MICROPROCESSOR REPORT
VOLUME 10, NUMBER 15
NOVEMBER 18, 1996
THE INSIDERS' GUIDE TO MICROPROCESSOR HARDWARE

Chromatic's Mpact 2 Boosts 3D

Mpact/3000 Becomes First Media Processor to Ship in Volume

by Yong Yao

Even as manufacturing partners LG Semicon and Toshiba are beginning volume shipments of the first media processor, Mpact/3000, Chromatic has disclosed its forthcoming Mpact 2 design. Announced at last month's Microprocessor Forum, Mpact 2 (code-named M2) is expected to double the overall performance of Mpact/3000 (code-named M1). The gain is much greater on 3D graphics, as new floating-point capabilities position Mpact 2 to meet the 3D-performance requirement for mainstream PCs in 1998.

The performance gains stem mainly from a doubling of internal clock speed, an additional Rambus channel, the addition of floating-point capability, and a new 3D rendering engine. Other enhancements, such as doubling the on-chip cache and supporting 66-MHz PCI, also contribute to the improved performance.

One of the biggest competitive advantages that Chromatic has over other media-processor vendors is the richness of its software offerings. The recent release of the Mpact software, Mediaware Release 1.0, contains 2D/3D graphics, MPEG-1 audio/video decoding, FM/wavetable synthesis, V.34 modem, and full-duplex speakerphone. We expect future revisions of Mediaware to enhance these functions and also add functions such as DVD playback, video editing, and videoconferencing.

Chromatic expects Mpact 2 to be in PCs for the 1997 holiday season. We believe the technical success of Mpact/3000 makes this goal achievable. The company intends to position Mpact 2 at the high end while Mpact/3000 covers the low end. Whether the PC market will accept that positioning remains to be seen, because Mpact/3000 may not have enough performance by the time Mpact 2 is in production.

Mpact 2 Doubles Mpact/3000 Performance

Doubling performance every 12 months is Chromatic's plan for keeping ahead of Intel's processor advances. To meet this goal for Mpact 2, Chromatic will increase the internal clock speed from 62.5 MHz in Mpact/3000 to 125 MHz or higher, replace 4K of cache with 8K, and add a second Rambus channel to reach 1,200 Mbytes/s of total memory bandwidth. The chip supports 300-MHz RDRAMs with an effective transfer rate of 600 MHz. Figure 1 shows the internal block diagram of Mpact 2, which is similar to that of the original Mpact/3000 (*see* **091404.PDF**).

The faster clock speed is achieved by using a 0.35-micron CMOS process, optimizing critical paths, and decoupling the internal clock from the Rambus interface clock. Unlike its predecessor, the Mpact 2 processor core can run asynchronously from the RDRAM, which provides the freedom to choose the RDRAM and internal clock speeds independently. One drawback to the asynchronous design is additional latency, due to clock synchronization, when accessing RDRAM.

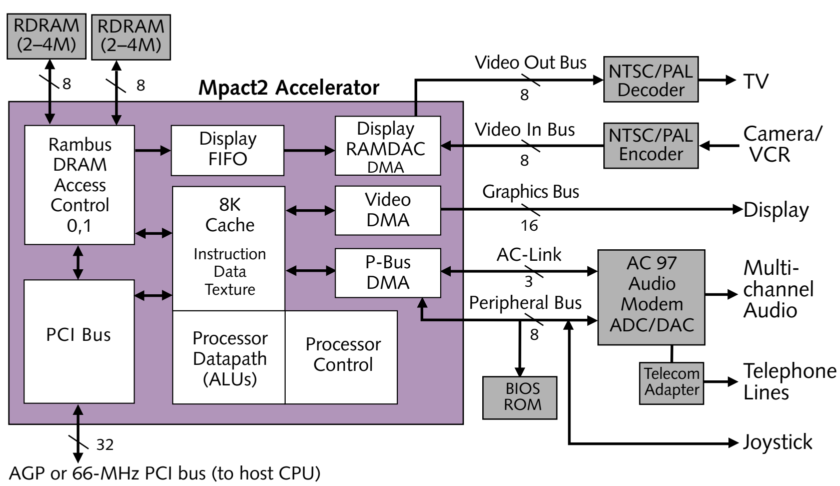


Figure 1. Mpact 2 doubles performance over Mpact 1 by increasing the internal clock speed, doubling the amount of on-chip cache, adding a second Rambus channel, and doubling the speed of the PCI bus. A multimedia subsystem requires few extra chips.

