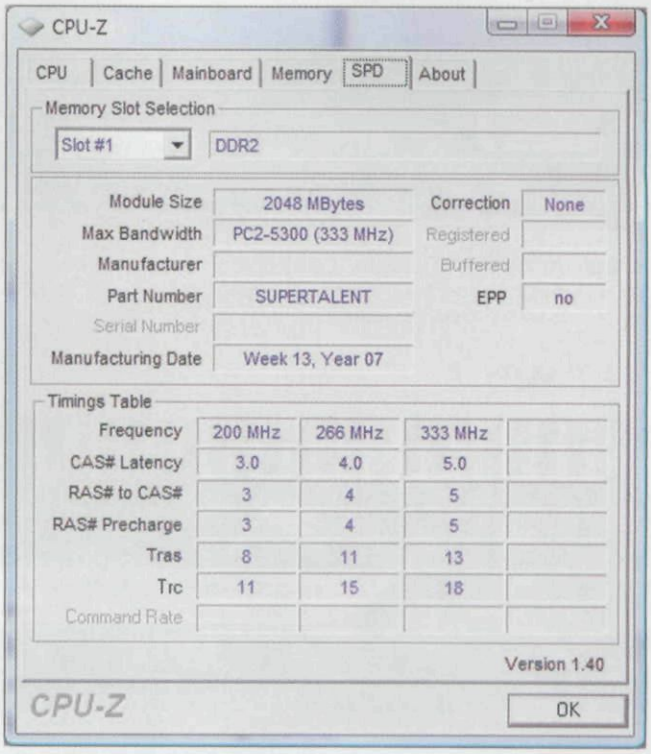
ESSENTIAL MEMORY SPECS

Today's system memory comes in three basic flavors, each at a variety of clock speeds. DDR2 is currently the most popular and cost-effective. DDR3 offers the greatest throughput—and the highest price tag.

	DDR	DDR2	DDR3
Rated clock speeds (MHz)	100, 133, 166, 200	100, 133, 166, 200	100, 133, 166, 200
Effective clock speeds (MHz)	200, 266, 333, 400	400, 533, 667, 800	800, 1066, 1333, 1600
Rated throughput (GBps)	1.6, 2.1, 2.7, 3.2	3.2, 4.2, 5.3, 6.4	6.4, 8.5, 10.7, 12.8
Typical latencies (CAS-RCD-RP-RAS cycles)	4-4-4-12	5-5-5-15	7-7-7-15
Voltage	2.5V	1.8V	1.5V
Number of pins	184	240	240
Price range (generic, 2GB)	$99–$130	$75–$130	$450–$500



A HANDY, FREE UTILITY Hit the Memory tab for CPU-Z and you'll get basic information about the memory in your system.



FURTHER INTERROGATION Hit the SPD tab and get more details about your system's memory, including latency timings.

memory module with detailed information, including rated speeds and latency settings. (See the screenshot on the right.)

Should You Upgrade or Not?

Once you know the type of memory you have, you can then decide whether an upgrade is worth the expense. Many systems out there, including AMD Athlon 64 systems and older Intel-based ones (those using Intel 845 chipsets, for example), are running variations of DDR SDRAM. Among these are DDR-266 (PC2100), DDR-333 (PC2700), and DDR-400 (PC3200).

Here's a money-saving tip: If you're running 1GB or more of DDR SDRAM, you don't want to buy more of it, because DDR2 is cheaper; prices have dropped considerably since January. In fact, we've seen 2GB DDR2 kits from name brands such as Super Talent and OCZ dip below $100 for a 2GB DDR2-800 kit, whereas 2GB DDR-400 kits are going for nearly $120. Instead, save your money for the inevitable system upgrade, because all new systems will support either DDR2 or DDR3.

For an even older Intel system using the Intel 850 chipset running RDRAM, you definitely want to avoid buying more memory. RDRAM is hugely expensive, when you can find it—as pricey as $500 for a pair of 512MB modules. You're much better off just buying an entirely new system.

Do You Need "Premium" Memory?

Now is a buyer's market for premium DDR2 memory. Your choices range from modestly overclockable modules with heat spreaders, which command only a slight premium over value memory, to bleeding-edge modules that can hit clock speeds as high as 533 MHz (DDR2-1066) and require voltages higher than 1.8V. Recently, we've seen DDR2 modules from PNY rated to use as much as 2.3V.

What are the advantages of premium memory? High-end DRAM chips are bin-sorted—a term manufacturers use to refer to sorting chips that can run at different speeds into "speed bins" to hit high voltages and frequencies. These chips can run at lower latency timings than standard DRAM. Finding exactly the right timing setting can be daunting. It's often a trial-and-error process that involves many reboot, test, and reset cycles.

