Digital Signal Processing: Its Ever-Increasing Role in Communications

Digital signal processing (DSP) is an important part of modern communications systems, and its role is growing. The functions of DSP have grown from its first applications in audio processing and coding to full IF filtering, modulation/demodulation, encoding/decoding, and system control functions.

DSP also has seen increased use in amplifier linearization systems, in both "analog" feedforward and digital predistortion methods. The devices used have benefitted from the overall improvement in semiconductor processes, with smaller geometries for higher density and lower power consumption, plus higher speeds to handle inputs at higher frequencies.

Device manufacturers have played a dual role in moving DSP technology forward—first, by responding to industry requests for performance, and second, by exceeding the immediate needs, thus creating an enabling technology for future development. The new product story that follows this report is a good example of that role, showing how one company has focused on maximum speed/power performance for their latest line of analog-to-digital converters (ADCs).

The DSP Advantage

There are two main advantages of DSP over analog techniques. The first is precision, which brings with it a stability that is rarely achieved in precision analog circuitry. DSP uses mathematics, while analog circuits use continuous transfer functions. Although the math functions are usually truncated, they are well-defined and highly accurate, with unchanging response—until re-programmed, a further advantage of digital implementation of operating functions.

The other advantage is size and cost, which can be combined as a single factor, since they are related. One might even expand the term "size" to include the amount of power consumption, which is much lower in typical CMOS digital circuitry than in silicon, SiGe or GaAs RF circuitry. Cost factors include lower component count, less testing and adjustment, and the ability to make changes in firmware instead of re-designing equivalent analog circuitry.

Performance Factors

There are several key areas where wireless, high-speed wireline and optical communication systems have special requirements:

1. Analog-to-Digital Conversion

Translating an RF or detected optical signal into digital form is probably the greatest technical challenge for communications DSP. The ability to digitize a signal at higher frequencies can eliminate analog RF/IF circuitry. It is often half-jokingly said that the ultimate radio is an antenna and a DSP.

The signal must also be represented with adequate precision, or number of bits of resolution. Common digital modulation schemes require 10- or 12-bit resolution, but emerging technologies and some non-communications high-speed systems like medical imaging require 14- or 16-bit resolution.

2. General-Purpose vs. Custom Processors

All-purpose DSP devices are valuable for development, and in systems that require the greatest flexibility in adaptability (reprogramming), such as multi-standard radios.

Standard-specific DSPs are common for specific wireless phone standards, and applications including IEEE 802.11 WLAN, BlueTooth® that have well-defined operating protocols. Custom ICs implementing these standards make efficient use of die area and power consumption, while permitting other functions to be incorporated onto the chip—up to and including a complete radio.

3. Algorithm Development

We should include firmware development on the list of technical challenges. Individual functions may be clearly defined, but sequencing or combining functions is a creative exercise that can significantly increase the efficiency of the processing. This part of DSP development is especially important as the industry moves toward multi-standard radios and, ultimately, to software-defined radios (SDR).