RISC Volume Gains But 68K Still Reigns

Consumer Applications Still Drive Sales, Technical Innovation

A Look Back 97 98 A Look Ahead

by Jim Turley

For another year, Fortress Motorola defended its position on top of the 32-bit embedded hill. Its position is not unassailable, however. Battered by RISC chips with better performance, the 68K may eventually succumb to larger numbers. The invasion will be led mostly by 10-year-old boys armed with Christmas lists.

In 1997, consumer electronics—particularly games—were the volume driver for 32-bit embedded chips. The past year provided ample evidence that low cost and high performance are not mutually exclusive, and that power efficiency is a powerful force in the market. New CPU cores geared toward ASIC development continue to be a source of growth, with low power and peripheral integration the key elements.

Two new 32-bit architectures were introduced to the world in 1997, and none of the existing ones dropped out of sight. Embedded processor sales grew by an average of 66% across the board, with a few families doubling their volume. Still more new vendors and architectures are just over the horizon, as media processing, signal processing, and image processing become vital differentiators.

Motorola Stays on Top; Other Players Double

Worldwide volume in 32-bit embedded microprocessors surpassed 180 million units, as Figure 1 shows. Of that total, three architectures—68K, MIPS, and SuperH—accounted for 80% of shipments in 1997. All the top vendors maintained their relative positions, although in some cases the gaps between players narrowed.

ARM, MIPS, and PowerPC won the biggest advances in terms of multiples. The first two more than doubled from 1996 to 1997, growing by 129% and 138%, respectively. MIPS also enjoyed the biggest unit increase, shipping 24.8 million more chips and CPU cores than it did the previous year. PowerPC is still in startup mode, multiplying from half a million in 1996 to about 3.9 million in 1997.

Motorola's 79.3 million units put it on top, as usual. Its 68K line has been the embedded 32-bit volume leader since it created the category. As the figure shows, sales of 68K chips were about equal to worldwide sales of PCs. Taken together, that's one new 32-bit microprocessor for every man, woman, and child living in the United States.

The company declined to break out its sales among 68K families (680x0, 683xx, and ColdFire) but suggested that ColdFire played a much more important role than in previous years. Given that ColdFire accounted for only about 1 million units in 1996, that trend is unsurprising.

Editor's Choice
VR4300
Best Embedded Processor

Although MIPS grew by a larger percentage, 68K shipments increased by almost as many units: 24 million for 68K versus almost 25 million for MIPS. Thus, MIPS and 68K sales trends have similar slopes, but the 68K line would be higher up on the graph. For Motorola, 24 million units represents a more modest—though undeniably healthy—44% increase.

MIPS Collects Gold Stars for Another Banner Year

The MIPS camp followed 1996 with another very good year, rocketing ahead to 44 million units. The lion's share of MIPS volume was due to the Nintendo and Sony game consoles. These two systems accounted for about 36 million units, or 80% of the year's receipts. (There is one MIPS processor in the PlayStation and two in each Nintendo 64: one in NEC's R4300 processor and one in Nintendo's graphics chip, which is based on the Silicon Graphics Reality Engine.)

Even without these two monster design wins, MIPS would have ranked in the top five, shipping about 8 million units. One could argue that without the games, other embedded sales would have suffered, as many customers no doubt selected MIPS on the strength of its presence in the consumer market. Clearly, NEC had a winner from the outset, and has successfully extended the product into printers and other markets, earning the R4300 the Editor's Choice award for its combination of price, performance, and flexibility.

