VXIbus Systems in Military Applications
by

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Racal Instruments has a long history of providing test and measurement instruments and systems to the aerospace and defense industries. As a founding member of the VXIbus Consortium, Racal has taken a lead in developing high performance modular solutions for a wide variety of applications. The company has introduced a large number of products that have found many uses in military applications. Backed by the Racal Electronics Group, Racal Instruments has a global presence testing electronics for all branches of the military services, on land, at sea and in the air.

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Abstract

VXIbus instruments and systems have been the mainstay of automated test and measurement systems in the military and aerospace communities for the past 12 years. The VXIbus standard was developed with strong influence from the United States military to standardize a modular instrumentation backplane that would offer a much smaller footprint and higher communication speed than traditional rack-and-stack devices controlled by IEEE-STD-488 interfaces. VXI-based systems are used in flight-line applications, on sea-going vessels, in maintenance depots as well as on assembly and production lines. Several examples of systems and the advantages that VXI brings to the architecture will be presented.

Introduction

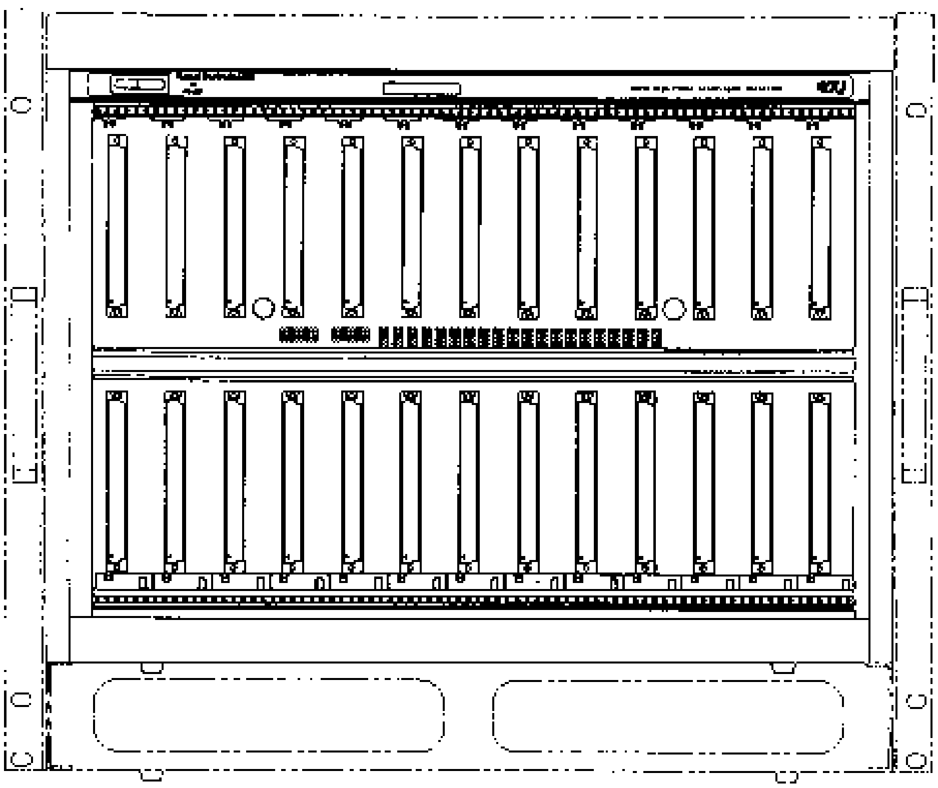
In 1987 the U.S. military served an ultimatum to the test and measurement industry requiring a standardized, modular platform. If industry did not develop a commercial viable standard, then the military would develop one and industry would be forced to follow it if it wanted to continue to do business with its defense customers. Industry met the challenge and released the VXIbus standard in October 1987. This original document described a modular, high speed bus architecture that was optimized for high performance automated test equipment. It consolidated many of the system requirements into a defined, standard backplane facilitating the development and implementation of automatic test systems.

To put the types of systems that the military and aerospace industry requires into perspective, most applications are high-performance. They contain high channel counts, require instruments with high speed processing, high speed communication and frequently generate or analyze high speed signals. These systems must address high numbers of devices under test with a high number of interactions between many instruments, requiring a high degree of interoperability. The test must result in a high quality outcome which means high integrity of signals in the system and high reliability of the test instrumentation. The only deviation to the “high” requirement is that the physical footprint of these systems must be small.

The VXIbus Specification

The VXIbus Consortium which consists of a number of major industry players including Hewlett-Packard (now Agilent), Tektronix, National Instruments and GenRad created a document that met these objectives. The standard covers in detail mechanical design, electronic issues and electro-mechanical subjects to ensure that many instruments plugged into a common backplane will interoperate robustly. The Consortium started with a known and widely-used backplane standard, the VMEbus. In 1987 VME was the highest speed standardized computer backplane available with many capabilities in data acquisition, processing and analysis. However, the VME standard was not optimized for many of the requirements of classic test and measurement instruments configured into automated test systems. It was these functions that the Consortium added, thereby creating the VMEbus eXtensions for Instrumentation, or VXIbus standard.

