

Upgrading to a PowerPC G4 Processor

Technical White Paper

(9/30/1999)

Overview

This white paper discusses issues of interest to those who are thinking of upgrading their Macs with G4 processors. The G4 is the latest generation of PowerPC processors from Motorola, originally announced by the company in October 1998.¹

What are the advantages of the G4 over the G3?

The G4 will incorporate several new technologies that will improve its performance over the G3, including:

- AltiVec technology (which Apple refers to as the G4 Velocity Engine)
- full support for multiprocessing
- improved FPU performance
- support for L2 caches up to 2 MB
- support for wider (128-bit) system buses

These technologies are described here briefly. For additional information, see the performance section, below.

AltiVec technology. AltiVec technology is Motorola's name for the G4's vector-processing unit, which can carry out as many as 16 simultaneous calculations. Apple calls it the Velocity Engine, which is how this document will refer to it. The Velocity Engine fulfills the same role as DSP add-in cards designed to accelerate specific functions that require a lot of computing power. Examples of such functions include Photoshop filters, video compression and 3D rendering. The Velocity Engine can improve the speed of such operations dramatically. On some computing tasks, software modified to take advantage of the Velocity Engine is expected to run as much as 30 times as fast on a G4 as it does on a G3.² (Typical real-world speed gains will likely be less, but will still be very impressive.)

Multiprocessing. The G4 is well suited to multiprocessing (MP), i.e., systems containing more than one processor. The PowerPC 604 also had this capability, and many applications were MP-enabled when Apple, DayStar and UMAX were selling multiple-604 systems. The G3, on the other hand, is not an effective processor for multiprocessing. MP-enabled software will be able to take immediate advantage of systems that have two or more G4 processors installed in them.

Faster FPU. The G4's FPU will be up to 40% faster than the G3's for processors running at the same clock speed. Any software that makes heavy use of floating-point

processing, such as a 3D-rendering application, will see an immediate benefit from the G4. Software will not need to be modified to take advantage of the G4's increased FPU speed.

Larger L2 cache. The G4 supports L2 cache sizes up to 2 MB. The cache-size limit for the G3 is 1 MB. It is not yet clear how significant a benefit this will turn out to be. Applications that re-use large amounts of data, such as image-processing applications, stand to benefit most from larger caches. The Power Macintosh G4 systems that Apple began shipping in September 1999 contain 1 MB of L2 cache.

128-bit system bus. There will be two versions of the G4 processor: a 64-bit version and a 128-bit version.¹ The 128-bit version will be able to process information at up to twice the speed of the 64-bit version. All software should benefit to some extent from a wider system bus. Applications that handle large images, audio and video streams, or 3D animations will benefit most.

But there's a catch. Existing Macs upgraded with G4 processors will be restricted to using the 64-bit version of the chip. Only Macs with newly designed logic boards that contain a 128-bit system bus will be able to utilize the 128-bit version of the G4 chip. Apple has said nothing about when it might offer such systems.

When will G4 systems and upgrade cards be available?

Apple began shipping Power Macintosh G4 systems in September 1999. At present, however, G4 processor chips are in extremely short supply, and only 400 MHz Power Mac G4s are available.

Most companies currently manufacturing G3 upgrades, including XLR8, have tested, have announced and plan to ship G4 processor-upgrade cards for desktop systems in Q4 1999, as soon as G4 chip supplies increase. No company has publicly announced support for G4 upgrades for PowerBooks. See the section on Compatibility, below, for a detailed list of supported systems.

When will dual-G4 systems be available?

Apple has not made any public statement regarding its future plans for MP systems. XLR8 is currently investigating the possibility of developing G4 upgrade cards for PCI-based Power Macs and Mac clones.

I've heard that only Motorola will produce G4s. What are IBM's plans?

At present, only Motorola is manufacturing G4s with AltiVec technology. IBM instead plans to focus on using its advanced chip-manufacturing process to produce faster G3 processors. Using this process, IBM expects to achieve processor speeds as high as 670 MHz by the end of 1999, and 1 GHz in 2001.³

Was the G4 designed specifically for the Macintosh?