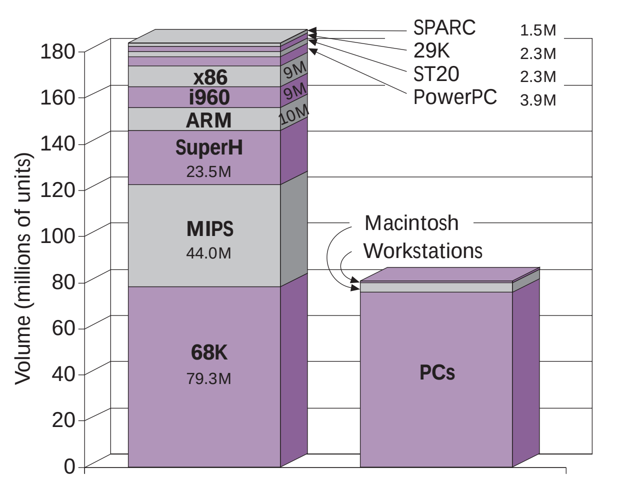

Figure 1. In 1997 embedded shipments again dwarfed those of all other forms of 32-bit systems. Motorola's 68K franchise is still the dominant architecture, but MIPS and SuperH are closing the gap. (Sources: vendors, Computer Intelligence, MicroDesign Resources)

SuperH's Rapid Growth Appears Stalled

Hitachi saw 28% growth in SuperH shipments, an enviable statistic in any other industry but lower than nearly all of its competitors. The company continues to wean itself from Sega. From its early dominance of SuperH sales in 1995, Sega dropped to about half of SuperH volume in 1996. In 1997, Hitachi estimates that only about 30% of SuperH shipments were destined for the Saturn game system. This drop has not been due to any downturn in Saturn sales; instead, Hitachi has done a good job of cultivating design wins in automotive, office-automation, and other consumer-electronics systems. Not surprisingly, a number of Hitachi's designs are with Japanese companies, which are traditionally reticent about advertising the microprocessor inside their products.

Looking ahead, Hitachi will continue to rely on Saturn for a large portion of its SuperH sales through 1998 until Sega's new system, code-named Katana (formerly Dural), appears. Shipments of SH-4 chips to Sega should begin about 3Q98, in time for the Katana rollout, which is now expected to be early in 1999. Even if Katana makes it in time for Christmas 1998, Hitachi can't count on more than a few hundred thousand units before the end of this year. The SH-3 and SH-4 generations will hold the company for the next few years, until the SH-5 comes on line in 2001.

The next-generation Sega system may be a mixed blessing for Hitachi. Saturn contains three SuperH parts; Katana needs only one. Even if Katana outsells Saturn 2:1, SuperH shipments to Sega will plummet by one-third. Unless Hitachi makes much better margins on SH-4 chips than it does on SH-2, Sega's switchover could be dismal news for Hitachi.

ARM Has Mixed Year, Betting on 1998

ARM racked up an even 10 million units, according to the company and its licensees. ARM credits a range of designs—printers, disk drives, modems, and Newtons among them—for its success in 1997. Digital cellular telephones, which have long been the prototypical example of an ARM design win, actually accounted for relatively few sales in 1997. The company expects digital phones to spearhead some very strong growth in 1998 now that all three major vendors (Ericsson, Nokia, and Motorola) are using ARM7.

ARM's most famous offspring, StrongArm, accounted for only 250,000 of those 10 million units. Unfortunately for both Digital and ARM, StrongArm sales tapered off suddenly in 4Q97, as customers sat on their orders following Intel's move to purchase StrongARM. Until the U.S. government approves (or denies) the purchase, OEMs seem unwilling to commit to the part. Given the traditional pace of government investigation, StrongArm sales may not pick up again until halfway through 1998.

At that point, StrongArm sales should pick up vigorously, led by the SA-1100. Digital expects quite a few new SA-1100–based systems to be in production by 2H98, including Web-enabled telephones from Philips, Lucent, Uniden, Siemens, and Nortel, plus some new Windows CE devices.

MIPS Ponders Its Future

Amid all the rejoicing in the halls at MIPS, there is unrest as well. With Silicon Graphics unofficially adopting Intel's Merced for at least some future systems, the ownership—or survival—of the MIPS group is uncertain.

With only one in a thousand MIPS cores winding up in Silicon Graphics systems, it's not clear why the computer company needs to maintain an embedded business. The MIPS group has become an unnecessary appendage, a remnant of an earlier business.