High-speed communication and processing: The VME standard already provided for 16bit communication between hosts and modules in the backplane as well as for 24bit and 32bit block moves of large data packets. This was a tremendous increase in speed over the standard in test and measurement which was, and is, GPIB (IEEE-STD-488). The VXI Consortium adopted these communication protocols as they were defined in VME and added a new type, named Message-based protocol, that was similar to GPIB, bridging the technology between the two specifications. Over time instruments have been developed that take advantage of all of these protocols, optimizing the manner and speed in which data can be moved and processed in any given application.



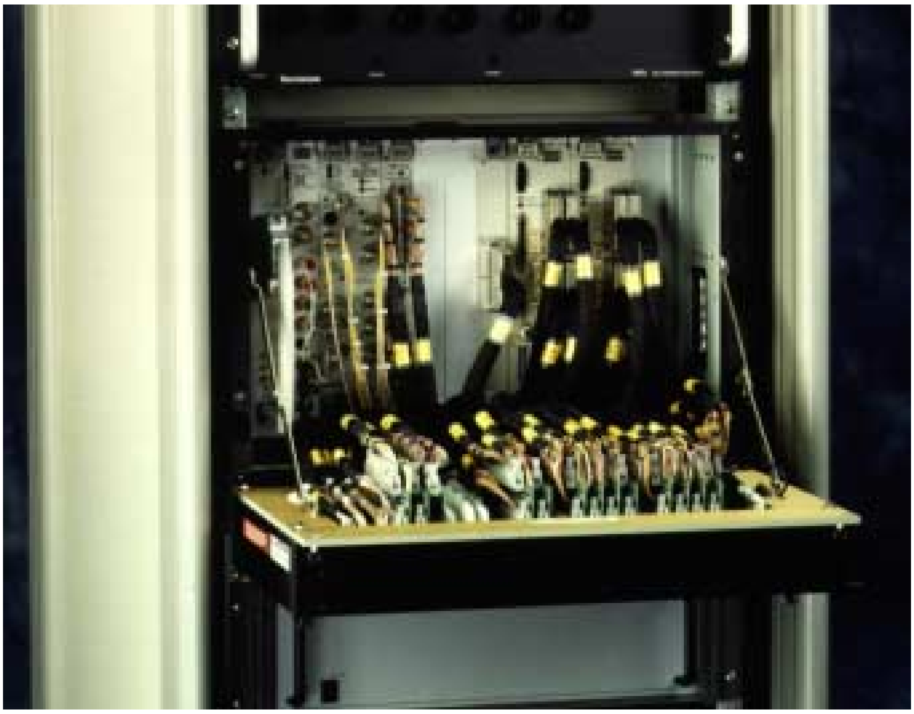
13-Slot VXIbus Backplane

High-speed signals: The military and aerospace makes great use of the upper bands of the frequency spectrum. Therefore instruments in automated test systems must be able to adequately handle a wide range of signals, up to and including microwave and optical. This capability was ensured by the Consortium's addressing issues such as EMC, both radiation and susceptibility, and including plenty of ground points in the mechanical specification. The integrity of the voltage rails that powered the modules was carefully considered and defined, with requirements for chassis manufacturers to meet stringent ripple and noise specifications and to publish the power capability of every chassis. Consideration was made to produce special chassis with cleaner, linear power supplies. And there are options for system integrators to install standardized, inter-module shields and RF finger gaskets on backplane connectors to improve EMC performance.

High number of Devices under Test (DUTs): One of the biggest problems in system integration is to connect many DUTs to one set of system resources. In the military and aerospace environment a common Automated Test System is developed and then multiple means of connecting the basic instruments to many types of assemblies, PCBs, components and other devices is created. Over the years a number of mechanical connectivity means have been developed, one of the most common being the Interface Connector Assembly (ICA), Receiver Mechanism and the Interface Test Adaptor (ITA). Because the VXI modules are so small and located so close to each other in a chassis, there is a significant advantage over rack-and-stack systems. The switching can be included in the VXI chassis as additional instruments instead of as a separate box or chassis, facilitating the wiring between the inputs and outputs (I/O) on the front panel of the instruments. The receiver mechanism can be mounted directly on the front of the VXI chassis, with very short cable runs. Then multiple ITAs can be connected to the receiver, making use over many applications of the instruments in the VXI chassis.

Tester for High Number of DUTs

High Channel Count on Each DUT : Another feature of many defense and aerospace systems is that the Devices-Under-Test have many channels, many I/O ports or a large number of parallel communication points. As for the requirement to test many DUTs with one test system, similar problems exist trying to test one DUT with many cables connected to it. Because of the close proximity of the instruments and switching as well as the ITA mounted on the front of the VXI chassis, VXI-based ATE systems provide significant advantages in maintaining signal integrity in large channel-count applications. The cable runs are very short between the DUT and system instruments. And because of the number of system signals (triggers, clocks, interrupts, communication) on the standardized backplane, there are few additional cables required external to the VXI chassis besides those directly connecting the DUT to the receiver.



