caseSTUDY

Improving Development Time of Complex Microwave Test Adapters by Incorporating COTS Components

OVERVIEW

Creating a unique test system design dedicated to a specific target test article can often be costly, especially in large-scale production environments. This same reason has caused a shift in industry methods, where many companies are focusing on creating a common core approach in which a single base architecture is capable of testing a wide range of line-replaceable units (LRUs). This is the ideal method as it allows an organization to scale their development efforts and reduce maintenance costs through a unified equipment resource pool. Interface test adapters (ITAs) play a key role in a common core environment, providing the mechanism for interfacing different LRUs to a test instrument through a common mass interconnect patch panel. Often times the test adapters are benign, passive boxes restricted to containing wiring between test system instrument and UUT I/O. This is especially true for low-frequency domains. However, when the UUT is a complex radar or guidance subsystem operating in the RF and microwave domain up to 40 Ghz, the design of the test adapter can become quite complex.

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CHALLENGES

- Multiple unique signal distribution topologies
- RFIU usage within each ITA
- High frequency signals made design requirements much more precise
- Incorporation of as much COTS components as possible
- Provide nearly transparent switching
- Ensure simple maintenance of units

BENEFITS

- Flexible ITA infrastructure consisting of nearly 100% RF COTS components and a COTS LXI-based communications and control interface
- Design tools provided access to LXI and IVI compliant COTS based infrastructure
- Well documented and supportable
- Efficient design process reduced cost
- Removable drive control cables for simplified maintenance
- Scalable Architecture

In early 2012, engineers at a prime aerospace manufacturer (referred to as "prime") were assigned the task of replacing several existing ITAs that had been used to support the testing of multiple LRUs belonging to an Air Force program. One stated objective was to replace the existing ITAs with as much COTS technology as possible. These ITAs were to be used in combination with a common core ATE system as well as embedded complex microwave switching matrices which were customized to LRU specific requirements. The engineers recognized that the ITA designs were prone to failures and were compromising system up-time. In order to satisfy the test requirements of the LRUs, the engineers had to incorporate the use of an RF Interface Unit (RFIU) within each ITA. This provided attenuation, filters and switching that routed and conditioned test instrumentation signals and allowed them to be placed as close as possible to the device under test. The high frequency domain of these signals made the challenges of design even more difficult. Engineers had to pay particular attention to isolation, insertion loss, and VSWR, and had to incorporate LRU specific/custom designs in order to minimize the effects the insertion of an RFIU between the signal path has on signal integrity.

Although the number of RF components and configurations of each ITA was unique, the engineers found it more efficient to develop a common infrastructure to contain the RF components and a common communications interface back to the host called the Internal Integrated RF Interface System (IRIS). VTI Instruments was tasked with providing the IRIS assemblies, and tight collaboration between the engineers at VTI and prime resulted in a flexible ITA infrastructure that included nearly 100% RF COTS components and a COTS LXI-based communications and control interface. VTI design tools provided with the interface allowed engineers at prime to take advantage of standards such as LXI and IVI, providing a COTS-based infrastructure for the ITAs which would be well documented and supported. This reduced the customization effort required across the program and enabled the RF engineering experts to focus on the design details which are within their area of expertise.

MAXIMIZING COMMON COMPONENTS

Each of the six IRIS assemblies interfaced to the same test station through its ITA and therefore shared the same station resources. The IRIS assemblies within each ITA derived power through the mass interconnect, therefore it was intuitive to design each IRIS such that it used the same station power resources. The six IRIS assemblies had unique signal distribution topologies, and the superset of components included splitters, filters and switches. A decision was made to design a common component housing tray that could be integrated into the IRIS assemblies even though not all IRIS assemblies made use of every component. None of the IRIS assemblies required a fully populated tray; however, designing one assembly lowered cost to build by minimizing the number of unique sheet metal parts as well as a reduced number of drawings needed for the project.

In a similar vein, relays and components were selected to reduce the number of unique components. The relay topologies chosen were limited to SPDT and SP6T to provide opportunity to achieve cost benefits through volume purchase while also simplifying the spares resource pool.

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The prime engineers selected the LXI-compliant EX7000-OEM (figure 1) communications and control interface as the COTS core for all IRIS assemblies.

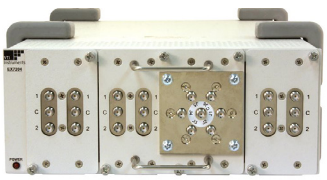
Figure 1: EX7000-OEM LXI Interface Board

RF PERFORMANCE REQUIREMENTS

The IRIS provides the routing between all RF/Microwave signals between the test system assets and the LRU, including electromechanical relays. Each IRIS was strategically placed on one of the vertical sides of the ITA. This provided the best mechanism for routing the RF cabling between the IRIS relays and the LRU I/O and resulted in the flexibility to minimize cable lengths to minimize loss, while matching path lengths as required to ensure phase coherency.

