Software-defined radio: The next wave in RF test instrumentation?

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Test equipment manufacturers are constantly challenged to develop new solutions for testing their customers' latest devices, but they've traditionally developed specialized hardware to meet this challenge. The communications market is still more challenging due to the rapid development of new standards, which often require new stimulus and measurement capabilities. To keep pace, test vendors must find new approaches that reduce instrument development times and allow instruments to adapt to new requirements. Software-defined radio is one technique that can help.

"Software-defined radio"(SDR) can be defined as a radio communication system that uses software to modulate and demodulate radio signals. Economics is the driving force behind the growing use of SDR. These systems can achieve high flexibility at a lower cost than traditional analog designs. Figure 1 illustrates an SDR system.

In the purest sense, digital-to-analog (D/A) and analog-to-digital (A/D) conversion would occur at the carrier frequency and no analog up- and down-conversion

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would be required. Today's SDR applications typically have at least one analog up- and down-conversion stage. Clearly, the A/D and D/A converters are key elements of an SDR system. The speed and resolution of the converters will determine how much analog frequency conversion is required. Converters need sufficient resolution (bits) to produce or capture the modulation data adequately, and more complex modulation formats will require converters with even greater resolution. The speed of the converters will limit the maximum signal frequency that can be created or sampled. Converter technology continues to advance, providing higher combinations of resolution and frequency.

Digital signal processing is another key element of SDR because it performs several functions traditionally performed with analog circuitry, including frequency conversion, modulation, demodulation, and filtering. Digital signal processing also allows better performance than analog designs by supporting functions such as waveform pre-distortion and decimation. Pre-distortion of transmitted waveforms takes into account the known non-linearity of the analog circuitry and modifies the baseband waveform to compensate for it, producing a better quality modulated signal.

Three basic approaches can be used to implement digital signal processing. The first approach is to do all the signal processing in software using generic computing resources, such as those provided in PCs. The second approach is to define a logic circuit to perform the signal processing, then program that circuit into a field programmable gate array (FPGA). The third approach is to use programmable hardware devices designed to implement the functions required for digital signal processing. These devices include digital signal processors (DSP) and digital up-conversion (DUC) and digital down-conversion (DDC) devices.

All three approaches can fulfill the primary objective of SDR: providing a highly flexible system. However, to control costs, the other primary objective of SDR, it’s important to consider both development and per-unit costs. The cost of the solutions will vary, influenced largely by the system’s real-time bandwidth requirements. Wider bandwidths will require more processing power, driving up costs. However, for a moderate level of performance, the FPGA approach will likely be the most expensive solution, while the DSP system will likely be the least expensive.

Frequency generation is a key element of any communications system. Direct digital synthesis (DDS) is a technique for using a D/A converter to create sinewaves at very precise frequencies. Direct digital synthesis allows for very fast frequency switching at a low cost. Advancements in semiconductor technology have led to rapid progress in DDS technology as well. Today’s DDS devices can produce sinewaves with frequencies of several hundred megahertz with microhertz frequency resolution.

SDR approaches are increasingly popular for applications that demand economical flexibility, such as military communications systems and multi-function cellular base stations. These applications tend to share the following characteristics:

&#149Moderate to high flexibility requirements
&#149Low to moderate volumes
&#149Moderate to high complexity

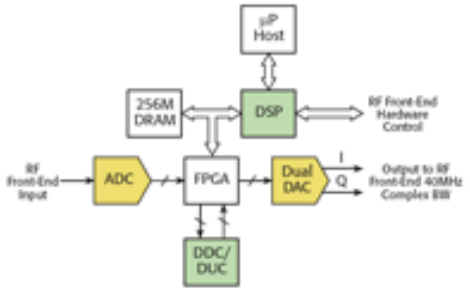
Test instrumentation shares many characteristics with the other applications that employ SDR techniques. Test instrumentation tends to be very complex because of the level of performance required to measure leading-edge systems with a reasonable margin. Test instrument volumes can be considered low to medium when compared with high volume items like cell phones or base stations. Flexibility continues to be an important characteristic in test instrumentation, especially in the area of communications.

The key technical and economic requirements in test instrumentation related to communications include wide modulation and demodulation bandwidth, wide dynamic range, and fast throughput.

Digital communication systems have changed rapidly in recent years, particularly in the area of modulation formats. New standards mean that test instruments like

signal sources must be able to generate new modulation waveforms and signal analyzers must be able to demodulate and analyze them. Key performance parameters tend to vary from standard to standard, so new analysis routines are often required.

These changes have created a demand for test instruments that can be upgraded quickly and easily to add new modulation standards rather than forcing their owners to replace them. While



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upgradeability is obviously desirable from a cost standpoint, it’s equally desirable from a time-to-market perspective. Communication system and device manufacturers can’t afford to wait for the next generation of test equipment to be developed. Communications standards also change frequently during development, which can require modifications to signal generation and analysis routines.

These requirements make SDR a very desirable approach for test instrumentation. The same cost and performance tradeoffs that apply to generic SDR applications apply to test instruments. The first SDR test instruments used either the software processing or the FPGA approach. Advances in digital signal processing devices like DSPs and DDC/DUCs provide the power to make that approach viable for test instruments. This approach can provide the best balance of cost and performance for test equipment.

Test instruments employing SDR techniques offer advantages to both equipment manufacturers and their customers:

&#149**Easy upgradeability to new communication standards.** Signal generation and analysis are largely performed by routines programmed into the digital signal processor. When new standards emerge, it’s easy to create new DSP programs for the new functions and distribute them to the owners of existing instruments via firmware upgrades.

&#149**Improved throughput due to faster frequency switching and signal analysis.** Wide bandwidth A/D converters and fast DSP devices can process large FFTs very efficiently. For example, a DSP-based analyzer can provide measurement times several orders of magnitude faster than traditional spectrum analyzers, under conditions of wide spans and narrow resolution bandwidths. Direct digital synthesis provides significantly faster frequency switching than traditional approaches allow. Fast frequency switching will improve the throughput of both signal generators and

signal analyzers.

&#149**Faster time to market for test instruments.** Test equipment manufacturers can leverage the capability of leading-edge, commercially available signal processing devices and achieve instrument-level performance from them. This reduces the amount of development required for test instruments dramatically. Also, the basic digital design can be shared across a range of instruments, further reducing development costs. For example, Figure 2 shows the digital architecture used in Keithley Instruments' Model 2810 Vector Signal Analyzer and Model 2910 Vector Signal Generator. Both instruments share the same digital processing design.

Communication standards are likely to continue evolving. At the same time, test cost pressures from communication system and device manufacturers will keep forcing test equipment vendors to provide cost-effective instruments that offer continuing performance value. Together, SDR techniques and high end signal processing devices provide test equipment manufacturers with invaluable tools to meet these requirements.

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