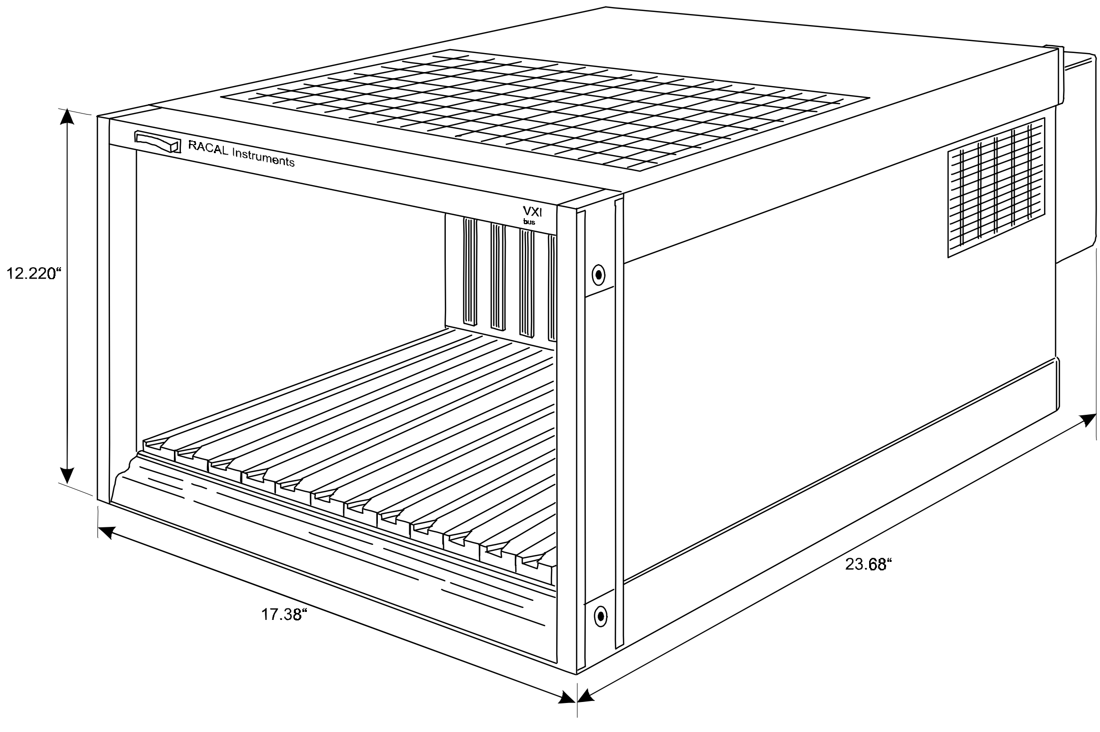
High Channel Count System
Wiring to Interface Receiver

High-reliability: If one thinks about the devices being tested in a typical defense or aerospace system, it is easy to understand that high reliability is very important. Lives may depend on the integrity of test results of DUTs such as flight controllers, power train systems, communication-command-control systems, and weapons systems. VXI-based systems have proven to improve reliablility significantly over older rack-and-stack systems. One reason is the decreased number and length of cables between instruments, controllers and the DUT. This not only significantly improves signal integrity, but also reduces the number of points at which a system can break. Another significant area is that VXI modules do not each have their own power supply, fan or front panel circuitry. By consolidating these functions into a high-reliability chassis, there is much less to break, burn-up or otherwise malfunction.

High Interactivity: VXI is a system technology. Because it is a modular architecture, no single VXI module stands alone. VXI applications are always configured with a computer controller, and are typically most practical in applications where there is a high number of instrument functions, either input or output, as well as a high level of interactivity between the instruments and the DUT. The VXI specification was designed with a great deal of capability for hardware communication on the backplane between modules. As measurement sequences become more complex and require action from many instruments, VXI simplifies the setup and data retrieval because the backplane contains triggers, interrupts and high speed data paths, all working together with little external software intervention and no external cabling. This VXI feature simplifies the integration and functionality of automated testing.

<u>High Interoperability:</u> One of the most important goals of the VXI Consortium's efforts in developing the VXI standard was to ensure that the specification was clear enough and gave enough details to verify that implementations of VXI modules would all work together in different chassis and with different controllers and still perform without interfering with each other. To make sure that this robustness of interoperability was realized the VXI Consortium holds periodic Interoperability meetings. Manufacturers of instruments, chassis, controllers and software would bring all of their new products to gathering and have the opportunity to try them with as many combinations of hardware and software as possible. Problems were found that caused some changes over time in the VXI specification. But this process also ensured that all VXIbus-compliant products truly work with all other VXIbus-compliant products and since 1990, when the VXIbus specification was updated to Revision 1.3, there has been almost complete interoperability.