MAINTAINABILITY

From lessons learned in the initial production phase, the engineers found the ease of which the IRIS components could be maintained extremely desirable. Originally, troubleshooting any component of the ITAs was tedious and time consuming, particularly caused by the tightly packed components and cables. The prime engineers designed the IRIS concept such that the IRIS component tray bolted to the side of the ITA, while the driver and control interface boards attached to a gasketed door. Power cabling from the mass interface was neatly dressed with enough service loop to allow the door to swing fully open, which provided clear access to the IRIS component tray. This greatly facilitates maintenance as the drive control cables to any component could easily be removed, while an access through the top plate allows quick removal of RF cabling. Using this approach, faulty relays could be easily removed without disturbing anything else in the system.



EX7204: 4-Slot, Half-Rack, Modular Microwave Switching Mainframe

EX71HD: 1U High-Density, Modular 26.5 GHz Microwave Switch

COMMUNICATIONS/CONTROL CORE

The functional block diagram shown in Figure 2 depicts the two primary components of the LXI-compliant IRIS core, the digital communications interface board and the relay driver board. One communications board per IRIS assembly is required to provide the interface between the host controller and the IRIS. Each relay driver board is capable of driving up to 72 relay coils, with the flexibility to control relays operating in the range of 5 – 48 V dc. The IRIS core is a scalable architecture designed to accommodate larger channel count requirements by simply daisy chaining additional driver boards.

The IRIS communications/driver core is designed to work with virtually any type of microwave component available in the industry, regardless of coil voltage requirements, latching or non-latching configuration, and can provide additional confidence in operational success by taking advantage of status/readback bits when available.

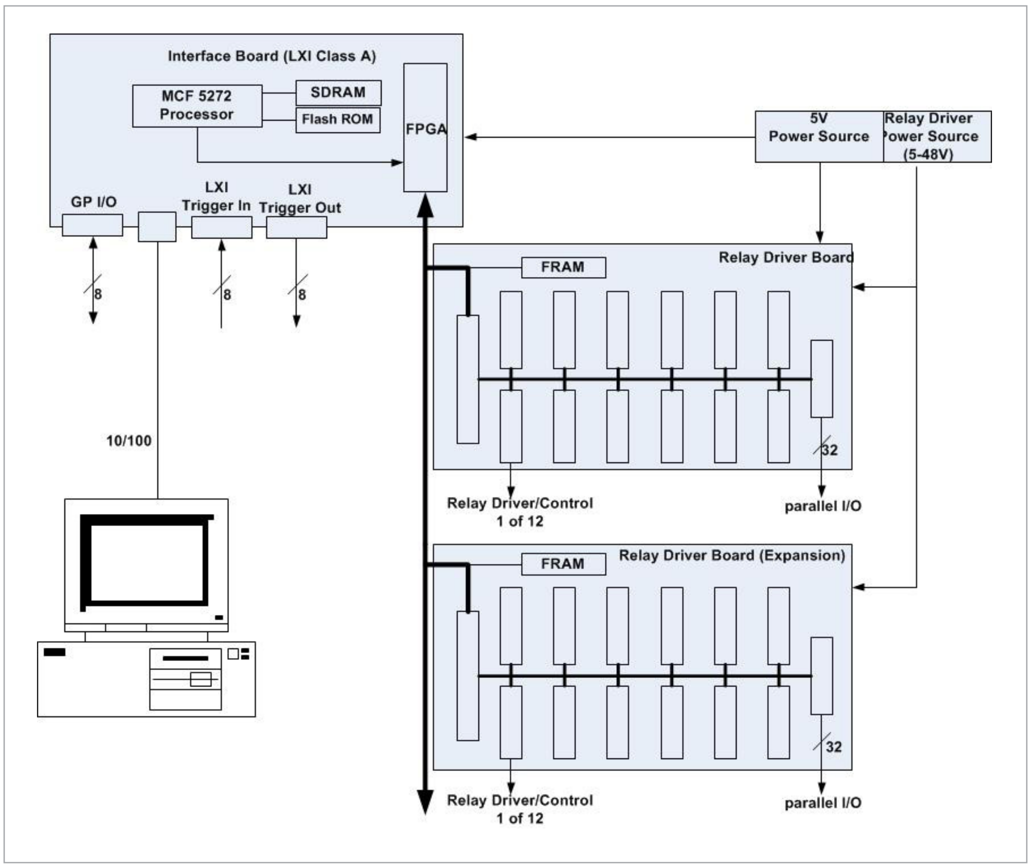


Figure 2: IRIS Communications/Control Core

As the main communication interface between the IRIS and the host PC, the digital controller board embeds the main features required by the LXI specification - including LAN discovery which allows the IRIS to be identifiable by any industry standard discovery tool such as VTI's LInC-U Utility, AMETEK LXI discovery browser, and LXI Discovery tool from the LXI Consortium.

