



Configuring Functional ATE Systems

Introduction

Many years ago, when a company's product was in the manufacturing cycle and needed to be tested, it was common for product verification to be performed manually by test technicians or operators. Test procedures detailed required test equipment necessary for running the test. It was not unusual to visit a factory test floor and find storage lockers or racks full of multimeters, oscilloscopes, custom load boxes, power supplies and test leads that were used during verification. Manual test introduces the element of human error, and increases the chances of false failures or worse yet, passing faulty product. The introduction of the general purpose instrumentation bus (GPIB) as an industry standard a few decades ago, allowed test designers to implement the automation of product verification, thus increasing confidence in test and also greatly improving product throughput.

Automated test is a catchall phrase which really indicates that at least some part of the test procedure is controlled by a CPU. There are now a host of different automated instrumentation platforms at the disposal of a systems designer in addition to GPIB, including VXI, VME, ISA/PCI/Compact PCI and Ethernet-based communications. VXI, VME and Compact PCI are chassis-based subsystems. In these systems, instrumentation functionality is designed on a modular card that plugs into an industry standard chassis. Communication to the devices takes place across a backplane built into the chassis and extended to a PC bus via a single cable. It is not uncommon to see a test system comprised of more than one platform. Software is written that allows the host controller to send commands to instruments and receive responses back across the instrumentation bus without operator intervention.

Developing Your ATE System

The first step in developing a test procedure and defining instrumentation requirements is obtaining a thorough understanding of the product(s) and the specifications to which they must be tested.

A generic list of required instrumentation can be compiled by going through each paragraph of the specification. However, there are still many questions that need to be answered before compiling a 'wish list' of specific instrumentation.

What is my budget?

First and foremost, budget needs to be considered. A smaller than expected budget could mean that you need to revisit and refine your test specifications, possibly eliminating tests that might require high-end equipment that pushes you over budget.

Is throughput a concern?

If you are designing a system that will be part of the production cycle, there may be a requirement to test a minimum amount of product per day in order to keep up with the output of manufacturing. If this is the case, the VXIbus platform offers an attractive option, because it supports superior data transfer rates versus rack and stack and proprietary systems. With the release of VXI 3.0, transfer rates of up to 160 MB/s can be theoretically achieved with products designed to that specification. This allows your system to process more commands in a shorter period of time and overall test time can be dramatically reduced.

Is floor space limited?

Your facility may have limited space available for an ATS, and may have to adhere to size requirements in addition to performance specs. Standard PC's can be configured for small test applications, and the VXIbus offers chassis small enough to fit on a desktop. Additionally, instrument-on-a-card platforms, require less footprint than traditional rack and stack devices.



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Does the application require portability?

Your ATS may be required to be transportable in the field. In this case, a smaller size is a definite advantage, as is durability. For data acquisition, there are a number of notebook-sized signal conditioning cards that communicate directly to a laptop. For test and measurement, high-density instruments on the VXI platform such as the VMIP™ can also be controlled by a laptop. Small VXIbus chassis typically come with a handle for portability and weigh around 20 lbs.

Are there environmental concerns?

Extremes in temperature and humidity can become a major disruption to the test process. Instrumentation is usually specified by the vendor to meet prescribed accuracies at nominal temperatures and humidity. If testing is to be performed in a very hot environment, it is critical to ensure some form of cooling method, otherwise, the test equipment might not meet the stated specs and false failures could result. Additionally, shock and vibration specs might be necessary for portable applications. Vendors should be able to provide this environmental data.

What is the mix and volume of products to be tested?

If a number of different types of products need to be supported by the same tester, or there is a large volume of product to be tested, then the interconnect from the UUT to the instrumentation I/O must be carefully constructed to minimize test set down time due to faulty connections. This includes broken pins on instrumentation, broken cabling, etc. You may want to consider an efficient method for mass interconnecting such as MacPanel or Virginia Panel interconnect assemblies.

Can you make use of signal switching?

Signal switching is typically the heart of every ATE as it is responsible for routing test assets to product

I/O. Multiplexers or switch matrices may allow you to limit the number of dedicated test resources you need to purchase, which in turn reduces the overall cost of the system. The VXIbus has proven to be the defacto standard for switching applications because of the incredible densities that can be achieved as well as the ability to handle low-level or high-voltage and current requirements

Will the system need to be expandable?

Accounting for expandability for future growth is critical, particularly when floor space is limited. If the ATE rack is fully loaded, new requirements may necessitate adding another rack which might be difficult in tight spaces. It is always a good idea to allow for future growth in the initial system layout. If a VXI-based subsystem is utilized, it is recommended to leave a couple of slots open (unpopulated) for a seamless expansion path.

