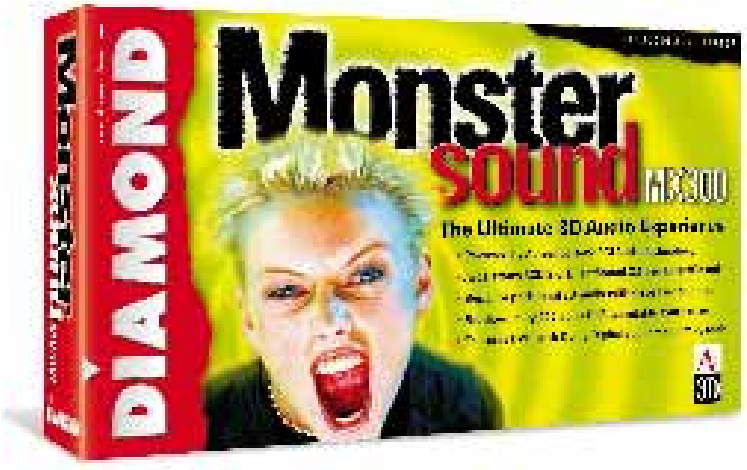

Surround sound on a budget, including 5.1-channel Dolby digital output (receiver not included) (courtesy Diamond Multimedia).

The *high-end* PC looks for a home

IN THIS ERA OF SUB-$1000 AND EVEN "'FREE" PCs, IS THERE ANY ROOM IN THE AVERAGE HOUSEHOLD FOR A MORE EXPENSIVE COMPUTER? DOES THE LONG-TOUTED VISION OF THE PC AS THE HOME'S ENTERTAINMENT HUB HAVE ANY REALITY BEHIND IT—NOW OR IN THE FUTURE? JOIN ME AS I UNCOVER THE REALITY BEHIND THE HYPE AND EVALUATE SOME COOL HARDWARE AND SOFTWARE IN THE PROCESS.

AS *EDN*'S RESIDENT MULTIMEDIA EDITOR, I'm on the receiving end of countless pitches from media-relations people, who daily call me up wanting to tell me about the "next big thing" for PCs. Microprocessor vendors all claim *EDN*'s readers need the latest, fastest, most complex, and most expensive CPUs (**Figure 1**). Memory suppliers want to tell me about denser, higher performance DRAM. Mass-storage companies all tout their biggest, fastest hard drives. And the graphics and video folks overwhelm me with polygon counts, fill rates, lines of resolution, and esoteric image-quality features. Their hype is one reason for this study: to build a high-end system for myself and benchmark it against a more mainstream alternative (**Table 1**). Intel's Pentium III introduction this spring highlighted Internet- and multimedia-related applications, so this area is where I focus my testing. The mainstream system, based on a Pentium II-400, is the PC I use every day in my job and offers features comparable with those of new Celeron-based computers. I'll first find out whether an application works as its vendor claim it will and then whether it works better on a high-end computer.

More important, though, I'll also judge whether each application has significant value and therefore justifies the money you spend on the more expensive PC to run it. This evaluation is especially important for a function such as the "digital VCR," because many of you have one or

more VCRs in your house or for any other capability that mimics something you probably already own. I'm admittedly more likely than the average consumer to get excited about the latest electronic gadgets, so I've also enlisted my wife to participate in the evaluations. She's a hospital pharmacist with a doctorate, so she has a technical mindset but she's definitely not as enamored of computers as I am.

My other motivation is more specific. Like *EDN* senior editor Dan Strassberg, I've historically been skeptical about stand-alone digital TVs, especially the pricey high-definition versions (**Reference 1**). I hold this opinion even though I was impressed by the quality of the displays at the Consumer Electronics Show in January (**Reference 2**). However, TeraLogic's unveiling in March of its Janus chip, a hardware-based digital-TV (DTV) decoder for PCs, challenged my thinking (**Reference 3**).

Figure 1

Is a high-end Pentium III-based PC a valid long-term investment or a waste of money? (courtesy Intel Corp).

Instead of buying a brand-new, approximately $10,000 DTV and decoder box, why not select a slightly larger monitor than you might otherwise pick and spend a few hundred dollars on a DTV decoder add-in card for the PC you already own or plan to buy? In the era of DTV, does the long-touted vision of the PC as the entertainment hub for the home finally begin to make sense? TeraLogic loaned me early beta versions of both its reference board and its drivers so that I can further explore the potential of this approach (**Figure 2**).

A few other comments before we dive into details. This study is a platform-versus-platform—not a graphics-chip-versus-chip or any other subsystem-versus-subsystem—analysis. CPU usage percentages (through WinTop, part of Microsoft's Windows 95 Kernel Toys suite) and game frame rates provide the number sets I use to derive some of my conclusions. However, these results depend as much on other portions of the system as they do on the microprocessor and graphics chip.

For this study I don't measure AGP bus traffic, cache-hit ratios, or any other detailed system parameters, as *EDN* technical editor Markus Levy has done in his hands-on projects (**references 4** and **5**). Instead, I approach my evaluations both as an engineer who might design his own PCs and as an end user.

THE TELEVISION

I'm organizing this article around the various consumer electronics devices currently in most homes, beginning with the TV. The first step was to install a Real3D i740-based AGP card with video I/O and hardware DVD into the Pentium III-based system and hook it up to my 31-in. NEC TV/video monitor. I hadn't connected a computer to a TV since the Commodore 64 days and hoped that image quality had improved. It hadn't, although in retrospect I shouldn't have been too surprised.

NTSC video specifies a vertical resolution of 525 horizontal lines and a horizontal resolution of 440 vertical lines. The usable portion of that resolution is only around 480×330 lines, however, which is why 250-line VHS and 8-mm videotape images are acceptable for most consumers. A monitor-quality TV such as mine might support higher resolutions, such as for 480-line DVD, but most don't, and the video-encoder chip inside the PC also limits resolution.

TVs just don't deliver enough resolution to adequately display fine detail, such as text, even at a computer's 640×480-line VGA display setting. Increasing the font size only crowded the Windows 98 desktop and didn't dramatically improve readability. The poor display quality was plainly evident when comparing DVD playback using the graphics card's Zoran decoder through the PC onto the TV with that of my stand-alone DVD player directly driving the TV. This isn't a Real3D/Zoran limitation; all of the graphics cards and DVD player software I looked at exhibited the same problems.

