Action-Packed Fray for Newest Video Games

MIPS and NEC Roll Out Magic Carpet; Hurt by Nintendo Delay

by James L. Turley

Almost simultaneously, Nintendo, Sega, Sony, and 3DO have revealed designs for their respective next-generation home video games. Each of these new 32- or 64-bit machines promises to run circles around the current crop of 16-bit game players, with faster graphics, better rendering, CD-quality audio, and live video, all for less than $500. In many ways, the new game players outperform most personal computers and have the potential to overturn preconceptions about which microprocessor architectures will be successful in the coming years.

Although Nintendo revealed its Ultra 64 game player at the same time as its competitors' new machines, the company quietly admitted that development of the long-awaited 64-bit game player has slipped. First deliveries are now not expected until April 1996, entirely missing the critical end-of-year holiday buying season. With the industry's biggest player on the sidelines, the competition for market share in the coming months will be all the more fierce.

MIPS's Hopes Riding on Magic Carpet

Perhaps to draw attention away from Nintendo's embarrassing delay, the suppliers of Ultra 64's most crucial components announced the formation of a multimedia processing architecture and chip set called Magic Carpet. A combined hardware and software architecture, Magic Carpet is the product of collaboration between MIPS Technologies (MTI) and its parent company, Silicon Graphics. Several vendors have already announced their intention to ride the Magic Carpet to new multimedia consumer products.

The Magic Carpet specification consists of three ingredients: a MIPS microprocessor, a "media accelerator" chip, and the Magic Carpet application binary interface. The first implementations will use the R4300 microprocessor *(see **090601.PDF**)*, currently built by NEC, with a MIPS-designed graphics accelerator chip. Both chips have been licensed to multiple vendors, but except for NEC, none of those vendors has been identified, although Philips, IDT, and LSI Logic are possible choices.

Several companies, not all MIPS licensees, have agreed to use the Magic Carpet chip set and software interface in a range of new products due out in the next two years. AT&T Network Systems, Philips, Samsung, and Time Warner all plan to use Magic Carpet in future products. AT&T will use the chip set in an upcoming line of interactive "any-media" home terminals. Philips would publicly commit only to using Magic Carpet in future "multimedia applications." Samsung will manufacture for Time Warner a line of set-top boxes that complies with the Magic Carpet specification.

Media Accelerator Assists R4300 CPU

In conjunction with the R4300, the $50 media accelerator chip adds the functions necessary for graphics-oriented consumer applications. Magic Carpet is generic enough to be used for television set-top boxes, video games, low-end workstations, Windows NT systems, or add-in cards for multimedia acceleration.

Figure 1 shows a typical Magic Carpet implementation in a set-top box. In this diagram, the core logic is surrounded by application-specific input and output converters. For a set-top box, the front-end logic might include a satellite down-link converter, cable converter, and VCR hookup. All these peripherals are connected to the accelerator's 8-bit I/O bus. The back-end logic would perform the conversion to television (NTSC or PAL) video and audio standards.

Also connected to the R4300 bus is the media accelerator chip, which MTI calls the MIPS media accelerator, or MMA. The accelerator is an intelligent slave device, similar to workstation graphics and rendering accelerators, dedicated to video- and graphics-oriented tasks. Its design and internal architecture are based on Silicon Graphics' Reality Engine accelerator board for its workstations. The core functions of the workstation accelerator have been shrunk to a single 160-pin PQFP

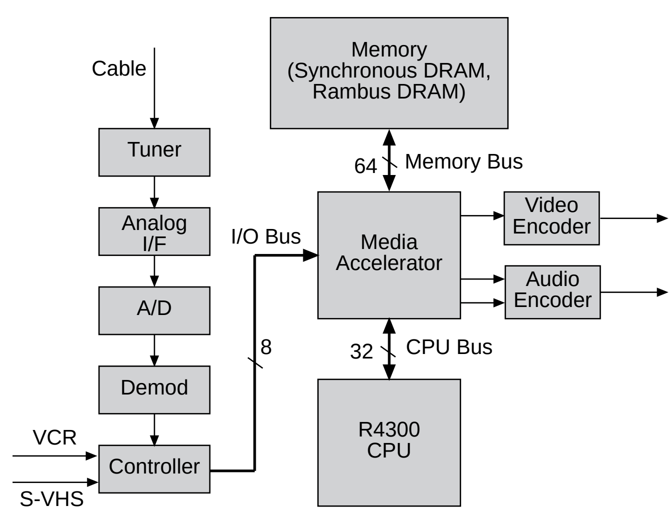

Figure 1. The Magic Carpet chip set lends itself to low-cost television set-top boxes with the addition of minimal logic.

