PDAs Begin Shipping in 1993

Many Processor Vendors Target Small But Growing Market

YEAR IN REVIEW 1993

by Linley Gwennap

During the past year, the much-discussed personal digital assistant (PDA) became a reality as several vendors began to ship products. Despite the high price and limited capabilities of these initial devices, many processor vendors remain excited about the potential of eventual high volumes. In 1993, these vendors announced several processors aimed specifically at PDAs and similar handheld systems.

While some CPU vendors used existing instruction sets such as x86 and 680x0, others took advantage of the lack of software standards in the nascent market to create new architectures, such as NEC's V800 and Hitachi's SH7000, tuned for the low cost and low power required by these handheld systems. Previously obscure architectures such as ARM and Hobbit have vaulted to prominence by winning key designs.

The ultimate success of these processors will be closely tied to the system hardware and software available for them. The 1993 debut of real systems using the ARM, Hobbit, and x86 chips shed new light on the capabilities of these processors. The next year should prove equally enlightening, as products based on Motorola's Dragon and Intel/VLSI's Polar are slated to appear. At this point, it is far too early to identify a winner, but some of these processors are in a better position to succeed.

Newton Catapults ARM into Lead

The ARM610 has an early lead as the best-selling microprocessor for PDAs. Since the much-anticipated Newton launch in August, Apple says that it has shipped 50,000 of these devices, topping estimated shipments of other PDAs, such as the Tandy/Casio Zoomer and Eo's Personal Communicator. Many of these Newtons went to developers, not end users, so it is difficult to project future sales, but it is worth noting that 50,000 units would be an outstanding design win for most RISC processors.

The first Newton, dubbed the MessagePad, is a $799 notepad-sized device that contains an ARM610 processor, 4M of ROM, 640K of SRAM for system and user memory, and a single complex ASIC that handles most of the I/O interfaces, as the CPU itself contains no on-chip peripherals or system logic. Newton licensees can purchase this ASIC from LSI Logic, although that company will not quote a general price for the part, since it is not available on the open market. The ARM chip itself is available from a variety of vendors: VLSI, GEC/Plessey, and, later this quarter, Sharp.

Cirrus Logic has obtained licenses from both Apple and ARM to build system chip sets for future Newton products. The current MessagePad requires a slew of analog and digital buffer and control chips, along with the major components listed above; Cirrus plans to collapse all the logic into a two-chip set that will support current and future ARM processors. Ultimately, Cirrus expects to combine this system logic with the ARM core to create a single-chip (just add memory) PDA. Although the former effort may bear fruit in 1994, the single-chip PDA will not be available before 1995.

ARM itself has announced its next-generation CPU core, the ARM7, which it expects to begin shipping in volume in 2Q94. The new core can operate at 3 V while matching the 20-MHz clock rate of the ARM610 at 5 V, providing the same performance with a significant decrease in power. Alternatively, the ARM7 core can operate at 33 MHz using a 5-V supply, delivering a performance boost at a power level similar to the 610's. The ARM7 core has the highest Dhrystone MIPS rating of any PDA processor, although Hobbit is close behind.

We expect Apple to use the ARM7 core in second-generation Newton devices appearing around midyear. The current MessagePad will probably get a CPU upgrade to give the handwriting recognizer more horsepower. Apple is also planning to broaden its Newton line with additional form factors, including a tablet-sized device similar to Eo's Communicator.

Other Newton licensees—Sharp, Motorola, Matsushita, and Siemens/Rolm—may deliver their own Newton products in 1994. Sharp is currently reselling the MessagePad (which it manufactures for Apple) as the PT-1000, and Rolm has announced a telephone docking station for the MessagePad.

PowerPC Could Compete with ARM

Motorola's partnership with Apple prompted a recent disclosure that Apple will port the Newton operating system to PowerPC. Since all Newton applications are written in NewtonScript, an interpreted language, the same application programs could run on either ARM- or PowerPC-based Newtons. Apple did not set a timeframe for the PowerPC port, but it will probably not ship in 1994.

Apple is probably too busy to do the port right away, but there are also no current PowerPC chips suitable for PDAs. Even the forthcoming 603 uses 3 watts at 80 MHz, far too much for a PDA. The 603's power could be reduced

A Look Inside the Casio/Tandy Zoomer

The Zoomer PDA, a joint project between Casio and Tandy, rejects widely discussed processor options and instead relies on an in-house chip set designed by Casio and based on an 8086-compatible CPU core from NEC's V-series. The custom processor runs at a leisurely 7.4 MHz and combines the CPU core with a display controller. The remaining system peripherals—except for analog input—are integrated into another companion chip. A third "helper" chip has an additional 4,400 gates of logic and is used to tie the pieces of Zoomer together.