Simply doubling clock speed would not double the overall performance if there were not enough data to feed the engine. Mpact 2 satisfies this need by doubling the external memory bandwidth as well as the amount of on-chip cache. By simply adding a second Rambus channel, Chromatic doubles the memory bandwidth while adding only eight data pins to the package.

As Figure 2 shows, the new cache is divided among a 2K instruction cache, a 2K texture cache, and a 4K data cache. The data cache has six read ports and six write ports. In the first-generation Mpact design, there is no dedicated cache for textures, and the single 4K cache holds both data and instructions with only four read ports and four write ports.

In addition to PCI and other standard hardware interfaces supported by Mpact 1, the new chip adds support for Intel's AC '97. The AC '97 interface *(see* **1009MSB.PDF***)*allows Mpact 2 to use any off-the-shelf AC '97–compliant audio codec, reducing the cost of the audio subsystem.

The PCI interface has been modified to operate at 66 MHz, twice the frequency of the standard PCI bus. This higher speed enables Mpact 2 to store textures in main memory and increases bandwidth to the rest of the system. Few chip sets exist today to drive a 66-MHz PCI bus, so Mpact 2 will operate the bus at 33 MHz if necessary.

By the time Mpact 2 appears, however, chip sets that support the AGP interface *(see* **100803.PDF***)* should be appearing. These chip sets will connect to Mpact 2 using 66-MHz PCI. For this reason, Chromatic describes its chip as AGP-compliant. The initial Mpact 2, however, does not support any of the advanced features of AGP, such as dual clocking and split transactions.

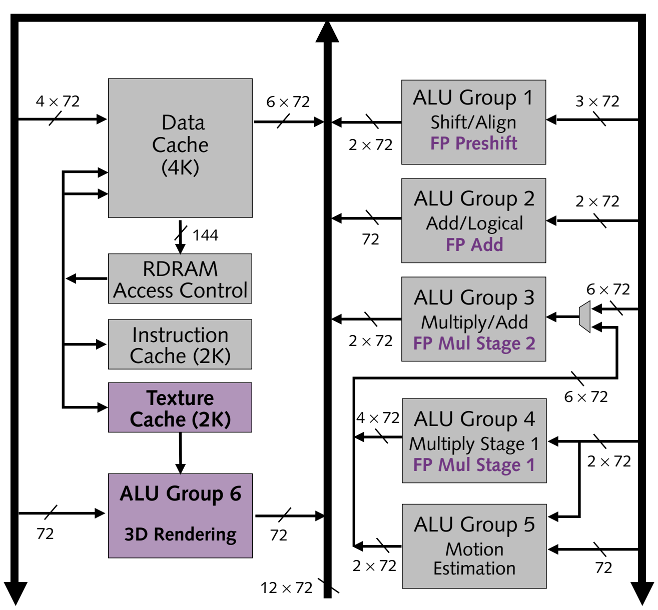


Figure 2. Mpact 2's internal data paths are all 72 bits wide, with a 792-bit crossbar carrying 11 results back to all six ALU groups and to the on-chip caches. Changes from the previous design are highlighted in purple. ALU groups 1–4, for example, are modified to support FP operations.

Mpact 2 integrates a 220-MHz RAMDAC on chip. The high-speed DAC supports displays up to 1,600 × 1,200 × 18 with a refresh rate of up to 85 Hz.

Mpact 2 Adds Floating-Point Capability

Because Mpact/3000 lacks floating-point capability, the chip's biggest weakness is 3D graphics. Without strong 3D performance, a PC media processor cannot succeed in the long run. At the Forum, architect Stephen Purcell said that improving 3D graphics performance was a major design goal for Mpact 2.

The key to 3D geometry processing is floating-point performance. Instead of adding a separate floating-point unit, Chromatic modified the four general-purpose ALU groups to perform FP operations, as Figure 2 shows. This change has made a minimal impact on die size. All FP operations are performed in single-precision mode, since 3D graphics for a PC rarely use double-precision. To take advantage of the 72-bit data paths, each ALU in Mpact 2 performs two single-precision operations in parallel. This method is similar to the paired-single format in the MIPS V instruction set *(see* **101505.PDF***)*.

