

Smart Instruments Keep Up With Changing R&D Needs

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New classes of "smart" instruments are helping researchers on the leading edge of technology to reduce their cost of test while accelerating product development.

SEMICONDUCTOR and passive component industries are continuously pushing their development processes to higher levels of integration and complexity to keep pace with consumer electronic needs. As the complexity of electronic devices grows, and new materials are required, the amount and sophistication of testing increases. Researchers and development engineers are faced with increasing pin counts on new electronic devices, and a wider array of materials that must be evaluated for possible use in these devices. In both cases, more measurement channels are needed in test systems to maintain acceptable throughput and lower costs. (Figure 1).

All this takes place in a very dynamic environment. As soon as a new design goes into production, the development process starts

over again with new materials, designs, and different test requirements. Design cycles keep getting shorter and shorter. Furthermore, in basic research the hot study topics with available funding are always changing. Therefore, test hardware and software should be adaptable to the changing needs of this

environment. Otherwise, new test system may be needed, causing capital investment and the cost of test (COT) to escalate.

Good instrument design can help reduce test cycle time and COT, but that is only part of the story. Reducing COT in R&D also requires the testing of more devices simultaneously, using less bench space, and re-using test equipment more efficiently.

Test System Design

Managing system design to lower these costs requires efficient instrument integration, test techniques, and test routine development. The way individual instruments interact with a PC controller has a major impact on the efficiency of system design and operation – and ultimately on COT.

Factors to consider in designing automated test systems include:

Multiple Channels – Multichannel test systems with parallel test capability offer significant throughput advantages by allowing simultaneous testing of multiple materials, or different sections of a complex device. Still, systems need to be scalable for effective management of capital investment costs.

Software Development – Depending on the instruments and other test equipment, developing test routines and a test executive to run them can be a major cost element. Instruments supplied with software that reduces programming time, or eliminates it altogether, have a major impact on lowering COT. For example, some instrument manufacturers supply interactive software that allows user to quickly configure the system,

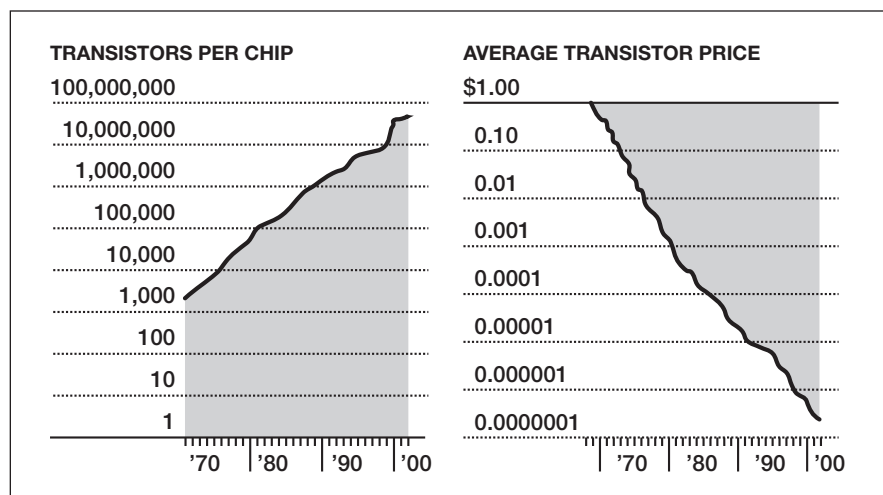


Figure 1. New electronic devices are more complex, have higher pin counts, and are pushing the limits of test system technology.

run tests, generate I-V curves, and analyze data without writing a single line of programming code.

Modular Instrument Architecture – The pace of new component and material development makes it impractical, if not impossible, to design special systems for every new test requirement. Flexible, scalable, and reconfigurable systems are needed to test multiple device types and to handle new materials with minimal system redesign. A modular instrument architecture makes it possible to build a multi-channel system one day, and few days later separate multiple instruments for use in different labs. Commercial test equipment with such flexibility eliminates the need for custom designed turnkey systems, and maximizes equipment reuse.

Test Sequencer and Memory – Instruments with a built-in sequencer and memory to run test routines with minimal PC control can improve throughput significantly. This type of design cuts down on data communications between the instruments and a test system controller, and frees up the PC for other functions. Modern test sequencer instruments can store customized test routines with hundreds of steps that call up built-in functions such as a pulse generator, arbitrary waveform generator, I-V sweeps, and associated measurements for device-specific tests. However, making this work properly can be problematic when it entails multiple channels across multiple instruments. Some instrument designs make it much easier than others.

