In these days of rapid innovation and breathtaking change, the term digital media is wonderfully flexible. Digital media can be anything from content on a CD or a set-top box to the bits streaming through the ether or over fiber. From my point of view and major area of interest, digital media starts with the hardware bits and pieces necessary to bring all the elements together in one place at one time for human consumption. When we consider processor cycles—for both humans and machines—digital media is mostly about images, which are formed from computer graphics or video. Audio and communications constitute important parts of the equation, of course, and we wouldn’t have much of a media experience without them. However, our brains and machines spend most of their time processing images.

Digital media traces its roots back to a couple of places, depending on your point of view and definitions. The notion of electronic media started with analog television in terms of a full user experience. With the advent of computers, we’ve been trying to do as well ever since. Embodied within the notion of digital media is the concept of convergence, which also has several meanings depending upon who is using it. Basically, convergence refers to the marriage of computers and television, or to the marriage of digital media and the Net (see Figure 1). It’s a maddening and exciting potpourri of terms and technologies. We are trying to get every source into every device, and create an equal experience through all of them—a plan for the future known as everything, everywhere. Although we can’t achieve everything, everywhere with today’s technology, there is general agreement that it’s just a matter of time before we can. Thus, the related industries are investing massive amounts of money and effort toward that goal. Because the visual aspect of digital media technologies is so pervasive and resource consuming, that’s where a majority of the effort is going.

As advances in silicon fabrication bring the vaunted system on a chip within reach, digital media is propelling itself from the domain of the PC into consumer electronics.
The technology developments in the digital media market are primarily in semiconductors. Communications, display technology, and software are secondary areas of effort—though certainly not of secondary importance to those working in these fields.

**Shrinking the system**

The primary enabler of the movement toward everything, everywhere has been, and will continue to be, semiconductor fabrication technology. When commercial high-volume production of chips with 0.25-micron features became pervasive and we entered the era of million-plus-transistor devices in 1998, the possibilities for semiconductor engineers expanded dramatically. It was as if this breakthrough unleashed the industry’s collective imagination, and all our visions and fantasies came within reach. It didn’t take long for the industry to break the 0.15-micron threshold, and today we speak casually about sub-0.11-micron designs. As line width decreases, the density of transistors in a given area goes up by the square. While we only recently marveled at a million-transistor chip, today we worry about how we’ll use tomorrow’s 100-million-transistor budget.

But some in the field don’t worry at all—in fact, they hunger for even more. These are the architects, designers, and visionaries who long to build the elusive system on a chip.

**Combination devices**

Equator, http://www.equator.com  
National (Geode), http://www.national.com  
Philips/Trimedia (Nexperia), http://www.semiconductors.philips.com  
LSI, http://www.lsilogic.com  
PalmChip, http://www.palmchip.com

**Tuners**

Broadcom, http://www.broadcom.com  
Mitsubishi, http://www.mitsubishielectric.com  
Microtune, http://www.microtune.com

**TV subsystems**

Broadcom, http://www.broadcom.com  
TeleCruz, http://www.telecruz.com/home.html

**Communications**

Broadcom, http://www.broadcom.com  
Connexant, http://www.connexant.com

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**Technology trends and developments**

The technology developments in the digital media market are primarily in semiconductors. Communications, display technology, and software are secondary areas of effort—though certainly not of secondary importance to those working in these fields.

**Where Digital Media Comes From**

The technology for digital media devices comes from many sources. Here are a few of the most prominent.

**PC graphics controllers**

ATI, http://ati.com

**Audio parts**

Cirrus Logic, http://www.cirrus.com  
ESS, http://www.esstech.com  

**DSP chips**

Texas Instruments, http://www.ti.com  
BOPs, http://www.bops.com/

**CISC chips**

AMD, http://www.amd.com  

**RISC chips**

ARM, http://www.arm.com  
MIPS, http://www.mips.com
bine all three. SOCs will contain mixed-signal technology, and they will incorporate smart power management to turn off sections not in use and turn down parts that are getting too warm or don't need to run as fast. They will have inherently super-fast core frequencies in the multi-GHz range. They will embed functions such as encryption, copy protection, language engines, and several codecs to minimize the bandwidth I/O requirements. They will process RF, high-speed serial data, and various forms of digital data including Very Large Word Format (VLWF). They will approach the universal do-everything-anywhere machines envisioned in science fiction since the 1930s.