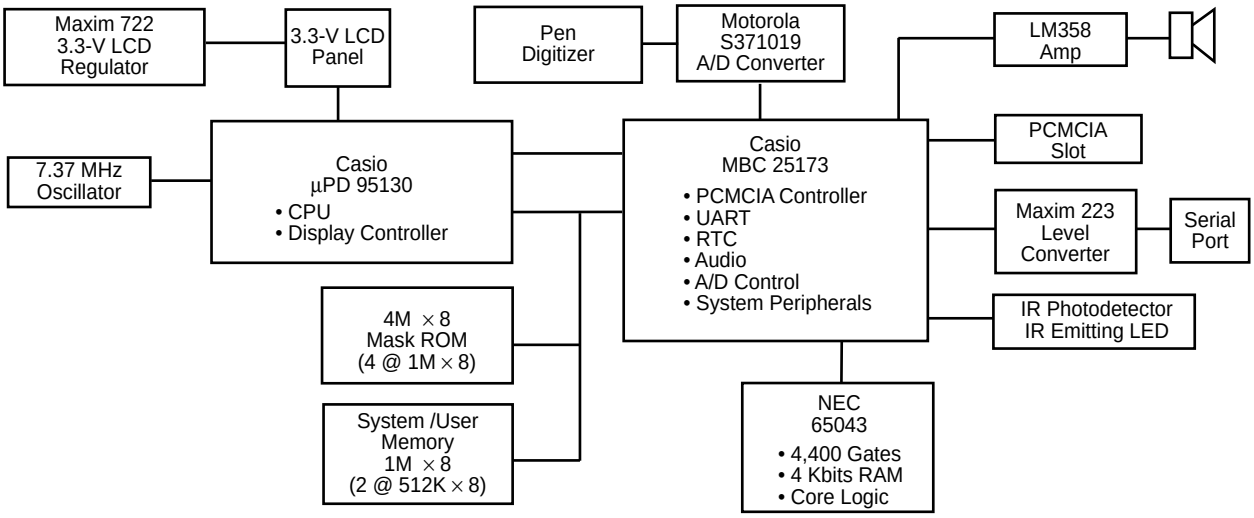
Zoomer is a mixed-voltage system: the CPU and display operate at 3.3 V, while the gate array operates at 5 V, and the peripheral chip is a mixed-voltage IC. The ASIC integrates a basic asynchronous RS-232 port, while a MAX223 level converter handles the 5-V-only electrical interface for the RS-232 port. The PCMCIA controller is also integrated into the system ASIC; like most integrated PCMCIA controllers, it lacks hot insertion capability.

Zoomer comes with 4M of ROM, using four 8-Mbit ROMs. Data storage is provided by 1M of pseudo-static DRAM, implemented with two 65V8512 4-Mbit PSDRAMs from Hitachi.

Zoomer operates for about 100 hours from a set of three standard alkaline AA batteries, which together typically have about 7 watt-hours of power. Measurements made by MicroDesign Resources show that Zoomer uses about 135 mW during heavy processing and about 55 mW when in a low-power idle mode. When turned "off," the PDA consumes 0.5 mW to maintain the PS-DRAM state. This low dissipation means that a Zoomer could maintain its data for up to 16 months if left unused in a desk drawer—hopefully not the fate of most PDAs.

Casio has no plans to make its chip set available on the open market, but it will sell complete systems to OEMs. AST is reselling Zoomers under its own label, and other vendors may follow suit.

—DM



by running it at a lower frequency (it has performance to spare) but the cost would still be prohibitive for all but the highest-end devices. Both Motorola and IBM are working on low-cost, low-power versions of PowerPC for embedded applications, and these chips will be better suited for PDA systems.

PowerPC versions of Newton would give Apple tremendous flexibility in trading off price, power, and performance. One scenario has PowerPC appearing first in larger, higher-priced Newton devices while ARM continues to be used at the low end. Ultimately, PowerPC might be able to fill the entire product space.

At this point, however, PowerPC must be considered a longer-term threat. Apple's immediate focus is on improving the current Newton, and we expect it will wait for suitable chips before making the PowerPC port. If Motorola does announce a Newton device in 1994, it will probably use an ARM CPU. By 1995, however, it is likely that PowerPC will be a player in the PDA market.

Zoomer Uses 8086 CPU

With sales estimated at about half those of Newton, Zoomer was the second most successful PDA in 1993. The $699 device, a joint effort of Tandy and Casio, is physically similar to Apple's PDA but uses the Geos operating system instead of the Newton OS. The Zoomer software comes from Geoworks, which takes a different approach to software design than Apple. Geoworks focused on creating very compact machine-coded software. Despite its small size, Geos provides a wide range of services to applications, reducing their size as well; GeoWorks' word processor, for instance, uses only 80K of ROM.

The Zoomer is built around a custom processor chip from Casio, which is based on an 8086-compatible CPU core from NEC. Ironically, the futuristic Zoomer uses a processor similar to that in the original IBM PC, introduced in 1981. Casio's CPU runs at 7.4 MHz, yielding much lower performance than Newton's fleet ARM chip, although using less power and probably lower in cost. Zoomer uses a two-chip set, also designed by Casio, for system and peripheral interfaces (see "Zoomer" sidebar).