<u>Small Footprint:</u> All of the other advantages of VXI become minor points if the standard had not made high performance test and measurement instrumentation smaller. The military needs to be able to easily move high-performance systems to the tarmac for testing avionics and power on aircraft. Sea-going vessels must have small systems that fit into already cramped spaces in ships' holds and on-deck. Satellite ground systems are frequently housed in small structures, yet require monitoring of large channel counts of high frequency signals. Many military organizations move high performance machinery to the front line in battle and must have the ability to test the electronics. The small size of VXI instruments, the high performance capability of the electronics, the large number of signals on the backplane which obviate massive interconnecting cables are all significant features of VXI for applications requiring small footprints.



<u>Military Applications</u>

As listed above, there are a great many advantages to VXIbus technology for high performance Automated Test Systems. Globally the VXIbus architecture is being adopted for military and aerospace applications as it meets many of the requirements for these types of systems: high performance, high quality, high reliability yet small and compact. There are many examples of implementations of VXI in military test systems. The applications to be reviewed here include an IFF Transponder Tester, a general purpose high-speed digital tester for many old DUTs used in naval applications, a board-level analog tester for a large number of avionics DUTs, a radio tester and applications for rechargeable battery testers.

The descriptions will necessarily be generic. However, an attempt will be made to review the types of equipment designed into the systems and the advantages of building the system in VXI. An overview of the connection scheme between the instruments, controller and the DUT will also be covered.

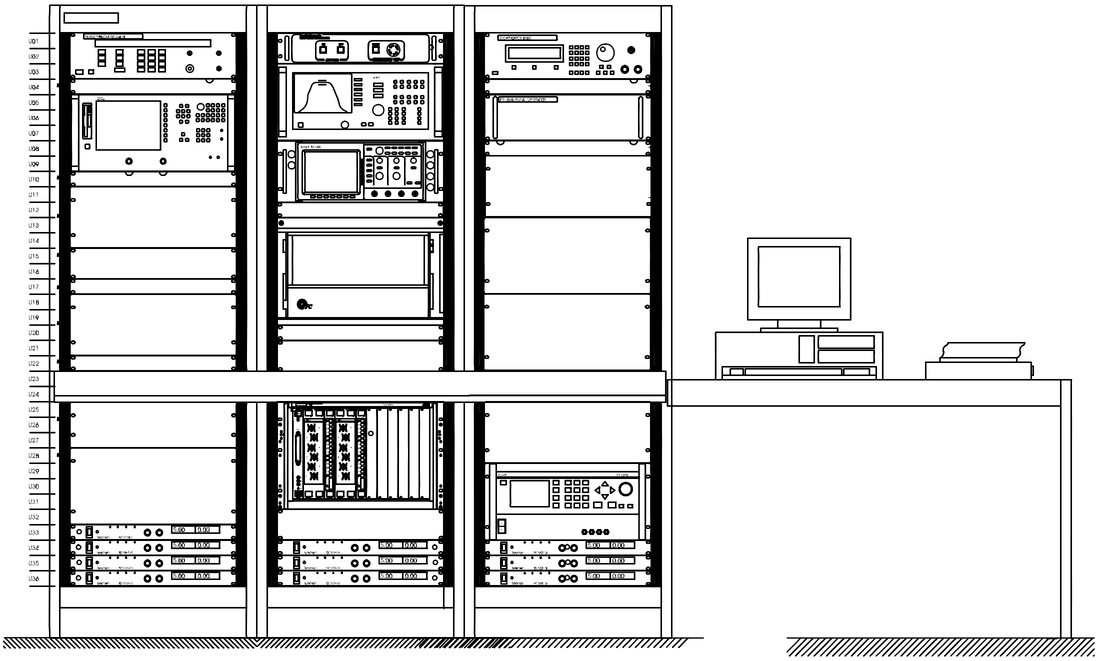
It should be noted here that almost all systems listed are hybrids of several technologies. The heart of these complex systems will be one or two VXI chassis with instruments and switching. However, VXI chassis in a system environment seldom stand alone. The controller can be in the VXI chassis, but typically resides as a separate box. There is some instrumentation that does not make sense to be configured in VXI. This could be due to the physics of the inputs and outputs, such as power supplies. Business constraints may make more sense to develop products in GPIB format, such as volumes and amount of applications in which a measuring device is used stand-alone or with other instruments. Therefore the systems described will contain several communication and connectivity technologies besides VXI.

IFF Transponder Tester: Several implementations of testers for IFF Transponders have been developed by a number of suppliers and users. These systems range across many application areas. They could be applications in Research and Development for product validation or production test systems where they are used to test product being built on the production floor. Or they could be long-term ATE testing the devices as “black boxes” undergoing regular maintenance and repair in a depot test facility. These testers are a good example of GPIB rack-and-stack and VXI in a mixed technology test stand. The general purpose test and measurement instruments are housed in the VXI mainframe with the heart of the tester being a dedicated Transponder Test Set. Combining the two technologies allows for a high perfomance production Transponder Test System and high coverage of test parameters in the maintenance shop.