As the graphics card first scales and, if necessary, deinterlaces the video image for a computer monitor and then reconverts it to video for the TV, the image significantly degrades. For this reason, companies—such as Gateway with its Destination PCs—sell computers with large-screen computer monitors, not TVs. Ironically, some of the best looking TV output came when I played older, low-resolution games, such as Doom and Quake. Mitsubishi's MegaView Pro 27 is a higher end version of the Destination monitor (**Figure 3**). The Gateway unit specifies only an 800×600-pixel maximum resolution and at low refresh rates, which produced noticeable flicker in low light settings.

The MegaView Pro 27 supports resolutions as high as 1600×1200 pixels at 75-Hz refresh and handles RGB, composite video, and S-video inputs and stereo-audio inputs and outputs. At approximately $3500, the Pro 27 is not cheap unless you compare it with a DTV

Figure 2

The Janus reference board brings hardware-based DTV decoding and resolution scaling to PCs (courtesy TeraLogic).

AT A GLANCE

- ▷ High-end PCs offer performance that typical users don't exploit, and emerging multimedia programs simply replace consumer-electronics devices you probably already own.
- ▷ Digital television may finally provide the long-sought killer application that moves computers into your living room.
- ▷ Looking for a time-shifting digital VCR? For now, stick with ReplayTV and Tivo.
- ▷ Performance and quality improvements in 3-D graphics far outpace the dictates of Moore's Law, and you benefit.
- ▷ Spend as much money as you can on DRAM and then spend a little more
- ▷ The project went more smoothly than I predicted, but Windows' non-real-time capabilities hampered several peripherals, and voice recognition remains a not-quite-here technology.

costing thousands of dollars more. The display quality is gorgeous, and the monitor's plug-and-play support includes drivers bundled with Windows 98. The unit's 4-to-3 aspect ratio, however, created black bars at top and bottom of screen when projecting 16-to-9 source material and, therefore, didn't take full advantage of either the resolution inherent in the monitor or in the wide-screen DVD and DTV broadcasts.

Although using the computer on a TV was less than impressive, I was pleased with the NTSC video display on the Mitsubishi monitor, using the 3dfx 3500 graphics card with TV tuner (**Figure 4**). I noticed some deinterlacing and scaling artifacts, especially at 1024×768-pixel and higher resolutions, but their annoyance factor significantly diminished when I got more than a few feet away from the screen. Speaking of viewing distance, I'm using Logitech's wireless mouse and keyboard and am pleased with both their low response delays and long battery life (three months so far) (**Figure 5**). However, I wish I could operate them farther than 11 ft from the receiver, the longest distance that I can reliably maintain a connection.

Previously, I'd used WebTV for a Windows program bundled with Windows 98, a sort of online *TV Guide*, to check channel listings and show descriptions. Now, when I select a channel, I can also view a preview window of the show currently being broadcast. If I double-click, the show appears in full-screen mode and takes up little of my CPU bandwidth (**Table 2**). The 3Dfx VisualReality software offers similar video-display capabilities. However, unless I'm tuning in off the air, the channel-changing capabilities are somewhat superfluous. My local cable operator scrambles all but the most basic cable channels, meaning that the multimedia graphics card and software can't replace my set-top box.

Figure 3

A large-screen, high-resolution, fast-refresh computer monitor is a credible alternative to a DTV (courtesy Mitsubishi Electronics America Ltd).

What about DTV? TeraLogic and I are still working on getting its Janus-based card up and running in my system. The company has had good success with "clean" machines based on Windows 98 Second Edition (SE) and non-Intel motherboards, but my PC uses the earlier Windows 98 Gold and an SE440BX-2. My computer also contains a few more resource-consuming peripherals than TeraLogic's computers do, and I was the first non-TeraLogic user of the hardware and software.

The TeraLogic card supports dual-monitor, VGA-pass-through, and video-module-interface-port display modes. In dual-monitor mode, which works fine, the graphics card and TeraLogic card drive separate displays. In VGA-pass-through mode, which also works fine, the graphics-card output feeds into the RGB input of the TeraLogic card, which contains a keyboard-toggled video switch. In VIP mode, which does not work correctly, the Janus chip feeds the video signal to the graphics card, which displays it in a separate window on the Windows desktop. By building otherwise-identical PCs, TeraLogic and I think we've tracked the problem down to differences in the dynamically linked libraries between Windows 98 Gold (even after installing all released patches) and the newer Windows 98 SE.

I've seen the card decode and display 1080i and 720p source material across the antenna on TeraLogic's roof in Mountain View, CA, with less-than-5% CPU usage for the video. TeraLogic bundles a defeatured version of MGI Software's Zoran-developed SoftDVD to handle the audio decoding. We even successfully tuned in one DTV channel using $10 Radio Shack nonamplified rabbit ears from deep within the TeraLogic building. This test was critical, because many residences that cable TV serve lack roof-mount antennas. Access the online version of this article for an update based on our debugging over the next few months (see **sidebar** "A work in progress").

TABLE 1– SYSTEM CONFIGURATIONS

	Mainstream PC	High-end PC
Microprocessor	Pentium II-400	Pentium III-550
Motherboard	Intel SE440BX	Intel SE440BX-2
DRAM	320-Mbyte PC-100 CAS3	768-Mbyte PC-100 CAS2
Sound	Built-in (Crystal ISA/PCI)	Built-in (Yamaha PCI), Diamond Multimedia MX300
Graphics	8-Mbyte Intel Express 3-D (AGP)	16-Mbyte 3dfx Voodoo 3500 (AGP), 32-Mbyte Creative Labs Savage4 (PCI), 32-Mbyte Creative Labs TNT2 Ultra (AGP)
Monitor	NEC 21-in. MultiSync E1100	Mitsubishi 29-in. MegaView Pro 27
DTV decoder	None	TeraLogic Janus reference board
Hard-disk drive	6-Gbyte, 5400-rpm, four-partition FAT32 Western Digital	13-Gbyte, 5400-rpm, single-partition FAT32 Western Digital
DVD-ROM drive	Hitachi GD-2500	Hitachi GD-2500
CD-RW drive	None	Philips PCA460RW
Other mass storage	Iomega Zip 100 (SCSI), Iomega Ditto 800 tape, 3.5-in. floppy	Iomega Zip 100 (IDE), Iomega Ditto 2G tape, 3.5-in. floppy
Operating system	Windows 98 Gold, DirectX 6.1	Windows 98 Gold, DirectX 6.1

Notes:
1. All systems include the latest drivers and Windows 98 updates as of mid-September 1999.
2. All evaluations were conducted with systems at approximately 75%-free system resources unless otherwise indicated. System was rebooted between evaluations.

