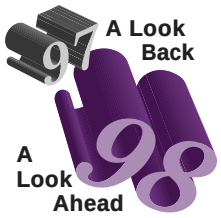
VOLUME 11, NUMBER 17
DECEMBER 29, 1997

MICROPROCESSOR REPORT

THE INSIDERS' GUIDE TO MICROPROCESSOR HARDWARE

RISC Disappointments Mount

Digital Bails, PowerPC Ails, SGI's Beast Fails as IA-64 Unveils



by Linley Gwennap

We launch our year-in-review coverage in this issue by focusing on RISC processors and 3D accelerators (see MPR 12/29/97, p. 17). In the next issue, we'll look at x86 chips, embedded CPUs, and media processors.

With the specter of Intel's Merced looming on the horizon, RISC vendors have already begun to run in circles and scream and shout. In public, of course, they loudly proclaim that Merced is no tougher than the competition they already face. In private, however, panic has set in.

How else to explain the series of events that has unfolded during the past year? Digital, while continuing to profess its love for Alpha, decided to sell its entire chip operation to archrival Intel while adopting Merced for some of its systems. Silicon Graphics killed its next-generation Beast processor, designed to go head-to-head with Merced, while also adopting Intel processors for some of its systems. Calling into doubt the ongoing role of the PowerPC design center, known as Somerset, a Motorola executive bluntly said, "We don't plan to compete with Merced."

IBM intends to compete with Merced using a series of proprietary PowerPC processors but will release Merced-based systems as well. Even Sun, the staunchest opponent of Intel among the RISC vendors, is porting its Solaris operating system to Merced, making it easier for the company to someday drop its opposition. HP, which committed to Merced more than three years ago, now seems like a visionary compared with its RISC rivals.

With Merced still far from shipping, the RISC makers continue to compete among themselves. During the past year, Digital and HP fought for the top spot in the performance race while the others fell behind, particularly on the integer side, as Figure 1 shows. Sun fared the worst, lagging its rivals and even Intel's Pentium II in integer performance. Several new RISC processors failed to appear as scheduled in 1997, including the 21264, Exponential's x704, the RM7000, and the UltraSparc-2i.

For the sixth straight year, we bestow our RISCie awards on the best and worst RISC processors of 1997. As usual, we have excluded x86 processors and embedded RISC processors from the competition, but we're treating the unreleased Merced as an honorary RISC chip. Note that all performance comparisons are based on SPEC95 (base) unless otherwise indicated.

Digital Bails Out of Chip Business

The Alpha vendor made up for a relative dearth of new processors in 1997 with its soap-operatic battle with Intel. Digital earns a **Pearl Harbor** citation for its surprise attack on Intel, filing a massive lawsuit on May 13 before the sun had risen on Intel's headquarters. The suit alleged that Intel's Pentium and Pentium II products infringed on Digital

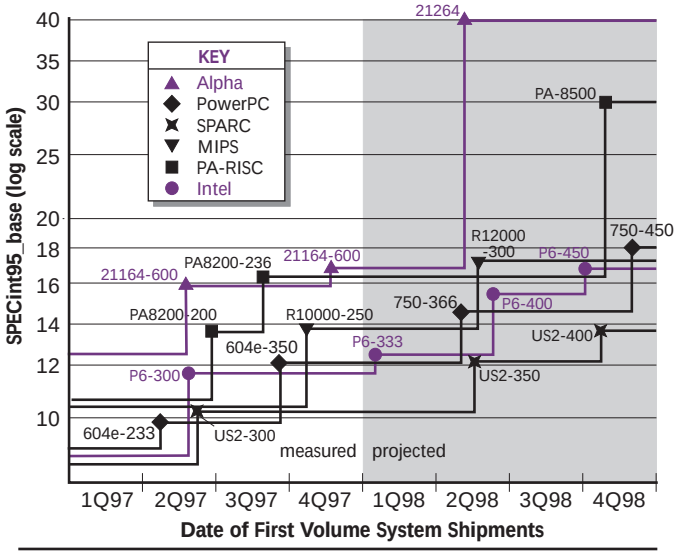


Figure 1. Digital and HP have been dueling for the integer performance lead while the others fall behind. (Where two points are shown for the same processor and clock speed, the vendor later released better results.) (Source: SPEC, MDR projections)

patents. Intel quickly countersued and, more important, terminated Digital's access to information about future Intel processors, which Digital uses in its PCs and servers.