To perform a floating-point add or subtract, the operands are first sent to ALU Group 1, which performs a preshift operation to correctly align the operands. This operation uses the existing shifter in that ALU. Using the crossbar, the operands then move to ALU Group 2, which performs the actual add operation. Thus, FP addition is fully pipelined with a latency of two cycles. Similarly, for floating-point multiplication, the operands are first sent to ALU Group 4, then the multiplication is completed in ALU Group 3 on the following cycle. Again, FP multiplication is fully pipelined with a latency of two cycles.

Each cycle, a pair of single-precision FP adds can be launched along with a pair of single-precision FP multiplies.

3 stages	Input polygon
3 stages	Generate spans from polygon
3 stages	Generate pixels from spans
10 stages	Apply perspective (divide step) to pixels
3 stages	Generate texture address and present to texture cache
2 stages	Access texture cache and format texel
2 stages	Apply filters
2 stages	Blend/modulate pixel/texel; diffusion, specular lighting
2 stages	Apply fog effect
5 stages	Cluster final pixels

Figure 3. The 3D-rendering pipeline in the Mpact 2 consists of 35 stages, broken down as shown. Such a long pipeline is not a problem for 3D rendering because there are no pipeline hazards.

At 125 MHz, the peak performance of the Mpact 2 design is thus 500 MFLOPS.

Chromatic added about 30% more instructions to the original Mpact instruction set, many specifically for the new floating-point capability and the 3D graphics unit. Unlike on the integer side, there is no direct support for FP multiply-accumulate; this operation is synthesized from a multiply and an add with a total latency of four cycles. There is also no FP divide instruction; this operation can be synthesized by a sequence of multiplies and adds.

New 3D Unit Speeds Rendering

Even the strong performance of the general-purpose Mpact engine is inadequate for high-speed 3D rendering. Chromatic's design philosophy is to use the programmable engine for general processing and for algorithms that may change, but specific hardware may be required to accelerate fixed algorithms. This philosophy led to the addition of a hard-wired motion estimator (ALU Group 5 in Figure 2) in the original Mpact and, in Mpact 2, a new 3D rendering unit.

The 3D unit, ALU Group 6, contains a 35-stage pipeline that runs concurrently with instruction execution. Since 3D graphics operations don't contain any pipeline hazards such as data dependencies or mispredicted branches, the long pipeline provides high throughput without reducing performance. Figure 3 shows this 3D rendering pipeline.

Other hardware improvements also aid Mpact 2 in 3D graphics. The addition of the 66-MHz PCI bus, the dedicated texture cache, and the wider path to external memory all improve 3D rendering performance.

One of the advantages that Mpact 2 has is its flexibility in allocating 3D tasks. The media processor can handle geometry, setup, and rasterization, or let the host processor take over geometry and/or setup. If triangle setup is performed in Mpact, it will be done in firmware using floating-point operations. Chromatic claims Mpact 2 can achieve one million triangles per second with 50-pixel triangles, Gouraud shading, 18-bit Z depth, perspective-correct textures, bilinear filtering, alpha blending, and fog. If delivered, this performance would put Mpact 2 right in the mainstream for PC 3D in 1998.

Although Mpact 2 is not a part of Microsoft's Talisman reference platform *(see* **101102.PDF***)*, some of Talisman's features have been incorporated into the Mpact 2 hardware. According to Chromatic, features included are chunking, image and texture compression, and affine transformations. Like Talisman, Mpact can also choose to render particular objects below the frame rate but composite them at the full frame rate. These features may help Mpact 2 support Talisman-enabled 3D games and perhaps become an officially supported Talisman platform in the future.

Price & Availability

Mpact 2, packaged in a 304-pin SBGA, is slated to sample in 1Q97 with volume production in 3Q97. Pricing has not been determined. Contact Chromatic (Sunnyvale, Calif.) at 408.752.9100 or access the Web at *www.mpact.com*; contact LG Semicon (San Jose, Calif.) at 408.432.5024; contact Toshiba (San Jose, Calif.) at 408.526.2612.

Chromatic Releases Mediaware 1.0

Mediaware is the fuel for the Mpact hardware engine. Chromatic recently shipped version 1.0 of Mediaware for Mpact/3000. The release includes an Mpact real-time kernel, Mpact resource manager, 2D/3D graphics, audio, video, fax/modem, and telephony (see sidebar, page 4, for details). Mpact 2 is software-compatible with its predecessor; therefore, the existing Mediaware will run on Mpact 2.