AST Research has announced that it will market the Zoomer hardware under the name Grid 2390. AST will sell the 2390 with either Geos or the PenRight OS developed by its Grid subsidiary for Grid's existing line of 8088-based pen systems. (The latter systems are not considered PDAs because they are used mainly for vertical applications.)

Other Vendors Use Mature CPU Cores

Amstrad, a UK computer company, is shipping a PDA based on an even older CPU. Its PDA600 uses three Z80 processors: one for the main program, one for character recognition, and one for power management. The device uses a proprietary OS and provides many of the features of other PDAs but costs significantly less: $450. Although the Amstrad device began shipping before Newton or Zoomer, it has not sold well due to a lack of marketing channels and application software.

IBM has developed a product called Simon that is being marketed by Bell South. Simon is a cellular phone with a small LCD screen on the handle between the mouthpiece and earpiece. In phone mode, the screen displays a set of buttons that can be pressed by hand to dial the phone. Simon can also send and receive faxes, e-mail, and pages, and it provides many of the organizer functions of other PDAs. The $899 system uses what IBM describes only as an "x86-compatible CPU."

Although Bell South has been quick to latch onto the hot marketing term "PDA" for Simon, we would not agree with this assessment. Simon uses a proprietary OS, and Bell South has chosen not to reveal the interfaces to third parties. Still, Simon demonstrates a potential form factor for true PDAs from other vendors.

Sharp, a Newton licensee, also markets a Geos-based device called the PT-9000, a notebook-size PDA that recently began shipping. Like many other vendors, Sharp (which also markets the Wizard handheld organizer) is betting on multiple horses in this race, increasing the chances of finding a winner.

While these CISC-based systems cannot match the raw performance of Newton, their performance is adequate for many simple operations. Also, the compactness of Geos and its applications allows the Geos-based systems to use memory more effectively than Newton or other operating systems. The initial versions of both Newton and Zoomer include 4M of ROM, but Zoomer packs a large number of applications into its memory, while the Apple device can barely hold the Newton OS and a few critical programs.

Eventually, however, PDA users will demand better handwriting recognition and more complex applications. Z80 and 8086 performance will not be adequate for these systems. Geos can migrate to more powerful x86 processors, and its compact size could give it a cost advantage (because less system memory would be needed) over other pen-based operating systems.

Major PDA Events of 1993

First Newton offers highly integrated design *(see **071303.PDF**)*; new ARM7 processor core cuts power, increases performance *(see **071503.PDF**)*; Sharp to manufacture and sell ARM processors *(see **0704MSB.PDF**)*; Cirrus to build and sell Newton chip sets *(see **0705MSB.PDF**)*.

AT&T buys Go for Eo *(see **0712MSB.PDF**)*, expands Hobbit family with new chip sets *(see **071403.PDF**)*.

VLSI previews Polar, Draco *(see **0709MSB.PDF**)*; Polar sets new course for PDA design *(see **071302.PDF**)*. AMD's new Elan chip for handheld systems *(see **071404.PDF**)*.

8086 processor used in Tandy/Casio Zoomer *(see **0709MSB.PDF**)*. NEC announces 0.5-micron 8086 core *(see **0713MSB.PDF**)*.

Motorola announces 68349 "Dragon" processor *(see **070803.PDF**)* for PDAs using General Magic software *(see **070303.PDF**)*.

Motorola and IBM announce low-power PowerPC 603 *(see **071402.PDF**)*; IBM is developing embedded PowerPC chips for future PDAs *(see **0711MSB.PDF**)*.

Hitachi announces first SH7000 chips *(see **070802.PDF** and **071103.PDF**)* and lays out roadmap for future versions *(see **0714MSB.PDF**)*.

NEC announces V800 family *(see **070802.PDF** and **071406.PDF**)*.

Alpha targets mobile market with forthcoming low-end processors *(see **0710MSB.PDF**)*.

Sony, HDL develop low-cost MIPS cores that could be used in future PDAs *(see **071506.PDF**)*.

AT&T Invests Heavily in Hobbit

Over the past year, AT&T has made several moves to consolidate its PDA strategy. The company purchased a majority interest in Eo, which builds its Personal Communicators around AT&T's Hobbit processor; partners Matsushita and Marubeni continue to own portions of Eo. AT&T then purchased Go, which supplies the PenPoint operating system for Eo's products. In a somewhat related move, the telecommunications giant also purchased McCaw Cellular, giving it access to the wireless infrastructure needed by Eo's Communicators.

AT&T Microelectronics has continued to develop

new versions of Hobbit. Unlike ARM, which focused on developing a new CPU core, AT&T rolled out a set of derivatives of its existing 92010 CPU. The new 92020S uses a larger on-chip cache to increase performance, while the 92020M and MX chip sets reduce cost and board size by increasing system integration. AT&T is sampling the new chips and expects volume shipments by March.

The success of Hobbit is closely tied to PenPoint, the only PDA operating system that it supports. PenPoint originally began as an x86 product but got lost among PenDOS, Geos, Windows for Pen, PenRight, and others. As part of Eo, new versions of PenPoint will support Hobbit only and not x86.