Now, it was time to tackle the antenna. Any computer claiming to be multimedia-capable had better support traditional-TV off-the-air antenna and cable inputs. The 3dfx Voodoo 3500 card provides this support and even offers an FM-tuner feature. However, the FM tuner barely worked for me, although the root cause may have been my antenna choice or the EMI that all of the computers and other electronics in my office created. Considering that the $10 clock radio in my office pulls in stations just fine, I'm inclined to give the 3dfx card at least part of the blame here.

No matter; my wife and I rarely listen to the radio anymore. Why bother, when, thanks to an always-on Internet connection you can hear hundreds of stations worldwide and obtain traffic and weather reports without commercials and inane DJ chatter? I continue to be pleased with the asymmetric-digital-subscriber-line (ADSL) "Internet antenna" that I set up this spring (**Reference 6**). Pacific Bell's news server is sometimes down or slow, and the outgoing mail server occasionally gets bogged down and rejects requests, but, aside from those infrequent speed bumps, it's so far been smooth driving on the information superhighway.

My wife's computer use has noticeably increased since we got our ADSL connection. The bandwidth is great, although I frequently find that the server on the other end is the bottleneck that doesn't let me reach the full 1.5-Mbps pipe potential. I think the most appealing factor for my wife, though, is the always-on aspect of the connection. She wasn't willing to hassle with the long modem-log-on sequence every time she wanted to look something up, but answers are now just a mouse-click away. For me, frankly, the killer application so far has been all of the Grateful Dead and Phish MP3 and Shorten concert audio files I've downloaded from FPT sites and newsgroups (**Reference 7**).

I invested in a dedicated router for my LAN instead of a software proxy program, not wanting to keep a PC always on, and chose Ramp Networks' WebRamp 700s. It handles Dynamic Host Configuration Protocol (DHCP) services for all of the network nodes and is easy to set up through a browser. It embeds a Web server and Java-powered configuration program, but the installation wasn't glitch-free. My previous analog-modem-based router, Intel's Internet Station, used a different default-LAN address range, and the Intel print server by default hard-coded an Internet Protocol (IP) address. Initially, the 700s couldn't find the print server, although strangely

NOT READY FOR PRIME TIME

During this project, I unfortunately but not surprisingly stumbled across some major disappointments, two of which involve the Windows operating system's non-real-time behavior: The CD-RW drive can't tolerate interruptions, and the Opcode Universal Serial Bus (USB) adapter installed a dubious "Win 98 USB-driver upgrade" to minimize errors during USB's streaming isochronous mode.

Multimedia files take up a lot of storage space, and even a 13-Gbyte hard-disk drive eventually fills up. I invested in a CD-recordable/writable (CD-RW) drive and found a good deal on a Philips PCA460RW. Philips and Sony developed the CD format, and Philips supplies the drive mechanics and electronics to several other CD-RW-drive manufacturers, so I figured the company would be a safe bet. I figured wrong.

After making two 10-packs of CD-recordable (CD-R) discs into worthless coasters during debugging, enduring a dozen technical-support calls, and wading through the contradictory information I received in them, I can reliably burn CD-Rs. The contortions that I have to undergo, however, make the solution unfeasible for the average computer user. First, I can write at only 1 or 2× speeds not at the 4× rate that the drive claims it supports. Next, I must have at least 95%-free system resources, which means that I need to manually shut down all running tasks, except for Explorer and Systray, through the control-alternate-delete task window.

To Philips' credit, the bundled software has a user-friendly, simple interface. However, it doesn't warn me until I tell it I'd like to copy more than 700 Mbytes' worth of files, even though the most common CD-R discs hold only 650 Mbytes. It also doesn't reserve sufficient disc space for the table of contents. If I don't follow the above rules about running only at 1 and 2× speeds and having 95%-free system resources, I invariably get a buffer-underrun message or another cryptic error message, or the system simply locks up, usually and frustratingly after burning most of the disc. I've installed new revisions of both the software and the drive's firmware without any apparent effect.

I wish I could tell you that a different drive, perhaps with a bigger onboard buffer, from a different manufacture, or using a (USB) interface or SCSI would give better results. However, newsgroup postings from other frustrated users indicate that the problems I experienced are nearly universal. Even with a correctly burned disk in my hands, the Philips' drive limitations don't end. It recently quit recognizing audio CDs. Sometimes, it doesn't even read CD-Rs that it has just made. Philips claims that I'm experiencing a rare laser-alignment problem and wants me to send the drive back to the factory for repair or replacement. I'll let you know whether this approach fixes the problem, although I'm skeptical.

Ironically, although a more robust PC's "muscle" usually helps it avoid problems that might plague a lower end system, the reverse appears to be the case here. CD-R burning is an interrupt-intolerant process. Ideally, Philips wanted me to put the drive on the secondary IDE channel all by itself in the master connector. However, I had three other drives that I needed to incorporate, the DVD-ROM drive required that it be on the master connector, and I couldn't put the CD-RW drive on the same channel as the hard-disk drive containing the files I was attempting to burn.

TABLE A–HIGH-END-SYSTEM-DRIVE CONNECTIONS

Drive	Channel
Hard disk	Primary/master
Zip	Primary/slave
DVD-ROM	Secondary/master
CD-RW	Secondary/slave

Table A shows my final configuration.

SAY WHAT?

My wife is plagued with painful carpal-tunnel-syndrome-like tendinitis if she spends too much time on the PC at work, using either a keyboard and a mouse or a light pen to enter and edit pharmacy orders. It would be an understatement, therefore, to say we were enthusiastic to try out voice-recognition software. This application received special highlight at Intel's Pentium III rollout, and I had heard claims of greater-than-99% accuracy even under so-called natural-speech operating conditions, so we hoped for impressive results. We were disappointed, however.

The installation process for Lernout & Hauspie's VoiceXpress Mobile Professional Version 4 was one of the best I've ever experienced with a Windows program. The company bundles a headset with a microphone and a speaker, and the software automatically calibrates both based on your speaking volume and background-noise level. VoiceXpress includes excerpts from several books that you read to the software so that it will "learn" your voice characteristics.

I'm from northern Indiana, and, although my wife's parents emigrated from Cuba and she speaks fluent

enough it appeared in Windows 98's Network Neighborhood.