Some of the larger MIPS licensees may strike out on their own. NEC has shown it's willing and able to design its own MIPS chips, with or without help from SGI. Its R41xx parts are NEC designs that execute the MIPS instruction set. Startup Lexra (see MPR 1/26/98, p. 13) has shown that it's possible to create a MIPS-compatible CPU without the benefit (or cost) of a MIPS license.

MIPS could try to tighten the reins, but the company has little legal leverage to prevent licensees from going it alone. If companies like NEC, IDT, and LSI Logic begin ignoring mandates from MIPS HQ, the MIPS group may become more of an annoyance than a partner.

In that case, MIPS can either fold its tent or become a different company. MIPS could become essentially its own licensee, a fabless chip company like QED, selling chips under the MIPS Technologies or Silicon Graphics brand. Such a move would probably put it in direct competition with at least some of its current licensees. Collecting royalties with one hand while marketing competitive products with the other would certainly antagonize more than a few MIPS licensees, perhaps accelerating the breakup of the homogeneous architecture.

MIPS could also become an intellectual-property company in the model of ARM. As before, MIPS could create and license CPU cores but also do designs-for-hire, renting itself out to semiconductor vendors.

In the near term, we expect the MIPS instruction set to fragment more than it already has. MIPS' authority has been challenged, and the individual vendors have too much at stake to stand on the formality of preserving the purity of a shared instruction set. Different media extensions are likely to appear in the coming year. Different code-compression schemes will probably not happen, as MIPS-16 provides what vendors and customers are looking for.

None of this is necessarily bad for system designers. For high-volume applications, broad software compatibility with a nominal architecture specification isn't important. As long as the CPU vendor can supply a credible tool chain, the system designer is happy—and happier still if the MIPS-derived chip offers some unique features for the intended application.

Embedded Events of 1997

Motorola unveiled **M•Core** (10/27/97, p. 12) and licensed a new 68000 from EXD (12/29/97, p. 11). **ColdFire** got updated (11/17/97, p. 8) as prices fell.

NEC's R4300 **MIPS** chip appeared in the product catalog at Toshiba (8/25/97, p. 5) and Philips (12/8/97, p. 9). NEC boosted its R4111 to 100 MHz (10/6/97, p. 13) and R4310 to 167 MHz (10/27/97, p. 11). QED took the high ground with the RM5260 (3/31/97, p. 5) and 200-MHz RM5270 (10/27/97, p. 11). NKK bowed with an integrated R4650 (12/8/97, p. 9). The first MIPS-16 compression was in Toshiba's 1904AF (8/4/97, p. 9). Philips weighed in with its 31700 (5/12/97, p. 13).

Hitachi rolled out **SuperH** chips with DSP (3/31/97, p. 4), floating-point (10/27/97, p. 11), PDA support (8/4/97, p. 4), and geometry acceleration (12/29/97, p. 12). A new joint venture with SGS-Thomson was announced for SH-5 (12/29/97, p. 10).

Rockwell got a **PicoJava** license (4/21/97, p. 5), then blew the dust off JEM1 and discovered it didn't need one (10/27/97, p. 10). Sun bought information-appliance designer Diba (8/25/97, p. 4) and introduced the MicroJava 701 (11/17/97, p. 9).

Motorola did a cheap **PowerPC** EC603e (10/6/97, p. 8); IBM followed suit two months later (12/29/97, p. 10). The 403GA, 'GC, and 'GCX all sped up (3/10/97, p. 5). Plans for embedded PowerPC enhancements were codified in Book E (10/27/97, p. 10).

Intel finally released two long-awaited **i960** chips, the 'HD and 'HT (10/6/97, p. 8). The 'RD hit 66 MHz (2/17/97, p. 5).

ARM signed Motorola (3/31/97, p. 4), LSI Logic, Philips (4/21/97, p. 4), Lucent (6/2/97, p. 11), Sony, and Hyundai (8/4/97, p. 4) while the ARM7 core reached 120 MHz (10/6/97, p. 9). ARM9 promises to double performance in 1998 (12/8/97, p. 10).