A full year after the first Eo systems debuted, the Hobbit/PenPoint combination is moving slowly. The initial Eo products, the Models 440 and 880, are large notebook-size devices with an optional cellular telephone attached. Even without the phone, the Model 440 is now priced at $1,599 after being introduced at $1,999. Although Matsushita, NEC, Olivetti, and Toshiba are working on Hobbit-based PDAs, none has yet announced a product. NEC announced a year ago that it would second-source the Hobbit CPU in 1994; the company now plans to wait for the next-generation Hobbit chips.

Hobbit offers about the same performance as the ARM7 chips and more than any other PDA processor. Backed by AT&T's deep pockets, Hobbit will be in the game for quite a while, giving it time to gain market momentum. Lower-priced systems will help; Eo is said to be developing a Simon-like system that will sell for under $1,000. The new family of highly integrated Hobbit chips should enable it to reach this price point; such a product could ship by midyear.

Can a PC Become a PDA?

While AT&T brings tremendous financial and communications resources to the table, the troika of Intel, Microsoft, and Compaq will attempt to leverage their dominance of the PC market into success in the PDA space. These companies see the PDA, at least initially, as a "companion" to the desktop PC and are building their products accordingly.

Intel teamed with VLSI to develop the Polar chip set, which combines a 386 CPU core with system logic and peripheral interfaces from VLSI. The two-chip set contains nearly all the logic required for a typical PDA. The first customer for Polar is Compaq, which plans to ship its PDA in June.

The Compaq device, currently known only as the PC Companion, will run a Windows-family operating system built around the Microsoft At Work kernel. This OS, code-named WinPad, is intended to provide seamless connectivity between the Companion and a desktop PC. Not only data can be shared; applications can be ported easily between Windows and WinPad.

In the near term, most PDAs will probably be purchased by people with desktop computers, and odds are that that desktop is a Windows PC. These users may appreciate the ability to download addresses and other data from their desktop system instead of entering lots of information by hand (literally). Current PDAs are not well integrated with desktop systems, although Apple (for one) says it will fix this problem soon.

Microsoft's philosophy contrasts with that of Apple and other PDA vendors, which are trying to develop a new breed of computer systems friendly enough for even technophobic consumers. The first generation of PDAs, while showing promise, doesn't meet this goal. Microsoft argues that it will be years before PDAs are ready for the consumer market, and by that time the company hopes to have evolved its software strategy to meet this need.

Although WinPad will support much of the Windows API, it does not use any Windows (or DOS) code; instead, it is based on the entirely new At Work software, which is a real-time, preemptive-multitasking kernel designed for embedded applications. Microsoft plans to fit WinPad into the same 4M of ROM space used in Newton and Zoomer, but it is not clear how much room will be left in the ROM for applications.

While Compaq is expected to be the first to ship a WinPad device, other companies said to be working on such products include Epson, Toshiba, NCR, and Motorola. This is an odd group: Toshiba is also committed to the Hobbit/PenPoint platform, NCR is a subsidiary of AT&T, and Motorola seems to have its fingers in everybody's pie. It is hard to imagine Motorola buying Intel processors, but nearly any x86 processor could be used.

For example, AMD has announced the 386SC as the first member of its Elan family. The AMD chip incorporates all the logic for a simple PDA onto a single chip. To accomplish this feat, some sacrifices were made, and it appears that 386SC-based systems will have slightly lower performance than products using Polar. Unlike Polar, the AMD part is compatible with DOS and is primarily intended for subnotebook PCs. The company says that it could easily reconfigure the part—substituting a pen interface for the keyboard interface, for example—for PDA applications once a customer is identified, but no such announcement has yet been made.

Both the Intel/VLSI team and AMD plan to extend their processor lines over time. The former plans to deliver Draco, a 486-based follow-on to Polar, around the middle of this year. Draco will be a two-chip system-logic set that can be coupled with one of Intel's low-voltage 486 processors, giving system designers greater performance in exchange for higher cost and less integration. AMD also has 486 processor cores in its portfolio but has not indicated a specific schedule for incorporating them into the Elan family.