How soon do you need to be up and running?

And also, how much test expertise is in house? If there is a very aggressive schedule and manpower is scarce, there are many ATE system providers available who can build to print or provide a turnkey system including all test software. Documenting the system is also an unwanted burden and ATE system providers have years of experience in providing fully documented test stands utilizing VXI products.

What software platform do you plan on using for test development?

Typically this is answered by what expertise is in house. However, there are a number of languages (such as CVI, LabVIEW or VEE) that are tailored toward the test development environment. The graphical languages (LabVIEW or VEE) will require some level of training and months of working knowledge before developing the proficiency required for completing even middle-of-the-road applications. Additionally, VXI products are provided with VXI *plug&play* drivers that provide an API that can be implemented in other popular languages such as Visual C++ and Visual Basic.

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Selecting a PC/Host Controller

The brain of any test stand is the CPU since it manages all aspects of test execution and data processing. The only real question here is whether to take that 'brain' and embed it in a chassis, or employ a standalone or desktop unit. Table 1. can be used to assess whether an embedded or standalone processor is a better fit for your application.

In general, for most functional test applications, cost is usually somewhat of a factor, as are maintenance and sparing, while portability is not as critical. Therefore, unless there are some unusual circumstances dictating otherwise, a traditional PC is a more logical approach.

Software Development Platform

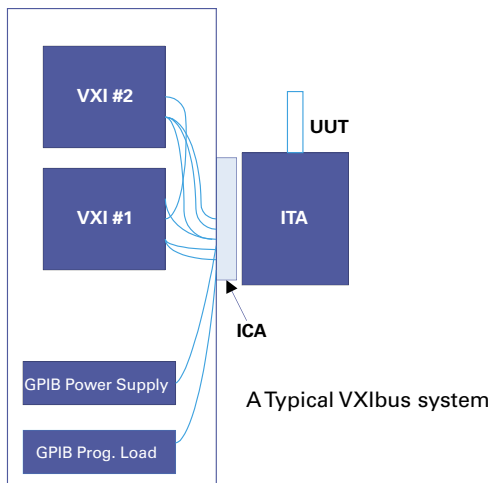
Software is typically developed in either text-based languages such as C/Visual C++ or Visual Basic, or graphical languages such as HP VEE or National

Instruments LabVIEW. Experienced instrument vendors will develop a software driver set that allows their devices to work in any software environment. Instrument drivers take the form of a library (like a Windows .dll) that programmers can link to and call instrument specific functions. Most VXI vendors will supply VXI *plug&play* drivers with their product. A VXI *plug&play* driver includes a virtual instrument soft front panel for direct control of a device, a collection of functions in a compiled .dll for program use, and a help file that quickly brings programmers up to speed on device capabilities.

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Table 1

Factor	Impact
Cost	Embedded processors can be 3-5x the cost of traditional PC's.
Portability	If a system will be moved around the field quite a bit, a laptop or embedded processor might make sense.
Footprint	An embedded processor will occupy a couple of slots of a chassis, but no additional floor space.
Speed	'Real-time' applications often require embedded processing capabilities. High throughput functional test applications can usually be accommodated via external processors with high-speed interfaces (e.g. MXI-2).
Maintenance	Software downloads and repairs are much simpler on desktop PC's. Many embedded processor units do not offer built-in CD-ROM drives. Must send embedded units back to factory for repair.
Sparing	Traditional PC's are abundant and largely interchangeable.
Upgrading	Processor speeds improve every six months and the cost differences favor traditional PC's.



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Two major software development efforts for ATE include a test executive and the test program sets. ATPs is developed for each type of product being tested. The TPS may contain the sequencing of steps necessary for running the test from start to finish, as well as making pass/fail determination and logging data. However, if multiple product types are to be tested on the same stand, the sequence management, pass/fail determination and data logging would need to be duplicated for each test program. This is where a test executive fits in. The test executive manages all generic operations, while each TPS will contain product specific code. A well written test executive can also be beneficial during product troubleshooting by allowing easy access to breakpoints, looping etc. A test executive should be viewed as an asset that is developed once, and all test program sets are modules that are called by the executive. IVI drivers (interchangeable virtual instruments) have emerged as the next level of drivers within the software community. This is a natural extension of the existing plug and play drivers. IVI drivers rely on instrument class specifications that are common within a particular type of instrumentation (e.g., multimeters). The biggest benefit of writing code using an IVI layer is that the code becomes vendor independent - you no longer need to worry about obsolescence. Additionally, IVI drivers offer performance benefits such as state caching. For more information on how IVI drivers might work for you, visit the IVI website at www.ivifoundation.org/.