Mediaware 1.0 is designed to run on any Pentium processor. Chromatic is currently revising its software to take advantage of the MMX extensions incorporated in Intel's P55C Pentium and other forthcoming processors. The new code, called MMX Mediaware, is planned to ship in 1H97.

As Figure 4 shows, there are seven Mediaware modules, corresponding to the seven main multimedia functions. These modules, plus the Mpact real-time kernel, reside on the media processor. The rest of Mediaware software—Mpact DirectX drivers, MMX Mediaware, and the Mpact resource manager—run on the host processor.

When Chromatic originally announced its Mpact chip last year, the company expected to include MPEG-1 encoding and full DVD (MPEG-2 video and AC-3 audio) decoding in its initial Mediaware, but these functions have not yet appeared. Chromatic's software efforts were hampered by changing APIs at Microsoft as well as the relatively small size of the company compared with the task at hand.

For future Mediaware releases, we expect Chromatic to add DVD audio and video decoding, 3D positional audio,

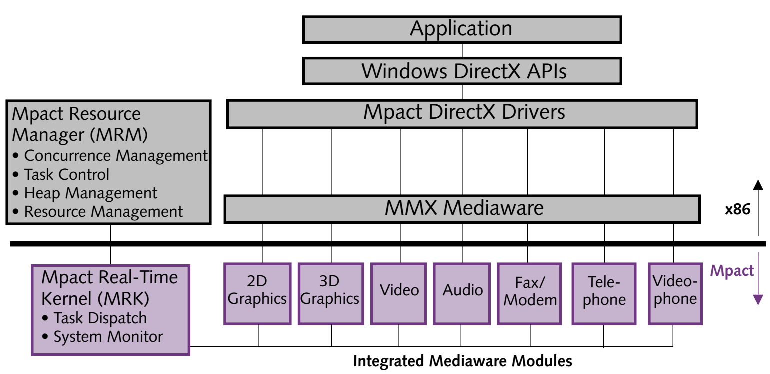


Figure 4. The Mpact Mediaware provides seven multimedia functions. It interfaces to applications using Microsoft's DirectX APIs.

Complete Contents of Chromatic Mediaware Release 1.0

The most challenging problem in supplying a media processor for PCs is not the hardware but the software. While the Mpact processor is a complex piece of work, the associated Mediaware performs a huge array of functions. To deliver all of these functions, Chromatic has roughly twice as many software engineers as hardware engineers.

Without functional software, a media processor is worthless. Of course, none of the emerging media processors has an established software base, so all of this code must be created before the first systems can ship. By bringing its Mpact processor and Mediaware to market first, Chromatic has established a significant lead over other media-processor contenders. The list of software functions below demonstrates the barriers to entry in this market and sets a standard for competitors to match.

Video

Full support for the OpenMPEG command set; real-time MPEG-1 video decode at 30 frames per second, 18-bit color; system layer timestamp-based video/audio synchronization; fully accelerated color-space conversion, bilinear interpolation and filtering; full screen or video in a window; crisp synchronization with graphics output; fully accelerated video CD playback; patented hardware motion-estimation and image processing; PAL/NTSC video input and output.

Audio

DOS and Windows 95 audio through WAVE, MIDI, DirectSound API; MPEG-1 (layers 1 and 2) audio decode; wavetable synthesis, 32 simultaneous voices, complex envelopes and filters; precise audio control through support for key layering, velocity switching, variable keyboard scaling for alternate tunings, sharpness of attack, and speed of decay; general MIDI-standard compatibility with 128 original instruments and 60 drums, 7 additional Roland GS and Yamaha XG drum kits; up to 8 simultaneous play and record channels with different formats and frequencies resampled up to 44 kHz, with 36-bit internal precision; psychoacoustic minimization of quantization noise; Sound Blaster compatibility; Mpact Audio Process Manager for minimizing synchronization overhead between audio tasks; HMI and Miles driver support; industry-standard joystick with MIDI; industry-standard MPU-401 MIDI port.