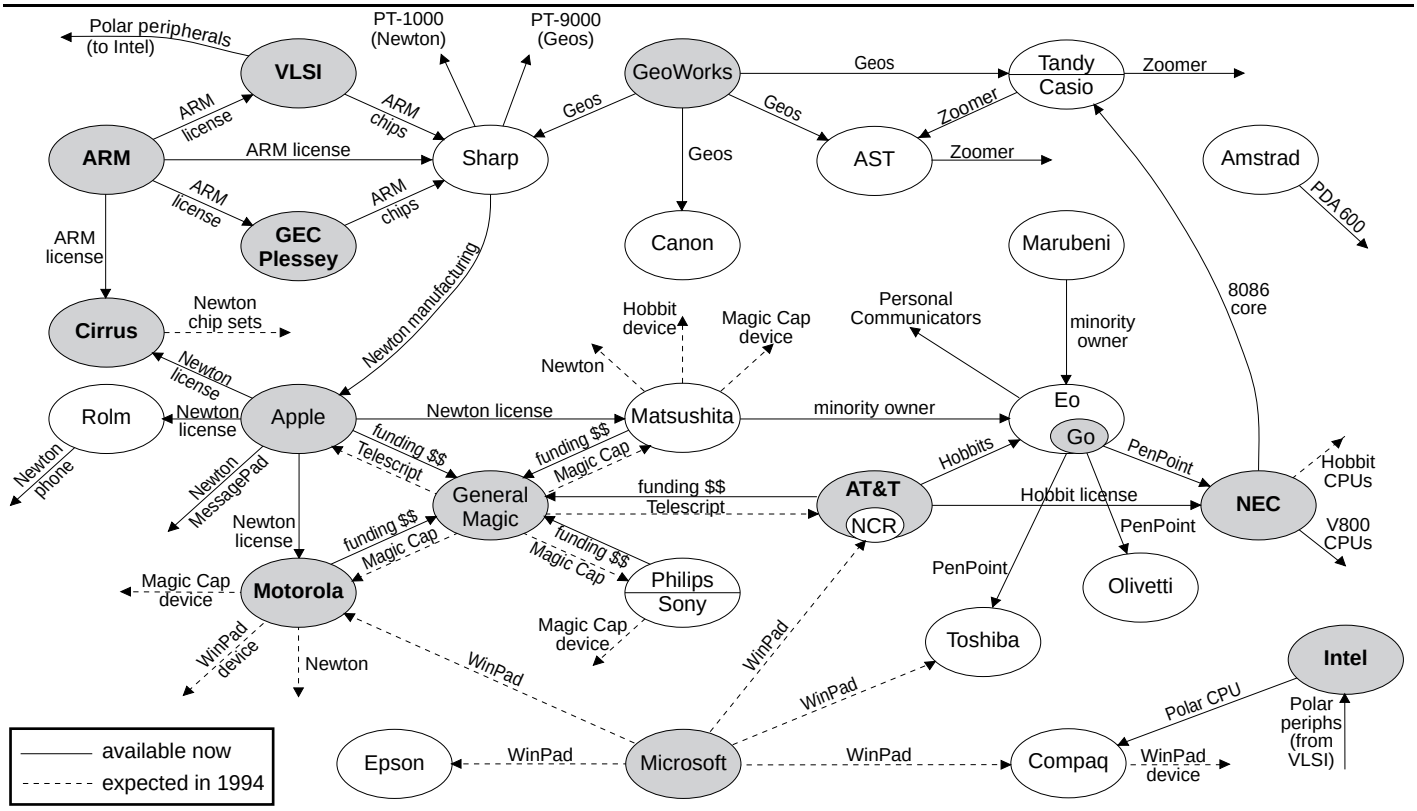


Figure 1. A look at the main relationships among players in the PDA market shows a number of companies playing several sides at once. Shaded ovals indicate technology suppliers; microprocessor vendors are in bold.

The Dragon and the Magic Cap

Motorola has yet another play in the PDA market, this time using a processor of its own design, the 68349. Also known as Dragon, this CPU combines a 68020 core with 6K of on-chip memory and some system logic. The company is working with General Magic (GMI) on a second chip, code-named "Astro," that provides PDA logic and interfaces, but most of the details of that chip remain unreleased.

Motorola plans to build a PDA combining Dragon and Astro with GMI's recently announced Magic Cap operating system *(see **080102.PDF**)*. The device will probably begin shipping in 2H94, after a spring announcement.

Alert readers have noticed by now that Motorola is planning PDA devices based on three operating systems (Newton, WinPad, and Magic Cap) and up to four processor types (ARM and/or PowerPC, x86, and 68000). The company claims to have a plan to differentiate these devices. Newton is aimed at consumers with a need to organize information on a portable device, while WinPad will appeal more to business users who already use PCs. The Magic Cap device will take advantage of Motorola's wireless-communications prowess, probably looking something like IBM's Simon or Eo's Communicator.

Figure 1 shows the tangled web created by multiple alliances in the PDA market. Along with Motorola, consumer-electronics giants Matsushita and Sharp—plus Toshiba, NEC, and AT&T/NCR—are betting on multiple architectures and operating systems. The General Magic business model shows money coming in and technology flowing out; on the other hand, the Eo model (not including new subsidiary Go) shows money and technology going in and a few products trickling out. Note that, while many companies are talking about marketing PDAs, few have actually announced products.

NEC, Hitachi Design New Architectures

Both NEC and Hitachi caught the PDA fever, rolling out completely new instruction-set architectures designed for these devices as well as for traditional embedded designs. In 1993, NEC began shipping three implementations of its V800 architecture, which uses a combination of 16- and 32-bit instructions to improve code density and reduce memory accesses, lowering system cost and power. The low-cost V805 and the V810 are basic CPUs with a small on-chip cache, while the more-integrated V820 includes some simple system logic as well.