After figuring out what was going on and temporarily expanding the LAN-address range setting, I accessed the print server's embedded Web server, where I configured the IP address as DHCP. I also had to hard-code my desktop PC's DHCP-assigned IP address into my Windows CE handheld PC before the two would synchronize over Ethernet, something that Internet Station doesn't require. Finally, the original version of Internet Explorer (IE) 4's Java Virtual Machine (JVM) was incompatible with the 700s, although Netscape Navigator 4 worked fine, and later IE JVM versions also ran correctly.

In "Home network contenders steer a collision course," pg 125, in this issue, technical editor Warren Webb explores phone-line-networking alternatives. As I was setting up my LAN, none of the vendors shipping products could deliver the bandwidth I wanted between my hub in the office and the high-end system in the living room. Wireless- and power-line-based networking didn't deliver the speeds I wanted, either. So I chose a brute-force approach, crawling under the house, drilling holes in floorboards, and running Category 5 Ethernet cable from one room to another.

Intel's claims that the Pentium III processor enables a richer Internet environment so far match up with neither my experiences nor those of other PC analysts (**Reference 8**). Most content on the Web is still created with 56-kbit modems in mind, and I get the same tiny video windows and low-fidelity monaural sound on my high-speed connection. Even when a site offers a high-bandwidth stream option, I notice no difference, regardless of which desktop PC I use to access it, as long as I'm not artificially locked out of the site because my mainstream system lacks a Pentium III. As servers get faster and more robust in the number of simultaneous connections they can support and as a greater percentage of those connections become ADSL or cable, the number of performance-, and therefore Pentium III-, enhanced sites may increase.

THE VCR

Now that I've got TV coming into my computer, can I "tape" the broadcasts? This application was the primary reason I put such a large hard drive into the high-end system. When I built the PC, 7200-rpm drives were significantly more expensive than equivalent-density and -interface 5400-rpm versions. The disk-drive company salespeople I spoke to as-

Spanish, she's Chicago-born. I expected that our "flat" Midwestern accents would present little challenge to the software. We both dutifully read four passages each from L Frank Baum's *The Wizard of Oz* and Ray Kurzweil's *The Age of Spiritual Machines*. These readings took each of us around a half-hour. The software required that each speaker read only one five-minute passage, although it mentioned that more training would improve accuracy, so we thought we were helping it out.

The results "speak for themselves," so to speak. First, here's what the computer typed when I quoted a famous line from Alan Jay Lerner and Frederick Loewe's *My Fair Lady*: "The rain in Spain falls mainly in applying." Not bad. More entertaining, though, was VoiceXpress's attempt to decode my spoken lyrics to the Eagles' *Hotel California*. Yes, I know what the lyrics are *supposed* to be, so input error isn't responsible for the results that follow:

One a dark desert highway
Cool wind in my hair
War is no after the test
Rising not through the air
Up ahead in the distance
I saw shin marine light
Of a good heavy and my site
through DM
I had to stop for the night
There she stood in the doorway
I heard the mission dial
And I was thinking to myself
This to be having or this could
be held
And she knew that the candle
And she should be the way
Your voices than the corridor door
I thought or heard them say...
Hmmmmm....

The tape deck

I enjoy attending music concerts, and several of my favorite rock 'n' roll bands allow audience taping. So what better multimedia application for me to evaluate in this article than digital audio capturing, editing, archiving, and streaming? My first step was to go to ebay.com and buy a used portable digital-audiotape (DAT) recorder and microphones. Most DAT decks record at a 48-kHz sampling rate, and the resulting audio files require resampling as part of the editing before burning them to a CD-R. However the recorder I chose, Sony's TCD-D8, natively supports both 48-kHz and audio-CD-compatible, 44.1-kHz sampling modes.

To get the audio into the PC, I *could* route it from the DAT deck's analog-line outputs to the computer sound card's analog-line inputs. I've taken this approach with the high-end and mainstream PCs' motherboard sound chips and the MX300 sound card. The resultant audio files, both in native WAV format and in *MusicMatch Jukebox*-converted MP3 and Windows Metafile, sound good. However, I had to take the audio through digital-to-analog and analog-to-digital conversions, sound-card analog inputs are notoriously noisy, and their A/D converters sometimes cut corners on quality to save a few pennies. Why not keep the audio in its pristine digital format?

You can transfer digital audio to and from the PC without degrading analog conversions but not without USB configuration hassles (courtesy Opcode Systems).

A number of sound cards offer Sony/Philips digital-interface (SPDIF) outputs, primarily for use with Dolby digital-encoded movies. Few of them, however, include SPDIF inputs, and those that do either are expensive or automatically convert the sample rate. My other option was Opcode Systems' SPDIF-to-USB adapter (**Figure A**). The company's DATPort accepts SPDIF RCA coaxial connectors, as does the SonicPort, and the SonicPort Optical incorporates a Toslink optical interface. Both SonicPort versions also include analog inputs with 20-bit A/D converters. I chose the SonicPort Optical and Sony's seven-pin digital-to-Toslink optical-adapter cable.

Opcode bundles a Microsoft upgrade to the USB drivers in Windows 9x, which supposedly minimizes the probability of errors during USB's isochronous-transfer mode. As I was running the Opcode software, I thought back to the dozen or more USB peripherals I'd installed over the past few years and my 100% success rate getting them to work both independently and with each other. I suspected that enough USB-bandwidth or system-performance headroom would be available to let me simultaneously run the USB videocamera and the SonicPort Optical. However, given my track record, I didn't expect to have any compatibility problems.

Although this was the first time I'd ever heard of a Windows 98 USB-driver update, I said "OK" when the Opcode installation program asked me if I wanted to install it. I rebooted my system and found that my videocamera no longer worked. Whenever I attempted to access it, it froze with a constant-on LED exposure indicator, and the application calling it locked up.

Opcode, 3Com, and I are beginning to debug this problem. Opcode's drivers may have problems with some USB configurations, or 3Com's software may have a problem when you install the SonicPort. Alternatively, Microsoft's mysterious USB-driver upgrade may have a bug. Stay tuned.

sured me that, as long as I wasn't simultaneously accessing the hard-disk drive for other purposes during recording or playback, the slower versions would be fast enough. The claims on the outside of the 3dfx Voodoo 3500 box and on the vendor's Web site imply that I might have a ReplayTV- or Tivo-killer on my hands. Not quite.