No. Motorola initially designed the G4 as an embedded processor, for integration into its communications devices. Many computing functions required by communications devices — digital quantization of audio signals and encryption are two examples — can benefit from the Velocity Engine. Because vector processing can benefit multimedia functions as well, Apple is promoting the G4's Velocity Engine as a means of boosting the Mac's multimedia performance.

Compatibility

Can I upgrade my current desktop Mac with a G4 processor?

You will definitely be able to upgrade any PCI-based Power Mac, Mac clone or original (beige) Power Mac G3 with a G4 processor. The initial version of the G4 processor will be pin-compatible with G3s.¹ Apple has not publicly committed to supporting G4 upgrades for blue & white Power Mac G3s. XLR8 and other vendors, however, will offer G4 upgrades for the blue & white G3. These upgrades are expected to begin shipping in Q4 1999.

NuBus-based Power Macintoshes. No upgrade company has announced G4 upgrades for these original Power Macs. The NuBus standard on these systems may pose problems for future upgrades because Apple no longer supports NuBus.

PCI-based Apple Power Macintoshes. These will be fully supported by all major upgrade card vendors. Note that there are two ways of upgrading these systems. The traditional approach is with a dedicated processor-upgrade card whose processor is soldered directly onto the card. The more recent approach is to upgrade a system with what is known as a “carrier” card, a processor upgrade card that in turn contains socket for a ZIF processor daughtercard. With a carrier-type upgrade card, it is easier and less expensive than with a traditional card to upgrade a computer with a series of ever-more-powerful processors as they become available, because only the daughtercard needs to be replaced. Information on XLR8’s CarrierZIF upgrade adapters can be found at the company’s Web site: www.xlr8.com.

Mac OS Clone Systems. In general, clone systems based on Apple’s PowerSurge (removable CPU daughtercard) Power Macintosh architecture can be upgraded using the same upgrade strategies as with G3 upgrades. Supported clone systems include Power Computing’s PowerWave and PowerTower Pro; UMAX’s S900 and J700; and DayStar’s Genesis MP and Millennium. G4 upgrades have not been announced for any of the Motorola StarMax clones, the UMAX C500 or the Power Computing PowerBase, PowerCenter, PowerCenter Pro and PowerTower.

Power Macintosh G3 (beige). All major upgrade companies have announced G4 upgrades for these machines. This version of the Power Macintosh G3 can be upgraded to G4 using standard ZIF (Zero Insertion Force) socket cards, similar to the card used in the 400 MHz Power Macintosh G4.

Power Macintosh G3 (blue & white). Current firmware on Apple’s blue & white G3 systems does not support the G4 processor. Nevertheless, XLR8 and PowerLogix have announced that they are developing G4 ZIF upgrades for these machines. XLR8’s G4 upgrades for blue & white G3s will be bundled with a software patch enabling G4 support.

Power Macintosh G4. Current G4 systems use the same ZIF socket as the blue & white G3s. As faster G4 processors become available, it will be possible to upgrade these systems using standard ZIF processor daughtercards.

My current Mac has a slower system bus than today’s Power Mac G3s. Will that matter for G4 upgrades?

No more than for G3 upgrades. Of course, any processor will perform better on a system with a faster bus than it will on a system with a slower bus. On the other hand, the backside L2 caches present on G3s and G4s minimize the importance of system-bus speed.

Most of the benefit of a processor upgrade can be achieved even with a relatively slower bus.

What is more important is that your Mac's system bus speed sets an upper limit on how fast a processor you can install in it. The maximum processor speed supported by a system is the product of two factors: the computer's rated system-bus speed multiplied by the processor's maximum CPU multiplier.

For example, consider an old (pre-G3) Power Mac or Mac clone with a 50-MHz bus, upgraded with a G3 processor. Until recently, the maximum CPU multiplier on G3s was 8x; this limited to 400 MHz (50 MHz x 8) the speed at which these older Power Macs could run. Even if you installed a faster G3 in such a system, it would not reliably be able to run faster than 400 MHz.