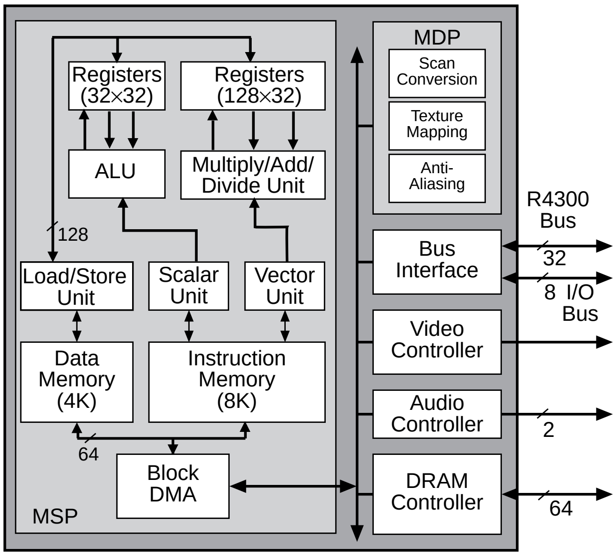

Figure 2. The MIPS media accelerator (MMA) contains two main compute units: the DSP-like media signal processor (MSP) and the media display processor (MDP).

with approximately 3 million transistors.

The MMA itself is divided into two main function blocks, as Figure 2 shows. It contains a 32-bit integer DSP block and a graphics accelerator block for antialiasing and texture mapping. In keeping with the multimedia-oriented nomenclature, MTI calls these the media signal processor (MSP) and the media display processor (MDP).

As the block diagram shows, the DSP portion of the accelerator has two execution units: a scalar integer execution unit and a vector processor. Each has its own register file, but both fetch their instructions from the same instruction memory. Both execution units can operate in parallel, given the right mix of instructions. The best throughput is achieved by alternating instructions for the two execution units in the instruction memory.

The MMA also directly controls a bank of shared DRAM. All memory requests (including cache misses) from the R4300 are serviced through the MMA. No memory is available on the processor's local bus. The DRAM controller prioritizes requests from the R4300, the MMA's internal DSP and graphics accelerator, and external sources. The DRAM controller is designed to handle either synchronous DRAMs or Rambus DRAMs.

Magic Carpet MMA Works with R4300

To begin an operation, the R4300 writes a command word into the MMA's command registers. After reading the command word and fetching address pointers from shared memory, the DMA controller transfers a block of MMA commands from shared memory into the internal instruction memory. The MMA then executes the downloaded program. The program can access the MMA's on-chip data memory, but it cannot modify its own program memory. The MMA can pass status information to the host by writing to command/status registers, which the R4300 can poll. The program can also interrupt the R4300 by writing to an internal MMA control register.

Although it has substantial data-manipulation capability, the MMA stops short of performing actual MPEG-2 decompression. Instead, the chip provides a set of function units that the Magic Carpet firmware uses to build graphics primitives. The R4300, in turn, calls these primitives to perform MPEG-2 audio and video decompression. Together, a 100-MHz R4300 and a 100-MHz MMA chip can decompress and display two full-screen MPEG-2 audio and video streams and still have about 20% headroom. This remaining bandwidth can be used to create and display graphics overlays and text or to perform local processing.

This mixed hardware/firmware decompression scheme allows set-top box manufacturers to change the decompression algorithm used, should MPEG-2 give way to another standard after the box is already deployed. It also gives hardware vendors the flexibility to implement different encoding schemes (e.g., DigiCipher) for their customers without hardware changes.