Digital extended its **StrongArm** line with 21285 support logic (3/10/97, p. 5), SA-1100 PDA processor (9/15/97, p. 1), and SA-1500 media controller (12/8/97, p. 12). The products were sold to Intel (11/17/97, p. 1).

Integration was key to **x86** chips as AMD tapped Elan410 (3/31/97, p. 5), Elan400/410 reached 100 MHz (10/27/97, p. 10), SGS-Thomson revealed STPC Consumer (8/4/97, p. 1), and National rolled out, then killed the 586L, (10/27/97, p. 16). Intel's Pentium was officially embedded on modules (6/23/97, p. 10) and standard packages.

SPARC made a modest showing with Temic's new SPARClet telecom controller (5/12/97, p. 17).

NEC breathed life into the **V830** line (6/2/97, p. 22) and made a new A/V processor (9/15/97, p. 5).

Siemens introduced **TriCore** (11/17/97, p. 13).

No Sudden Moves From Intel's i960

Intel maintained a glacial pace with its i960 family, neglecting to announce a single new part and only three clock-speed upgrades for the year. The 33-MHz i960RP spawned the 66-MHz 'RD in February. The family then mounted to the dizzying speed of 80 MHz with the arrival of the 'HT-75 and 'HD-80 in October, a scant three years behind schedule. And at $70 apiece in quantity, the H-series chips offer spectacularly poor price/performance.

Even so, Intel managed to increase its volume by almost 50%, shipping 9 million i960 parts in 1997. The bulk still go to printers and network boxes, but a growing proportion are now used in RAID controllers from Mylex and others. The company's participation in the I_2O initiative also increases the number of potential designs for i960 parts.

x86 Among the Smaller Players

The omnipresent x86 architecture continued to not dominate the embedded market, shipping a total of about 9.25 million units into embedded systems. That total was divided fairly equally between Intel and AMD, with SGS-Thomson and TI each taking a few hundred thousand as well.

AMD's 3.98 million embedded x86 sales were about evenly split among 386- and 486-based Elan chips as well as 486DX4 and 'DX5 processors. There were no appreciable sales of the K6 into embedded systems in 1997, and demand for the K5 is nearly nonexistent.

Intel shifted in the neighborhood of 5 million embedded x86 parts—a good 25% more than AMD but a small fraction of its sales into desktop systems (see MPR 1/26/98, p. 1). The bulk of Intel's embedded sales were in 386 processors, with the next biggest portion going to Pentium; the company has no equivalent to AMD's 486DX5 or integrated Elan parts.

AMD 29K Not Dead Yet; SGS-Thomson Thrives

AMD's 29K spent the past year circling the drain at the rate of 2.28 million units for the year, up 9%. More surprising is that 29K sales grew at all, two years after AMD sabotaged all future development of the architecture. With no marketing or R&D funding going into the line, the moribund 29K should at least generate some nice profits as it edges toward the abyss.

Among the smaller players, SGS-Thomson had more success with its unusual ST20 products than with its better-known x86 chips. ST delivered 287,000 of its 486DX2 and 'DX4 processors into embedded applications, but almost 10 times that number of ST20 chips, which are popular in TV set-top boxes. Although the ST20 family is mostly unknown in the general-purpose embedded world, ST managed to ship a healthy 2.3 million of the repackaged Transputer chips to cable and satellite TV vendors in 1997.

PowerPC Now More Embedded Than Ever

With combined volumes of about 3.5 million units, IBM and Motorola shipped more PowerPC chips into embedded systems than into Macintoshes. In 1996, embedded shipments accounted for just 10% of all PowerPC volume; now, they are about half. In part, that's due to declining sales of Macintosh, but it's mainly from a sevenfold increase in embedded sales. PowerPC is strong in TV set-top boxes and communications gear. Motorola's long-awaited design win with Ford (see MPR 3/25/92, p. 4) has yet to enter production.