Despite predictions that the spat would drag on for years, the companies announced a stunning settlement less than six months later. Digital agreed to withdraw its suit if Intel would buy most of its semiconductor business, including its money-losing fab, for essentially book value. In addition, Digital agreed to adopt IA-64 in its future systems. Digital will retain its Alpha design team and plans to continue advancing its RISC products, but asking the Merced maker to also build Alpha chips seems like letting the **Fox Guard the Henhouse.** We expect the deal will lead Digital to convert from Alpha to IA-64 over time.

With all of this excitement, we barely noticed that Digital's only new high-end product in 1997 was a 600-MHz version of its 21164, extending the performance of a product that had been shipping for two years. Nevertheless, this was enough for the company to fend off HP and win another **World's Fastest Microprocessor (shipping)** title.

The much-anticipated 21264, however, failed to appear on schedule in 1997; the Alpha chip is now expected to ship in systems in 2Q98. Digital raised the performance estimates for its superchip to 40 SPECint95 (base) and 60 SPECfp95 (base), keeping the title of **World's Fastest Microprocessor (announced)** for at least another year.

Sweeping the performance awards, Digital recently began shipping the 21164PC, which wins in the **World's Fastest Microprocessor (under $250)** category. At just $225 for the 400-MHz version, the mighty mite recently began shipping in systems selling for as little as $2,000 (sans monitor). On native applications, these Alpha systems deliver about the same integer performance as Pentium II units but significantly better floating-point performance. The x86 systems, however, sell for about the same price and typically include the fast AGP graphics interface, which the Alpha boxes do not. Thus, the 21164PC is best suited only for those users with heavy floating-point needs.

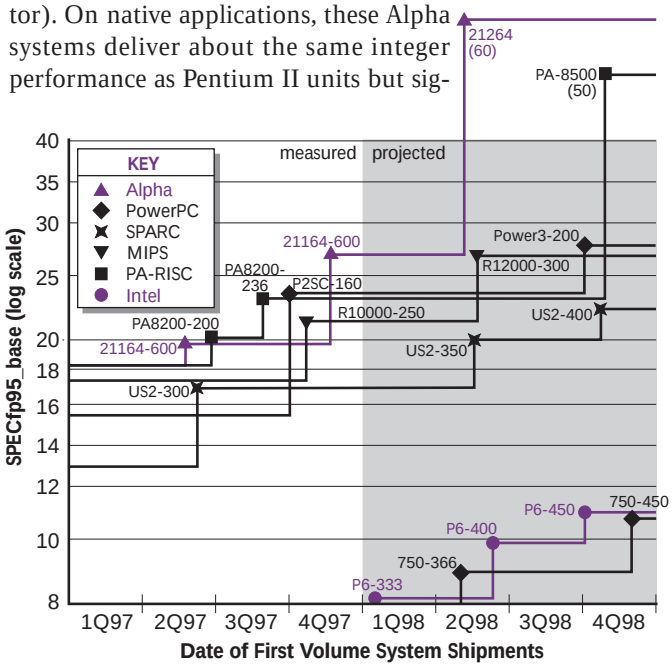


Figure 2. Digital also leads in floating-point performance, but other RISC vendors are close behind. Intel trails badly on this measure. (Source: SPEC, MDR projections)

In 1997, erstwhile Alpha partners Mitsubishi and Samsung both shipped significant quantities of Alpha chips for the first time. The Asian vendors are supplying the 21164 and 21164PC to several small system makers. Digital plans to withdraw from the merchant Alpha market, leaving the field to its two partners. At best, these two companies could establish a small but profitable niche for Alpha in the PC market; at worst, they could be **Left Holding the Bag.**

PowerPC Delivers Hot Chips to Cold Markets

With Apple continuing to self-destruct (see MPR 12/29/97, p. 25), the best news for PowerPC fans was on the processor front. Chip makers IBM and Motorola shipped the 750, their first new PowerPC core in two years. With only a few key changes from the 603e, the 750 barely rates as new, but the combination of these improvements delivers a big increase in performance, particularly on Macintosh applications. Based on MacBench, a 266-MHz 750 is 85% faster than a 250-MHz 604e. The 750 achieves this outstanding performance with a die size of just 67 mm^2, grabbing our **Editor's Choice** award for its combination of strong performance and low cost.

