Future military test systems hinge on synthetic instrument development

The DoD's next-generation automatic test system, NxTest, will rely on synthetic instrumentation for lower cost, more flexible, interoperable test gear that spans the requirements of all military services.

By Gene Heftman, Contributing Editor

Ten years ago, the Department of Defense (DoD) authorized the Navy to begin developing new types of automatic test systems (ATS) to test military and avionics weapons systems at all levels of maintenance from the front lines to the factory. Up to that time—and even now—each service (Navy, Army, Marine Corps, Air Force) used individualized ATS dedicated to its own equipment needs and organizational requirements. Most military test equipment is specialized and only experienced technicians can operate some. In addition, there is little standardization of instruments, interfaces and software among DoD testers. Such a structure does not permit interoperability of ATS among services and is expensive to operate and support. To overcome these drawbacks, three main goals were assigned to the Navy for future ATS: 1) reduce the total cost of ownership of DoD ATS; 2) provide greater flexibility to the military through joint services interoperable ATS; and 3) reduce the logistics footprint (i.e., fewer spares, support systems and training, and greater interoperability).

To achieve these goals, a few years ago the Navy instituted the next-generation automatic test systems program called NxTest for short. One of the key elements of NxTest is for the Navy to work closely with instrument makers and defense contractors to take advantage of advances in commercial test technologies to develop an architectural framework that will enable ATS interoperability across the services. The advance that will have the greatest impact on NxTest is synthetic instrumentation (SI). An SI system uses a common set of modular, reusable

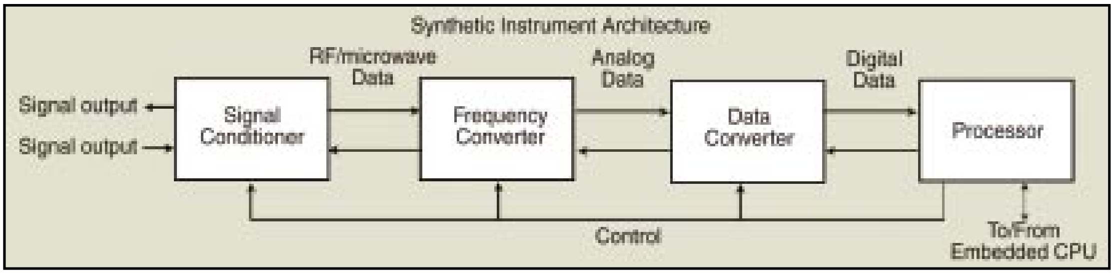

Figure 1. Synthetic instrument test system architecture is based on a combination of hardware blocks (shown here) and software to replace conventional test instruments used in most ATE systems.

Figure 2. A prototype synthetic instrument system developed by Agilent Technologies incorporates various SI modules that emulate the stimulus and measurements functions of conventional test equipment.

Figure 3. This SI combination of a Phase Matrix downconverter and local oscillator provides a modular microwave front-end based on the VXI bus architecture for ATE systems.

hardware components together with software building blocks to perform test functions on electronic circuits or systems. These blocks emulate a traditional piece of test equipment. SI synthesizes the stimulus and measurement functions through a set of core hardware components and software that performs specific stimulus and measurement operations. The idea behind SI is to eliminate individual box or card-based dedicated instruments in ATE systems.

An SI-based ATE system (Figure 1) offers considerable advantages over a conventional so-called rack-and-stack test system that is the basis of today's testing methodology. A rack-and-stack system uses a combination of benchtop instruments and instrument-specific modules interconnected through cables and connectors to the device to be tested. Application-specific software commands the functional capabilities embedded in the instruments to apply the appropriate stimulus and make the required measurements. SI, on the other hand, is optimized for computer control and does not require the operator to have physical interfaces such as knobs and buttons. An operator interacts with an SI system through a graphical user interface (GUI) that is software defined. The GUI simulates the SI or its individual components through software.