Set-Top Market Still in Its Infancy

The first product to use Magic Carpet will be from Time Warner Cable. The broadcasting company has so far deployed about 60 set-top boxes during its trials in Orlando, Florida. That box is a bulky, first-generation design that basically combines a motherboard from a Silicon Graphics Indy workstation with a front-end cable decoder. Using a special remote control, residential customers can select from a number of services—including movies, shopping, travel reservations, and video games—all on demand. The digitized video is stored in remote SGI servers. Time Warner Cable will rapidly increase the number of test households to 4,000 by the end of 1995 as it starts to deploy its new design based on Magic Carpet.

The set-top market is still in its infancy, with standards, interfaces, and applications up for grabs. The success or failure of this particular set-top architecture depends more on Magic Carpet's backing—the content suppliers and distribution companies supporting it—than on any material difference in Magic Carpet itself. Its target price may lead to just that kind of backing.

The architecture defined by MIPS and SGI lends itself to other video-intensive, interactive applications, like video games. The requirements of video games and television decoders are not substantially different; one could argue that video games were the first digital set-top boxes. And while the perennial predictions for set-top box predominance seem to be perpetually postponed, video games have already shipped millions of units, and the number keeps growing.

Video Game Competition Heats Up

The total installed base of home video games in the United States has passed 40 million, according to published reports, triple the number of home PCs with a CD-ROM. More than 16 million of those game units were shipped in 1994 alone, representing 40% of the installed base and more than $1.4 billion in revenue to Sega and Nintendo. Software (game title) sales, a portion of which flow back to the system maker in the form of royalties, generate roughly triple the dollar volume of the players themselves. A lucrative market, to be sure. But past successes may not necessarily mean good times ahead.

The first big success was Nintendo's original 6502-based NES unit, introduced in 1985, quickly crushing industry pioneer Atari. As late as 1989, Nintendo had the home video-game market nearly to itself. That year, newcomer Sega introduced its first 16-bit product, the Genesis, based on an 8-MHz 68EC000. Game buyers snapped up the faster Sega systems as quickly as the company could produce them and, by 1993, Sega had surpassed Nintendo in sales volume. It wasn't until 18 months after the arrival of Genesis that Nintendo parried with its own 16-bit player, the Super NES. Nintendo's U.S. market share for 16-bit systems eventually grew to 57% in 1994.

The SNES is based on a 16-bit version of the antediluvian 6502, the handcrafted 65816 from Western Design Center *(see **080903.PDF**)*. Although the new CPU featured backward compatibility with the 6502, potentially allowing Nintendo to offer a compatible upgrade path for its installed base, physical limitations prevent the SNES from using earlier 8-bit NES game cartridges.

Sega took a different upgrade approach, plugging the new 32X adapter directly into the game cartridge slot of the original Genesis. Cartridges then plug into the top of the 32X. The design of the Genesis system allows the 32X to access the resources of the Genesis motherboard, complementing the original 68000 CPU with a pair of Hitachi SH7604 microprocessors.

This new and lucrative business did not go unnoticed by Sony, 3DO, or Atari. By 1994, all three had entered the market (Sony only in Japan) with technically superior products. Still, the 3DO MultiPlayer and Atari's Jaguar together accounted for fewer than 500,000 units in the U.S. in 1994, or less than 4% of the market.

Nintendo Ultra 64 Slow Out of the Gate

Ironically, the highest-profile design win for the R4300 does not comply with the Magic Carpet specification. Nintendo's Ultra 64 video game uses NEC's R4300 but replaces the MIPS-designed MMA with Nintendo's own Reality Coprocessor accelerator. The two chips are nearly identical, but Nintendo's chip is simpler, lacking

Company	Model	CPU	Resolution	Retail
Apple	Pippin	PowerPC 603	640 × 480 × 24	$500
Atari	Jaguar	Custom	720 × 576 × 24	$160
3DO	MultiPlayer	ARM60	640 × 480 × 24	$400
	M2	PowerPC 602	640 × 480 × 24	N/A
Nintendo	NES	6502	256 × 240 × 4	$50
	SNES	65816	512 × 448 × 8	$90
	Ultra 64	R4300	N/A	$250
Sega	Genesis	68000	320 × 224 × 6	$90
	CD	68000	320 × 224 × 6	$200
	32X	SH7604 (2×)	320 × 224 × 6	$150
	Saturn	SH7604 (2×)	640 × 224 × 24	$400
Sony	PlayStation	Custom R3000	640 × 480 × 24	$300

Table 1. A comparison of home video-game specifications shows how features and capabilities have improved over time.