Hitachi debuted the SH7032 and SH7034, which include on-chip RAM and (for the 7034) ROM along with basic system logic. The chips implement a new architecture that uses 16-bit instructions only; as in the V800,

the instruction set is designed to save cost and power. Both the Hitachi and NEC chips use a full 32-bit data path internally.

Unfortunately, these chips have a long way to go to make an impact on the PDA market. Although both are competitive with other PDA processors in power and performance, neither company offers system-logic and PDA peripheral chips for its CPUs. None of the initial chips includes an MMU, which is required for every major PDA operating system except Magic Cap. Finally, neither company has any announced design wins with PDA system or software vendors.

Initially, these chips will compete for consumer-product designs; the V810 already has a high-volume win for Nintendo's CD-ROM system, while Hitachi's chips will be used in a forthcoming Sega game system. Hitachi has clarified that its first chips are more suitable for "fixed-function PDAs" (such as the Sharp Wizard) but that eventually its processors will be targeted at true, reprogrammable PDAs. Hitachi plans to incorporate an MMU in its third-generation SH7000 chips, due in 1995. By that time, the company may be able to form the software and system alliances that are critical to success in this market.

	AT&T Hobbit			Intel/VLSI Polar	AMD Elan 386SC
	92020S	92020M	92020MX		
Clock Rate	20 MHz	20 MHz	20 MHz	33 MHz	33 MHz
Dhrystone MIPS	16 MIPS	13.5 MIPS	11.5 MIPS	6 MIPS	6 MIPS
On-Chip Cache	6K	6K	3K	2K	none
Memory Bus	32 A, 32 D	32 mux'd	32 mux'd	22 A, 16 D	22 A, 16 D
Voltage	3.3 V	3.3 V	3.3 V	3.3 V	3.3 V
CPU Power*	210 mW	250 mW	290 mW	550 mW	550 mW
Number of Chips	4 chips	3 chips	2 chips	3 chips	1 chip
PCMCIA Slots	4 slots	2 slots	1 slot	1 slot	2 slots
Serial Ports	3 ports	3 ports	3 ports	2 ports	1 port
Parallel Ports	none	none	none	none	1 port
LCD Support	640 x 480	640 x 480	640 x 480	640 x 480	640 x 400
CRT Support	1024 x 768	1024 x 768	none	none	none
Frame Buffer	separate	separate	shared	shared	separate
Chip Set Power*	530 mW	490 mW	390 mW	600 mW	550 mW
Chip Set Price	$101	$80	$63	$58	$49
Availability	1Q94	1Q94	1Q94	1Q94	2Q94

Table 1. For those PDA processors with complete system solutions openly available, AT&T chip sets offer the best performance and price/performance. *Typical power into 50-pf load. (Source: vendors)

Other RISC Vendors Target Mobile Market

Although Digital initially focused its new Alpha architecture on high-performance applications, the company has ambitious plans to eventually supply processors for "palmtops to supercomputers." Last summer, Digital started a new Alpha design team to develop low-cost, low-power processors. While the initial chips will end up in high-end embedded applications, the company expects to have a processor suitable for handheld devices by 1995. At this time, Digital has not revealed any specific system or software plans for a PDA product.

In the fall, both Sony and a Silicon Valley startup called HDL revealed designs for tiny MIPS processor cores. The HDL core, the smaller of the two, measures just 9 mm^2, comparable to the ARM core. Like the V800 and SH7000 chips, neither core includes an MMU, limiting their options for PDAs.

One possibility for these MIPS processors is Magic Cap, the only prominent PDA operating system that does not require an MMU. Sony is a backer of General Magic and plans to build Magic Cap devices. Although GMI has not revealed any plans to port its OS to MIPS, Sony's influence could lead to such a product in the future.

Sun has formed a subsidiary called First Person to develop consumer computing devices, possibly including PDAs. It is likely that these systems would use SPARC processors, but no specific details have been released, and products are not expected this year. These announcements leave the i960, 29000, and PA-RISC as the only major processor architectures without announced plans for PDA applications.

Choosing a Processor for a PDA

It remains difficult to evaluate PDA processors, as comparisons of critical metrics such as cost and power must be made at a system level to be valid. Unfortunately, only Hobbit, Polar, and Elan are commercially available as complete PDA chip sets. Apple has released some information on its Newton ASIC but has withheld two key figures: power and price. Motorola's Dragon is only half of a system; more details on the Astro chip are needed. Even less information is available about the Zoomer chip set, and PDAs using the SH7000, V800, PowerPC, MIPS, and Alpha architectures are too far in the future to evaluate at all.

Table 1 compares those chip sets for which complete system configurations are available. Of these, the RISC-based Hobbit offers much better CPU performance than the 386-based Polar and Elan but comes at a higher price. The fairest comparison is between the low-end 92020MX chip set and the two 386-based chips, which offer similar system features at about the same price; of these, the MX delivers twice the performance, based on Dhrystone 2.1, using one-third less power.