Recently, however, IBM began shipping G3s that support a 10x CPU multiplier. This makes it possible to push systems with 50-MHz buses to run at 500 MHz (50 MHz x 10). Higher multipliers are expected in the future. Motorola has not yet announced what the G4's highest CPU multiplier will be.

What versions of the Mac OS will work with a G4?

G4 processors should work with all Mac OS versions 7.5.2 or later, including Mac OS X. Mac OS 9 will be the first version of the Mac OS that incorporates Velocity Engine acceleration.

Will I have to upgrade to new software if I upgrade to a G4?

That depends. Although there will no doubt be a few wrinkles to iron out, software that works well on a G3 processor should continue to work on a G4 processor. But if you want to take advantage of the G4's Velocity Engine and multiprocessing capability you'll need updated software that has been modified explicitly to support these features. See the Performance section below for more details.

Will my current desktop Mac support a dual-G4 upgrade card?

Any Mac that can support a G4 upgrade should be able to support a dual-G4 upgrade as well.

Performance

The Benefits of the G4 Velocity Engine

How does the Velocity Engine work?

To answer that question, it helps to understand that processors traditionally work by performing a single operation on a single element of data at a time. To perform a Gaussian blur on an image on a system with a G3 processor, for example, Photoshop must operate on each 8-bit channel of each pixel one at a time.

In contrast, a Velocity Engine-enhanced version of Photoshop (running on a system with a G4 processor, of course) could pack 8 bits of data from 16 separate pixels at once into the

G4's Velocity Engine and operate on all them with a single instruction. Similarly, the G4's Velocity Engine could speed up a 3D-rendering application by performing four simultaneous floating-point instructions. In addition, some Velocity Engine instructions combine several steps of an operation into one. This approach allows for performance gains far beyond those obtained by simply operating on multiple data elements at the same time.

AltiVec technology (the Velocity Engine) is built-in to the G4 processor, along with more-typical integer and floating-point processing units. All three units can operate in parallel.

What software will benefit from the G4's Velocity Engine?

Apple plans to take advantage of the Velocity Engine in the Mac OS itself.⁴ QuickTime in particular will get an immediate boost from the G4. Video compression is well suited to parallel processing. Supporting G4 in QuickTime codecs (compressor/decompressors) will enable any video application that uses QuickTime to capture video with higher frame rates, larger images and better image quality.

Many types of third-party applications will also benefit from being modified for the Velocity Engine. Image-processing, video-compression, video-effects-processing, and 3D-rendering applications should all benefit greatly from implementing support for the Velocity Engine.

What will software vendors have to do to take advantage of the Velocity Engine?

Applications must be modified to capitalize on the Velocity Engine. To utilize the Velocity Engine, software developers will need to isolate portions of their applications that are mathematically intensive and repetitive. Developers will need to rewrite the code for these operations using the G4's new vector instructions in place of the older integer (or, in rare cases, floating-point) instructions.

When will applications that take advantage of AltiVec be available?

Adobe has produced plug-ins for Photoshop 5.5 that take advantage of the Velocity Engine to accelerate many filter operations and other functions. At present, however, the only way to obtain these plug-ins is to purchase a Power Mac G4 from Apple; they are bundled with the new systems. Adobe has not yet made the plug-ins available for download from its Web site or for bundling with third-party processor upgrades. Until they do, or until third-party G4 upgrade vendors develop plug-ins of their own, users upgrading older system to G4 processors will not be able to take advantage of Velocity Engine acceleration in Photoshop.

Several other vendors, including Avid Technology Inc., Bungie Software, Casady & Greene, Macromedia, Media 100 and Terran Interactive have also announced their intention to support the Velocity Engine in future software releases. You can expect to see this list grow in the coming months.

The Benefits of Multiprocessing

What software will benefit from the G4's multiprocessing capability?