The PowerPC makers deployed the **First 0.25-Micron Microprocessors**, using advanced IC processes to speed both the 603e and 604e. The latest process moves the 604e up to 350 MHz while cutting its die size to just 47 mm^2, making it the **Smallest RISC Processor** for general-purpose systems. According to initial published SPEC results, the fastest 604e is about 10% ahead of Intel's Pentium II on both SPECint95 and SPECfp95 (base).

On the downside, Exponential Technology's innovative PowerPC chip never made it to market, earning the **Burnt-Out Light Bulb** award. The bipolar processor didn't meet its target clock speed, and even if it had, its performance probably would have been overshadowed by the muscular new PowerPC chips from Motorola and IBM. Thus, Apple withdrew its commitment to the Exponential processor, and the startup shut down.

The market for PowerPC chips suffered another blow when Apple decided to close the Macintosh clone market and withdraw its support for the PowerPC reference platform known as CHRP (see MPR 12/5/94, p. 8), earning the **Honey, I Shrunk the Market** award. With Windows NT and OS/2 support already gone, Apple is now the only significant customer for PowerPC chips outside of IBM. Worse yet, the Mac vendor's market share has sunk to about 4%, down from 7% in 1996 and as high as 10% in the previous year.

To make matters worse, Apple is developing a new operating system, Rhapsody, that runs on Intel processors as well as PowerPC chips. Given the company's lack of a clear

strategic direction, we aren't sure when or if Rhapsody will supplant Mac OS as Apple's high-volume operating system, but any significant move to Rhapsody could further damage PowerPC's hopes. At this point, we believe PowerPC's share of the general-purpose computer market has peaked, and **It's All Downhill From Here.**

IBM Charts Solo Course

Although IBM is moving its processors from its original POWER instruction set to PowerPC, the company clearly plans to maintain its own line of processors for workstations and servers rather than rely on Motorola and the Somerset design center for help. This past fall, the company began shipping a 0.25-micron version of its P2SC processor that increased the clock frequency of that part to mere 160 MHz, the **Slowest Clock Speed** among high-end RISC processors.

Although clock speed may be a misnomer in this case, Figure 2 shows that the P2SC produces competitive floating-point performance, aided by the **Best Main-Memory Bandwidth** among microprocessors (see MPR 12/29/97, p. 31). Even in the new process, however, the P2SC weighs in at a hefty 255 mm^2 and retains its **Highest Manufacturing Cost** title, according to our cost model.

In September, IBM deployed its first systems based on a 64-bit PowerPC processor. No, not the PowerPC 620, the **Flying Dutchman** of microprocessors that still hasn't found a port. Instead, the company has modified one of its 64-bit AS/400 processors, which run a hybrid of PowerPC and AS/400 instructions, to be a pure PowerPC chip. With the RS64, IBM earns the dubious distinction of being the **Last RISC Unix Vendor to Reach 64 Bits,** although the company can take solace in Intel's ongoing lack of a 64-bit solution (at least until Merced appears).

IBM's next 64-bit processor will be the Power3, due to appear in 2H98 at clock speeds of 200 MHz. IBM earns a **Misleading Press Release** citation for issuing a release saying "The initial Power3 microprocessor … will ship in systems in 1998. The Power3 will … achieve clock speeds of more than 500 MHz," conveniently omitting that the 500-MHz version is not expected until the turn of the century.

Like the P2SC and RS64, the Power3 will be available only in IBM systems and will not be sold to other vendors; Motorola will not have access to these designs. Thus, it appears that IBM alone will push PowerPC into the workstation and server markets using its proprietary processors; Somerset's role will be to serve the shrinking Macintosh market as well as the high end of the embedded market.

Major RISC Events of 1997

Digital sued Intel, alleging patent infringement (6/2/97, p. 26); Intel countersued (8/25/97, p. 8); Digital agreed to sell its chip business to Intel as part of the settlement (11/7/97, p. 1).

Digital announced its 21164PC chip (3/31/97, p. 9), which later began shipping in PCs (12/8/97, p. 5). The company also boosted the speed of its industry-leading 21164 to 600 MHz (4/21/97, p. 4). Samsung shipped its first Alpha chips (8/25/97, p. 5).