Parts List:

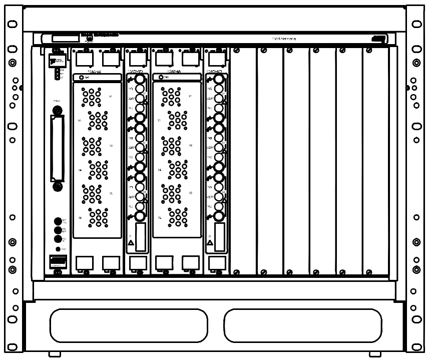
VXI Instruments	**GPIB Instruments**	**System Components**
13-slot chassis X2	Pulse/CW Microwave Ctr	Power Controller
MXI Controller X2	Network Analyzer	AC Power Source
DMM	Programmable Power Supplies	PC
Waveform Generator	0-8VDC, 0-125A	Laser Printer
Waveform/Dual Pulse Generator	0-150VDC, 0-7A	LabWindows/CVI software
D/A Converter	0-33VDC, 0-33A X 2	VP90 Receiver
Switching:	2 channel power meter	25 pin-blocks
High densityMUX	Signal Generator	
80 channel SPST	Spectrum Analyzer	
96 channel Digital I/O	Digital Oscilloscope	
500MHz MUX		
10A switch		
100MHz, 75ohm MUX		
100MHz, 93ohm MUX		
18GHz 1 X 2 MUX X 2		
18GHz 1 X 6 MUX X 2		
200MHzTimer/Counter		
Serial Communication I/F		

While this system takes up three bays, depending on the complete configuration implemented, if the majority of the instrumentation were not VXI, the size would double, requiring a very, very large area on a production or shop floor for the equipment. The connectivity between the modules and instruments is facilitated by the 25 block receiver residing behind the VXI chassis that contains the majority of the VXI modules. The second VXI chassis is used only for microwave switching, making it easier to bundle cables with sensitive signals.



FRONT VIEW
IFF Transponder Test System

The Test Program Set (TPS) for the IFF Transponder Test System is written in LabWindows/CVI. A significant advantage to using this type of software language is the standardized instrument drivers available for most of the VXI and GPIB instruments. These tools, along with the standardized software layers offered by VXI*plug&play* make developing the software much easier and faster than using older-style languages where the TPS writers must also spend a great deal of time understanding the instruments and writing the instrument drivers.



1261B CHASSIS 2U25
(MODULE LOADING)
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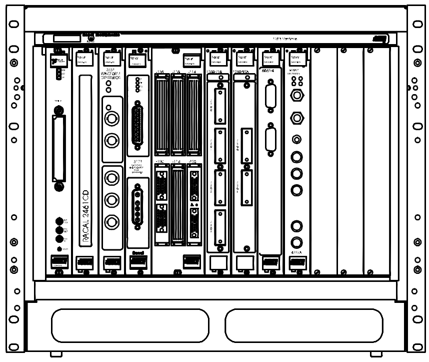


1261B CHASSIS 2U14
(MODULE LOADING)
(SCALE 1:2)

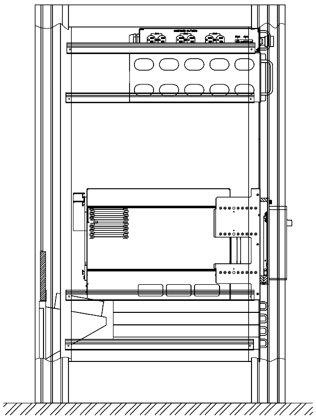
VXI Chassis with Instruments
IFF Transponder Test System

General-purpose High-speed Digital Tester: There was a requirement to replace a very, very large tester due to the obsolescence of the instruments and components. By using VXI technology and modern software, this high-speed tester, primarily used to test digital devices, is approximately 10% the size of the original test system developed 30 years ago. The original tester used many custom components, while the current replacement was able to provide the speed and performance required by using commercial-off-the-shelf (COTS) instrumentation.

