*Special Issue:* Celebrating the 25th Anniversary of the Microprocessor

VOLUME 10, NUMBER 10
AUGUST 5, 1996

MICROPROCESSOR REPORT

THE INSIDERS' GUIDE TO MICROPROCESSOR HARDWARE

# Microprocessors Changing the World

## *Proliferation Only Beginning—Biggest Changes Ahead*


*by Michael Slater*

When the microprocessor emerged 25 years ago, its impact on the semiconductor and computer industries was far from clear—and its ultimate impact not only on businesses of all kinds but also on everyday people was unthinkable. Today, microprocessor-powered devices are perhaps the most significant change agents in the world. Consider, for example, the role of fax machines and e-mail in political upheavals worldwide, as well as the radical restructuring of the publishing, entertainment, and communications industries now under way.

In its early years, the microprocessor was thought of mainly as an alternative to hard-wired logic for implementing control functions. By enabling a system to be customized by changing bits in a memory, it allowed mass-produced microprocessor and memory devices to serve a very broad range of purposes. And because software complexity is more manageable than hardware complexity, control algorithms could be more complex, incorporating more heuristics and other advanced algorithms. Software has enabled machines to act in far more sophisticated ways, though managing software complexity remains a significant challenge.

These advantages have led the microprocessor to redefine products ranging from traffic lights to elevator controllers, from medical instruments to automated factories. Repertory-dialing telephones and set-back thermostats existed before microprocessors, but they would not have been as feature-rich or as inexpensive without them. Other products, such as desktop calculators, were driven to dramatically lower cost points by microprocessor technology. Medical instruments, such as blood-glucose meters, that previously were affordable only by hospitals and doctors, have become consumer products.

Microprocessors also led to the shift in consumer-electronics interfaces from knobs and switches to push buttons and displays. In the hands of engineers without much appreciation for human factors, this change sometimes led to horrible user interfaces, but it also enabled a wide variety of new functions. Audio CDs put the microprocessor right in the signal path as consumer audio switched from analog to digital storage; DVD is about to do the same for video.

Microprocessor-enabled devices have enhanced the quality of life for the gadget-happy and have no doubt even saved some lives, but their impact has been incremental. Most of us have homes and cars that contain dozens of microprocessors. Although they may perform useful func-

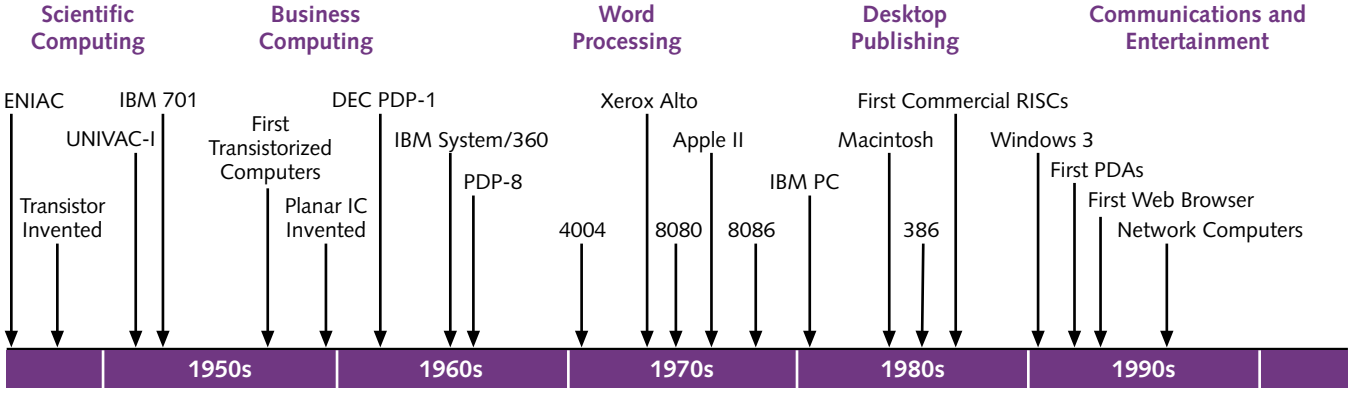


**Figure 1.** In electronic computing's 50-year history, applications have evolved from scientific computation to communication and entertainment. Microprocessors, in existence for only half that time, have been at the heart of computing for 20 years.

tions and provide pleasure and convenience, in the larger scheme of things, the changes they have wrought have been minor. The deepest changes to result from microprocessors will derive from their use in communications devices, ranging from Internet-connected computers to handheld phones.

## A Brief History of Computing Applications

For more than 100 years, the first computers—whether mechanical or electronic—were used for arithmetic. From tax collection to census statistics to ballistics trajectories, the demand for the machines came from the burden of performing calculations that were of great practical use and were well within man's grasp to define, but that could not be calculated in an acceptable period of time without mechanical help.

After World War II ended, as Figure 1 shows, computers began to move into business applications. Accounting and engineering computations remained the predominant uses of computers for many years, however. The use of computers for engineering and business simulations—making possible "what if" questions that could never before be answered in a practical timeframe—remains a key application.

