Digital signal processors were once the backwater of the chip industry. These processors, also known as DSPs, had limited uses and appeared only in such products as modems and fax machines. They were not a rapidly growing segment of the processor market, and they received little media coverage.

However, the embedded systems revolution has placed the relatively inexpensive chips in many consumer devices, including cars, consumer electronics products, and even medical equipment.

With the ability of today’s programmable DSPs to provide real-time performance for a few specialized tasks, such as compressing data, the low-cost processors can enable valuable consumer-grabbing features without making products much more expensive.

Microprocessors can perform multiple tasks, often very quickly, but they are more expensive than DSPs and cannot offer real-time service as reliably.

DSPs’ ability to provide real-time performance is particularly valuable in cellular phones and other products that cannot tolerate performance delays.

DSPs can also manipulate digital signals, including those that have been converted from analog signals. Hence, the processors play a vital role in the increasingly popular digital versions of such traditionally analog consumer products as stereo systems and cameras.

These factors have helped make programmable DSPs the rising star and fastest growing segment of the processor industry. This trend may well continue because companies are finding new uses for the different types of embedded DSPs. In addition, researchers are improving DSP technology and development tools, and chip production costs are decreasing.

The primary challenge the industry now faces is making DSPs fast, functional, inexpensive, and plentiful enough to keep up with demand.

**Background**

A DSP is a specialized microprocessor whose architecture has been optimized to rapidly execute arithmetic instructions, such as matrix multiplications, multiply and accumulate operations, and Fourier transforms.

DSPs analyze, enhance, manipulate, or modify digital signal information to achieve a specific result, such as converting digital TV signals to an analog format. The capability to process and manipulate digital information makes DSPs a critical part of digital technology. Analog-to-digital and digital-to-analog signal converters are frequently added to DSPs as peripherals. As shown in Figure 1, this permits the processors to take analog signals, digitize them, manipulate them, and output them as analog signals.

**Fast multiplies**

The key to most signal processing is the quick multiplication of numbers. Multiplication is the critical part of the math used in the transforming algorithms that manipulate signals in DSPs, said Jim Turley, senior editor of Microprocessor Report.

DSPs, which currently run at speeds between 100 and 300 MHz, achieve fast multiplies because they execute most instructions and often execute multiple instructions in one clock cycle.

A DSP achieves such performance with special architectural characteristics, such as a single-cycle multiplier, a single-cycle arithmetic logic unit, separate buses for instructions and operands, and pipelining.

Currently, DSPs generally perform up to 300 million multiplies per second, according to Turley. He predicted that DSP speeds will increase to over one billion multiplies per second by 2000.

**Software-based functionality**

As is the case with microprocessors, DSPs use software instructions to perform their specialized tasks. DSPs are programmed primarily in C, C++, and assembly language.

**New World for DSPs**

DSPs have become increasingly popular because they can be used in many new ways. For example, in new voice-, gesture-, and handwriting-recognition systems, DSPs compress and decompress data as necessary for fast throughput. They also perform analysis functions and send output, all in real time.

Video games are more lifelike because DSPs manipulate in real time the huge amount of data necessary for lifelike sounds and images.

In cars, DSPs perform potentially life-saving real-time calculations for antilock brake systems.

**Programmability**

The increased demand for DSPs is also due to the technology’s ability to perform more tasks more effectively.
These capabilities are primarily provided by software. Thus, they can be designed, implemented, and changed more quickly and less expensively than would be the case if their functionality depended on hardware.

This should save DSP makers millions of dollars and many months in development time, said Robert Worden, a microprocessor analyst at Frost & Sullivan. The result is more flexibility to adapt to changing market needs, he said.

Lothar Koob, vice president of Siemens Medical Systems’ Ultrasound Group, noted that software-based applications for ultrasound equipment with embedded DSPs can be written, tested, and delivered 10 times faster than hardware applications.

The ability to program DSP functionality could also make it easier for product vendors to implement product upgrades. Some day, said Ad Huijser, director of Philips Electronics’ Philips Multimedia Center, vendors could download new software over the Internet to upgrade a DSP-based system, such as a set-top box, without the consumer even knowing.

In addition, a programmable multifunction DSP could replace multiple single-function chips in many products. This, along with other technology improvements that have reduced processor size, will make it easier to embed DSPs in increasingly smaller products.

DSP technology has proven so useful that is even sparking some convergence with microprocessor technology. For example, microprocessor manufacturers, such as Intel, are incorporating DSP technology in their products. Meanwhile, DSP makers, such as Texas Instruments, are making their products more useful by incorporating microprocessor technology, such as microcontroller functions, in their chips.

### Digital signal manipulation

DSPs can manipulate digital signals in a variety of ways. For example, Philips’ Huijser said, his company has developed stereo systems in which the processors manipulate digitized signals to produce high-quality stereo sound like that produced by analog systems.

The chips can also compress signals, which conserves bandwidth. This makes DSPs particularly valuable for wireless products, which have relatively low bandwidth.

Because they can compress and otherwise manipulate data, DSPs will also be valuable for various Internet-related products, including modems, and audio and video applications, said Nikil Jayant, director of Bell Labs’ Multimedia Communications Research Laboratory.

### Replacing system processors

DSPs can perform an increasing number of tasks currently performed by system processors. Using DSPs would thus reduce system processors’ workload.

In some cases, DSPs could perform their specialized tasks better than system processors. For example, DSPs could better compress and decompress data for Internet telephony, which would reduce transmission delays, said Gedas A. Sakus, Northern Telecom’s president of technology.

### THE FUTURE

As the demand for DSPs increases, companies that use the chips will want processors that can accomplish new functions more effectively.

### Needs

Siemens’ Kooib said faster DSPs would let ultrasound systems handle huge volumes of patient data and still produce real-time results, even with 3D viewing and image manipulation.

More power-efficient DSPs would be very useful for portable devices, which depend on batteries, said Michiharu Nakamura, director and general manager of Hitachi’s Central Research Library.

### Challenges

There are significant challenges to achieving these goals, said K.C. Murphy, Cadence Design Systems’ senior vice president for corporate strategy.

Perhaps, Murphy said, the biggest challenge is that, like other chip makers, DSP manufacturers must keep up with a growing demand for their products while increasing processor complexity and performance, minimizing size, lowering power consumption, and decreasing production time and product price.

One significant step the industry could take is to continue efforts to develop, integrate, and use standardized components, a growing trend in semiconductor design, he explained.

Many industry observers believe DSP vendors will overcome the obstacles and have a bright future. Tom Starnes, a principal analyst at Dataquest, a market research firm, said there will continue to be a need for dedicated DSPs because they will always perform many tasks better than general-purpose microprocessors.

This will be important, he said, because applications will continue to demand more performance than general-purpose microprocessors can provide.

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