An often-used analogy is to compare an SI system to a software-defined radio (SDR) communications device. An SDR consists of a digital signal processor (DSP) engine, a generic digital-to-RF transmit circuit, a generic RF-to-digital receive circuit and an antenna. The transmit and receive circuits convert digital data to and from modulated radio signals, while the DSP handles most of the radio functions. The functionality of the SDR is programmed into the DSP through software algorithms that define the communications and processing functions. If the SDR is to perform in a manner different from its original purpose, only the software need be changed. This eliminates the need to design new hardware every time a new communications application or protocol for the radio comes on the scene. Thus, the software is application specific but the hardware is generic. The same principle applies to an SI test system. A common set of hardware can be rearranged or partitioned as needed to perform specific test functions, but it is not necessary to change it each time a new circuit or system must be tested. The software, however, is modified as necessary to perform the required testing.

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SI architecture

An SI system contains so-called core hardware that synthesizes the input and output signals that are fed to and received from the device under test (DUT). These hardware elements are signal conditioning blocks, frequency upconverters and downconverters, analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). To convert an RF signal to a digital signal, the RF passes through a downconverter and an ADC before going to the host processor or DSP. To convert a digital output from the processor to an RF signal, the digital signal passes through a DAC and an upconverter and back to the DUT.

The important components are the frequency converters and the ADCs and DACs. The downconverter is a critical element since it does the frequency translation and filtering functions and must faithfully reproduce the target baseband signal that is modulated onto the microwave carrier. Any conversion loss, filtering or phase errors will corrupt the downconverted intermediate frequency (IF) signal that is being digitized by the ADC and sent to the processor. The ADCs and DACs are also critical since they must have adequate bandwidth and distortion-free dynamic range.

The core hardware elements are found in many conventional test instruments and a high-performance set of such elements can replace conventional instruments such as a spectrum analyzer, oscilloscope, network analyzers and others. This is important for the next generation of military ATS for a number of reasons. First, there is a significant ATS size reduction using modularized core hardware in place of physical measurement instruments. Second, the same core hardware could be used in a variety of test systems, eliminating redundant hardware and software and reducing acquisition costs.

Common module definition should promote competition among commercial suppliers, further reducing acquisition costs. A common set of modules could provide forward and backward compatibility enhancing the longevity of military ATS. For the military this is a key goal since military systems can remain operational for 20 years or more. Obsolescence is a major concern because test software is written around instrument-specific hardware that can become obsolete. A common set of core hardware applied across all the military services would eliminate this problem.

Future SI directions

At present, SI-based NxTest is a work in progress with many details covering the architecture, busing and other aspects of the program still in the planning stage. Yet, a few architectural models are beginning to emerge. According to Mike Granieri, vice president of business development for Phase Matrix Inc., three classes of SI are possible for future ATS configurations. "All are very similar," said Granieri, "differing only in terms of implementation; they are generic SI, COTS SI and military application-specific SI."

In generic SI, also called loosely coupled SI, a company does its own signal conditioning design and uses a commercial downconverter such as the type manufactured by Phase Matrix, then selects ADCs and DACs based on its requirements. The test system uses COTS components selected from instrumentation manufacturers and internally designs the hardware and software interfacing that binds everything together. In a COTS SI test architecture, a company does less internal design and relies more on purchasing complete integrated systems such as a downconverter, signal analyzers and other instrumentation modules from third-party manufacturers. Military application-specific SI is aimed directly at the DoD's desire to procure generalized, small ATS that can operate at all levels of military repair facilities—depot, intermediate and organizational—without becoming obsolete over time. An example of such a system is the Agile Rapid Global Combat Support (ARGCS) system, which is part of the FY04 Advanced Concept Demonstration Project intended to develop a single tester incorporating all of the commercial test technologies now becoming available. An ARGCS integrator contract was awarded by the DoD to the Northrup Grumman Corporation in September of this year.

Commercial instrument makers are ramping up their capability to produce SI systems that could be the forerunners of the type of ATE the DoD is looking for in its NxTest program. At this year's Autotestcon show, Agilent Technologies Inc. demonstrated a prototype COTS microwave SI package designed to meet the DoD's requirements for flexible, modular instrumentation (Figure 2). All modules in the test set are SI versions of physical instruments in the company's product line. Included are a 20 GHz upconverter with greater than 1 GHz modulation bandwidth, a 20 MS/s digitizer, a 26.5 GHz cross-point matrix with switching bandwidth up to 50 GHz, and application software based on the company's 89600 series vector signal analyzers.