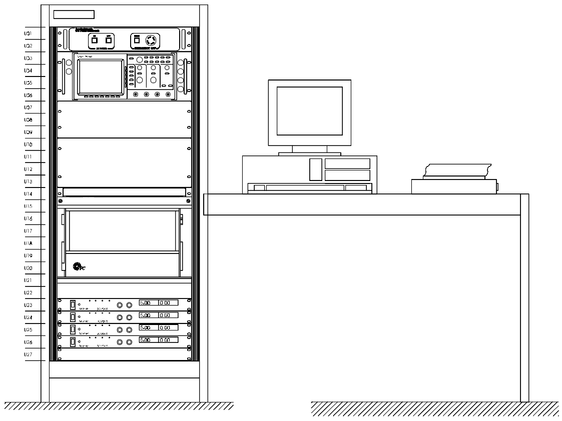
Parts List:

VXI Instruments	**GPIB Instruments**	**System Components**
VXI Chassis	Power suppy, 0-33VDC, 0-33 A	Power Controller
GPIB Slot 0	Power suppy, 0-33VDC, 0-50 A	PC
DMM	Digital Oscilloscope	Printer
Counter/timer		VP90 Receiver
Waveform Generator		LabVIEW
80 channel SPDT Switch		
Bus emulator/Word Generator		
Timing module		
I/O Programmable Module		
TTL I/O Module, 16 channel		
Accessory Module		

The small size of the high-speed digital modules allows this system to be very small. It fits entirely into one rack that is less than five feet high (1.43 meters), with room left over for additional instruments. The system can make time, frequency and voltage measurements as well as provide digital stimulus and measurement. The receiver and ITA are located directly in front of the VXI chassis and modules installed, providing for very short cable lengths between the instruments and Devices Under Test. It is programmed in LabVIEW, a very easy to use graphical programming language for instrumentation, allowing fast transport of the old TPSs to the new system. Another advantage of the VXI technology selected is the backplane communication speed. VXI allows large blocks of data, including large digital patterns, to be loaded into instruments very quickly—in seconds rather than in minutes or hours if using previous technologies such as GPIB.

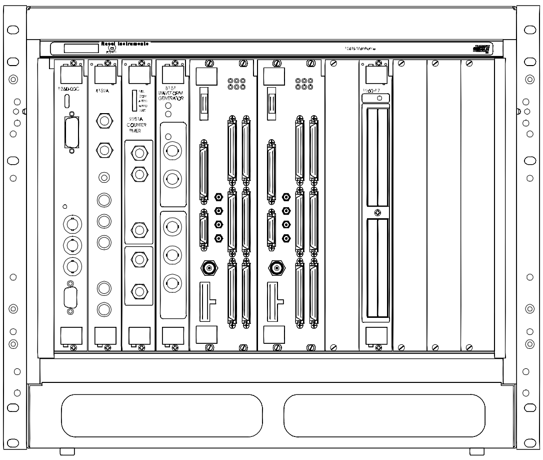


SIDE VIEW
SIDE COVER OMITTED FOR CLARITY



FRONT VIEW

High-speed Digital Tester



1261B CHASSIS
(MODULE LOADING)

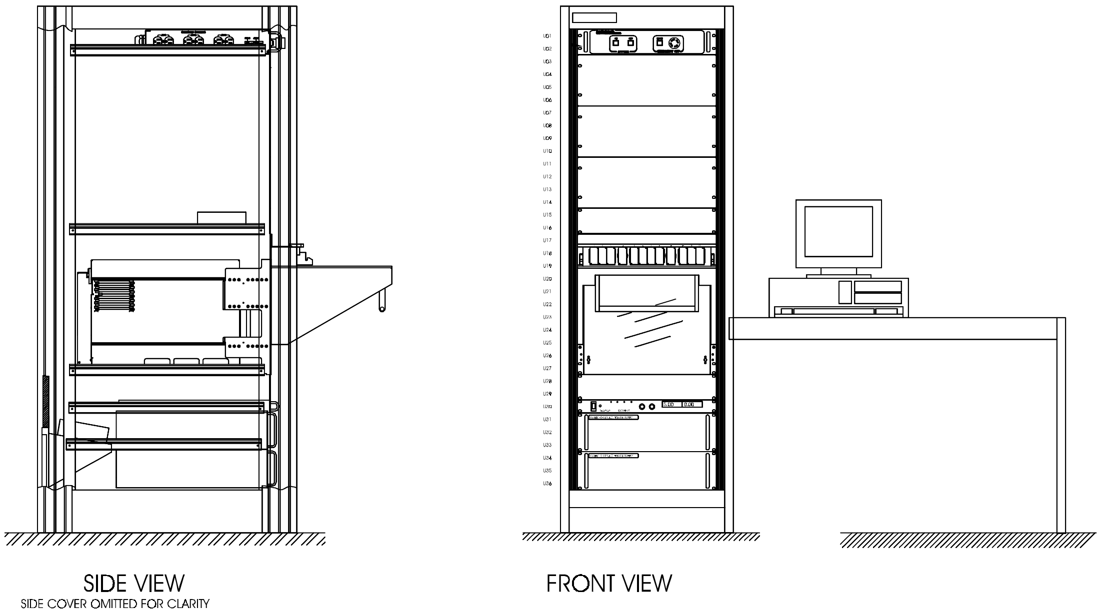
VXI Chassis and Instruments for High-speed Digital Tester

General Purpose Analog Tester: The requirement for this tester was primarily for analog avionics devices that needed testing during production and then continual testing on the maintenance floor. The specification demanded that the instruments and components of the test system be COTS for easy replace-ability and upgrade-ability over the long life of the test system as well as ease of supporting new products as they are developed.

