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The system-on-a-chip, microsystems computer industry

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The inevitability of complete computer systems on a chip will create a microsystems industry. In addition, forecasters predict 32-Mbyte memory chips by 1999. So by 2002 we would expect a personal computer on a chip with at least 32 Mbytes, video and audio I/O, built-in speech recognition, and industry-standard buses for mass storage, local area network, and communications.

Technology will stimulate a new computer industry for building application-specific computers that require partnerships among system customers, chip fabricators, ECAD suppliers, intellectual property (IP) owners, and systems builders.

The volume of this new microsystems industry will be huge—at least two orders of magnitude more units than the PC industry. For every PC, there will be thousands of other kinds of systems built around a single-chip computer architecture with on-chip interconnection bus. This architecture will be complete with processor, memory hierarchy, I/O (including speech), firmware, and platform software. Powerful processors will enable firmware to replace hardware.

Silicon Graphics (Mips) supplies the key technology for Nintendo and Sony to build games, and WebTV to build an Internet access set-top. Netscape's Navio licenses software to build Internet consumer access devices including phones, games, and television sets that attempt to replace PCs. (Partners included IBM, NEC, Nintendo, Oracle, Sega, and Sony.) Sun's Microelectronics Division is designing and licensing special processors for the Java language and environment. Acorn licenses its ARM processor. Oracle is licensing its network computer to sell server software. Microsoft has various alliances for designing pocket and set-top computers.

The emerging microsystems industry will encompass

- customers building microsystems for embedded applications like automobiles, room and person monitoring, PC radios, PDAs, telephones, set-top boxes, videophones, and smart refrigerators;
- about a dozen foundries that fabricate microsystems—many in Japan and Korea;
- custom companies such as VLSI Technology and LSI Logic that supply "core" IP and take the systems responsibility;
- existing computer system companies like Digital Equipment Corporation, Hewlett-Packard, IBM, Silicon Graphics, and Sun that have large software investments tied to particular architectures and software;
- fab-less and chipless IP companies that supply designs for royalty;
- ECAD companies that synthesize logic and provide design services (Cadence and Synopsys);
- circuit wizards who design fast or low-power memories (VLSI libraries), analog for audio (which is also a DSP application), radio and TV tuners, cellular radios, GPSs, and micromechanical structures;
- varieties of processors from traditional CISC and RISC to DSP and multimedia;
- computer-related applications that require designers to understand a great deal of software and algorithms (communications protocols and MPEG); and
- proprietary interface companies like Rambus developing proprietary circuits and signaling standards (traditional IP).

Like previous computer generations stemming from Moore's law, a microsystem will most likely have a common architecture. It will consist of an instruction set architecture such as that of the 8088, Mips, or ARM; a physical or bus interconnect that is wholly on the chip and used to interconnect processor memory and a variety of I/O interfaces (disk, Ethernet, audio); and software to support real-time and end-use applications. As in the past, common architectures are essential to support the myriad of new chips economically.

Will this new industry just be an evolution of custom microcontroller and microprocessor suppliers, or a new structure like the one that created the minicomputer, PC, and workstation industries? Will computer companies make the transition to microsystems companies, or will they just be IP players? Who will be the microsystems companies? What's the role for software companies?

Thirty-six ECAD, computer, and semiconductor firms announced an "alliance" for this purpose on September 4, 1996. *[See* IEEE Micro, *Oct. 1996, p. 2.—Ed.]*

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The consumer market segment, rather than the business market segment, is driving PC development in this area. Although the business market struggles with how to interpret and present enormous amounts of information more clearly, home users are leading business people in discovering creative ways to solve problems graphically. There are huge opportunities for enterprising application designers to incorporate 3D visualization in clarifying complex business information. More powerful processors with powerful graphics make it easy to display information visually rather than numerically and therefore easier to interpret the information. PCs with smart user interfaces will enable their users to become