MPEG-2 support. The Ultra 64 has its own programming interface, also proprietary to Nintendo (which is what allows the company to collect royalties on all Nintendo games). In overall function and feature set, however, the Ultra 64 and Magic Carpet are quite similar.

Due to the delay, few details are available about the Ultra 64. The system uses Rambus DRAMs controlled by the Reality Coprocessor, much like Magic Carpet does. Given that NEC is a licensee and manufacturer of Rambus DRAMs, this was a logical design decision.

As Table 2 shows, Ultra 64 will be priced about $50–$150 less than most of its competitors, primarily because it does not include a CD-ROM drive. The 3DO MultiPlayer and Sega's Saturn both include a CD-ROM drive, and Atari offers one as a $159 add-on for Jaguar. Nintendo's decision to eschew CDs for ROM cartridges lowers the cost of its machine. Reading from a 32-bit ROM cartridge is also much faster than from a serially accessed CD. Nintendo believes that the high bandwidth and negligible latency of the ROM cartridges will translate into a compelling difference in game play.

Nintendo's reliance on ROMs, however, seriously limits the amount of graphics and/or video footage that can be delivered in a game because of the cartridges' limited capacity compared with CDs. Most best-selling games today use 2M of mask ROM, but a typical CD has 200 times as much storage capacity. Pressing a CD in volume costs between $1 and $2 per disk—far less than the $10 or more for a cartridge-based game. In the end, although the Ultra 64 platform may be less expensive than its competitors, the software for it may cost more.

Sega Launches Migration to Saturn

Hoping to get a head start over Sony, 3DO, and archrival Nintendo, Sega began shipping its newest Saturn system in May, months before the PlayStation's U.S. release and nearly a year before Ultra 64's. Saturn promises to be the most expensive platform of the lot, at around $400, largely because of its complexity.

The Saturn system, which has been selling briskly

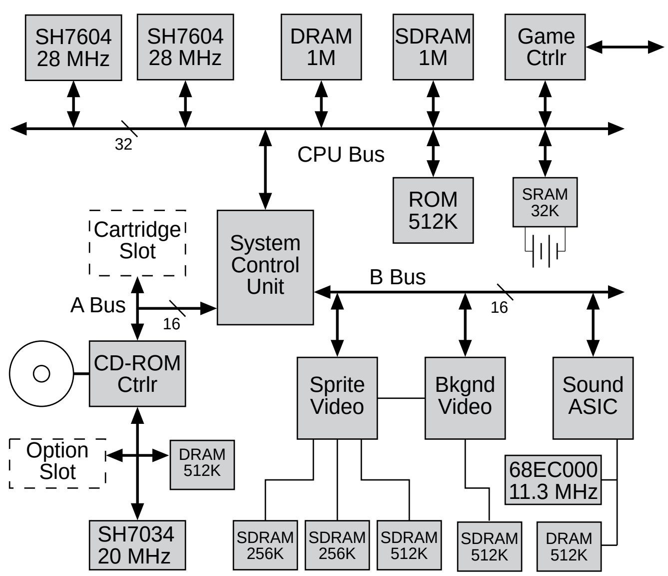

Figure 3. Sega's Saturn system includes four separate microprocessors and six large ASICs.

in Japan, keeps the pair of SH7064 processors found in the 32X and adds a third Hitachi processor, the SH7034, to manage the Saturn's CD-ROM drive. As Figure 3 shows, it still uses a 68000, though only for audio management. The system also carries more than 5M of memory: 2M of DRAM, 2.5M of SDRAM, 512K of ROM, and 32K of battery-backed SRAM.

Saturn's features are typical of many of the new systems. It has a cartridge slot, but only for inserting nonvolatile memory cartridges. These are intended to let gamers back up scores, team statistics, and other vital data. Sega's cartridges are expected to come in 2M and 4M capacities. It also has a proprietary expansion slot, accessed through a recessed rear panel, for future enhancements. In Sega's case, an MPEG decoder option could be added directly on the CD-ROM bus. Saturn also bears a high-speed serial port for linking systems in multiplayer games.

One of the system's most unusual architectural features is its pair of host processors. Both chips are identical, and game programmers are free to allocate tasks to either CPU as they see fit.