The 3dfx "digital-VCR" function uses Ligos Technology GoMotion codecs for MPEG-2 encoding and decoding and integrates the user interface into the 3dfx VisualReality application. The company limits the encoding video window size to a maximum 320×240-pixel resolution at 30 or 15 frames/sec, regardless of system speed, because increased resolution degrades performance (**Table 2**). The company plans to offer more PC-tailored resolution flexibility in future releases.

Even at one-fourth VGA resolution, MPEG-2 encoding gobbles many of the Pentium III's resources, and the board's documentation says to not even bother trying to encode on the PII-400. I find this fact ironic, considering the specifications that Ligos Technology's Web site touts. Ligos claims that a PIII-550 should be able to encode a 720×480-pixel, 30-frame/sec IBP (intra, forward-predicted, bidirectional-predicted) stream, including MPEG-2 audio, and that a PII-266 would handle Standard Intermediate Format (SIF) 352×240-pixel 30-frame/sec IPB encoding with audio (**Reference 9**). Ligos should have added a "mileage-might-vary" note. CPU headroom, even on high-end systems, is insufficient to handle the simultaneous encoding and decoding needed to duplicate ReplayTV or Tivo's time-shifting feature.

Audio-video-interleaved (AVI) encoding retained more system headroom but at the expense of file size. A 1-minute MPEG-2-encoded clip of an episode of *Star Trek, Next Generation*, using IBP framing, has a file slightly larger than 450 kbytes. A 1-minute AVI-encoded clip is 24 Mbytes. Imagine the size of a longer AVI clip, or one encoded at a 4-times-larger 640×480 pixel native resolution.

Playback of the 1-minute MPEG clip produced more interesting results. **Table 2** shows the CPU usage on both systems, using the 3dfx VisualReality application on the high-end PC and the software DVD player on the mainstream PC. Scaling the 320×240-pixel window to 1024×768 pixels on the high-end machine produced a blurry and blocky image. On the mainstream PC, compression artifacts were even more visible, and jerkiness during scene transitions indicated that the program was also dropping frames. Neither the 3dfx Voodoo3 nor the Intel i740 contain inverse discrete cosine transform (IDCT) or motion-compensation hardware that would have assisted the MPEG-decoder software. The i740-derived graphics core in Intel's 810 and 810e chip sets, which appear in many of today's Celeron-based systems, *do* provide hardware acceleration.

Microsoft's Windows Media Player on the mainstream PC reported that it lacked the necessary codecs to play the 1-minute AVI file, but I could play it back on the high-end PC using both Media Player and the 3dfx VisualReality program. CPU usage was identical in both cases, and the scaled 1024×768-pixel image, although still unacceptably blurry, was free of MPEG artifacts. However, playback was choppy. Dropped frames occurred every few seconds, a phenomenon that baffled me until I saw the hard-drive access light glowing a constant red. Defragmenting the hard drive didn't noticeably improve the results. I can't help but wonder whether a 7200-rpm drive or an Ultra ATA/66-compatible motherboard would exhibit the same behavior, and the large files exclude AVI from consideration as a "digital-VCR" archive format.

Figure 4

Voodoo 3500 combines high-performance graphics, FM, and NTSC TV tuners; DVD playback; and "digital-VCR" capability (courtesy 3dfx Interactive).

THE DVD PLAYER, AMPLIFIER, AND SPEAKERS

If decoding a 320×240-pixel MPEG-2 video frame swamps the mainstream PC, what would DVD decoding look like? In a word, "terrible." My testing used portions of four of my favorite DVDs, each of which contains difficult video-encoding problems, such as rapid scene-to-scene changes, moiré pattern-inducing stripes, and objects moving from the top to the bottom of the screen. I chose the final pursuit scene from *Blade Runner*, the taxi-chase scene *in The Fifth Element*, the closing credits of *Lost in Space,* and the Dave Bowman character's fall through the Star Gate in *2001: A Space Odyssey*.

In all cases, the mainstream PC reliably reproduced the audio stream. Video was another matter. Dropped frames occurred in response to even a moderate amount of scene transition, and I noticed a profusion of blocky compression artifacts throughout the video. The decoder more faithfully rendered objects that moved diagonally or side to side, particularly in *2001: A Space Odyssey*, than those moving vertically. This fact is somewhat baffling because the original source material is noninterlaced film, not interlaced video, which might suffer from insufficient bob-and-weave translation. Perhaps the poor rendering of vertical motion reflects a subpar

TABLE 2–CPU USAGE FOP VARIOUS TASKS

	DVD decode			NTSC TV playback			MPEG-II encode*		
	Minimum (%)	Average (%)	High (%)	Minimum (%)	Average (%)	High (%)	Minimum (%)	Average (%)	High (%)
Pentium III-550 (3dfx)	42	48	54	1	1	2	74	80	85
PII-400 (Intel)	91	94	97	NT	NT	NT	NA	NA	NA

Notes: NT=not tested, NA=not applicable.
***320×240 pixels, 30 frames/sec**

DVD encoding for which the decoder could not compensate. Terminating all background-running programs to increase the amount of available system resources and free additional CPU headroom didn't noticeably improve the mainstream PC's results.

DVD decoding on the high-end PC, on the other hand, produced beautiful results, especially noticeable on the 27-in. monitor and with reasonable system headroom left over for background tasks. I noticed only one glitch with the InterVideo WinDVD 1.2 software: During installation, it overwrote Windows Media Player's MP3 codec with its own, which not only produced subpar audio quality but crashed when I tried to play an MP3 file larger than approximately 3.5 Mbytes. WinDVD's behavior didn't seem to affect any of the other MP3 player software on my system, such as *MusicMatch Jukebox*, *RealPlayer*, *RioPort Audio Manager*, and *Winamp*. Deinstalling WinDVD returned *Media Player* to normal operation, and InterVideo reports that Version 1.3 corrects this problem.

Both PCs contained motherboard-resident audio chips, with the high-end PC's AC'97-compatible Yamaha decoder supporting pseudo-3-D processing for two-speaker systems. I matched the high-end PC with Labtec's LCS-2414 three-piece speakers, which included a subwoofer and generated surprisingly good midrange and treble from the tiny main speakers. For the mainstream PC, I used the higher end Labtec APX-4620s, which include user-customizable surround-sound processing and user-accessible bass and treble controls and microphone and headphone jacks (**Figure 6**).