New ISAs for 1998

This past year saw the birth of two new 32-bit instruction sets and the promise of at least one more. Motorola's M•Core and Siemens' TriCore debuted in 1997, although neither will ship before the middle of this year. Sun's PicoJava 2 got instruction-set extensions to improve its performance. Hitachi and SGS-Thomson mailed out announcements for their first joint venture, christened SH-5 or ST50, before the end of 1997, but the result isn't expected until 2001.

No processor architectures dropped out of sight in 1997, although some, like Patriot's ShBoom and Mitsubishi's M32R/D, barely made a showing. Far from shaking out, the embedded processor market is flourishing and nurturing a growing number of new architectures. Expect still more new instruction sets and instruction-set extensions to be announced in 1998.

PDAs Still Looking for Right Recipe

The business for handheld electronic organizers, PDAs, and handheld PCs picked up in 1997. There were a number of announcements on the silicon front. Several new handheld PCs (HPCs) made the scene, and, for the first time, hundreds of thousands of units actually found their way into customers' hands.

NEC and Digital were the most active developers on the PDA-processor front. NEC continually revamped its low-power lineup, replacing the R4100 with the R4101, then the R4102, and then the R4111. In each case, the $25 part neatly replaced its predecessor with the same price, better performance, and lower power consumption.

Digital went all-out with its SA-1100, bundling a complete Newton-like handheld system into a single chip. Unlike NEC's diminutive R41xx series, however, the SA-1100 totes a high-end processor core. Starting at just $29, the SA-1100 is easily the best price/performance PDA processor.

On the retail front, half a million Windows CE–based HPCs were built in 1997, according to published reports, but only about half of those were actually sold. Early HPCs with version 1.0 of Windows CE are now being discounted heavily, with retailers advertising prices as low as $99, ushering in the era of the sub-$100 PC.

Microsoft Gets Serious About Handhelds

Fall Comdex saw the debut of Windows CE 2.0 and a spate of new HPCs that use it. Although fundamentally similar to the first generation of HPCs, each new unit differs in some significant way from its predecessor, as vendors search for the right combination of features that will finally hook customers. For the most part, keyboards changed size and screens added color.

The Palm Pilot, in contrast, continues to be the envy of PDA vendors everywhere. This homely, underpowered device passed the one-million-unit mark around the end of 1997 and continues to lead the way in usability and customer loyalty. For Motorola, the 68328 that powers the Pilot has become a diamond in the rough.

Microsoft is responding to the success of Palm and Windows CE's relative lack of same with a new design it calls the Palm PC (see MPR 1/26/98, p. 13). Code-named Gryphon, the Palm PC couples a slightly different version of Windows CE with a hardware reference design that looks suspiciously like a Palm Pilot. Unlike current WinCE units, Palm PCs use a stylus instead of a keyboard and sport smaller LCD screens for a pocket-sized outline. Current HPC backers Philips, Casio, and Samsung are already showing prototype Palm PCs, as is newcomer Palmax. Production-level units are expected to ship in 2H98 priced at $399 and up.

Yet another new category of Windows CE products is in the works. Code-named Jupiter, these systems will be bigger than HPCs but smaller than today's notebook computers. With a (relatively) full-size screen and keyboard but no disk drive, Jupiter systems will be like laptops with a longer battery life. Like HPCs, Jupiter "sub-subnotebook" computers can be based on a number of different CPUs. Some of the faster, more integrated processors are potential winners, with the SA-1100 a likely candidate.

Network Computers Coming—Tomorrow

Another year came and went with no noticeable success for network computers (NCs, thin clients, lean clients, et al). The sound and fury surrounding NCs continued unabated, but prognostications regarding their eventual rise were consistently optimistic.

The growing popularity of sub-$1,000 computers is turning up the pressure on NCs. First-tier PC vendors now offer systems starting at $800. With only a small difference in price between a hypothetical NC and a PC running Windows, NCs must prove their worth. In the consumer space, that hasn't happened; Magnavox and Philips introduced NC boxes into the retail channel in 1997, but both were greeted with indifference.