**Showing off**

Display technology has also taken advantage of miniaturization processes. On the large scale, displays for our TVs and computers are increasing in dot resolution per square area while offering more brightness and richer color spectrums than ever. Screens of almost any size with full HDTV resolutions will soon be available in massive quantities, with subsequent price elasticity. We now have laptops with 15-inch screens capable of displaying 1,280 × 1,024 pixels—good enough for most workstation needs. LCD panels for both on-screen and behind-screen projectors provide resolutions at 2,000 × 1,300 pixels, outstanding brightness, wide-angle viewing, and vibrant color. All these products owe their existence to advances in miniaturization processes and affordable display controllers.

Screens are getting not only bigger and brighter, but smaller and denser as well. Developers of microdisplays have taken full advantage of the new semiconductor fabrication processes, and it soon will be possible to have an HDTV display on your cell phone or PDA. Clever viewing systems using low-cost, thin, inexpensive plastic lenses will make it possible to see these personal devices’ displays in virtual space at any size. If you think it’s strange now to see people walking through airports and restaurants talking to the air, imagine watching people staring and pointing into space as well. All media anytime, anywhere—coming soon to a location near you.

Today you can buy lightweight viewing glasses with a 640 × 480-pixel, full-color LCD screen for each eye. (What’s next? Yes, stereovision.) And, a new class of lightweight projectors for road warriors with resolution up to 1,024 × 768 pixels can be had for not much more than the cost of a good laptop.

**What’s missing?**

Along with the visual aspects of new digital-media systems, communications technology is developing rapidly, as are the classic multimedia components—audio, video, and graphics. Switches, transceivers, and codecs are also advancing. However, the infrastructure, although highly heralded, is advancing at a slower pace. This is simply because of the physical size of the necessary media and the vast distances it must cover. To lay in a 100-GHz optical cable from San Francisco to San Jose, or Boston to New York, or Austin to Dallas is a massive works project involving huge machines, right-of-way issues, major construction, and all the associated legal, union, and community issues. Wireless solutions might seem an obvious shortcut, but conflicts among standards, government regulations, and interoperability issues make these difficult as well. The limitation on bandwidth infrastructure is holding back the interactive potential of TV as well as convergence.

Despite these difficulties, software is the primary laggard in the development of digital media. We’ve had the ability to display 3D images on our computers and game consoles for almost a decade. However, we see little 3D on TV or DVD except for a few advertisements where logos come tumbling out or goofy gas pumps wiggle around.

When one asks why there’s no 3D, the standard answer is, “There’s no content.” When one asks why there’s no content, the answer is, “Users don’t want it,” or “There’s no demand.” Since when in technoville has that ever been a reason not to do something? Users never asked for 3D sound on their PCs, or MP3, or the strange worlds and amazing weapons of video games, but we have all of those. (And I’m pretty sure no user asked for the 3D commercials.)

The lack of software is holding back the development and deployment of SOCs and advanced graphics controllers in consumer electronics because designers don’t know what to include in their SOCs. Should they have high-performance 3D and THX/Dolby sound?

Some years ago I coined the term Free-D. Well, the idea is more applicable today than ever: Why not put 3D in all the SOCs and near-SOCs that are being built for today’s consumer electronics? You know, “If you build it, they will come…”.

**Key products and services**

However, digital media systems aren’t built just using SOCs. They’re constructed from chips, proprietary circuit boards, PC add-in boards, and large-scale circuit boards. Digital media systems—also known as digital entertainment boxes—consist of seven primary product types:

- digital TVs, including HDTV,
- set-top boxes (tuner-based devices such as cable and satellite boxes, DTV-to-analog converters),
- DVD players,
- Internet TV, also known as Web TV,
- personal video recorders, also known as time-shifters,
- game consoles, and
- entertainment PCs and virtual appliances.

Today, all of these devices are vying for the consumer’s dollar. At the same time, each is trying to assimilate the functionality of the others. The list doesn’t include the master controller, which in many homes is the audio-video mixer and high-powered stereo amplifier with Dolby Surround Sound, Digital Dolby, THX sound, or all three. An FM tuner, a cassette player, and a VCR round out the home entertainment ensemble.