System Size – Higher pin counts and greater test complexity demand more measurement channels. This tends to increase the space needed for a bench or floor mounted rack system, which has cost implications. Higher density instruments make it possible to pack more source and measurement channels into the limited space allocated to a test lab.

Until recently, few solutions were optimized for multichannel source-measure applications. Test engineers were often forced to choose between:

1. Relatively simple, but slow instrument-based systems using PC control.
2. Faster, but complex instrument-based systems using custom trigger, digital I/O, and communication controllers.
3. Highly integrated and speedy mainframe systems that were neither cost-effective nor space-efficient.

Today, “smart” source-measure units (SMUs) offer a fourth alternative that combines a built-in test sequencer with the scalability and flexibility of rack-and-stack instruments, providing the integration and high throughput of mainframe-based systems. They can handle multiple channels easily and provide high-speed, nonstop testing in R&D and production environments.

Flexible Multi-function Designs

Smart, single-box SMUs are available that combine a power supply, DMM, and precision bias source, along with a low frequency pulse generator and arbitrary waveform generator. This simplifies testing and reduces costs by allowing a single instrument to be used in many different ways. These smart instruments also have an on-board processor and bundled software so they can perform many test functions without having to communicate with a remote controller via a GPIB (*Figure 2*). In addition, they have a simple programming interface that allows users to quickly develop high-speed, multichan-

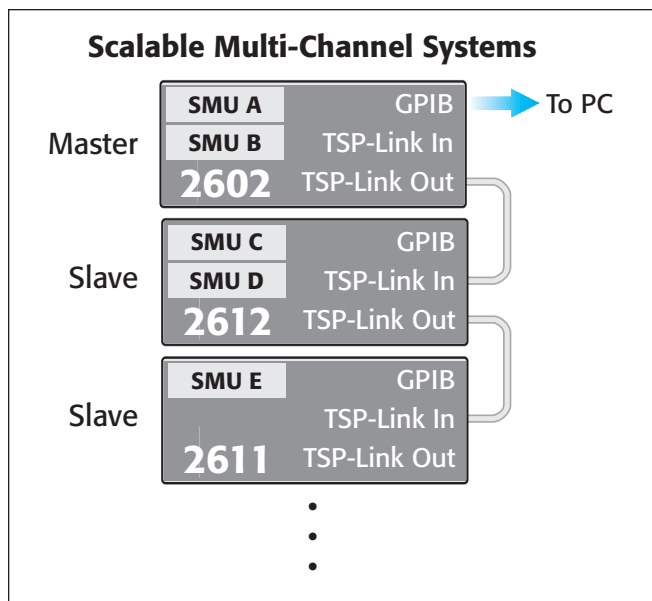


Figure 2. “Smart” SMUs can stand alone as a complete measurement and automation solution, with the master unit controlling source, measure, test sequencing, and pass/fail decisions. Their high-speed interface links multiple instruments in a master/slave configuration, and all instruments in a system can be programmed and operated under the control of the master unit, as if they were all housed in the same chassis.

nel test sequences without writing a lot of test routine code.

Because these instruments have no mainframe restrictions, users can typically create integrated test systems with up to 64 nodes, which can be scaled up to 128 SMU channels. These features support the development of optimized systems at significantly lower cost per channel and overall smaller capital investment.

Communications between test equipment and the system controller can be a significant throughput bottleneck. To avoid consuming valuable test time, command and data transfers are commonly done while a prober or handler performs mechanical operations. However, this arrangement is less viable as test systems grow increasingly more complex and require more controller/instrument interaction. The processor and software embedded in smart SMUs allow entire test programs to be downloaded into one instrument in the system, which then controls its own operation and that of the other instruments via a high-speed interface.

Programs can be downloaded into either the volatile or nonvolatile memory of one “master” unit. That unit controls its own operation and that of all its “slave” units as though they were a single instrument. This capability frees the system controller to interface with other instruments more frequently, increasing overall system throughput. Further, modern SMUs have significant amounts of memory, which also reduces how often the host controller needs to interact with them.