The **PowerPC** 603e hit 300 MHz using a 0.25-micron process (4/21/97, p. 1), while the "Mach 5" 604e reached 250 MHz (7/14/97, p. 4) and then 350 MHz (8/4/97, p. 8) using a similar IC process. Arthur (2/17/97, p. 10) shipped as the PowerPC 750 (8/4/97, p. 8).

Exponential delays (5/12/97, p. 5) led to the collapse of the company and its PowerPC chip (6/2/97, p. 4).

Apple disclosed its Rhapsody OS plans (1/27/97, p. 5), but later moved to terminate the Mac clone market and the common hardware reference platform (CHRP) (9/15/97, p. 5) (10/6/97, p. 4).

IBM pushed its P2SC processor to 160 MHz and shipped its first 64-bit PowerPC chip (11/17/97, p. 5). The company plans to deploy its next-generation Power3 processor (11/17/97, p. 23) in 2H98.

HP shipped the first PA-8200 systems at 200 MHz (6/2/97, p. 5) but later gained the performance lead by pushing that chip to 236 MHz (10/6/97, p. 4). The company revealed plans for the PA-8500 (3/10/97, p. 4), which includes 1.5M of on-chip cache (11/17/97, p. 20).

Silicon Graphics disclosed plans for a next-generation MIPS processor code-named Beast (5/12/97, p. 14) then killed it (8/4/97, p. 4) in favor of the R12000 (10/6/97, p. 1). The company also said it will build Intel-based systems (10/6/97, p. 23). The 0.25-micron R10000 shipped at 250 MHz (10/6/97, p. 5).

Sun finally began shipping UltraSparc-2 systems at 300 MHz (5/12/97, p. 9). The company later disclosed the design of UltraSparc-3 (10/27/97, p. 29), which is expected to ship in 1H99.

Intel and HP disclosed the first details of the **IA-64** instruction set (10/27/97, p. 1). A key patent application regarding Merced was disclosed (3/31/97, p. 16) and later issued in the U.S. (7/14/97, p. 4). The companies are also working on a follow-on to Merced (5/12/97, p. 4).

MIPS Progress Slows

MIPS fans hoping for a performance upgrade to the 200-MHz R10000, which had been holding down the high end of the line since early 1996, finally got one when NEC began shipping a 250-MHz part in 4Q97. That chip, a simple shrink of the 0.35-micron original, had been expected to ship in 1Q97, but NEC had problems getting its 0.25-micron process running. This 25% performance gain over nearly two years falls so far behind Moore's Law that we must create a new **MIPS Law** to describe it.

Naturally, this showing leaves the R10000 well behind the leaders in integer performance, but the MIPS chip shows

SPEC95 Losing Relevancy

SPEC benchmarks and RISC processors apparently have similar lifespans, and the SPEC95 suite is nearing the end of its useful life. The first problem with the suite is that it doesn't really test the bandwidth between the CPU and main memory. The SPECint95 suite is almost entirely resident in a 1M level-two cache, common in RISC systems today. A few of the 10 SPECfp95 programs exercise the main-memory interface, but for the most part, even that suite is cache-resident. Unfortunately, few interesting applications fit into today's caches, making SPEC95 less representative of application performance.

Until recently, however, SPEC95 served as a good metric for CPU/cache performance, and it is our benchmark of choice for comparing high-end microprocessor performance. But over the past few months, vendors have posted results that show significant increases in performance for the same or similar CPU/cache subsystems, indicating that compiler optimizations have come dangerously into play.

For example, IBM's SPECfp95 score for the 160-MHz P2SC is 45% higher than for the 135-MHz part, despite an increase in clock speed of only 20% and no other system changes. Digital increased the SPECfp95 score for its 600-MHz 21164 by 35% simply by increasing the L2 cache size from 2M to 8M. These increases came on the "baseline" version of the metric, which is supposed to be less sensitive to compiler optimization.

We suggest using caution when comparing SPEC95 scores of various processors, as some have been revised upward recently while others haven't. We eagerly await the release of the SPEC98 suites, which should solve this problem—at least for a while.

surprising strength on the floating-point side: as Figure 2 shows, it is close to the performance lead on SPECfp95.

In 1H98, Silicon Graphics expects to get a bigger boost with the R12000, a slightly modified version of the current device that improves a few performance bottlenecks. The new chip also has circuit-design enhancements that should allow it to reach 300 MHz in the same 0.25-micron process.