Sony Enters Crowded Market

Sony's PlayStation has been available in Japan since December of 1994 and has sold an impressive 700,000 units in just a few months. The company will export PlayStations to North America beginning in September, the company's first move into the U.S. home video-game market. The heart of the system is a single ASIC with a MIPS R3000-based CPU core integrated with audio- and graphics-decompression logic *(see **080902.PDF**)*. The chip is fabricated by LSI Logic in a 0.5-micron process and runs at 34 MHz—an unusual clock frequency for a general-purpose computer, but a logical multiple of the NTSC television scan rate.

The LSI/Sony chip is relatively large, estimated to be about 64 mm^2, but includes most of the functions of the combined R4300/MMA chip set. In integer performance, the LSI/Sony chip is no match for the R4300. Its MIPS-II core has only a 32-bit internal architecture to the R4300's 64 bits, it runs at one-third the clock frequency, and its 4K/1K caches are dwarfed by the 16K/8K caches on the NEC part.

Another difference between them is in integration. Sony chose to place the R3000 core and caches in the center of an integrated CPU/graphics processor chip with its own 3D transformation processor, decompression logic, seven-channel DMA controller, counters, timers, and even serial ports. Very little outside logic is needed to make the PlayStation go. This gives Sony a significant cost advantage over Sega, reflected in the $100 retail price difference between the two boxes.

Sony's implementation also has its own DRAM controller with a dedicated 32-bit memory bus and a separate I/O bus for peripherals. Its "video" decoder is dedicated, and it handles only the so-called Motion JPEG format, not MPEG-1 or the considerably more taxing MPEG-2 format. For game systems, Motion JPEG resolution is adequate for animated intro screens and helps simplify the system logic.

Like the MIPS and 3DO ASICs, the Sony chip includes dedicated multiply-accumulate hardware for graphics acceleration. The PlayStation integrates the major hardware ingredients for 3D rendering differently than the others do. The 3D transformation coprocessor is on the same chip as the microprocessor, but the chip must then transfer the rendered data to an external graphics chip.

The Magic Carpet implementation, on the other hand, separates the CPU (for now) and merges the multiply-accumulate hardware with the graphics display controller. Sony claims 180,000 3D flat-mapped polygons and 180,000 texture-mapped, Gouraud-shaded polygons per second. MTI specifies its chip set a little differently, claiming 500,000 polygons or 100,000 3D, antialiased, shaded, texture-mapped, z-buffered, blended polygons per second.

Atari Takes the Low Road

Atari's 32-bit system is the lowest-priced unit in the bunch, with a retail price of just $159 for the Jaguar. Like the 3DO MultiPlayer, it has been on store shelves for more than one year, where it largely remains.

Jaguar's design centers around two custom ASICs, Tom and Jerry, each with its own proprietary 64-bit CPU, plus a 68000 for I/O management. Atari does not release details of its CPU design, but it was strongly influenced by the 68K instruction set with enhancements for graphics and pixel management. Jaguar also includes 2M of conventional DRAM, 8K of SRAM, and a mere 256K of ROM for booting the machine.

Dark Horse 3DO Pins Hopes on M2

The 3DO Company licensed its first-generation MultiPlayer design to Panasonic, Goldstar, and Sanyo. Panasonic was first to manufacture the system, with Goldstar (now called LG Electronics in the U.S.) and Sanyo following one year behind. At an introductory price of $700 (now closer to $400), and with few titles available, the 3DO machine didn't catch on quickly, accounting for only about 500,000 units to date. The hardware license is royalty free; 3DO makes its money on software royalties, to the tune of about $6 per disk.

The original 3DO MultiPlayer design used a cacheless ARM60 processor with three external ASICs for graphics and system control. The ASIC count shrunk to two, known as Clio and Madam, and then to one, Anvil. Following the company's recent agreement to license the ARM6 core, 3DO will make the final step, integrating the ARM core directly into Calvin, the newest MultiPlayer's lone ASIC. This series of chip shrinks has contributed to 3DO's consistent price decline.

For its next-generation game system, called M2, 3DO chose to replace the ARM60 with a PowerPC 602 chip *(see **090203.PDF**)*. In what must be a first in the embedded-processor industry, the M2 machine retains an ARM processor for backward software compatibility but uses the 602 to run all the new titles. The company evaluated software emulation for backward compatibility but found that an ARM processor was cheaper than the ROMs required to emulate one.