ATE Bus Interfaces

The bus interface is the means through which the host controller communicates with the instruments in a test stand. The instruments may have a GPIB (IEEE488), Ethernet, FireWire (IEEE1394) or VXI-MXI2 interface, for example. The rate of data transfer and communication speed varies as does the cost. RS232 is the simplest form

of communication, least expensive and also the slowest. GPIB has been in existence for almost 30 years and offers data transfer rates at about 1MB/s. FireWire achieved its credentials in the consumer electronics market and has seen limited usage in the industry, primarily in data acquisition applications. It is a high-speed serial link and offers data transfer rates in the neighborhood of 14 MB/s, although there is a first byte latency that is apparent when passing commands. MXI-2 offers the fastest bus speed, rated around 20 MB/s-25 MB/s. A VXIbus FireWire can communicate to the host controller through GPIB, MXI-2, and FireWire interfaces. These interfaces populate the leftmost slot of the VXI mainframe and are commonly referred to as Slot 0 interfaces. In a multiple chassis subsystem using MXI2, each chassis requires a Slot 0 interface; one chassis will connect directly to the host, and the rest will be daisy-chained together.

Selecting Instruments

Once a test requirements document has been defined (TRD), it is time to select test instrumentation necessary for powering the unit under test (UUT), applying test stimulus and measuring the response. Test instrument specifications are compared to test requirements to determine which device is the best fit. Many system developers find that circumstances like minimizing footprints or cost will dictate the selection of a particular platform. It is common for a system to contain a mix of platforms. For example, demanding power supply requirements are most often satisfied on the GPIB platform because providing this function in a chassis-based system presents many difficult challenges. If there is a large mix of instrumentation, and/or higher channel count requirements, the VXIbus offers the best cost and performance solution. Modular VXIbus designs, like the VMIP™, allow up to 36 discrete test devices in a minimal amount of space.

Handling Special Cases

Occasionally test requirements may be unique and there will not be test instrumentation available off-the-shelf that will be able to provide the necessary functionality. This is where communication between the product design

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team who defines the test requirements and the test development team in charge of implementing the test is crucial. It is often the case that the product designers have written difficult to perform tests into the TRD that are not absolutely necessary for acceptance testing. In these cases, it is much more efficient for the test team to determine which tests may be eliminated from the test procedure. The alternative to this is approaching vendors for custom or modified solutions, which more often than not results in non-recurring engineering expenses. VXI Technology started business as a "custom engineering house" and still maintains a custom engineering group. In addition, prototyping modules on the VMIP™ allow users to implement custom designs on an open-architecture platform.

Instrument Specifications

Reading and comparing instrument specifications should really be considered a form of art. Very rarely do instrument manufacturers specify like products in the same manner, which would make it simple for the system designer to determine what product is the best fit for the application. An excellent example of potential confusion is found in the data acquisition market. One vendor might specify a 64-channel A/D device at 100 kHz, priced at \$3000, while another vendor offers a 16-channel 100 kHz board at \$6000. At first glance, the first product looks to be an exceptional value when compared to the second. What is not immediately apparent is that the first board uses a scanning A/D architecture (one A/D with a 64-channel FET mux), while the second product implements 16 independent A/D's. What this means is that the second product can sample all 16 channels simultaneously at its specified sampling rate of 100 kHz. The first product's specified rate is actually an aggregate value, and the fastest that 16 channels can be sampled at the same time is about 6 kHz-7 kHz which also adds channel-channel skew. So, depending on the application, the second product may be the best selection. It is important to read the critical specifications thoroughly, and if there are any questions, contact an applications engineer for assistance. This is also a good barometer of the type of support that can be expected from the vendor after equipment has been purchased.

Utilizing Switching Systems

One way to reduce overall cost of capital equipment in test stations is through effective use of signal routing through switching systems. There are switches available to route signals from dc to lightwave frequencies, microamp to 30 A or greater and systems that have varying degrees of modularity and density. The switching primer included in this catalog provides an excellent introduction on the different types of switches available. Ultimately, switching systems allow the system designer to minimize test assets by routing multiple I/O points to a common resource. For example, continuity and isolation tests between numerous test points can be routed to a single DMM through a multiple-channel scanning switch (multiplexer). Matrices allow several test resources to be connected to various I/O points. Also, Form C (SPDT) or Form A (SPST) can be used to connect and disconnect input voltages to signal pins. Signal switching has become so widely used in automated test that it is often referred to as the 'heart' of the system.