Even the minicomputer and personal computer did not entirely break the computer out of its mathematical mold. Word processing was the first widespread application to use the computer as a communications tool, and desktop publishing took this to the next level of paper communication.

The shift in the 1980s to graphical, direct-manipulation user interfaces made computers vastly more accessible, but still the communications function of most computers was limited to preparing printed materials. The more dramatic shift in the personal computer's primary function from a computation device to a communication and entertainment device is the driving force behind its proliferation. Widespread connectivity, in the form of the Internet, is enabling a dramatic increase in the personal computer's significance.

## Internet Multiplies Microprocessor's Value

The Internet, lurking for years in scientific circles, burst into public view when the protocols and access software evolved to support point-and-click access (via Web browsers) and nearly seamless interoperability of servers worldwide (thanks to the HTML standard). The Web took off so quickly because all the hardware technology needed to exploit it was already in place.

The explosive growth of the Internet is moving us with startling rapidity into a world of ubiquitous connectivity, in which computers and other microprocessor-based devices will be our predominant tools for all communication that is not face-to-face.

Today, personal computers are the primary client device for connecting to the Internet. Microprocessors are, of course, at the heart of all PCs, but their importance to the Internet goes much deeper. Network routers and modems are equally dependent on microprocessors, as are the servers that provide information to the network.

Consumer use of the Internet is still in a very early phase, with astounding growth rates. The Web today is still embryonic, and while the sheer growth rates in servers and clients connected cannot continue unabated, dramatic increases are still to come.

The growth in the quality and value of the information available will be staggering—creating, incidentally, an increased demand for human editors who can help sort out the vast amounts of information and separate signal from noise. Most businesses are just starting to put their information on the Web. Already, it is a valuable source of information for many kinds of research as well as for customer support. We are not far from a time when information on virtually any company, product, or subject will be only a few clicks away.

The most valuable databases are still kept on private networks and on-line services, where the economic models are more established. As secure transactions and payment systems become commonplace over the next few years, however, most databases will become accessible via the Web.

## Web to Revamp Shopping and Publishing

Companies will begin conducting more and more transactions via the Web. Today's on-line shopping catalogs are anemic and of limited value, but as these catalogs are made richer—and higher-bandwidth connections become commonplace—the mail-order shopping business will move largely to the Web.

The Web is also triggering a metamorphosis of the publishing industry that can only be compared to the change that followed the introduction of the printing press. Many Web publishing pioneers are still struggling with their business models, but this is hardly surprising: the Web changes all the rules. The incremental cost of distribution for electronic information diminishes to essentially zero, and attractive, free content becomes the primary method for luring new customers.

The relative ease of publishing is also radically changed. Today, the barrier to getting a book published is substantial. It is uneconomic to publish anything very short or for a very small market, and there is no practical way for an interested user to search the content of the books that are available to find obscure publications of interest. The Web changes all this by enabling anyone to publish anything at little cost, and prospective consumers of that information can find it through search engines.

Newspapers almost surely will be radically changed by the Web. Every day, billions of pages of newspapers are printed. Only a tiny fraction of each copy is ever read at all, and a vanishingly small part is read more than once before it is tossed. We are so accustomed to this activity that it seems normal, but when viewed from a distance it is an unconscionable waste of paper. The Web, or some combination of the Web and e-mail, will provide an attractive alternative that will also eliminate much wading through stories that aren't

of interest. Magazines will be reshaped as well; their lower frequency and higher-quality graphics, however, make them a secondary target for replacement by the Web.

### Better, Cheaper Access Devices Needed

The missing component that keeps electronic media versions from replacing paper newspapers today is an acceptable and affordable client device. Some people—typically those who are most comfortable with computers—already are switching much of their news reading to Web-based services, such as the *Personal Journal* version of *The Wall Street Journal*. But for most people, a CRT or notebook computer display just isn't going to replace ink on paper for reading newspapers and magazines.

If a large, thin tablet with a high-resolution display and wireless connectivity were affordable, however, electronic media could begin replacing paper publications on a broad scale. Within ten years, acceptable tablets should be available, but at prices too high for mass adoption; another five or ten years later, electronic media could become truly mainstream.

In the meantime, the Web is becoming widely used within a significant segment of society, and this is spurring the development of many new computing devices. The low-cost, high-resolution tablet must wait for better, cheaper display technology, but low-cost devices using CRT monitors or televisions can be built today—the much-discussed network computer. The existence of low-cost, high-performance microprocessors is a key enabler of such devices. This is a controversial area today, with many companies developing devices and the PC industry fighting back with scorn and derision. Many of these devices will probably fail, but some will succeed; in time, full-fledged personal computers will be only one of the ways that people access the Web.

### Computers Reshape Entertainment

Microprocessors first became a force in entertainment with the introduction of video games. Today, personal computers have become a popular game platform, and the combination of PCs and the Internet is enabling multiplayer games. As 3D performance improves, the PC will become a great game platform. At the same time, DVD drives will enable computers to serve as outstanding video playback devices.