The Polar and Elan solutions are fairly similar, except that Polar requires two chips plus an external controller for each PCMCIA slot; the 386SC integrates all system logic plus two PCMCIA controllers onto a single chip. To achieve this integration, however, AMD could not include any cache or graphics acceleration on its chip,

	ARM 700/710	AT&T Hobbit 92020S	NEC V810	NEC V820	Hitachi SH7032	ARM 610	Motorola 68349	Intel/VLSI Polar	AMD Elan 386SC
Clock Rate	20 MHz	20 MHz	16 MHz	25 MHz	12.5 MHz	20 MHz	16 MHz	33 MHz	33 MHz
Dhrystone MIPS	18 MIPS	16 MIPS	11.5 MIPS	18 MIPS	10 MIPS	11 MIPS	6 MIPS	6 MIPS	6 MIPS
Voltage	3 V	3.3 V	3.3 V	5 V only	3.3 V	5 V only	3.3 V	3.3 V	3.3 V
CPU Power*	120 mW	210 mW	100 mW	750 mW	130 mW	500 mW	300 mW	550 mW	550 mW
On-Chip Math	none	none	FPU	FPU	MAC	none	none	none	none
On-Chip MMU	64 entry	64 entry	none	none	none	32 entry	none	yes	yes
System Logic	none	none	none	some	some	none	yes	yes**	yes
Peripherals	none	none	none	serial	some	none	serial	many**	many
On-Chip Memory	8K cache	6K cache	1K cache	1K cache	8K RAM	4K cache	6K mixed	2K cache	none
External Bus	32 mux'd	32 A, 32 D	32 A, 32 D	32 A, 32 D	16 mux'd	32 mux'd	32 A, 32 D	22 A, 16 D	22 A, 16 D
Transistors	341,000	640,000	240,000	380,000	593,000	359,000	550,000	910,000**	335,000
Die Area	46 mm^2	125 mm^2	53 mm^2	114 mm^2	92 mm^2	71 mm^2	98 mm^2	138 mm^2**	n/a
IC Process	0.8 µm, 2M	0.6 µm, 2M	0.8 µm, 2M	0.8 µm, 2M	0.8 µm, 2M	1.0 µm, 2M	0.8 µm, 2M	0.8 µm, 3M	0.7 µm, 2M
Est. Mfg. Cost	$15	$25	$12	$35	$20	$13	$23	$35**	~$30
CPU Price (10K)	$35	$37	$20	$80	$32	$20	$28	$50**	$49
Vol. Availability	2Q94	1Q94	3Q93	1Q94	4Q93	2Q93	4Q93	1Q94	2Q94

Table 2. A comparison of the leading processors for PDAs shows the newest Hobbit CPU and the forthcoming ARM700 as the performance leaders among low-voltage processors. *Typical power, load varies. **Includes both chips in set. (Source: vendors)

unlike Polar. These shortcomings could reduce the application performance of the 386SC relative to Polar.

Since the AMD chip is intended for subnotebooks, it includes a single serial port and a parallel port. Most PDAs, however, connect the pen digitizer through a serial port; this would leave a 386SC-based PDA without an external serial interface. AMD counters that a digitizer could be connected through the parallel port, but a better solution would be for AMD, using its modular design strategy, to create an Elan chip with two serial ports.

Table 2 compares a broader range of processors for PDAs. It is more difficult to do a fair comparison if only the CPU is considered, given the range of functions provided on the different chips. It appears, however, that the newer RISC processors all deliver significantly better performance than the chips using older 386 and 68020 CPU cores.

The ARM700 and 92020S top the performance list among low-voltage processors, offering about the same Dhrystone ratings as a 486SX-33 but with much lower power dissipation; this comparison will be more relevant when Intel and VLSI announce their Draco chip set for the 486SX. The new ARM and Hobbit chips can both operate at 5 V as well, raising performance well above that of the V820 or any other 5-V processor in the table.

The ARM700, SH7032, and V810 use the least power, but this is misleading because these chips include little in the way of PDA peripheral interfaces; system power dissipation will depend on the power consumed by the peripheral ASIC.

There is little variation in list price among these chips, reflecting the open competition for design wins. The integrated Polar and 386SC appear to be more expensive but are quite competitive considering their higher level of system integration. One exception is the V820, which carries far too high a price for its feature set.

The manufacturing cost estimates show that the smaller die sizes of the ARM and V810 chips could enable their vendors to more aggressively price their processors at higher volumes.

Choices Depend on Software, Alliances

Given the lack of differentiation on price, the choice of a PDA processor depends on a variety of business issues. With PenPoint now emphasizing Hobbit support almost entirely, the choice of a processor selects a specific PDA operating system, and vice versa; the only exception is the x86, which supports both Geos and WinPad. The operating system determines the number and type of applications available for a given system.