Utilizing the VXIbus there have been many advancements made in signal switching. Modular systems, such as SMIP//™ platform, provide the greatest density and flexibility, while being the most cost-effective solution. Up to 36 different switch modules can be housed in a single VXI chassis using the SMIP//™ family of products. In addition to increased density and lower costs, the SMIP//™ is designed for very high throughput. For example, in multiplexing systems, where a number of measurements must be made sequentially, the implementation of the scan lists is all done through hardware, thus completely eliminating software processing from the loop. Scan lists greatly reduce overall test time since the handshaking between the measuring device (communicating to the switch that its measurement is complete), and the switch (communicating back to the measuring device that it has settled) does not require host controller intervention.

Selecting Racks and VXIbus Mainframes

The amount of instrumentation required will determine the height and/or number of racks needed to house all of the devices. Most test instruments used in ATE applications are designed to fit into standard 19" racks, and the amount of vertical space that a piece of equipment occupies is specified as 'U' where 1U = 1.75".

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The layout design of the racks should also allow for power distribution and cooling as well as future expansion.

A VXIbus chassis occupies the entire width of a 19" rack, and anywhere from 4 U to 9 U of vertical space depending on the number of slots in the chassis. Common chassis slot counts are four, five, six and thirteen. Available options include rack mount kits, slide rails to ease maintenance, cable trays to provide a convenient method for routing cables, and hinged doors to protect the instrument I/O and cabling from outside interference.

The most salient chassis specification is the amount of power it can provide to the cards inside. A VXI device can draw power from any or all of the seven supplies defined in the specification. Available power is the total amount of power that each supply line is capable of delivering. A mainframe's usable power specification indicates the total maximum power that can be delivered at any one time.

A typical 13-slot VXI chassis will provide 1000 W of usable power. All instruments specify how much power they draw in terms of current per supply line. The collective amount of current that all cards draw off any supply line must not exceed the capabilities of the chassis power supply. In addition, the sum of the power draw of the cards must not exceed the usable power spec.

Because the instruments dissipate a fair amount of heat and are packed closely in the chassis, cooling is also an important consideration. An effective cooling system will draw air in from the bottom rear and exhaust out of the top sides. Cooling system designs vary among manufacturers and are optimized to provide maximum cooling across occupied slots while minimizing 'hot spots'. Specifications may be defined in watts/slot or liters of air/second. A VXI chassis manufacturer should test their chassis on a VXI *plug&play* fixture for cooling specifications. This fixture is common and shared by all manufacturers to maintain uniform comparisons.

Hardware Interfaces

Once the racks are populated with the test instrumentation, a system designer is left with the task of interfacing the instrumentation I/O with the UUT. It is common practice to develop some sort of cabling method that minimizes the number of times connectors are

removed and resealed on the instrument front panel. If multiple UUT's are to be tested by the same tester, then a mass interconnect system, whether it be a patch panel or interface connector assembly (ICA) should be considered. An interface test adapter (ITA) which is specific to the UUT, mates to the ICA and provides I/O routing from the instruments to the UUT interface.

An ITA mates directly to the face of the ICA. The face of the ITA may take the form of a patch panel from which cables will connect to the UUT. In board level testing it is common for an enclosure to be mounted to the ITA. This enclosure will house cabling that runs from the ITA to an edge connector that mates to the UUT.

There are obvious advantages to using this type of interconnect system. Wear and tear at the instrument front panel is minimized since all of the insertions take place at the ITA/ICA interface. It is much easier to maintain and service ITA/ICA modules and pins as opposed to returning a test instrument to the vendor for repair. In production environments, these systems prove to be very valuable in reducing setup times since mating the ITA to ICA takes seconds and the need for operator intervention for routing cables is either trimmed or eliminated altogether.

Summary

Many steps are involved in developing an ATE system, beginning with preliminary definition of test requirements to selecting test instrumentation and software platforms. The selection of an instrumentation platform provides the foundation which the system architecture will be built upon. While it is quite common to mix platforms, such as rack and stack, PCI and VXI, the VXIbus has proven to be a standard that has the flexibility to adapt to new technologies accounting for its longevity. The number of products available on the platform increased by over 20% in the last few years (>1500 total), and the release of VXI 3.0 keeps the platform on pace to meet the evolving demands of the ATE marketplace.