2D Graphics

Full DOS and Windows 95 GUI acceleration through DirectDraw APIs; VGA register-level compatibility and Super VGA graphics modes; VESA BIOS Extensions 2.0 and UniVBE support; noninterlaced screen resolution up to 1,280 × 1,024 × 18-bit color at 60 Hz; full BitBLT acceleration engine, including transparent BLTs and device bitmaps, with ternary operations; GUI acceleration of two-point line draws and trapezoidal and polygon fills; accelerated YUV conversion, scaling, filtering, clipping, and hardware cursor; full text acceleration engine; full hardware and BIOS support for VESA Display Power Management.

3D Graphics

Full Windows 95 real-time 3D graphics acceleration through Direct3D API; acceleration of 3D-rendering pipeline rasterization; Z-buffering and double-buffered rendering; flat and Gouraud shading; accelerated 3D spans and 3D geometric primitives; diffuse and specular highlighting; true color (24-bit RGB) with decal and color-modulation texture blending; 2×2 ordered dithering; bilinear and trilinear MIP-mapped texture filtering; perspective-corrected texture mapping; support for texel formats including 555 and 565 RGB, 888 RGB and 8888 RGBα, 4-bit- and 8-bit-palletized; full transparency, including alpha maps for textures; full alpha blending support; depth cuing with atmospheric effects; subpixel accurate rendering; buffer/texture memory management through DirectDraw HAL.

Fax/Modem

Full Windows 95 support for Microsoft Unimodem V, TAPI and VCOMM APIs; data modulation up to V.34 bis; V.32 bis support; V.22 bis support, Bell 212A and Bell 103; V.42 bis data compression and V.42/MNP 2-4 error correction; V.8 compliance; fax modulation up to V.17 in answer and originate modes; full fax class 1, 2, and 2.0 command-set implementation; data automoding; DTMF generation, dial tone and busy detection, ring detection, and auto answer; V.14 async-to-sync conversion and RS-232 interface support; full range of baud rate and parity support on DTE interface with memory-to-memory interface.

Telephony

Support for Windows 95 TAPI and VCOMM APIs; adaptive full-duplex speakerphone with acoustic echo cancellation; answering machine and voicemail functionality; outgoing and incoming message support; concurrent DTMF detection; call-progress detection; IMA ADPCM voice compression/decompression; Caller ID support.

Mpact Real-Time Kernel and Mpact Resource Manager

Real-time operating system with oversubscription management; dynamic linking, loading, and profiling of all Mpact threads; RDRAM memory allocation and compaction; host and Mpact communication functions; Mpact dynamic resource allocation and degradation.

video editing, and videoconferencing over POTS, ISDN, and the Internet. With the increased performance provided by Mpact 2, Chromatic can also develop more compelling functions such as cable modem and ADSL-related support.

Mpact Delivers Strong Performance

Figure 5 shows some Mpact performance data provided by Chromatic, all compared to the performance of a P55C-200 system with basic graphics and audio subsystems. Some of the numbers are based on simulations and others on real measurements. Mpact's biggest gain over the P55C alone is in its video-motion estimation, since the current MMX does not include any instructions to aid motion estimation. Therefore, we expect Mpact-based products to perform well for applications such as video authoring, videophone, and videoconferencing, where motion estimation is required.

The figure shows a 2× improvement in overall multimedia performance (a composite of the seven main functions) between Mpact/3000 and Mpact 2. The enhancements in Mpact 2 have a much bigger impact on 3D graphics, delivering an 8× improvement in this area. Note the comparison in Figure 5 is against a P55C system with no 3D hardware support; we expect a P55C with a midrange 3D accelerator (not just a "free-D" chip) to match the performance of the Mpact 2 system. The price of Mpact 2 must be close to that of the 3D chip for the Chromatic part to be competitive.