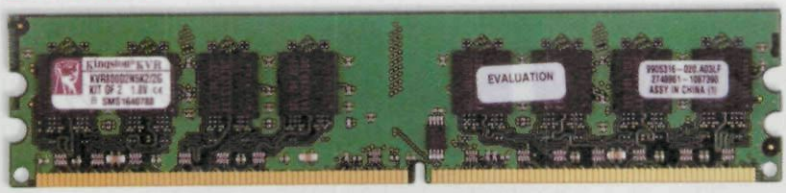
Most standard-grade memory won't run at the lower latencies at which premium-grade memory runs. For DDR2, that means latencies as low as at the standard 5-5-5-15 timings. To help you determine whether you need premium memory, see the sidebar "A Shortcut to Understanding Memory Timings" (page 71).

The serious overclockers among you will want to push the memory speed up to 1,100 MHz or more. Overclockers will also need to run their memory at higher voltages, so it's important to have a good motherboard with a beefy voltage regulator section and a BIOS setup that lets you tweak all your memory settings. For one example of a motherboard that allows very high memory clocks, check out our online story on the eVGA nForce 650i Ultra motherboard (*go.pcmag.com/ultramotherboard*).

Get Enhanced Performance Profiles in a Snap

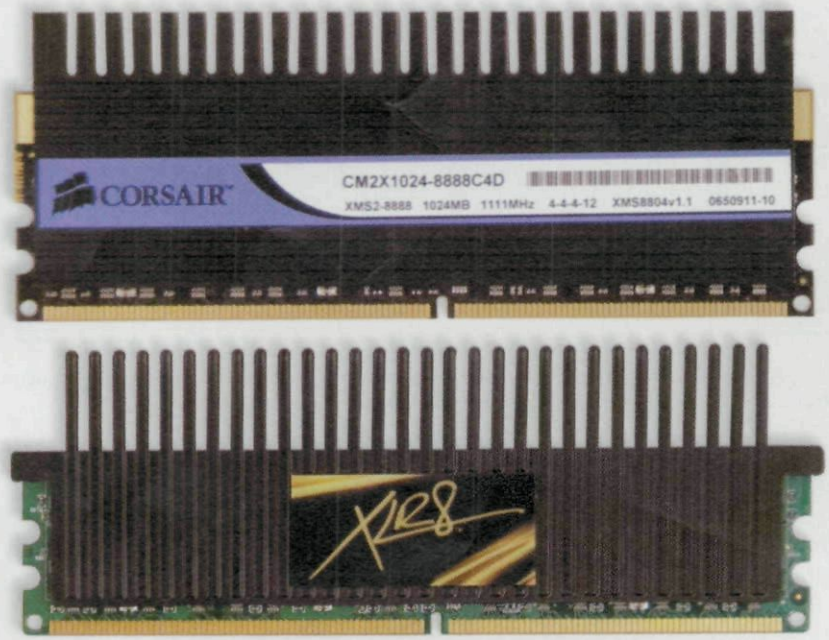
Last year, graphics chip maker nVidia and memory maker Corsair jointly proposed using the unallocated space in the SPD chip to make it easier to access all of the available memory features. nVidia dubs such memory SLI-Ready Memory,

BUDGET



SPEED UP VISTA This Kingston DDR2-800 module won't win any overclocking awards, but it'll boost your Vista system just fine. Cost: $110 to $130 for 2GB. Each kit comes with two 1GB modules.

PREMIUM



ATTENTION OVERCLOCKERS These premium DDR2 memory modules from Corsair and PNY offer the extra speed and lower latencies that overclockers need. Cost: $610 to $650 for 2GB Corsair kit; $309 for 2GB PNY kit.

MAXED OUT

EXTRA MEMORY These Kingston and Super Talent 4GB DDR2 kits give you a little over 3GB of effective memory. Speed may vary, depending on motherboard and BIOS. Cost: $380 for 4GB Kingston kit; $270 for 4GB Super Talent kit.

although it has little do with that company's separate SLI graphics technology.

Detailed profiles stored in the SPD chip are more commonly known as Enhanced Performance Profiles (EPP). Normally, the SPD contains only the basic spec that memory will run at when you set the BIOS to "auto" for its memory speed setting. EPP-capable memory, now available from many memory suppliers, stores several complete sets of information. For example, a module may be able to run at either CAS 3-4-4-12 at 2.0 volts, and a 200-MHz clock, or at CAS 5-6-6-18, with 2.2 volts and a 300-MHz clock.

Typically, you'd have to use trial and error to get to the best setting, whether it's low latency or high speed. With EPP memory and a system BIOS that supports it, you can now just select the full profile and all the settings are enabled—including the pesky voltage setting. It's guaranteed to be stable.

Currently, only motherboards using nVidia and ATI core logic support the standard. (Memory modules that display ATI's CrossFire Ready logo are really just memory modules with enhanced performance profiles.) There's nothing preventing motherboards with Intel chipsets to support EPP, but we haven't seen any in PC Magazine Labs.

EPP is a convenient way for casual overclockers to configure memory for near-maximum performance. EPP has different built-in settings for clock speeds, latencies, and voltages. All you need do is pick the profile you think is the best for your apps and then just let the system take care of all the settings. If you plan on tweaking your memory, then it's worth getting EPP memory as long as you've got a motherboard with a BIOS that supports it.

How Much Memory Do You Need?