I also dropped the Diamond Multimedia MX300 sound card with MX25 digital-output upgrade into the high-end system. The MX300 directly drives four speakers for surround sound, using the Aureal Vortex2 chip. For 5.1-channel surround-sound movies, you can connect the board's Sony/Philips digital-interface (SPDIF) outputs to a separate Dolby digital receiver. Both the MGI Software/Zoran and InterVideo software DVD programs correctly decoded multichannel Dolby digital-movie soundtracks.

Figure 5

Wireless connectivity lets you surf the web from your couch (courtesy Logitech).

THE GAME CONSOLE

Mainstream graphics accelerators are rapidly improving their capabilities (**Table 3**). When Intel announced the i740 graphics chip in February 1998, it topped many performance lists. Within weeks, however, Nvidia's TNT, 3dfx's 3-D-only Voodoo2, and other chips eclipsed it. Today, 18 months later, the i740 is obsolete. As you look at the specifications, remember that the i740-derived embedded graphics core in Intel's i810 core-logic chip set offers performance roughly 50% higher than that of the i740.

If this were an in-depth graphics article like the one I plan for a future issue, I would have subjected each graphics board to comprehensive 3-D Winbench and other test suites. Until then, you can check out the data on Mercury Research's Web site or in your favorite game magazine. I simulated the average user's experience with demo versions of the DirectX-based *Forsaken* and *Incoming* and the OpenGL-based *Quake2*. *Forsaken* offers a special Voodoo-optimized mode, which I suspect uses the Glide application-programming interface (API) but only at a 640×480-pixel maximum resolution. Therefore, I ran two sets of numbers for this game.

I set the games, except for *Quake2* on the Voodoo 3500, at their highest quality display combinations. I put *Forsaken* in demo mode and watched the frame rates scroll on the screen, memorizing the largest and smallest numbers I saw. *Forsaken* provides an average frame rate at the game's conclusion. *Incoming*'s demo mode directly outputs all three frame-rate values. The game can use the slower 32-bit rendering mode if the graphics chip supports it, a fact that limited the frame rate of the Intel and S3 chips but resulted in noticeably better image quality.

Quake2 provides no frame rates, but by hacking into the console you can configure it to output per-frame display times in milliseconds. For the Voodoo 3500, the minimum display time, which I frequently saw, was "0 msec,". I translated this rate to greater than 1000 frames/sec, or less than 1 msec/frame. The 3dfx OpenGL mode gave me the choice of 8- or 16-bit textures; I chose the default of 8 bits. I'd never before seen *Quake2* run under OpenGL, and the improved lighting and colors were impressive. Although both the Intel- and S3-based cards included an OpenGL ICD, I could not get *Quake2* to accept them, forcing me to run each board in the slower default software-rendering mode.

I hadn't planned to evaluate the S3-based Creative Labs Savage4 PCI card, but TeraLogic included it along with its DTV decode board. I'm glad I tried it, because I found its results the most interesting. The average frame rate for *Forsaken* approaches the maximum frame rate when you run the game in 1024×768-pixel mode, and the average and maximum frame rates mimic the set of results for 640×480-pixel mode, which should be faster, because the chip is rendering fewer pixels per frame. Two possible reasons exist for this strange set of data: Either the PCI bus is the bottleneck in shuttling polygons and texture data to the graphics chip, or the software drivers running on the host CPU are starving the Savage4 chip.

To solve this puzzle, I attempted to in-

MPEG-II decode*			AVI encode*			AVI decode*			HDTV decode		
Minimum (%)	Average (%)	High (%)	Minimum (%)	Average (%)	High (%)	Minimum (%)	Average (%)	High (%)	Minimum (%)	Average (%)	High (%)
26	27	28	23	25	26	5	7	8	4	5	5.5
92	99	99	NT	NT	NT	NT	NT	NT	NT	NT	NT

stall an AGP version of the Creative Labs board. Unfortunately, neither TeraLogic nor I could get past the blue-screen error messages when booting up Windows ; the graphics card didn't seem to like my motherboard. Creative Labs and S3 have parted ways with S3's purchase of Creative competitor Diamond Multimedia, and, indicative of that fact, Creative Labs released its latest driver-set revision in June. I have a Diamond Multimedia Savage4-based AGP card and will try to install it before this article's publication; check *EDN*'s Web site, www.ednmag.com, for any updates.

Swapping out PC-graphics cards can be a big hassle unless you follow this set of steps:

1. Deinstall any graphics-card-specific utilities, such as DVD decoders and TV-tuner software.
2. Reset the graphics adapter to "Standard Display Adapter (VGA)."
3. Reboot in Safe Mode and delete the old card references in Device Manager.
4. Shut down the system, remove the old card, and install the new one.
5. Boot the system and, using plug-and-play and keeping your fingers crossed, install the new drivers and utilities.

Even after I followed these instructions, my system froze when I attempted to run *Quake2* after I replaced the Voodoo 3500 with the Creative Labs Savage4 PCI card. Because *Forsaken* and *Incoming* worked fine, I was baffled until I remembered that 3dfx's installation program had placed MiniGL drivers in the *Quake2* directory, which deinstalling the 3dfx software apparently didn't remove. Deinstalling and reinstalling *Quake2* solved the problem.

I approached Internet-based telephony and videoconferencing with a few preconceptions: that audio quality would be

Figure 6

Who needs an expensive home stereo system when less-than-$100 computer speakers make your PC sound just as good? (courtesy Labtec).

tinny, that I'd deal with long delays between speaking and hearing a response, that the video window would be no larger than a postage stamp, and that the person I was communicating with would move as jerkily as Max Headroom. My skepticism went to a great extent unrealized, and I ended up impressed. Unfortunately, my Ramp Networks firewall's firmware doesn't currently support "holes" for NetMeeting 3.0 and other conferencing software, so I had to temporarily move the PC outside the LAN. I also didn't notice any performance- or image-quality differences between the mainstream and the high-end machines; the bottleneck is the Internet pathway between computers.

Audio quality was crystal clear and response time was acceptable, regardless of the time of day I called, the geographic location of the other person, or the bandwidth of the other person's Internet connection. The sound was fine as long as both participants had good microphones and speakers. I used the headset that came with my copy of Lernout & Hauspie's VoiceXpress voice-recognition software. If the other person had a standalone microphone or PC speakers, which sometimes caused feedback, or was in a noisy environment, the audio was subpar, but this scenario is analogous to using a cheap telephone.