Each IRIS also has a unique graphical user interface (web page) providing monitor and control capabilities and IEEE-1588 synchronization. It ensures that each IRIS-specific design connected to the driver board complies with LXI requirements, facilitating interoperability with other LXI devices on the test system network. The EX7000-OEM core enabled the IRIS to emulate a COTS RFIU by providing a well-documented communications interface, and delivered a framework in LXI that is designed to mitigate obsolescence.

RAPID SOFTWARE DEVELOPMENT

The value of providing hardware engineers with the freedom and capability to choose the component type and vendor that met their design requirements was important for software engineers as well. The software engineers were responsible for providing the tools necessary for integrating the IRIS in an automated environment. The LXI specification requires all LXI compliant devices be delivered with an Interchangeable Virtual Instrument (IVI) programmer's interface (API). The IRIS RFIU EX7000 core incorporates the IVISwitch definition as its API and defines instrument specific functions for programming non-switch devices through IVI instrument specific calls. This provided a common open-platform driver framework across all ITAs in this program.

IVI significantly simplifies the application development task by presenting I/O connection points at the API level by providing path-level programming. This means that programmers have the ability 'connect' only one end point to the other, and all relay closures required to establish that path happen 'under the hood', as opposed to requiring multiple calls to establish a path between a test instrument and an LRU signal.

In a complex RFIU design, there are many interconnections between relays that are otherwise transparent to the IVISwitch API. So while a connect call enables end-end programming calls, relay interconnections are not taken into account, and true end-end system level programming is not inherently achievable. However, VTI was able to quickly embed IRIS specific interconnect wiring knowledge into each EX7000-OEM non-volatile memory through the use of unique personality (device configuration) files. Each IRIS was delivered with a pre-configured file that contained a 'virtual schematic' of the target IRIS, and The prime software engineers were able to develop all application code using system-level end-end path level programming.

An example of this is shown in Figure 3 which depicts a top level block diagram of an IRIS configuration.