Parts List:

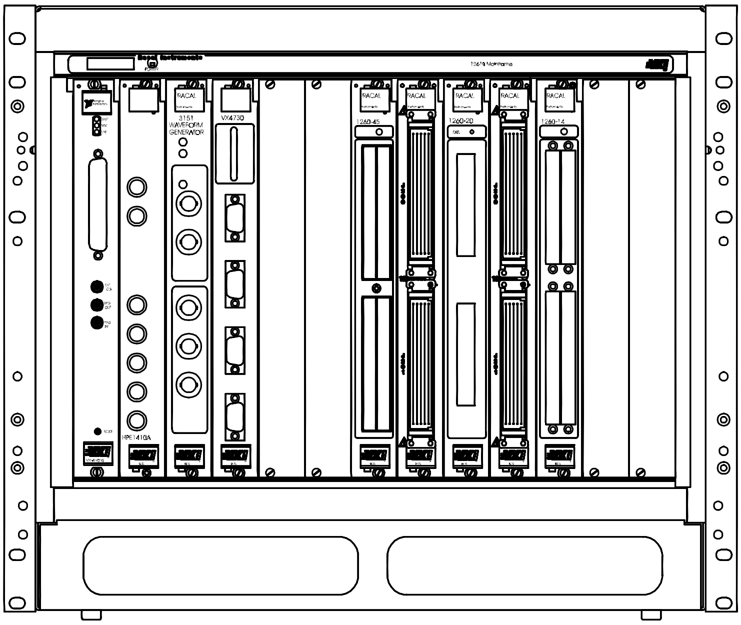
VXI Instruments	**GPIB Instruments**	**System Components**
VXI Chassis	Power Supply 0-150VDC, 0-7A	Universal Power Controller
MXI Slot 0 Controller		Fixed DC Power Supply
DMM		PC
Waveform Generator		LabWindows/CVI
D/A Converter		TTI Testron receiver

Switching
  4X32 Matrix
  High density MUX
  High power switch
  High density SPST
  96 channel Digital I/O



General Purpose Analog Tester

This system appears to be very simple based on the instruments installed into the rack and VXI chassis. However, it has all the necessary measurement functions to test analog devices. The large amount and variety of switching permits many different types of devices to be verified by this system, from high power to many channels connecting a large number of pins.



1261B CHASSIS
(MODULE LOADING)
(SCALE 1:2)

VXI Chassis and Instruments
General-purpose Analog Tester

The receiver mechanism is located right above the VXI chassis, permitting very short cable lengths between the chassis and the DUTs. Also, due to the clocks and triggers on the VXI backplane, it is not necessary to bring large numbers of wires to the front of the system. They remain shielded with standardized signals inside the chassis. An example would be to trigger a scan sequence between the DMM and high density MUX. The only external wire required is the one to the DUT through the receiver. The VXI backplane and a nominal amount of software can very quickly trigger a relay on the switch card to close, which tells the DMM to make a measurement. When the DMM has made its measurement, it triggers the relay to open and the next one to close. This highly automated sequence is standardized by backplane signals and permits high reliability and repeatable measurement sequences to be made.

General Purpose Analog Tester

Portable Radio Test System: It is very important to the military to ensure that front line communication devices are functioning correctly. To meet this need, a system was developed to transport, in rugged chassis or boxes, the test capability for many different types of radios on land vehicles. The system is broken into blocks and VXI chassis are installed into rugged cases. A receiver system is used as in the production and maintenance shop testers as this permits easy configuration of a system for many different DUTs.