As you would expect, the slower of the two Internet connections limited file-transfer times. Like audio, chat and white-board features ran smoothly. Video, however, was a somewhat different story. The 3Com HomeConnect USB videocamera I used worked great, at least until I tried to install another USB peripheral (see **sidebar** "Not ready for prime time"). The 3Com camera, based on both my experiences and other reviews, is notable not only for its high inherent frame rates but also for its usefulness across a range of illumination conditions, including low-light settings (**Figure 7**). The bundled software gives you a range of quality-versus-frame-rate environments that you can customize.

Early in the morning, when communicating with someone else on Pacific Bell's network and also on an ADSL modem, videoconferencing (and program sharing, another high-bandwidth task) was an acceptable experience with large video windows, smooth and fast frame rates, and rapid response. As the day progressed, quality degraded. It also noticeably suffered when I went outside the Pacific Bell network; got worse the farther away the other person was from me, reflecting more router "hops" between us; and throttled back, regardless of the other person's location if that person was on an analog-modem connection.

PARTING COMMENTS

Despite the problems, I was pleased with the experience of building the high-end PC. Most of the peripherals and software packages coexisted well with each other and did a good job of cleaning up after themselves when I deinstalled them. A few nagging quirks remain, such as

TABLE 3– 3-D-GAME FRAME RATES

	Forsaken (1024×768 pixels, 16-bit color)			*Forsaken* (640×480 pixels, 16-bit color)			*Incoming* (1024×768 pixels, 32-bit color)			*Quake II* (800×600 pixels, 16-bit color)		
	Minimum (frames/sec)	Average (frames/sec)	Maximum (frames/sec)	Minimum (frames/sec)	Average (frames/sec)	Maximum (frames/sec)	Minimum (frames/sec)	Average (frames/sec)	Maximum (frames/sec)	Minimum (frames/sec)	Average (frames/sec)	Maximum (frames/sec)
Pentium III-550 (3dfx AGP)	37	96.04	105	65	119.32	130	54.2	94.02	123.15	33.33	Not reported	>1000
Pentium III-550 (Creative PCI)	23	55.53	61	59	60.09	61	29.24	57.74	63.78	8.55	Not reported	23.26
Pentium II-400 (Intel AGP)	14	20.19	25	27	52.58	89	21.13	41.61	64.21	6.37	Not reported	21.74

programs that automatically make themselves the default for various file types, but the platform has nicely matured, as it should, considering that Windows 95 has been out for nearly a half-decade.

I've for more than a year been running the same Windows 98 arrangement on my mainstream system with a lot of peripheral swaps and program installations and deinstallations. Although the registry is probably bloated, the PC is still happily humming along. Normally, I'd chalk these experiences up to the fact that I, a computer geek, manage the entire LAN and sidestep potential problems before they happen. However, I asked my wife to install most of the software on the high-end system, and she—and the computer—did great.

The most consistent question I get when I describe the high-end system is: "Why do you need so much DRAM?"

Figure 7

Videoconferencing's time has almost come (courtesy 3Com Corp).

(**Figure 8**). Pardon the nonanalytical nature of my response, but the answer is "Why not?". With memory so cheap nowadays, it made sense for me to stuff the three-DIMM-socket machine with as much as it could take. After all, Microsoft now claims that Windows 2000 Professional without applications requires 64 Mbytes; Windows 2000 Server gobbles 256 Mbytes. With history as a guide, you should double or quadruple those figures for a usable configuration. The more DRAM, the less often Windows needs to cache to the disk drive with performance-sapping consequences.

Don't forget about the size of multimedia data files, either. A 9600-dpi, true-color, full-frame scan of a 35-mm negative creates a TIFF larger than 300 Mbytes. Each minute of 16-bit, stereo, 44-kHz-sampled audio translates to a 10.5-Mbyte Windows audio (WAV) file, and DTV's maximum data rate is 2.5 Mbytes/sec. For more information on the impact of additional memory on overall system performance, especially when balanced against more expensive processor upgrades, check out the Council on Computing Power, Kingston Technology, or Samsung Web sites.

FOR MORE INFORMATION...

For more information on products such as those discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use *EDN*'s InfoAccess service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Creative Labs
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Intel Corp
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Ramp Networks
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TeraLogic
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3Com Corp
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www.3com.com
Circle No. 471

3Dfx Interactive
1-408-935-4400
www.3dfx.com
Circle No. 472

Other companies mentioned in this article

Ahead Software
www.ahead.de

ATI Technologies
www.atitech.com

Aureal Semiconductor
www.aureal.com

Canon
www.canon.com

C-Cube Microsystems
www.c-cube.com

Council on Computing Power
www.rammatters.com

Crystal Semiconductor, a Division of Cirrus Logic
www.crystal.com

Gateway Computers
www.gateway.com

Hitachi Semiconductor
www.hitachi.com

IBM Corp
www.ibm.com

Inquest Market Research
www.inqst.com

Iomega Corp
www.iomega.com

Mercury Research
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MGI Software
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Micron Technology
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Microsoft Corp
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NEC Corp
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Nvidia
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Olympus
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Princeton Graphics
www.princetongraphics.com

Ravisent Technology
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Real3D
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S3
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Samsung Semiconductor
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Sonic Foundry
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Regarding DRAM performance, Bert McComas, principal analyst at Inquest Market Research, believes that, all if all other factors are equal, a system based on 2-2-2 (CAS 2) PC-100 DRAM should run real-life applications as much as 3% faster than that same system using 3-3-3 (CAS 3) memory. However, the results depend on how well the application uses L1 and L2 cache and how many other applications are vying for that same cache. Synthetic benchmarks run as much as 5% faster on a CAS2-equipped system than a CAS3-powered alternative. Note, however, that these numbers assume that both systems contain the same operating system, applications, hard-drive size and type, amount of DRAM, CPU and operating frequency, and core-logic chip set.

Figure 8

As long as there's a Microsoft, there'll be a need for more memory (courtesy Micron Technology).

Even with all this memory, I continue to struggle with occasional system lockups caused by low system resources; adding more DRAM doesn't solve this problem. When Windows boots, including loading all of the run-on-boot applets in the registry and StartUp folder, I end up with slightly more than 70% free system resources. Launching applications depletes these resources, and closing them sometimes causes memory leaks, making the free "pool" smaller than its previous size. Part of the cause is my usage model; I don't like to have a lot of programs running at once, so I open them when I need them and then close them. But if the programs were better behaved, I wouldn't have to think about modifying my behavior. As it stands, I avoid the problem by rebooting the PC every day to keep free resources higher than 40%.