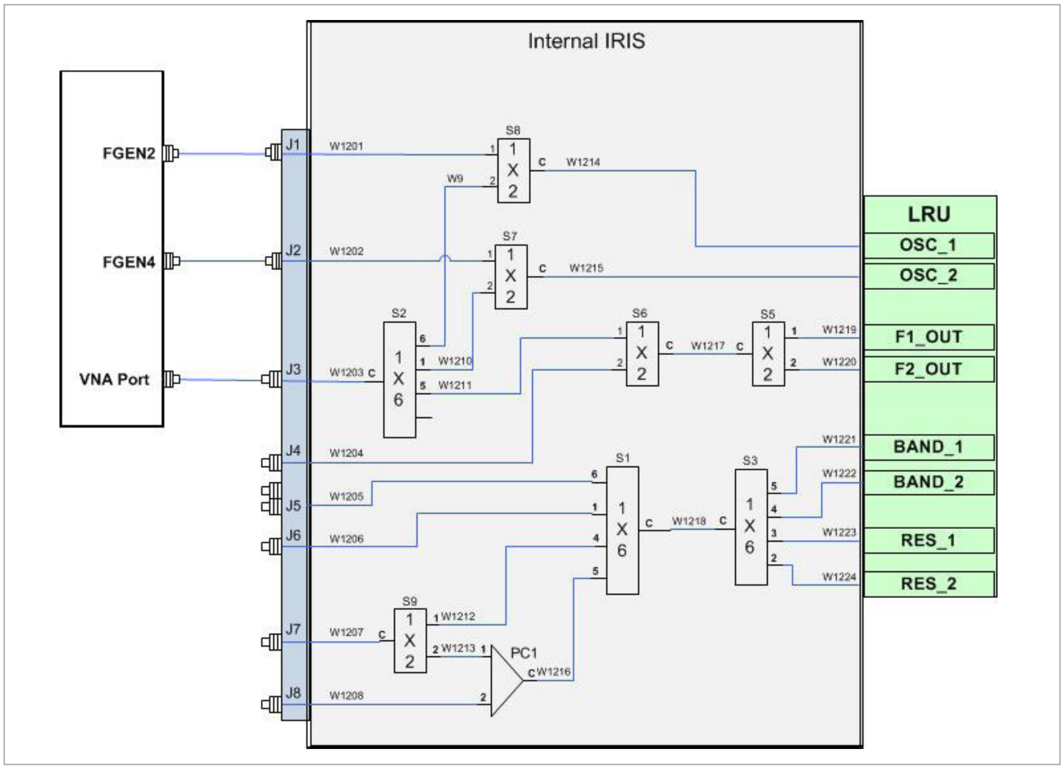


Figure 3: Representative IRIS Block Diagram

Instead of issuing multiple commands to close the three relays in the path connecting the VNA port to the LRU output labeled F1_OUT, the code is written connecting logical names representing end points on the schematic.

driver->Path->Connect ("VNA Port", "F1_OUT");

For lower level control, in effect, closing individual relays as opposed to paths, The prime engineers has lower level calls at the relay level that were available through the IVI instrument specific interface.

Since this is a secure program, VTI also provided a utility that facilitated the 'cleansing' of the personality file.

In addition to providing the framework for rapid application code development, the personality file is also used to form the graphical user interface through which the components in the IRIS could be monitored and controlled. However, unlike traditional soft front panels which are typically executables that reside on the host controller, the LXI dictates that all soft front panels shall be embedded into the instrument.   These interactive panels require no third party software tools (e.g. VISA) to operate aside from a standard browser utility. Each IRIS therefore, has a monitor and control panel that is specific to its configuration. See Figure 4 as an example.

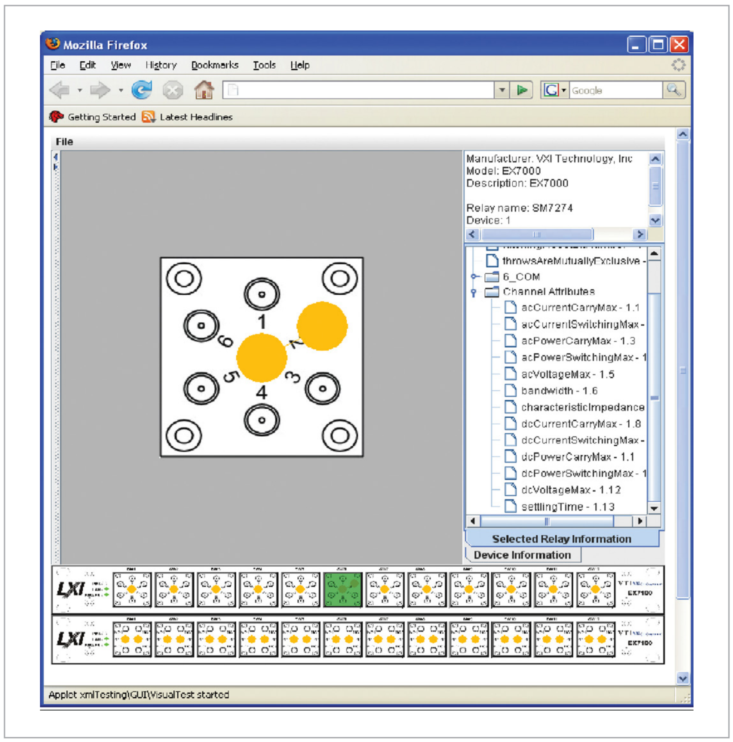


Figure 4: IRIS Communications/Control Core

This is a powerful tool and as applied to the IRIS, allowing engineers and technicians the ability to view the system contents; component attributes and also provides a password-protected mechanism for manual control of the device. In addition, the cycle count of each relay is tracked and can be viewed in the soft front panel, or retrieved through the API to predict relay end-of-life and aid in preventative maintenance.

SUMMARY

Microwave and RF test applications often drive the need for custom interface units; however, this does not imply that a solution must be based on a proprietary or non-standard infrastructure. Engineers at The prime Systems were recently tasked to redesign several ITAs that included complex RF switching and signal distribution systems on a large Air Force program that had a history of low reliability. Given a rapid development schedule, the design team identified areas in which the designs could leverage common components to accelerate the development and manufacturing process. By incorporating an LXI-based COTS communications and control interface into each ITA, the documentation and application coding efforts were also reduced.

VTI Instruments delivers precision instrumentation for electronic signal distribution, data acquisition, and monitoring. The company continues to lead in the development of open standards for test and measurement along with scalable, modular products that maximize performance in a small footprint. With nearly two decades of experience primarily in the aerospace, defense and power generation markets, VTI helps customers maintain a competitive edge and preserve the integrity of their brand.