SGI had hoped to follow the R12000 with a completely new design code-named Beast, but that project fell far behind its schedule and performance goals, forcing the company to kill the Beast in July. SGI quickly revamped its roadmap to include a 0.18-micron version of the R12000 in 1999, but by that time, the aging MIPS core is likely to be uncompetitive. The R12000 will be further limited by its poor memory bandwidth: at just 674 Mbytes/s, the chip has the **Lowest Memory Bandwidth** among high-end RISC processors and will fall behind Intel's 100-MHz Pentium II bus, due in 2Q98. SGI may be able to tweak the bandwidth in 1999, but major improvements must wait until the debut of the next-generation H2, now expected in 2000.

For its low-end workstations, Silicon Graphics is still relying on the feeble R5000, which offers only slightly better floating-point performance than a mere Pentium/MMX and much less integer performance. The company had expected QED to deliver the RM7000 by the end of 1997, but the low-cost chip has been pushed out to 1H98, earning SGI's low end an **Illegal Lack of Motion** flag.

In the longer term, SGI appears likely to abandon the low-end MIPS desktop; the company announced plans to deploy x86/NT-based systems in this market segment, possibly as early as 2H98. We expect these systems to offer better price/performance than the vendor's MIPS-based systems, leading many customers to switch to the Intel-based platform. SGI is likely to follow with Merced-based workstations in 1999, although the company won't admit this publicly. Given the company's previously zealous opposition to Windows NT, this about-face earns an **Eating Crow** award.

External events have left MIPS as essentially an in-house architecture for Silicon Graphics, except for a robust embedded market. The collapse of NT-on-MIPS in late 1996 blew away many MIPS supporters, leaving only Siemens-Nixdorf and Tandem. With Tandem now part of Compaq, that company's transition to Intel processors is likely to accelerate, and Siemens is also moving toward Intel-based systems. By the end of 1999, nearly all nonembedded MIPS processors will be consumed by SGI. With SGI itself pursuing a biplatform strategy, the unit volume supporting high-end MIPS chips will become slender indeed.

Sun Takes the Slow Road

Following MIPS Law instead of Joy's Law, Sun managed to eke out a speed improvement of only 20% in 1997, boosting UltraSparc-2 from 250 to 300 MHz. This lack of progress leaves SPARC in its traditional role of **Tail-End Charlie** in the performance race; even Pentium II delivers better integer (although not floating-point) performance.

Sun's low-end workstations fared even worse, as they continue to rely on Fujitsu's woeful TurboSparc, cited as the **Slowest RISC Processor.** That CPU has roughly the floating-point performance of a 166-MHz Pentium/MMX, a chip that Intel practically gives away for $112, and far worse integer performance. This situation has forced Sun to cut the price of its UltraSparc workstations to compete in the mid-range. The company had hoped to ship its UltraSparc-2i in low-cost systems before the end of 1997, but the integrated chip has now been pushed out to 2Q98.

Sun's plan for 1998 is to raise the speed of UltraSparc-2 as high as 400 MHz by taking advantage of Texas Instruments' 0.21-micron C07 process (see MPR 8/4/97, p.14). The next big step after that will be UltraSparc-3, which we expect to appear in systems in 1H99.

Fujitsu continues to maintain its own parallel line of SPARC processors, earning the **Redundantly Redundant**

award. Hal Computer Systems is shipping systems based on a 161-MHz multichip CPU; the Fujitsu subsidiary plans to deploy in 3Q98 a single-chip version of its processor, known as the Sparc64-III, that boosts the clock speed to 250 MHz. Although the Hal chip will deliver better performance per MHz than UltraSparc-2, we expect Sun to be shipping 350-MHz and possibly 400-MHz processors by that time, erasing any performance advantage for Hal.

Fujitsu has also funded Ross Technology to develop a 500-MHz SPARC v9 chip, code-named Viper, that the company claims will outperform Sun's UltraSparc-3. But as Mr. Spock would say, the odds of Sun adopting Viper instead of UltraSparc-3 are approximately **1 in 2,048,963.**

PA-RISC Performance Challenges Alpha's

Despite being the first vendor to announce plans to phase out its own architecture in favor of IA-64, HP hasn't let its PA-RISC product line wither on the vine. On the contrary, the company has provided the toughest competition for Alpha in the performance race and looks as if it will continue in that role in 1998.