M2 will be available in two forms: as a standalone player and as an upgrade for existing (or potential) first-generation MultiPlayer owners. Figure 4 shows a block diagram of the standalone version. The performance and capabilities of the two configurations will be identical.

The M2 design boasts even better graphics performance than the original MultiPlayer, thanks to a huge (2.5 million transistors) new ASIC and the increased performance of the 602. Both chips are fabricated by IBM. M2 has a big potential performance advantage over the competitors' platforms because the 602 can perform single-precision floating-point multiply-accumulate operations every clock cycle at 66 MHz. The M2 ASIC has a nearly identical FPU in it as well, doubling the system's FP throughput and accelerating polygon calculations, lighting, filtering, and Gouraud shading.

However, the company has not yet announced any hardware licensees, casting doubt on M2's eventual success. Unless 3DO, which has never made a profit since it was founded in 1992, can bring one or more system makers on board quickly, it may founder.

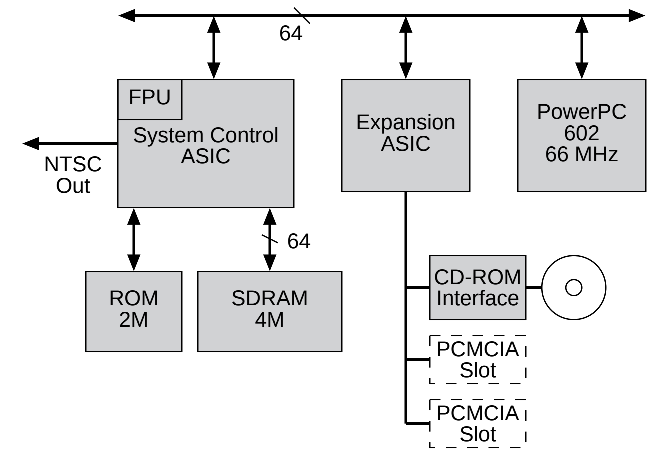

Figure 4. 3DO's new M2 system is based on two large ASICs. The system-control ASIC contains over 2.5 million transistors and is fabricated in IBM's 0.65-micron five-layer-metal process.

Apple's Pippin Leverages Mac Software

PowerPC's video-game hopes go beyond the uncertain prospects of 3DO's M2. Apple has also been casting covetous glances at Sega's and Nintendo's profits, looking for a way to leverage the company's system experience and installed software base while increasing the market penetration of the Macintosh. Apple's answer is Pippin, a Mac-like game and education system.

Pippin is, at its heart, the least expensive Power Macintosh possible. The upcoming game player from Apple is based on a PowerPC 603 chip and—like the Macintosh—has no graphics acceleration hardware. Graphics drawing routines are handled by the 603 with QuickDraw routines lifted from the Macintosh ToolBox.

Apple's business model for Pippin is similar to 3DO's, and a complete reversal of the company's established practice. Apple will not manufacture Pippin. Instead, it will license the design in the form of a reference platform to interested hardware manufacturers, which are then free to add distinguishing features as long as the hardware remains compatible with the reference design. Japanese toy-maker Bandai (of Power Rangers fame) is the only publicly announced licensee so far. Its Power Player system will be available near the end of 1995, around the same time as Sony's PlayStation.

To keep Pippin's cost as low as possible, the basic system does not include a hard disk, floppy drive, keyboard, mouse, or monitor. The machine does come with a 4× CD-ROM drive along with 6M of DRAM, 64K of NVRAM, plus two ADB ports and a GeoPort for low-cost modems. If the Power Macintosh is any indication, Pippin will also include prodigious amounts of ROM, in the range of 4M of firmware.

In place of a keyboard, Pippin will have a joystick/remote control plugged in through an ADB port. The system can be upgraded with an Apple-compatible

For More Information

3DO (Redwood City, Calif.) 415.261.3000
Sega of America (Redwood City, Calif.) 415.508.2800
Nintendo America (Redmond, Wash.) 206.882.2040
MIPS Technologies (Mt. View, Calif) 415.390.4208
NEC Electronics (Mt. View, Calif.) 800.366.9782
Sony (Foster City, Calif.) 415.655.8000
Atari (Sunnyvale, Calif.) 408.745.2000
Apple Computer (Cupertino, Calif.) 800.776.2333

keyboard and mouse through an ADB adapter for e-mail or online services. Pippin uses PCI for its internal bus but does not follow the PCI form factor. Thus, Pippin will not accept standard PCI expansion cards.