Many of the same applications that will benefit from the Velocity Engine ~~can~~ will also benefit from MP when dual-G4 systems become available. Moreover, many computation-intensive applications already have been modified to take advantage of MP. Adobe Photoshop, Premiere and After Effects, Strata Studio 3D and Deneba Canvas are among these MP-enabled applications.

Moreover, the MP implementation in Mac OS 8 is more limited than MP will be in Mac OS X. Apple's Mac OS 8 MP implementation only allows specialized functions within applications to be parceled out to different processors. Mac OS X, on the other hand, is designed from the ground up so that the OS itself can take advantage of multiple processors.

What will software vendors have to do to take advantage of multiprocessing?

Modifying an application to enable MP is much like modifying it to enable AltiVec technology. Both involve rewriting portions of the code so that it can be parceled out in small chunks. MP requires somewhat larger chunks than AltiVec, but the basic concept is much the same.

When will software that takes advantage of multiprocessing be available?

As mentioned above, a number of applications are already MP-enabled. When G4-based MP systems or upgrade cards are available, these applications will be able to take immediate advantage of them. Likewise, when Mac OS X ships, it will be able to take immediate advantage of MP.

Can the same application support both MP and the Velocity Engine?

Absolutely. Applications that do so will get a double speed boost from dual-G4 systems. Photoshop, which is already MP-enabled and which is being modified to support the Velocity Engine as well, is likely to be the first application to see this type of performance gain.

The Benefits of the G4's FPU and Cache

What software will benefit from the G4's faster FPU?

Any application that uses floating-point instructions will benefit automatically from the G4's enhanced FPU speed. Applications that will benefit most are 3D-rendering applications like Bryce and math-and-science apps like Mathematica. If these programs are modified to take advantage of the Velocity Engine as well — remember, the Velocity Engine can perform floating-point calculations four at a time — they will see an even greater speed boost from the G4.

Note, however, that most applications, even many computationally intensive ones, use primarily integer, not floating-point instructions. For example, it is a common misconception that Excel, because it is math-intensive, uses floating-point instructions. For

the most part, this is not true; Excel uses floating-point only for a limited set of operations, such as sines and cosines.

What software will benefit from the G4's larger L2 cache?

It's too early to tell. Cache sizes have increased steadily from zero to 1 MB over the course of the past few years. With each increase has come a corresponding speed boost in both system- and application-software performance. It's not clear, however, that a similar benefit will be achieved by the increase from 1 to 2 MB. The final word on this question will have to wait until extensive testing can be performed with real applications running on G4 processors with these larger caches.

Choosing the Best Upgrade

How do I decide whether a G4 or a high-speed G3 is best for my needs?

This is a tricky one. No one answer will work for everyone. Here are some points to consider:

1) Velocity Engine-enhanced software.

As of early October 1999, almost no Velocity Engine-enhanced software is available. By the end of 1999, however, Mac OS 9, which takes advantage of the Velocity Engine, and several enhanced third-party applications should be available. At that point, a G4 upgrade will be more enticing.

2) System bus speed.

Although IBM plans to produce G3 chips with ultra-fast processor speeds, at the present time (October 1999), 500 MHz is the maximum speed announced for either G3 or G4 chips. Once faster-speed G3 chips become available, if your computer's bus speed is high enough, you may be able to install a G3 chip that outperforms the fastest available G4. Although even a super-fast G3 chip won't speed up Velocity Engine-enabled apps as much as a G4 would, it will speed up everything else you do on your computer more than a G4 would. If you don't plan to use many Velocity Engine-enabled applications, a faster G3 may be a better choice.

3) Price.

At present, G4 upgrades are far more expensive than G3 upgrades. If you're looking to upgrade now, your best bet may be to upgrade to a G3. Later, when G4 prices drop, you can take advantage of XLR8's trade-up program.

4) Compatibility.

As with all new technologies, minor compatibility problems will no doubt crop up as software developers test their programs with G4 systems. Apple and third-party G4-upgrade vendors will do all they can to ensure a smooth transition. Still, you may want to verify that your existing software is compatible, or that updates are readily available, before upgrading your system with a G4 processor.