**Likely future developments**

Obviously, consumers won’t buy one of each of these boxes, plus an audio-video stereo amplifier/tuner to manage them. So eventually some of the seven categories will totally assimilate others, and some will dis-
3 In the next few years, some classes of digital media boxes will probably merge with others, eventually winnowing the field down to just a few.

appear as stand-alone boxes. (Of course, some stand-alone boxes will continue to be sold, just as TV/VCR combination units didn't totally replace stand-alone VCRs.) Ultimately, digital entertainment boxes will evolve into three major platforms (Figure 3):

- smart digital TVs (DTVs),
- game consoles, and
- virtual appliances, which will evolve from the entertainment PC.

Table 1. Divvying up digital media.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Processor</th>
<th>Operating system</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital TVs</td>
<td>ARM</td>
<td>O/S-9</td>
<td>Several</td>
</tr>
<tr>
<td></td>
<td>MIPS</td>
<td>Java</td>
<td>Philips, others</td>
</tr>
<tr>
<td></td>
<td>PowerPC</td>
<td>OpenTV</td>
<td></td>
</tr>
<tr>
<td>Entertainment PCs</td>
<td>Intel, AMD</td>
<td>Win/NT</td>
<td>Many</td>
</tr>
<tr>
<td></td>
<td>PowerPC</td>
<td>System 8</td>
<td>Apple</td>
</tr>
<tr>
<td>Game consoles</td>
<td>MIPS</td>
<td>SonyOS</td>
<td>PlayStation2</td>
</tr>
<tr>
<td></td>
<td>SH4</td>
<td>Sega CE</td>
<td>Dreamcast</td>
</tr>
<tr>
<td></td>
<td>PowerPC</td>
<td>NintendoOS</td>
<td>Dolphin</td>
</tr>
<tr>
<td></td>
<td>Intel</td>
<td>CE</td>
<td>Sys X-MS</td>
</tr>
</tbody>
</table>

Processor type, operating system, and suppliers will segment the three platforms. Table 1 outlines a possible scenario of this division, listing likely processors, operating systems, and manufacturers for the three digital media platforms.

The display and audio quality of these systems will also vary for several years, owing to the cost of the controllers and the display. Controller costs have dropped in price steadily since 1994 and are leveling off now as the market matures and suppliers—once overly abundant—exit the field. (In 1995, 75 companies claimed to have or to be...
working on a 3D controller for the PC. Today there are 11 companies in the PC market, three in the set-top box market, and two in the game console market making 3D graphics controllers.)

Although CISC and RISC processors have advanced according to Moore’s law, doubling in speed every 18 months, graphics controller performance, as measured in MHz, has improved even more quickly. Audio devices haven’t improved as fast in terms of clock performance—or have they needed to. They have, however, advanced in their use of DSPs and enhanced algorithms that use physioacoustic tricks to make inexpensive actuators—speakers and headsets—sound bigger and more numerous.

Even though processors have improved, graphics controllers in PCs have taken on more of the processing role, incorporating floating-point capabilities for real-time calculation of transform and lighting functions, commonly called T&L. Manufacturers are using these new T&L-capable graphics controllers in game consoles and in entertainment PCs and their descendents, virtual appliances. The performance developed for high-end entertainment (“games”) PCs and workstations is quite easily capable of satisfying the display controller requirements for HDTV—whether it is progressive-scan or interlaced.

Conclusions

The range and definition of digital media is vast, reaching from PCs to consumer electronics, but at the center of it all is the display controller. Powered by the advances in semiconductor fabrication and the expansion of the PC market, new graphics controllers, video processors, and audio processors have emerged that promise astounding home entertainment systems at affordable prices. Along with digital media advances have come developments in communications devices.

However, the cost of expanding the physical infrastructure is thwarting advances in communications. In addition, both the communications infrastructure problems and the lack of interesting or compelling 3D content are limiting the interactivity of the home entertainment system. But the pace of development and function assimilation continues unabated, and new amazing digital media devices and systems are appearing almost every week.