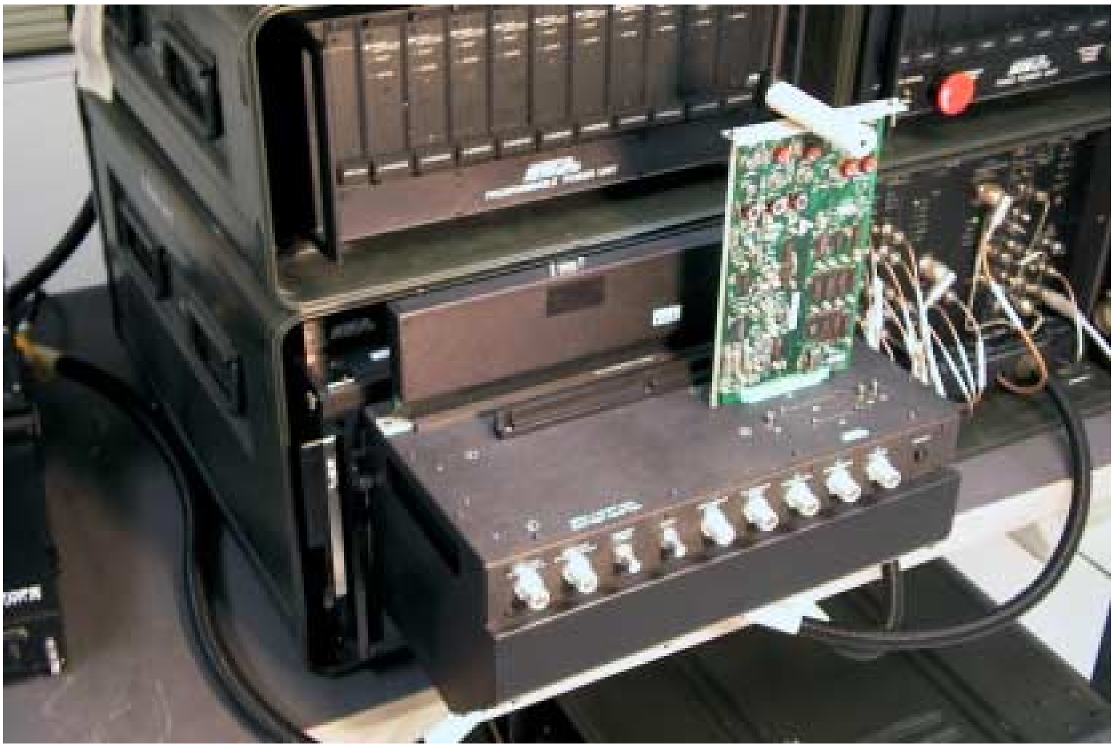
Parts List:

VXI Instruments	GPIB Instruments	System Components
VXI chassis X 2		PC
MXI Slot 0 Controller		Receiver, DC to 18GHz pins
DMM		
200 MHz Counter/timer		
Digital Oscilloscope		
Function Generator		
Arbitrary Waveform Generator		

192 digital I/O channels
- 25MHz patterns
- Troubleshooting
- -2 to +5VDC

Switching
- DPST DC power
- Low Frequency Matrix
- Low Frequency Switches
- Low Frequency MUX
- Med Frequency MUX
- 8.5GHz MUX

10MHz - 8.5GHz sig gen
8.5GHz counter
RF Measurement Analyzer
RF Power Meter



RF Radio Test System
Testing Low Level PCB Assembly

Because this system must be transportable, it was important to find as many instruments in VXI as possible to maintain a small size. The list of instruments includes almost every possible capability in analog and RF. The transportable cases with the VXI chassis have receiver mechanisms mounted on the front to ease connections of many, many DUTs. It is a matter of a few minutes to get the system configured to start testing in the field.

RF Radio Test System
Testing High Level Assembly

<u>Rechargeable Battery Tester:</u> One of the most important abilities onboard a ship is to be able to accurately determine the charge level of any battery and to be able to reliably charge and discharge it. Shipboard use necessarily means that the footprint of the system must be small, but must be able to work with many different batteries. A VXI solution was selected to fit the majority of the instruments into two racks, including the test and measurement devices as well as many different types of programmable loads.

Parts List:

VXI Instruments	**GPIB Instruments**	**System Components**
VXI Chassis	Programmable Power Supplies	PC
FireWire Slot 0 Controller	Programmable Loads	HP VEE
DMM		Universal Power Controller
High density MUX		VP90 Receiver
High Power switches		
Isolated D/A		
Pulse/function generator		

The driving factor for this system is that it must be small yet be able to handle many different types of batteries, big and small. It will be shock mounted on the deck to reduce perturbations due to vibration or shock, and will have some nominal environmental shielding. The heart of the system are the power supplies and loads. However, by using some very flexible and dense switching modules, it is possible to control many different aspects of the various batteries. The isolated D/A will be able to emulate many different battery profiles, and control the power supplies. The receiver mechanism will be mounted on the front of the chassis, making connection to the DUTs consistent and reducing cable lengths. The VXI backplane will be used to sequence measurements and profiles by using the clocks and triggers inherent to the VXI chassis. Using the FireWire connection to the host PC, large amounts of data can be recorded and decisions can be made on which next step in the charge/discharge process is to be enabled.

Conclusion

The momentum to develop the VXI specification was prodded by the military during its initial days. Over the past 12+ years, the standard has been used in a wide variety of applications, succeeding in its stated goal of a technology for small, high performance test systems with high speed communication and processing. The applications range from apparently slow, high power battery testers to microwave radios and communication devices to high reliability avionics “black boxes” who must be tested quickly and to a high quality.

VXI has continued to evolve as other technologies in the industry have been developed. Most systems today are controlled by a high performance Personal Computer, running a Microsoft Operating System. Commercial-off-the-Shelf test program languages have gained acceptance, easing the system integrator’s job as many of the instruments are shipped with full-functional drivers created by their manufacturers. Object-oriented programming is making re-useability of test programs a reality. New control architectures, such as FireWire (IEEE-STD-1394) are bringing down the cost of systems. And many vendors are removing the cost of modules by creating lower levels of modularity and reducing per-channel prices.