Rather than include the OS permanently in ROM, Apple chose a different approach. Each CD-ROM title will bear its own copy of the Pippin operating system, including as much or as little of the Mac OS as it needs to run. For example, AppleTalk communication routines might be omitted in educational titles but included in multiplayer games for networking. Apple recommends keeping application code size under 3.5M, suggesting that the operating system uses 2.5M for itself.

Apple is banking on the similarities between Pippin and Power Macintosh to attract software developers. Because the two machines share an operating system, processor architecture, and ToolBox ROM routines (including 680x0 emulation code), porting applications is a snap. Apple claims that existing Macintosh applications can be retargeted for Pippin in a matter of days. The biggest task, according to the company, is adjusting screen displays—especially text—for the lower resolution of a television. Pippin software will run unmodified on a Mac. Apple expects that ISVs already developing software for desktop PCs and Macintoshes will be attracted by the “two-for-one” potential of selling substantially similar applications for both Pippin and the Mac.

Bandai’s Power Player is expected to sell for about $500 at introduction. At that price, Pippin is more expensive than all the other game platforms but still about one-quarter the price of a bona fide Power Macintosh. Panasonic found that the initial $700 price tag of the 3DO MultiPlayer scared off customers in droves, especially since there was very little software available, but Pippin may have an advantage on that account. If Mac software is as easy to port as Apple says, then Mac developers may be willing to take a small gamble and port their existing game and educational applications. In fact, given that none of the new generation of game players (except 3DO) has any software legacy to speak of, Pippin may come out of the gate with the largest number of titles available. Pippin should also attract developers of educational software, something the game manufacturers are unlikely to do as easily.

On the other hand, $500 is a lot of money for a game player that promises to have the worst graphics performance of the bunch. At that price, buyers might consider a full computer instead. For current Mac owners, Pippin might make a nice second machine for the kids, but if exciting games are what they want, any of the competing products will deliver more compelling special effects.

No Software Compatibility

With the exception of 3DO (and to some extent, Pippin), none of the upcoming crop of new machines has any backward compatibility with previous generations. The move from 8-bit to 16-bit players was much smoother. Sega offered a simple and relatively inexpensive upgrade path for owners of its first machine, and saw its sales zoom past Nintendo’s in the process.

Now the slate is wiped clean and both competitors must start over, luring customers with flashy features and brand-new titles. The installed software base is useless in the new players, so owner loyalty will probably be low. Sega owners have no reason not to switch to Nintendo, Sony, 3DO, Apple, or Atari, and vice versa. Nintendo’s six-month slip is good news for Sony, Atari, Panasonic, and especially Sega. By the end of 1995, Nintendo—once the undisputed giant in the industry—will be the only vendor *without* a 32- or 64-bit platform.

Apart from Nintendo and the many game developers that depend on it, Ultra 64’s delay is also bad news for NEC and MIPS. The usual buying frenzy at the end of the year is make-or-break time for consumer items of this kind, and Nintendo will sorely miss the revenue it might have gained. More important, that lost time may give the company’s competitors a valuable head start.

The recent boom seen by Nintendo and Sega has added legitimacy to the home video-game market and attracted the attention of the world’s top microprocessor vendors. No longer are game boxes using cast-off, inexpensive 8-bit CPUs. Rather, they are relying on industry-leading microprocessors designed specifically for their particular needs. In most cases, the integer and graphics power of these “toys” exceeds that of most personal computers and some workstations. Significantly, the video games cost less than one-quarter the price of the computers.

The annual volume of video games has exceeded that of laser printers, long seen as a benchmark of success in the 32-bit embedded microprocessor industry. Those volumes drive design decisions. New chip designs like the R4650, SH7708, and R4300 emphasize integer DSP performance, bus bandwidth, and low cost in an effort to get a piece of that volume. And the low prices of mass-market items like television set-top boxes and video games promise to put unprecedented computing power into a large number of small hands. ♦