The price premium for DOS compatibility has been dropping. Although high-end x86 chips (Pentium, K6, etc.) still deliver some of the worst price/performance in the 32-bit market, the gap is at least narrowing. With slower Pentiums below $100 for the first time and 100-MHz 486 chips priced near $20, the "x86 tax" has fallen in recent years. The most competitive chips are, of course, not Intel's, but the overall trend has been downward across the board. At this rate, embedded x86 processors may offer competitive price/performance with MIPS, SuperH, and other architectures sometime in the next decade.

Java Support Still Percolating

Java, too, failed to deliver anything of value in 1997, as efforts to define subsets of the language for embedded applications stalled. The prognoses for JavaCard and EmbeddedJava are uncertain. In the meantime, Sun continues to revise Java, and embedded developers continue to evaluate it.

Whatever its eventual role in embedded markets, Java is at least supporting several new companies that offer Java tools and services. Startups like Bristol Technology survive by giving Java capabilities that naive programmers assume it already has, like the ability to print. (Silicon Valley venture-capital firm Kleiner Perkins Kaufield & Byers facetiously offers to buy any company that can find a way to print from a Java application.) Several small testing firms have sprung up to alleviate the burden of verifying the "write once, run anywhere" characteristic presumed of Java applications.

The first Java chips, which were promised for 1997, failed to materialize. None of Sun's five picoJava licensees (Rockwell, LG, NEC, Samsung, Mitsubishi) delivered chips last year, nor did Sun itself. The estimates now are for 2Q98 delivery. In the meantime, Sun revised and updated its picoJava core, pushing out production of its first chip to 2H98.

Technology Trends Point to Faster Clocks

To no one's great surprise, technical advances in desktop processors are finding their way into embedded chips. Caches, branch prediction, speculative execution, and superscalar cores are all features in some midrange or high-end embedded CPUs. Just as desktop processors mirrored advances in mainframe computers of a decade before, embedded chips look more like last year's desktop processor.

Where this trend breaks down is in the growing market for low-power microprocessors. To a great extent, neither desktop computers nor the large systems that preceded them were designed to minimize power consumption. Embedded-CPU designers today are at a crossroads: follow proven design techniques for better performance, or develop something new to squeeze more performance out of less power.

Like the tired RISC vs. CISC debate, the issue can be boiled down to complexity vs. clock rate—brainiacs vs. speed demons. Where ultimate performance is the goal, superscalar execution is a necessity, and out-of-order or speculative execution is the preferred solution. All of this extra logic consumes power, however, and it occupies a significant amount of silicon area. Where power consumption is a critical concern, these are expensive penalties to pay.

Low-power parts, therefore, have been getting their performance gains through higher clock rates. NEC's R4300, IDT's R4640 and R4650, and Digital's SA-110 are all examples of high-performance CPUs with comparatively simple, scalar pipelines, big caches, and fast clock rates. Fast processors also have the advantage that their clocks can be slowed for even more power savings. Superscalar units, in comparison, can't be jettisoned when they're not needed. Parasitic capacitance and leakage current means that extra units consume power whether they're active or not. Superscalar hardware also chews up costly silicon; faster clock rates don't.

Looking ahead, clock rates will certainly increase, fueled in part by more advanced process technologies. Pipelines will get longer to deal with the shorter cycle times, and caches will get bigger to prevent code starvation. The CPU core will become a vanishingly small part of the average embedded processor, swamped by on-chip memory and peripherals.

Lower Voltages a Mixed Blessing

The trend toward lower supply voltages started many years ago and was easy to predict. What many embedded designers couldn't predict, however, is exactly what voltages the new chips would use. Unfortunately for hardware designers, there's been no standard for low-voltage processors and no prospect of one in sight.

The first step toward lower supply voltages was the now-universal 3.3-V supply. Today, 3.3 V is often the maximum level the I/O pins can handle. Split power supplies are common among low-power chips, with different voltages for the CPU core and the rest of the chip. Core voltages of 2.5 V (SH7708), 2.0 V (SA-110), 1.8 V (SH7750), 1.65 V (SA-110), and 1.3 V (R4102) are already in production.

