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PowerPC 603e Hits 300 MHz

Faster 604e Also Ships; "Mach 5" Coming Soon

by Linley Gwennap

Clarifying their product plans for 1997, Motorola and IBM have announced speed upgrades to their current 603e and 604e parts while previewing a new product, code-named Mach 5, that will extend the high end of the PowerPC line later this year. This flurry of new parts will allow Apple and other Macintosh vendors to pump up their products and position PowerPC to remain competitive in performance after Intel's Pentium II debuts next month.

With an impressive leap, Motorola has become the first vendor to ship a microprocessor using a 0.25-micron process, beating even partner IBM to the punch. The new process propels the 603e to 300 MHz while further reducing its die size. IBM is not far behind, using a 0.27-micron process to boost the speed of its 604e to 233 MHz and reduce its cost. Both parts are currently shipping in systems.

The 300-MHz 603e is likely to be the last member of the 603 family, as the forthcoming part known as Arthur (see MPR 2/17/97, p. 10) will take over that line in the future. Arthur is the first of the third-generation (G3) PowerPC chips. As Figure 1 shows, the 604 line will get another kicker from a 0.25-micron version, code-named Mach 5, that is set for release in 3Q97, pushing clock speeds above 300 MHz. The companies continue to develop a G3 processor based on the 604 core, but this device will not be available until late this year or early next year.

Motorola First With 0.25-Micron CPU

Motorola's rollout of a 0.25-micron part ahead of the rest of the industry represents a major turnaround for the company. Until recently, Motorola's process technology was optimized for low-cost 68000 processors rather than high-performance RISC CPUs. Over the past few years, however, Motorola has invested heavily in modernizing its fabs, and that investment is bearing fruit.

The 0.25-micron process, which Motorola calls PPC3, is actually a hybrid technology that combines 0.25-micron transistors with metal layers more typical of a 0.35-micron process (see MPR 9/16/96, p. 11). For example, its 1.25-micron contacted metal pitch is about the same as for Intel's 0.35-micron P854 process (see MPR 7/10/95, p. 16). Even so, no other microprocessor has yet shipped with transistors of 0.25 microns or smaller, hybrid technology or not.

Although Motorola can claim bragging rights by shipping a 0.25-micron processor before Intel and IBM, this technology lead is smaller than it appears. Since Motorola has focused on transistor size, the circuit density of its PPC3 process is no better than for Intel's current P854 process. By the time Motorola deploys more advanced metal layers later this year, both Intel and IBM are likely to be shipping true 0.25-micron processes with similar parameters.

The PPC3 metal layers are slightly smaller than in the previous PPC2 process, producing about a 30% increase in transistor density. This change reduces the 603e's die size to just 42 mm^2, less than half the size of a P54C Pentium and nearly invisible by PC processor standards. The MDR Cost

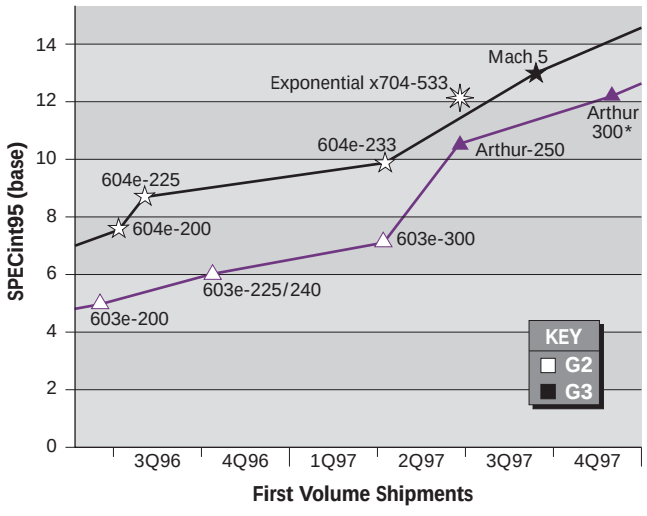

Figure 1. A roadmap of PowerPC processors over the next year shows the transition from the current 603e and 604e to the forthcoming G3 processors. (Source: vendors except *MDR estimate)

Model estimates the new chip's manufacturing cost at $25, versus $40 for a P54C or $55 for the newer Pentium/MMX. The new process results in relatively little change in cost from the previous version, because much of the cost of building a 603e is now in the testing and the package.

The smaller transistors and smaller die size result in a 25% increase in clock speed compared with the 0.27-micron PPC2 version, which reaches 240 MHz (see MPR 10/28/96, p. 5). At 300 MHz, the 603e is estimated to deliver 7.8 SPECint95 (base) and 5.5 SPECfp95 (base) with a 1M external cache and a 75-MHz system bus. Although this performance doesn't match that of the fastest 604 (or P6) parts, the 300-MHz part will be attractive to consumers who buy systems on the basis of clock speed, not benchmark ratings.