In *Figure 2*, master and slave units are connected via a combined high speed, serial communication bus and hardware trigger lines (TSP-Link) that form an inter-instrument real-time control and data exchange interface. This peer-to-peer interface provides communications only between instruments, and does not require communications between the instruments and a host computer. It operates with a simpler message exchange protocol and much lower overhead than

conventional interfaces, resulting in speeds approximately ten times faster than those of the GPIB.

Lowering R&D Test Costs

SMUs with built-in programming capability lower tests costs by reducing test and development times. They also save bench and rack space by requiring fewer individual instruments and by occupying a smaller footprint.

Shorter Test Times – After devices or samples are loaded into a test fixture, several time intervals account for the bulk of total test cycle time:

- Sourcing, settling, and measurement times
- Range change times for source-measure instrumentation
- Trigger delay between separate instruments or between a PC controller and the instruments
- Data communication times for test commands, digital I/O, triggers, and moving collected data to storage or PC memory
- Program execution time needed to compare measurements with acceptable limits or other measurements, and then exercise pass/fail or other logic functions

Complex testing may require the application of multiple source signals and response measurements for each DUT. Therefore, the first way to improve test time is to switch from individual instruments to integrated SMUs. This cuts trigger delay and data communication times. With internal program memory, data communication time and test program latencies drop further because the SMU can run the test sequences.

The latest SMU designs have program memory large enough to run hundreds of predefined tests, make limit comparisons, perform conditional test program branching, and work with or without a PC controller during test execution. There is no question that these SMUs can significantly improve test times for single-channel systems.

Reducing test time is more complicated in systems employing multiple SMUs because of the difficulty in managing multiple triggers and the test sequencer. As a result, some SMUs intended for multiple instrument systems may have a test sequencer that simply stores multiple GPIB commands, which can be executed with a single SCPI call from the

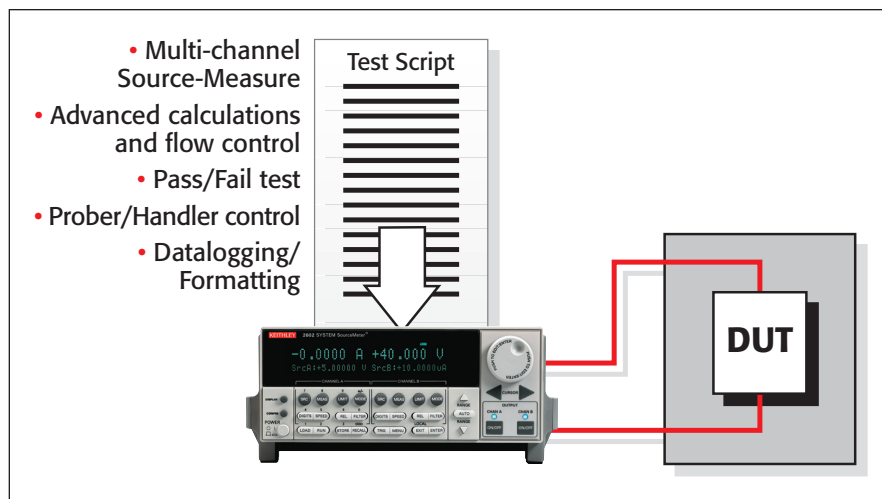


Figure 3. The on-board processor in modern SMUs can process and run complex test sequences right from the instrument. Test scripts provide up to 10X greater throughput than using PC control. Custom measurement functions can be created for nearly any component or material sample. Built-in programs may include algorithm-based tests like I-V sweeps with power compliance, linearity and latch-up test sequences, and thermal response tests.

PC controller. However, this arrangement does not provide the logic needed to perform efficient limit testing and make pass/fail decisions. It also involves a great deal of GPIB traffic on the data communications bus. In addition, these SMUs may not be as effective as they should be in multiple channel testing, because they access channels sequentially, instead of in parallel. Therefore, throughput improvement is marginal.

The fastest SMUs combine a test sequencer with an on-board script processor (**Figure 3**) and high-speed control bus that allows master-slave operation of multiple SMUs in a true parallel channel arrangement. This results in a multiple SMU system with throughput gains much higher than those of single-channel sequencers. In some cases, multiple SMUs connected with a control bus can be used as if they are part of the same physical unit for simultaneous multichannel testing, compared to sequentially accessing multiple SMU channels.