When HP introduced the PA-8200 (see MPR 10/28/96, p. 18), it promised that the chip would wrest the performance lead from Digital, but the CPU failed to accomplish that goal when it first appeared. Within a few months, however, HP identified and improved a critical speed path in the PA-RISC processor, boosting its clock speed from 200 to 236 MHz and making it the **World's Fastest Processor (interim basis)** on both SPECint95 and SPECfp95 (base). Since then, however, Digital has regained a slight lead (see sidebar, page 3).

In 2H98, HP plans to roll out the PA-8500, an impressive device that sports the **Most On-Chip Cache** (1.5M) by far of any announced processor. By eliminating the need for an expensive external cache, the PA-8500 will boost performance while reducing system cost, an impressive accomplishment enabled by a big jump from 0.5-micron to 0.25-micron CMOS. The chip has not yet taped out, however, raising doubts about the company's ability to ship it in 1998.

In contrast, HP's low-cost workstations have seen no CPU improvement in the past year, with little hope for 1998. The integrated PA-7300LC has been shipping at 160 MHz since 3Q96. With performance comparable to that of Pentium II, the 7300LC is losing competitiveness, but HP's roadmap shows no new low-end PA-RISC processors. Instead, the company is focusing on Pentium II/NT systems in this price range, leaving its low-end HP-UX customers sending an S.O.S. **(Same Old Stuff)** signal.

For the high end, HP plans to do another spin of the PA-8000 family in 1999, but by that time its focus will have shifted to Merced. The PA-8700 will probably have lower performance than the IA-64 chip, offering a bridge, albeit a narrow one, to those customers who don't want to make a rapid transition from PA-RISC.

Merced Still Foggy But Gaining Momentum

Intel's Merced is still more than a year away, but some details are beginning to emerge. Intel and HP revealed a few key characteristics of the IA-64 instruction set and coined the term EPIC to describe its mixture of RISC, VLIW, and other ideas. Intel confirmed that Merced will ship before the end of 1999 with "industry-leading" performance, but the company failed to provide any specific targets.

The toughest competition for Merced on the performance front will be Digital's 21264, which should be shipping in a 0.25-micron version in 1999, approaching clock speeds of 1 GHz. Sun's UltraSparc-3 looks as if it will fall behind Merced on SPEC95, but the SPARC chip's enormous memory bandwidth may give it an edge over Merced on certain memory-intensive applications and in systems with many processors. Other RISC products appear likely to fall well behind Merced in performance, bringing into question the long-term viability of these product lines.

There is some debate over the value of EPIC (see MPR 12/29/97, p. 22). But even if Merced only matches the performance of the best RISC processors, its combination of high performance and x86 compatibility will give it an advantage over any RISC. Operating systems with announced IA-64 support include Windows NT, Digital Unix, HP-UX, SCO Unix, and Solaris; Apple's Rhapsody is likely to follow suit. Thus, without even shipping, IA-64 takes the **Most Operating Systems** crown away from PowerPC. System vendors are also flocking to IA-64: Compaq, Data General, Dell, Digital, HP, IBM, NCR, Sequent, and Unisys are among the vendors committed to delivering IA-64 systems, and we expect Silicon Graphics to join that list, giving Merced the **Biggest Bandwagon.**

Many of these system vendors are merely moving existing x86 product lines to IA-64, a natural transition. But with Digital, HP, IBM, and Silicon Graphics supporting parallel product lines based on Intel and RISC processors, end users will be able to choose between IA-64 and RISC. Over time, we expect more and more will choose IA-64.

RISC vendors are trying to compete by pushing their processors into niches that Merced won't reach. Digital hopes that its deal with Intel will accelerate its access to 0.18-micron technology, allowing Alpha to provide better performance than IA-64. Future processors such as UltraSparc-3, Power3, and SGI's H2 will use enormous pin counts to deliver better memory bandwidth than is expected from Merced, although Merced II may close this gap. Even if these RISC processors find a high-end niche, however, the unit volume of this niche will be much smaller than today's RISC workstation/server market.

In the meantime, RISC vendors will vie with each other to establish stronger positions before Merced ships. With new products such as the 21264, PA-8500, R12000, Power3, RM7000, and UltraSparc-2i on tap, 1998 is shaping up to be a more exciting year than 1997. These products should deliver dramatic performance increases over current devices, revitalizing the RISC world. M