Our rule of thumb for memory requirements: Windows XP can run with 512MB, but the sweet spot is 1GB. If you're running memory-intensive applications, such as current-generation PC games or photo- or video-editing applications, you'll want 2GB.

Those of you running Windows Vista will want to bump that minimum up a notch. Vista runs fine with 1GB, but it's noticeably more responsive with 2GB of memory. If you're running 32-bit Vista, you may even want 4GB. Be aware, though, that if you drop 4GB of DRAM

into a 32-bit Vista or XP, your system may see only 3GB of actual memory. This happens because the system grabs about a gigabyte's worth of memory addresses for use by the system BIOS, I/O, and other functions. The memory is still there, but the addresses are used elsewhere.

Windows XP Professional 64-bit and Windows Vista 64-bit will use up every bit of the memory a desktop system can support. Most desktop PCs top out at 8GB of memory because of the limitations in the number of memory slots and the number of memory banks the system can support electrically. Also, 64-bit systems use more memory in general. For a 64-bit OS, 4GB is the minimum you'll want to run.

Recently, memory makers have shipped a number of 4GB DDR2-800 memory kits. If you're running 32-bit Vista or Windows XP, buying a 4GB kit gives you a little more memory. BIOS addresses still consume a chunk of address space, but you get a little over 3GB of effective memory. Previously, you'd need to run at lower memory speeds if you wanted to load up on more memory, while ensuring stability. Quite a few motherboards can't run four banks of DRAM at 200 MHz because of a degradation in signal integrity.

As it turns out, a DDR2-800 4GB kit may still not run at full speed. For example, in PC Magazine Labs we've discovered that the P5B Deluxe wouldn't run the Kingston KHX6400D2LLK2/4G kit at DDR2-800 speed, no matter how we set the voltage. Vista would generate a blue-screen crash on boot-up. Given the robust voltage regulator section in the P5B Deluxe motherboard, this may be a BIOS problem.

On the other hand, the Super Talent 4GB kit runs without a hitch in the same motherboard at full DDR2-800 speeds. Even then, we had to go into the BIOS and set the memory speed to 800 MHz. The SPD in the kit boots the memory up at DDR2-667 speed. So your mileage may vary, depending on your motherboard and your BIOS version.

Our Bottom-Line Buying Advice

Right now, very few early adopters are running DDR3 memory, but by the end of the year—as Intel moves its chipset line to support DDR3—more DDR3 motherboards and systems should be available for consumers.

The good news is that the just-announced Intel P35 and G33 core logic chipsets are also capable of running the less-expensive DDR2 memory. So if you're really hankering to upgrade to more DDR2, now is the time: Prices are good, and you'll be able to use it with a future upgrade to a DDR2-enabled P35 motherboard.

Even if your current system runs only lower-speed DDR2, it's still a good idea to move to DDR2-800. It will run just fine in your current system, and you'll get the added speed when you eventually move to a new system.

If you're planning to build a brand-new system loaded with an Intel CPU, consider a DDR3 motherboard. But you should factor in the likelihood that DDR3 modules will continue to sell at a higher price than DDR2 for the foreseeable future. There's always a price to pay for early adoption.□

A SHORTCUT TO UNDERSTANDING MEMORY TIMINGS

If **"DDR2-800 5-5-5-15"** makes you glassy-eyed, then read on to learn how to decipher it and why you should care. But first let's clarify how memory works.

Memory accesses don't happen in a single step. Memory is laid out on a chip in rows and columns, and it requires repeated pulses of electricity, referred to as "strobing," to reach each location. When memory is accessed, each strobing cycle takes a fixed amount of time, as follows:

tCL Column address strobe (CAS) latency; the number of clock cycles required to access a specific column of data. (The initial *t* refers to time.)

tRCD Row address strobe (RAS)-to-CAS delay; the number of clock cycles needed between a row address strobe and a column address strobe.

tRP RAS precharge; the number of clock cycles needed to close one row of memory and open another.

tRAS The number of clock cycles needed to access a specific row of data in RAM.

Now let's break down the DRAM label above. 800 is the *effective clock speed* in megahertz. That's the *actual clock speed* times data per clock *cycle* (200 MHz [for DDR2-800] X 4 [4 samples per clock cycle for DDR2]). DDR2-800 has a maximum bandwidth of 6.4 GBps. "5-5-5-15" refers to a **tCL** of **5, tRCD** of **5, tRP** of **5,** and **tRAS** of **15.**

Since latency is measured in clock cycles, the smaller the numbers, the better. That means less time is required for memory accesses. The time is measured in nanoseconds, with a typical system making millions of memory accesses each second. Latency and memory speed trade off. For example, the same DDR2-667 memory module can run at 333 MHz, with latencies of 5-5-5-13, or at DDR2-533 speed at 266 MHz with latencies of 4-4-4-11. Since higher clock frequencies represent smaller time intervals, the total time is practically the same for both these settings.

What you pay for with premium memory is the ability to run at high clock speeds *and* lower latencies. If your apps are sensitive to memory performance, premium memory can pay off in better performance. Games, media transcoding, and 3D rendering are all sensitive to memory latencies. Web browsing, office applications, and streaming media typically are less sensitive.—*LC*

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