Like its predecessor, the new 603e uses a 2.5-V core and has quite low power dissipation, about 3.5 W (typical) at 300 MHz. In contrast, Intel's Mobile Pentium/MMX-200 dissipates 6.5 W. The 603e will continue to be attractive for notebook as well as desktop Macintoshes.

Motorola is quoting 1,000-piece list pricing ranging from $333 for a 250-MHz 603e up to $618 for the clearly overpriced 300-MHz version. The slower part offers performance similar to that of a 200-MHz Pentium/MMX, which lists for $539. This price is likely to fall to about $400 when Intel makes its 4/28 price cut, closing the gap with PowerPC. Motorola's $618 price is higher than for any of Intel's current desktop processors, even the Pentium Pro parts that offer better performance than the 603e.

The new chip's tiny core size and low power may also open opportunities for non-PC applications. A shrink to PPC4 would further reduce the die size, and power could be slashed to below 1 W by turning down the voltage and clock speed. By the end of this year, Motorola plans to deliver embedded products derived from the 603 core, creating high-performance integrated devices for networking and telecom products.

IBM Shrinks 604e by 35%

IBM's new part, code-named Helmwind, is an optical shrink of its earlier 604e, which is shipping at 225 MHz using a 0.33-micron process (see MPR 8/5/96, p. 5). Helmwind uses a 0.27-micron five-layer-metal process called CMOS-6S. This change shrinks the die from 148 mm^2 to 96 mm^2, reducing our manufacturing cost estimate from $55 to $40.

Your 1997 PowerPC Lineup

Code Name	Product	IC Process	Speed	Avail.
Goldeneye	603e	PPC3	300 MHz	Now
Helmwind	604e	CMOS-6S	233+ MHz	Now
Arthur	n/d	CMOS-6S2†	250+ MHz	Mid-97
Mach 5	n/d	CMOS-6X††	300+ MHz*	3Q97

Table 1. Both die shrinks and new processors have their own code names, which are often used by the vendors when discussing their parts. †also Motorola's PPC3 process ††also Motorola's PPC4 process. n/d=not disclosed (Source: vendors except *MDR estimate)

The company announced only a 233-MHz version of Helmwind, barely faster than its earlier part. Clearly, the new part could achieve higher clock speeds; in fact, since Motorola's 603e is shipping at 300 MHz in essentially the same process, the new 604e could probably reach 275 MHz or so. IBM is already sampling 250-MHz 604e parts, and Power Computing has already announced a system based on the 250-MHz chip, so it seems likely that IBM will announce such a product soon. The chip vendor, however, will not commit to anything faster than 233 MHz at this time.

In addition to Power Computing, Apple and Umax have also announced Mac OS systems using the 233-MHz 604e. IBM's own RS/6000 group is also providing 233-MHz versions of several of its Unix workstations and servers in a surprisingly timely fashion. The company is also offering 233-MHz upgrades to users that have previously purchased certain 604-based RS/6000 systems.

IBM estimates that a 233-MHz 604e, with 1M of L2 cache, SDRAM memory, and a 66-MHz system bus, will deliver 9.8 SPECint95 (base) and 6.9 SPECfp95 (base). As one might expect, the 7-MHz boost provides only a 0.1 improvement in SPECint95. The new chip actually fares worse than the 225-MHz processor on the more memory-intensive SPECfp95 benchmark due to its slower bus; with its 75-MHz bus, the 225-MHz chip is rated at 7.6 SPECfp95 (base).

All of these ratings were obtained by IBM using a compiler that isn't shipping yet and system hardware that isn't shipping yet. The initial 233-MHz RS/6000 systems topped out at 8.29 SPECint92 (base) and 5.60 SPECfp92 (base), somewhat lower than the high-end estimates given above. A typical Macintosh configuration would fare worse yet.

IBM lists the 233-MHz 604e for $443 in 1,000-unit quantities. This makes the chip less expensive than a 200-MHz Pentium Pro but with better performance. The power dissipation of the new 604e is 15 W (typical), roughly the same as for the previous 200-MHz 604e. The 604e remains cooler than Intel's P6 processors, although still much too hot for portable systems.

Battling Bandwidth Limitations

The next step for the 604 is a product code-named Mach 5, which is due to ship in 3Q97. The companies call Mach 5 a G3 part, although it apparently will have few, if any, design changes from the current 604e. The chip will gain most of its performance from a shrink to a "true" 0.25-micron process, which should push the clock speed to 300 MHz or higher. The new process, which IBM calls CMOS-6X and Motorola calls PPC4 (see MPR 9/16/96, p. 11), uses transistors that are similar in size to the ones in PPC3, but the size of the metal traces is greatly reduced. As a result, the die size of Mach 5 could be about half that of Helmwind, reducing it to less than 50 mm^2.