Shorter Development Time – Software development has always been a major portion of total system cost, especially in complex test systems, and those based on mainframe designs. The software structure in smart SMUs provides a much simpler programming interface for test sequencing across multiple SMUs and channels, which can now be treated as if they were all part of a single entity. This shortens program development time significantly.

Besides their relatively low cost, script-

based SMU systems are highly flexible. They can be integrated seamlessly into a scalable “mainframeless” system with the high throughput of a multichannel, card-based system. These systems can be easily customized for different applications, and evolve as test requirements change. Users can standardize on one or two SMU models and reconfigure them by simply changing test scripts.

Creating and changing the test scripts is also easy with the embedded software tools that come with smart SMUs. For example, Keithley’s LabTracer™ software (supplied with its 2600 Series SMUs) allows quick, no-programming instrument start-up for I-V characterization and curve tracing. Multiple SMUs can be configured and controlled with a single keystroke for fast device parameter tests and data plots. For high-speed production applications, the Keithley Test Script Builder™ uses an uncomplicated command language similar to BASIC to create and modify customized code for an SMU’s test script processor. The 2600 Series also have a built-in suite of pre-written programs that can be quickly modified for specific applications. Studies have shown that by using these instruments and their associated software, users can cut system development time by 50% to 75% compared to previous generations of test sequencing instruments.

Reduced Footprint – Newer SMUs are available in 2U half-rack designs that substantially improve rack density. Systems ca-

pable of handling 128 channels are possible—sufficient for many high pin count devices. Moreover, scalable and easily integrated rack-and-stack test system designs are now possible. Rack-and-stack systems eliminate mainframe overhead, reducing the cost of test system hardware. They also occupy a smaller footprint, which generally equates to lower ownership cost in space-strapped facilities.

Conclusion

Modern source-measure units, capable of sourcing either voltage or current and simultaneously measuring voltage and current provide a convenient “one box” package for testing multipin electronic devices, and for the simultaneous testing of multiple samples. They provide significantly higher throughput than conventional set-ups, including mainframe systems with test sequencing capabilities. They can be used to build flexible test platforms that dramatically reduce test time and cost, and can be reconfigured easily to meet changing test needs. KEITHLEY

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Taking Advantage of SMU Test Sequencing

In switching from individual source-measure instruments to SMUs, the most dramatic gain in throughput comes from a change in system programming. Instead of using PC-based control, the SMU's test sequencer and program memory are allowed to control the testing. This takes advantage of a wide range of SMU features and functions, such as four-quadrant operation, voltage and current sweeping, built-in waveform generation, deep program memory, picoamp sensitivity, 5½-digit resolution, measurement comparator for fast pass/fail testing, and digital I/O for control of other equipment.

All this functionality is included in the Keithley 2600 Series, making their test sequencer extremely powerful. Users can do more with one instrument, and their hardware/software integration tasks are greatly simplified. They can create cost-effective,

scalable, high throughput solutions for precision DC, pulse, and low frequency AC source-measure testing.

Series 2600 instruments provide two to four times the test speed of competitive solutions in I-V functional test applications. They also offer higher source-measure channel density and a significantly lower cost of ownership. Analog-to-digital converters provide simultaneous I and V measurements in less than 100µs (10,000 readings/s), and source-measure sweep speeds of less than 200 µs per point (5,500 points/s). This high speed source-measure capability, plus advanced automation features and time-saving software tools make Series 2600 SourceMeter instruments particularly well suited to I-V testing of a wide range of devices.

Series 2600 instruments can be interconnected with their TSP-Link, a high speed system expansion interface that allows a master/slave configuration. Once

connected, all instruments in a system can be programmed and operated under the control of the master unit, as if they were housed in the same chassis. TSP-Link provides unlimited flexibility to scale a test system's channel count up or down as the application requires.

Series 2600-based systems can run high speed, embedded test scripts on the master unit's Test Script Processor (TSP). The test sequence is processed and run on the embedded computer in the instrument, rather than from an external controller, eliminating delays due to GPIB traffic congestion. TSP test scripts allow throughput gains of up to 10× over equivalent PC-based programs operating via GPIB. A single TSP test script can control all the SourceMeter channels in the system and acquire data from any instrument connected to the TSP-Link, which supports connections for up to 64 Series 2600 instruments. KEITHLEY

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