These changes, while of importance to the PC and semiconductor industries, will have a minor impact on society when compared with communications functions. And the changes are not entirely positive—it is far from clear that video games have made a positive contribution to the world.

The biggest effect that microprocessors will ultimately have on entertainment is the reinvention of television. As high-bandwidth digital connections become more widely available, video transmission will evolve from a broadcast paradigm to an on-demand approach, with vast amounts of content available any time. This has the potential to make a much wider range of content available and break TV out of

### A Personal View of Microprocessor History

The computer and microprocessor industries have moved so fast that it is hard to grasp—especially since expectations molded by any other industry fail to provide a meaningful context. I've found that looking back on where I was as the industry unfolded provides a helpful perspective on just how new all this technology is.

In 1955, the year I was born, William Shockley founded the first commercial transistor company—in Palo Alto, within blocks of where I started *Microprocessor Report* 32 years later. IBM was a significant computer manufacturer, but Univac was the leader. By the time I was a toddler, IBM's dominance was established, and the seven dwarfs were finding their niches.

As a child, I was fascinated by computers, but they were totally mysterious. Down the street from our house in Los Angeles was a large building with many windows, through which I could see the computers inside—flashing lights and jerkily moving tape drives.

In high school, I began playing with digital integrated circuits, but computers were still infinitely distant from anything I could build. The first microprocessor was introduced while I was in tenth grade—though I was unaware of it at the time.

My early college years marked the end of mechanical computing and the dawn of digital electronics as a consumer phenomenon. In my first-year physics classes, a slide rule was an essential tool. By my second year, electronic calculators were on the scene, and slide rules quickly became historical artifacts.

For my first computer programming classes I wrote programs on coding sheets, used a keypunch to produce a card deck, and submitted the deck to the computer center, whose CDC 6600 was mysteriously hidden behind a door through which mere undergraduates could not pass. When I was a junior at U.C. Berkeley, the first primitive personal computers appeared, but they had no role in the university environment.

By my senior year, a PDP 11/70 was running Unix, but I had lost interest in these big machines. In the lab, we had advanced from punched cards to paper tape and were writing programs for Intel 4040-based single-board computers. I built an 8080-based computer with 4K bytes of RAM and 1K byte of EPROM, implemented with Intel's pioneering 2102 SRAMs and 1702 EPROMs.

Over the course of my childhood and college years, computers went from mysterious behemoths produced in tiny numbers to universal elements of almost everything electronic. For someone who was to build a career around microprocessors, I was born at a fortuitous time.

— *MS*

the least-common-denominator mode dictated by the economics of broadcasting on a limited number of channels.

## Toward Ubiquitous Computing

Another level of microprocessor influence will become evident as computing devices become invisible and pervasive—what Mark Weiser of Xerox PARC has called ubiquitous computing (see *www.ubiq.com*) and MIT's Media Lab is researching under the moniker "things that think" (see *ttt.www.media.mit.edu*).

In this vision, microprocessors are quite literally woven into the fabric of society—in clothing, shoes, doorknobs, and so forth. Shaking hands with someone could transfer their business card information, and even a brief video of them, to your personal information store—possibly located in your shoes. Your house might keep track of which rooms you are using and adjust lighting and heating accordingly. Your refrigerator might notice you are out of milk and ask if it should e-mail an order to your on-line supermarket.

This vision is further from realization than is widespread use of the Web for two reasons. First, it requires more new technology, mostly in the form of very low power microprocessors and wireless communications. Second, it is likely to make people deeply uncomfortable and therefore encounter significant resistance. And in the end, it may not have nearly the significance that universal access to worldwide information and communications will have.

## Who Could Have Guessed?

It is quite striking how the microprocessor is enabling such profound change, despite the fact that it was an essentially incremental creation—the combination of the fundamental ideas of a machine that follows stored instructions, the use of digital logic to create extremely reliable systems, and integration using semiconductor technology.

In some sense, the real magic comes not from the microprocessor itself but from semiconductor technology. Because of continuous density improvements, semiconductors benefit from an almost unheard of trend that makes it a business like no other in history: nearly everything—cost, power per transistor, storage capacity, speed—gets better every year. The microprocessor has unleashed the power of semiconductor technology without requiring custom devices for every application. Memory technology has been equally critical; microprocessors with core memories wouldn't have gone very far.

## Where Do We Go from Here?

That the microprocessor has had an astounding impact on society already—and will have much more impact in the years to come—is beyond question. The value of this impact, however, is open to debate.

Electronic mail and pagers can be great productivity tools, but they can also fragment one's time and attention and intrude into what private time remains. On-line communication can enable both business and personal relationships to be more easily maintained over a distance—but if it becomes one's dominant mode of communication, it can lead to seriously underdeveloped social skills and a lack of rich human interaction. On-line libraries and shopping malls have real advantages over their physical versions, but they don't replace them as meeting places. Electronic games can be very entertaining, but if they lead to less physical activity and social interaction they can be quite destructive. It is up to each of us, as developers and users of the technology, to work to keep its impact positive. M