Another company demonstrating SI ATE at Autotestcon is Aeroflex Inc., which said Marvin Rozner, Jr., product manager for synthetic instruments, "Developed a new synthetic platform that takes all of the things we've been doing for the last seven years and makes it much more modular than it used to be." The company showed a full SI RF/Microwave subsystem, operating from dc to 26.5 GHz, wideband 400 MHz instantaneous RF bandwidth, up to 600 MHz instantaneous bandwidth on baseband, full S-parameter capability, and built-in calibration for the entire subsystem. The subsystem can emulate a microwave signal source up to 26.5 GHz and provides synthetic measurement functions such as a spectrum analyzer, power meter, network analyzer and noise-figure meter.

In a generic or COTS SI implementation, users can combine stimulus or measurement modules to obtain the desired functionality for the system. For example, a Phase Matrix 1313B downconverter and 20309 local oscillator can translate microwave frequencies to RF, and together with a digitizer, perform the functions of a number of different stand-alone test instruments (Figure 3). These SI modules are the front-end building blocks for various types of signal analysis—wideband, narrowband, fast acquisition—and fit the NxTest requirements for small size, interoperable, reduced cost ATE systems.

An SI type ATE system of the application-specific variety currently in use by the Air Force is the Improved Avionics Intermediate Shop (IAIS) manufactured by BAE Systems.

It is a mobile avionics tester capable of maintaining all types of complex avionics such as computers, radars, flight controls, fire controls and other flight hardware, and is now being offered in a commercial version. IAIS is modular and allows customization and reconfigurability to address specific specifications. It makes parametric and functional tests and can operate on a Pentium-processor-based computer running a Windows NT operating system.

Defining the SI bus

A top priority for instrument manufacturers and NxTest officials alike is to define a standard bus architecture for SI-based ATE systems. To tackle this task, a Joint DoD/Industry Working Group has been set up with government and instrumentation companies seeking to define an open standard usable by all manufacturers. As John Stratton, aerospace/defense program manager of Agilent Technologies System Products Operation and a co-chair of the Working Group put it, “The main goal is to define the I/O between the modules, both the hardware and software blocks. We have to have some kind of standard to allow the military to mix and match components in the system without doing a lot of work.”

Most test equipment has been designed to work with the VME/VXI (VME Extensions for Instrumentation) architecture, a well-defined backplane and communications bus that has a long history of use. But advances in computer technology have forced most equipment makers to move away from VXI to first the Peripheral Component Interconnect (PCI), and later to the compact PCI (cPCI), which has led to the instrumentation version, PXI (PCI Extensions for Instrumentation). While PXI has enjoyed considerable success the past few years in replacing VXI, instrument makers have concerns whether it will be capable of supporting the high speeds necessary to perform measurements at RF and microwave frequencies that will be required in many NxTest applications.

Agilent Technologies is proposing a replacement bus for the next generation of modular SI test systems based on local-area network (LAN) technology. Called LXI for LAN Extensions for Instrumentation, it promises to be more suitable for the high-performance (RF/microwave) test applications for NxTest because it is based on high-speed Ethernet technology. A group known as the LXI Consortium has been set up among instrument manufacturers to further develop and promote this bus as an open standard, not only for NxTest, but for all future SI-based test systems, both military and commercial. In addition to being able to operate at Ethernet speeds—10 Gb/s—LXI is relatively easy to implement in personal computers and instruments since it has a long history in the computer industry. Other benefits are relatively low implementation cost and the smaller size of proposed LXI instrument modules compared to their VXI/PXI counterparts. The small size will eliminate any need to reconfigure or expand existing card cages to accept LXI modules, and in fact, will result in size reduction. LXI could become the high-speed I/O bus needed to make the measurements on present and future military systems, and prevent any obsolescence issues well into the future. DE

ABOUT THE AUTHOR

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