The companies did not disclose the full design details of Mach 5, but it appears the chip will have essentially the same core as the current 604e and retain the same pinout and on-

chip caches. Even without extensive changes, the SPECint95 (base) performance should be about 12–13 at speeds of 300 MHz and above.

At these speeds, however, the 75-MHz system bus will become a major performance limiter. There are several ways to solve this problem. One is to push the bus speed to 100 MHz, an approach also being advocated by Exponential for its high-speed PowerPC chip, which uses the same bus structure. Building a three-tap bus (CPU, cache, and chip set) at this speed is difficult, however, so this design might require a special processor module or a new system-logic chip that isolates the cache from the processor bus.

Another approach is to integrate the L2 cache onto the processor chip. HP plans to put 1.5M of cache onto its 0.25-micron PA-8500 chip; with a CPU core of less than 50 mm^2, the 0.25-micron 604 could accommodate perhaps 1M of cache within a moderate die size, perhaps 200–250 mm^2. The on-chip cache would not only allow the 604 to have separate cache and memory buses, like Intel's P6, but it could respond more quickly than an external cache. A chip with an integrated L2 cache would plug into existing 604e sockets and provide a big performance boost.

A third solution is to add an external L2 cache bus, as the vendors have already done with Arthur, the 603-based G3 processor. We expect all three of these techniques to be used by one or both vendors as they extend the PowerPC line into 1998. Systems with a 100-MHz bus may be available in 2H97. IBM is rumored to be developing a 604 with a large integrated cache; such a device might appear in early 1998. The vendors have committed to delivering a G3 604 part with an external L2 cache bus similar to Arthur's, but the timeframe for this device is less clear.

IBM, Motorola Directions Diverge

During this transition from G2 to G3, Motorola and IBM are taking different paths. Motorola is continuing to enhance the 603e line and expects Arthur, once it is available, to fill in the upper reaches of its product line. Motorola has no plans to market Helmwind, waiting instead for Mach 5.

IBM, on the other hand, needs the faster 604e parts to deliver promised upgrades to its RS/6000 line and to push PowerPC performance faster than Arthur will go. In addition, the 604e offers better double-precision floating-point performance than the fast 603e chips, a key factor for IBM's workstation customers, and neither the 603e nor Arthur has the 604e's multiprocessor support, critical for servers and other high-end systems. For PowerPC chip buyers, this divergence ends up to be a good thing: together, the two vendors are offering a broader product portfolio than either could alone.

The one risk from this divergence is confusion among system makers and among end users. Even today, PowerPC parts are available at 225, 233, 240, and 250 MHz, for example, far more speed grades than are really necessary. The chip vendors seem to enjoy conversing in a confusing array of code names, some of which are listed in Table 1, and they have not even disclosed the actual product names of the G3 parts, which are scheduled to begin shipping in just a couple of months. Compared with Intel's megalith marketing messages, these issues make PowerPC positioning seem murky.

Price & Availability

Motorola's new 603e chip is currently shipping in volume at speeds of 250, 275, and 300 MHz. In 1,000-piece lots, the list prices are $333, $476, and $618, respectively. For more information, contact your local Motorola sales office or access *www.mot.com/powerpc*.

IBM's 233-MHz 604e is now shipping in volume with a 1,000-piece list price of $443. For more information, contact your local IBM sales office or access the Web at *www.chips.ibm.com/powerpc.*

Neither vendor has announced pricing for the chips known as Arthur and Mach 5. Both are currently sampling, with production expected in 3Q97.

New Parts Maintain Current Positioning

In actuality, the positioning is fairly straightforward. Today, the 603e handles mainstream desktop (Macintosh) and portable systems; the 604e is best for workstations, servers, and high-end Macs. By early next year, the 603e will still be found in low-end Mac systems but will be replaced by Arthur in most other Macintoshes. The 604e or its G3 successor will continue in a high-end role due to its superior floating-point and multiprocessor capabilities.

Positioning the PowerPC parts against Intel's line is more difficult and, given the completely divergent operating-system strategies for the two processors, probably moot. For those keeping score at home, the 233-MHz 604e puts the PowerPC line slightly ahead of Pentium Pro in performance, but Pentium II will soon erase this advantage. If Mach 5 meets our expectations, however, it could nose ahead of a 266-MHz Pentium II by 10–20% on SPEC. PC application performance will vary, but Apple has not demonstrated an application-level performance advantage significant enough to convince many PC buyers to switch platforms.

For IBM, the 604 family continues to power cost-effective workstation and server products, but its performance lags that of the fastest RISC chips, particularly on floating-point applications. This shortfall forces IBM to rely on its POWER family for its most powerful systems. Within the Macintosh world, the new PowerPC parts promise to accelerate performance improvements, particularly for midrange Macs. With these new parts, Apple can deliver Macintoshes at attractive price/performance points. M