These lower voltages are sometimes forced by the process technology. No vendor's 0.25-micron process, for example, can reliably handle anything more than a 3.3-V supply. The lower voltages are sometimes desirable features, as they directly affect the part's overall power consumption. Unless the usual law for power consumption, $P=cv^2f$, is repealed, voltage will continue to be a far more important component of power consumption than any other aspect of the chip.

Split power supplies can frustrate embedded designers, who now need to create a source for unusual voltages in their system. The lack of a low-voltage standard is aggravating, but at least it doesn't affect the choice of support logic. So far, all low-voltage microprocessors still support 3.3-V I/O.

Even this may not last, however. As process technology moves to 0.18-micron (which is on schedule to begin in 1999) and below, even 3.3 V will be disastrously high for leading-edge processors. To the pain of providing a separate core supply, add the difficulty of supplying low-voltage system logic as well.

Many Vendors Have Found Niches, Some Not Yet

The past year brought good news for both vendors and customers. Volumes rose, power consumption fell, and prices remained stable. The 68K maintained its dominant position, largely through the inertia of entrenched design wins but also with new ASIC-based designs with ColdFire cores.

MIPS had an undeniably good year, more than doubling over the previous year yet again. At this rate, MIPS could topple the 68K from the volume throne in just two to three years. Maintaining that rate, though, may be nearly impossible. Much of the architecture's success is tied to two systems that will soon peak in sales. Even though MIPS is broadening its base into new markets, none seems likely to repeat the successes of the PlayStation and N64. Handheld PCs, printers, and WebTVs just don't have the volume potential the game systems had. Digital cameras may be the closest thing to a hit consumer product in 1998, but MIPS is ill-represented in that application. Like the i960, MIPS may follow its top-RISC title with a long plateau.

Digital camera designs will swell in 1998. As their prices approach the range of a one-spouse decision, volumes will increase dramatically. That, in turn, will drive purchases of color ink-jet printers. Fujitsu's embedded SPARC chips are well positioned here, appearing in about half of 1998's digital cameras and a few printers as well. PowerPC is in other digital cameras, and ColdFire, MIPS, and SuperH all are well-represented in the midrange printer market.

Another hot seller for 1998 should be digital mobile phones, which bodes well for ARM. PowerPC, i960, and x86 have not staked out any particular territory, dabbling in many areas with a few hundred thousand chips here and there.

Embedded DRAM did not make much public progress in 1997. For the most part, vendors worked behind closed doors to perfect their processes before announcing parts. Combined microprocessors and DRAM are on their way, however. They're just a little slow coming out of the gate.

Other hybrid parts are likely to appear in the coming year as well. Mixing microprocessors and FPGAs has been a dream of many vendors (and customers) for a long time. Most FPGAs are built in processes that are more compatible with microprocessor processes than DRAMs are, so the technical hurdles should not be as high. More flash memory is likely to appear on CPUs, along with more merged CPU/DSP hybrids. Coprocessors for media processing, particularly for MPEG-2, will start to proliferate.

On the integration front, LCD controllers, Ethernet controllers, and interfaces to USB, FireWire, and the telephone network (modem) will pop up from many sources. Wireless front-ends will start to appear on microprocessor chips in 1998, fueled by the seemingly endless demand for wireless telephones, pagers, and data terminals.

With the increased performance of these new processors, as well as their improved ability to handle nonnumeric forms of data, user interfaces will evolve. Handwriting recognition is already well within the capabilities of many CPUs. With a little design attention, speech recognition (and synthesis) is not far off. The bigger question is, for what systems will spoken input be appropriate?

With moderately priced consumer items driving most of the volume and much of the innovation in the embedded market, the biggest issue facing designers will be not "What can we build?" but "What will people buy?" Whatever interesting new systems the coming year brings, they will provide yet another improvement over already robust sales of embedded microprocessors. M