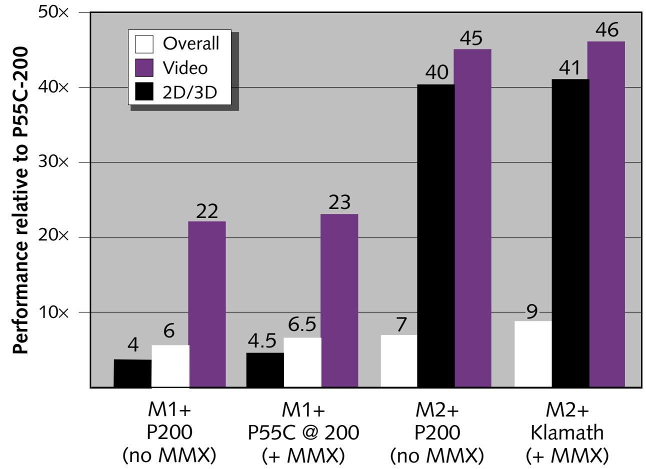


Figure 5. The M1 delivers a performance boost over a basic P55C system on most multimedia functions, as shown by the "overall" bar. The M2 further improves performance, particularly on video encoding and on 3D graphics. In all cases shown, the Mpact runs at 62.5 MHz and the Mpact 2 at 125 MHz. (Source: Chromatic)

Mpact "R" Offers Intermediate Solution

Table 1 lists media processors that Chromatic and its partners plan to offer in 1997. There are actually three versions of the M1 planned. The first is called Mpact/3000, reflecting its 3,000 MOPS of peak throughput. The second version, Mpact R/3000, is identical except for the inclusion of an on-chip RAMDAC (the same one carried forward into Mpact 2). The third offers a 20% speedup by clocking the RDRAM at 300 MHz and the CPU core at 75 MHz. This version is called Mpact R/3600, since it produces 3,600 MOPS.

Chromatic is already testing first silicon of the Mpact R design and expects LG and Toshiba to provide samples later this quarter, with production versions in 1Q97. The company had originally hoped to see widespread use of its Mpact/3000 in PCs during this Christmas season, but it has missed this window of opportunity. At this point, we expect many PC makers to wait until the integrated RAMDAC is available, reducing system cost and board footprint compared with the initial implementation. The Mpact R should quickly replace the original Mpact chip in the product line, with the two speed grades offering a price/performance tradeoff. When Mpact 2 reaches the market next fall, it will become the new high-end part.

Mpact Competes Effectively

Today, more than a dozen vendors are involved in designing and/or manufacturing media processors. The critical questions are how these devices will compete among themselves and how they can effectively compete against software-only and hardwired approaches.

The advantages of a media processor over a hardwired multimedia IC are easy-to-achieve functional integration, flexibility for evolving standards and improving algorithms, and the ability to deal well with real-time applications such as videoconferencing and surfing the Internet. The real-time advantage is due to the lack of real-time support in today's Windows 95 and NT. The programmability of media processors makes it easy to incorporate some kind of real-time kernel that can coexist with Windows. With dynamic resource allocation, a media processor can devote all its horsepower to the current application. This feature offers a potentially lower cost than the hardwired approach. In the hardwired system, if the current application doesn't use a particular function block, transistors dedicated to that function are wasted. The main disadvantages of media processors are programming overhead and design complexity.

A more interesting topic is how the Mpact architecture competes with other media-processor architectures. Like Mpact, Samsung's MSP *(see **101101.PDF**)* handles seven common multimedia functions. MSP's advantages include

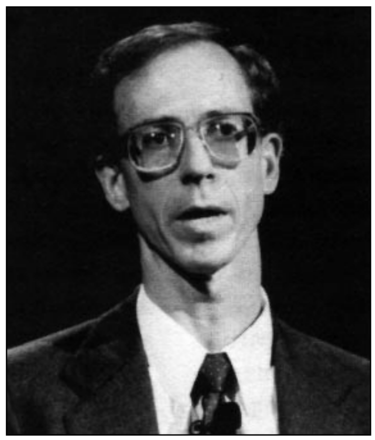
	Mpact/ 3000	Mpact R/ 3000	Mpact R/ 3600	Mpact 2/ 6000
MOPS (peak)	3,000	3,000	3,600	~6,000
Internal RAMDAC	No	Yes	Yes	Yes
RDRAM Bandwidth	500 MB/s	500 MB/s	600 MB/s	1,300 MB/s
3D Rendering H/W	No	No	No	Yes
Cache Size	4K	4K	4K	8K
AGP, 66-MHz PCI	No	No	No	Yes
Samples	Done	4Q96	4Q96	1Q97
Production	Now	1Q97	1Q97	3Q97

Table 1. By 2H97, Chromatic and its manufacturing partners plan to bring four Mpact media processors into the market. (Source: Chromatic)

an open software model, better potential 3D graphics, and a larger initial market. Also in MSP's favor is that Microsoft has chosen MSP as one of the key components for its Talisman reference design. Microsoft's real-time kernel will likely work with MSP first, and it will take extra time to port it to other architectures, such as Mpact, if Microsoft or Chromatic decides to do so.