The OS also provides the interface to the user, a critical aspect of these devices. From initial demonstrations, Magic Cap appears to be the most revolutionary interface, aimed at technologically unsophisticated users, while WinPad shares many features with current PCs. Newton and Geos are somewhere in between on this axis; the Apple software tries to deliver a wide range of functions while Geos focuses on small size and low cost. The acceptance of these operating systems will have a major impact on the success of the processors that they are associated with.

Newton's initial success has greatly benefited ARM. This platform has generated significant interest over the past year, with hundreds of developers working on applications. The ARM processor itself has the advantage of being available from multiple sources, and the ARM700 appears to offer the best performance among PDA processors. While Newton's potential ease of use may appeal to consumers, its price point attracts mainly business users.

WinPad systems will have no problem attracting ISVs due an API similar to Microsoft Windows. If Com-

paq's initial product sells well, other system vendors are likely to join in. Performance of these devices may be poor, however, due to the lower CPU performance of 386 processors relative to the RISC chips.

Zoomer and other Geos-based PDAs are using cheap 8086 cores that are available from a variety of sources. The compactness of Geos and its applications could allow these devices to carry a lower price tag than other PDAs, but Geos has attracted less ISV interest than Newton or WinPad. These systems could appeal to users that require only a few applications.

The Hobbit/PenPoint devices offer good performance and a mature operating system. Other than a few high-priced systems from Eo, however, products using these technologies have been slow to emerge. Eo's forthcoming lower-priced devices could help spur interest from end users and thus attract additional system vendors and ISVs.

Magic Cap and the 68349 have gotten a late start in attracting software and system partners but are beginning to gain momentum *(see **080102.PDF**)*. Both Motorola and Matsushita are committed to multiple PDA strategies, and it remains to be seen what Sony and Philips do, but it appears that the first Magic Cap device will not ship until late this year. Since Magic Cap does not require handwriting recognition, the performance of the 68349 may be adequate for initial products, but a port to MIPS or another RISC architecture would provide performance headroom for future devices.

Other PDA hopefuls—such as PowerPC, the V800, and the SH7000—must develop appropriate processors and recruit system, OS, and application vendors to support the new platforms. Although PowerPC and other workstation architectures offer much better performance than PDA processors, they cannot maintain this performance while matching the price and power levels required for the new market. These workstation processors may also suffer from the larger code size required by traditional 32-bit RISC instructions, increasing the cost (more physical memory needed) and power usage (more memory accesses) of system implementations.

Unfettered Opportunity for CPU Vendors

Processor vendors are drawn to the PDA market by its potential for large unit volumes, but it will be many years, if ever, before PDA sales surpass those of personal computers. The PC market, however, is currently locked up by x86 systems; vendors of other types of processors have had little luck selling into personal computers. PDAs, on the other hand, do not rely on the huge existing base of x86-based PC software, letting system (and processor) vendors work from a tabula rasa. While there is certainly some leverage between PC and PDA applications—particularly in Microsoft's opinion—the smaller, handheld devices require a new breed of easy-to-use, pen-based programs.

At this time, x86 processors appear likely to gain a significant portion of the PDA market but are unlikely to dominate it as they do the PC market, if for no other reason than that x86 dominance has not significantly benefited any PC company but Intel. Newton seems destined to be a major player among PDAs, which will give an initial boost to ARM. Since Newton applications are all written in processor-independent NewtonScript, however, ARM's hold on this market is tenuous; Apple can switch to PowerPC or another processor relatively easily.

If Newton gains a large share of the PDA market, the independence provided by NewtonScript could create a fierce competition among multiple processor vendors vying for a Newton spot, since any processor can run Newton applications simply by porting the Newton OS. Apple and other Newton vendors could have the luxury of choosing the processor best suited for a particular product, regardless of its instruction set. On the other hand, interpreted languages typically execute more slowly than binary programs; this could hamper the performance of Newton software relative to programs on other PDAs.

Hobbit and Dragon have a solid group of backers but have not yet gained market momentum. Magic Cap appears compelling but is late to market. On the other hand, the Hobbit/PenPoint combination was the first to reach the market but has not been helped by this fact. If the multiple backers of these processors can all deliver system products in 1994, the outlook for these chips would be greatly improved.

Like ARM, Motorola must be aware of the dangers of portable software: a MIPS-based version of Magic Cap could limit acceptance of the 68000 in PDAs. Magic Cap programs are not processor-independent, however, making it more difficult to switch architectures, but the initial application base will be small enough that an early switch is conceivable.

Other processors are still trying to collect a critical mass of system and software backers. Although it is certainly possible to assemble a winning coalition at this point, many major vendors are already committed to a particular platform. Far too many processor vendors are aiming for what is still a tiny market; some will never get off the ground, unable to attract sufficient numbers of system and software vendors.

It is much too early to call a winner or even rule any company out of this market; at this stage in the evolution of the PC, companies such as Altair and Northstar were leading the pack, and Microsoft was not a dominant OS player. Even as the PDA market matures, there should be a number of niches for different processor vendors to fill. Once the system and software issues are worked out, design wins should accrue to the processors that deliver good performance with the lowest cost and power. ♦