Occasional audio stutter is another baffling phenomenon. Both the mainstream

A WORK IN PROGRESS

I ended up with many more pieces of equipment and software than I had time to evaluate pages to tell you the results. I treat this project as "living," though, and I encourage you to periodically check the version of this **sidebar** on *EDN* Access for any updates.

Graphics performance is one key area begging for further analysis. I'd like to try an AGP version of an S3 Savage4-based board to help figure out whether the PCI bus or the drivers were behind the Creative Labs PCI board's 60-frame/sec maximum frame rate on *Forsaken*. I'd also like to see how the Creative Labs TNT2 Ultra board performs with the game demos. It would be interesting to rerun all the boards under the DirectX 7 application-programming interface, which Microsoft released on the day I filed this article. And, for an upcoming article, I plan to delve into whether APG 4× bus bandwidth and hardware-accelerated transform and lighting make a noticeable system performance or quality improvement, using boards based, for example, on Nvidia's GeForce 256 and S3's Savage2000.

TeraLogic and I still need to get the Janus digital-TV board's video-module-interface-port mode running on my system, and Princeton Graphics also has loaned me an AF3.0HD 16-to-9-aspect-ratio monitor so that I can view high-definition-TV (HDTV) broadcasts and DVD movies in full-screen mode. Ravisent Technology claims to have an all-software HDTV decoder that runs on the local bus of a 133-MHz Pentium III-600 using approximately 50% of the CPU. The company has probably taken more decoding short cuts than TeraLogic with its hardware-assisted approach; I'm curious to see whether I'll notice.

Ravisent's software decoder relies heavily on ATI Technologies' Rage 128 chip, which is notable among graphics accelerators in integrating both inverse-discrete-cosine-transform (IDCT) and motion-compensation logic functions. These capabilities should also substantially reduce the CPU usage during DVD playback compared with the 3dfx, Intel, and Nvidia chips, which provide neither IDCT nor motion compensation. ATI's All-in-Wonder 128 documentation claims that the board's "digital-VCR" feature encodes a 640×480-pixel IBP (intra, forward-predicted, bidirectional-predicted) MPEG-2 stream with the Pentium III-500. If that claim is true, that unscaled frame is four times larger than the frame size that the 3dfx board encodes.

In partnership with C-Cube, ATI also addresses the need for "time-shifting," the ability to play back a recorded MPEG stream while making an off-the-air recording. ATI's Video Wonder board uses C-Cube's DvExpress MPEG encoder/decoder and provides digital-video editing, TV tuning, instant replay, skip-ahead (to bypass commercials), and still and video capture. MGI Software's Pure Diva claims to accomplish the same tasks at as much as half-D1 resolution, purely in software, and also bundles a Web-TV-like electronic programming guide.

Once I get Opcode's SonicPort Optical to happily coexist with my 3Com HomeConnect Universal Serial Bus camera, I'll be able to make some 100%-digital transfers from the digital-audio-tape recorder to the PC. I did some taping at mid-September Phish concerts, the early-October High Sierra Music Festival, and at performances of my neighbor's Latino music band. After cleaning up the recordings using PC-based editing software, such as Sonic Foundry's Sound Forge and Syntrillium's CoolEdit Pro, I'll convert them to MP3, Shorten, WAV, and Windows-media-format files at multiple quality levels and post them on *EDN* Access for you to download, compare, and enjoy. I also hope that I'll have better luck archiving these files on recordable CDs with software such as Ahead Software's Nero, which newsgroup posters highly recommend for use with the Philips recordable/writable CD drive.

One application that I lacked the time to explore is video editing. ATI's and 3dfx multimedia graphics cards provide external video inputs, and several manufacturers have offered to loan me digital camcorders and 1394 add-in-cards. I also own a Canon Hi-8 camcorder. My wife and I will continue to use Lernout & Hauspie's Voice Xpress, and I'll let you know if the incremental learning improves its accuracy. The company also bundles an Olympus solid-state voice recorder and serial cable for PC transfer and voice-to-text conversion, and IBM has also sent me an evaluation copy of ViaVoice. I'll see if its results are any better.

I hope to gather more Pentium III-versus-Pentium II comparisons, such as putting the 3dfx Voodoo 3500 card into the mainstream PC. I had planned to use a Pentium III-600 for the high-end PC, but the motherboard was reluctant to release the Pentium III-550 in the socket. Not wanting to break anything, I gave up, but I'll try again and, if I succeed, rerun some of the tests. Finally, Intel offered to loan me an i820 (Camino)-based, Direct Rambus DRAM-equipped system for this study. I resisted this proposal because I didn't want to struggle with beta chip-set drivers in addition to all the other potential hardware and software issues. This decision now seems prophetic, given Intel's announcement to delay i820 production, but I'll need to use *someone's* AGP 4× chip set for the upcoming graphics article.

and the high-end PCs' audio chips are PCI-resident, not ISA-based. However, I still encounter frequent audio disruptions when the system is doing a task while playing a WAV file, such as during booting, or running a multimedia program such as *Liquid Player*, *Media Player*, and *QuickTime*. The other task might be as complex as launching an Office program or as simple as my navigating through IE or Windows Explorer with the mouse. The problem isn't reproducible, and I don't notice it when playing audio CDs.

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One final minor point became a major limitation to putting a PC in the living room. Boot times from power-off are still too long and inconvenient, analogous to Internet-connection logins in the pre-DSL days. Ordinarily, I'd just put the PC to sleep when I wasn't using it. However, my mainstream system doesn't allow this step because my Windows CE handheld PC synchronizing software is constantly running in the background. And I can't get the loud power-supply fan on the high-end system to shut off when the PC's in sleep mode.

Does the high-end PC justify its price tag? It depends. For today's common applications, such as Web browsing, e-mailing, and word processing, I have to say "no." Ironically, the high-end PC's boot time is 50% longer than that of the mainstream PC, indicating the high-end system's more diverse peripheral set, more extensive installed application suite, and consequently larger registry. However, locally stored (not Internet-resident) multimedia content reveals the hidden strength of the high-end machine.

Still-image and audio-editing tasks complete in a fraction of the time they take on the mainstream PC. DVD decoding produces a more pleasing presentation with system headroom left over. Also, 3-D games run at higher frame rates, at higher resolutions, and with better quality. Unless you're budget-challenged and particularly if you want to defer system obsolescence as long as possible and aren't afraid to build your own, the high-end PC makes sense. □

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