The Chromatic chip, on the other hand, is available now, costs less than MSP, and takes advantage of the computing power of the host CPU. Unlike Samsung's media processor, which replaces the host CPU when running multimedia tasks, Mpact assists the CPU. Mpact uses its resource manager for dividing multimedia workloads between the CPU and Mpact in real time. Under this cooperative computing environment, Mpact should be able to compete effectively in the PC market against any of the other media processors that have been announced so far.

Mpact's biggest advantage over other media processors is that it is real and in production; the others are simply prototypes. Trimedia says its TM-1 *(see* **091506.PDF***)* will enter production in 1Q97, but TM-1's software will not be completed until the end of 1997, a full year behind schedule. In the PC business, time to market is everything. If Chromatic and its partners execute properly, we don't believe that other media processors for PCs will present any significant threat to Mpact in 1997.


MICHAEL MUSTACCHI

At the Forum, Chromatic founder Stephen Purcell announces the second-generation Mpact 2.

Open ISA Has Advantages

The company's unusual business model includes a closed software environment: Chromatic is the only vendor allowed to develop software for Mpact. This restriction creates competitive disadvantages, especially since most other vendors claim their media-processor architectures are open. But Chromatic and its partners have nothing to lose by saying their architecture is also open, and we believe they will do so in the future.

The potential upside for opening the Mpact instruction-set architecture (ISA) is huge. For example, unlike Samsung and Philips' TriMedia, Chromatic focuses mainly on PC applications today. Mpact could be used for Macs and non-PC applications, but only if software is written for those applications, and Chromatic is not interested in doing so right now. The startup company is already stretched developing the required Mediaware for PCs.

Opening the software environment creates possibilities for third-party ISVs to bring Mpact to non-PC markets. This would allow Chromatic to use its limited software resources for PC applications while expanding the potential base of Mpact processor sales.

Enabling Mpact for non-PC applications is an important way to secure the future of Mpact. Non-PC devices will greatly expand the potential market size and make Mpact an interesting CPU for network computers, set-top boxes, videoconferencing devices, videophones, car navigators, and so on. There are many advantages to staying away from the "Wintel" architecture, where Intel and Microsoft dominate the entire platform. The majority of the Mpact development for non-PC applications will be software-related, but to encourage this, Chromatic must open its ISA.

Future Devices Are Promising

Mpact/3000 has proved Chromatic has a working architecture and not just a paper tiger. It also provides a means for kicking off Mpact software development. We believe that its lack of integration and 3D performance are limiting its acceptance, however. The forthcoming Mpact R/3600 and Mpact 2 parts solve these problems and should help propel Mpact into mainstream PCs.

Now that the Mpact 2 design has taped out, we expect Chromatic and its manufacturing partners to develop Mpact 2 derivatives. An obvious one is a notebook version that adds support for an LCD display and advanced power management. A notebook Mpact 2 would be a more compelling product than its desktop counterpart. First, the Mpact design saves space, power, and cost compared with a flock of fixed-function sound, graphics, video, and modem chips. Second, due to thermal restrictions, notebooks tend to use less powerful host CPUs. Therefore, the host needs more help to achieve strong multimedia performance.

Chromatic has already started the design of its third-generation Mpact, code-named M3. We expect the M3 will be fully Talisman-compliant, since Mpact must support the PC entertainment applications for which Talisman is designed. In addition, transforming from its own real-time kernel to the Talisman real-time kernel can be beneficial in providing a standard software interface for applications.

By late 1998 or 1999, the IEEE 1394 (FireWire) interface will be important in PCs. Therefore, integrating a 1394 interface into the M3, or at least one of its derivatives, would be useful. Besides adding 1394, some M3 derivatives may include new features such as a video codec or frame-buffer memory on the chip.

To succeed in PCs, Mpact must offer a significant performance gain as a complement to MMX. Mpact is good at real-time events, isochronous applications, and video encoding and decoding. Together with an MMX host processor, Mpact offers significant value over the MMX-only or fixed-function approaches for future multimedia-ready PCs. This value should gain Mpact design wins on both PC motherboards and add-in cards. M