CUSTOM MICROWAVE SUBSYSTEM DESIGN LEVERAGING COTS METHODOLOGY

Abstract – Designing test systems based on commercial-off-the-shelf (COTS) instrumentation can reduce non-recurring engineering costs and time to production by providing a reusable infrastructure that is usually based on industry standards. Custom designs can result in high maintenance costs due to premature obsolescence; these implementations often lack adequate documentation required for sustained support activities. The high frequency signal components resident in RF/Microwave subsystem designs often prohibit the use of more generic COTS-based solutions that are developed to address a broader range of applications, thus driving the need for a custom solution. This paper will discuss an innovative approach to RF interface unit development that leverages COTS hardware based on the LXI Class A standard. An innovative integrated web-based design wizard, created to simplify the build process resulting in significant time and cost savings from concept through production, is also discussed. Additionally, this paper will explore the inherent capabilities of LXI Class A instrumentation and how this instrumentation standard is ideal for these applications.

INTRODUCTION

RF/Microwave interface units (RFIUs) typically route high frequency signals between test instruments such as spectrum analyzers and synthesizers, and devices under test for a variety of application spaces and needs. Incorporating COTS hardware in the design helps manage costs by reducing non-recurring engineering hours as well as minimizing the lead times. Additionally, COTS solutions are generally well-tested and documented and enable a repeatable manufacturing process that can be supported for long periods of time.

There will always be instances that necessitate custom solutions and these can also benefit from a COTS design approach because of significantly reduced development times and lower non-recurring costs. The benefits of LXI Class A devices have provided the basis for a COTS core communications interface that VTI has leveraged into all of its RFIU designs. The communications interface integrates the versatility of Ethernet with additional features that ensure a high degree of synchronization as well as compatibility with a broad range of complementary products.

A web-based graphical toolset is incorporated to streamline the specification and development process that leverages a comprehensive online database of preferred components. The process continues with a design wizard that 'personalizes' the RFIU and lays the foundation for path-level programming. This tool automatically generates support documentation and web-based graphical user interfaces to allow system engineers to focus their time on the design and routing of the internal component layout specific to the application, greatly reducing time to production.

Selecting the Design Approach

A fundamental question that arises during the design process is whether to pursue a modular architecture utilizing COTS components or one that is fully integrated. A modular approach makes use of building blocks, or 'slices' that directly expose component I/O to the user (see figure 1). Modular designs are generally quite flexible and can be quickly reconfigured through external cabling to assume a variety of topologies.

Using the building blocks shown in Figure 1 (14 SP6T relays) external cables can define a number of different configurations such as dual 1 x 36 multiplexers, or a 6 x 6 matrix. This approach can provide significant cost savings as it reuses common assets to address multiple requirements. However, the additional cables and connections will add insertion losses and degrade the overall integrity of the signals passing through the interface. Test requirements will dictate whether this approach can yield acceptable results.

Figure 1: Modular RF Switch Building Block

When critical system performance characteristics cannot be compromised an integrated design must be considered. Integrated designs are customized to meet specific application requirements, and embed the entire solution within a subsystem chassis (see Figure 2). This approach will ultimately result in the best performance and deliver the highest level of signal integrity; however, it is application specific and offers very few reusable components for future designs.

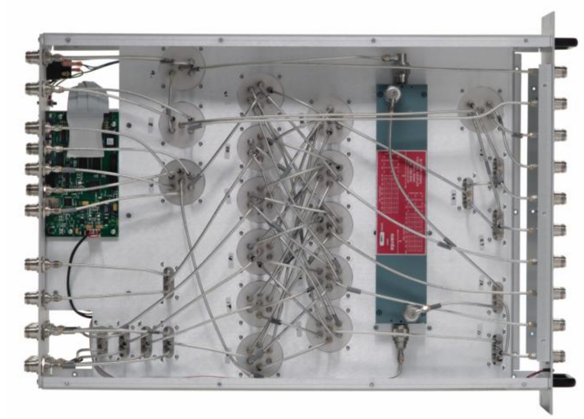

Figure 2; Integrated Box RFIU

Different application requirements will dictate which approach is to be used. Systems that must test a variety of devices will generally use a modular solution because it can be adapted to test different DUTs with minimal time and effort. Other systems may have more complex design requirements which require an integrated subsystem, but even these instances can benefit from a core COTS-base methodology.

COMMON CORE METHODOLOGY

Even custom subsystems incorporate a number of common operations that are repeated during the design and build phases; a number of these phases are identified below:

- Communications and control selection
- Component selection and qualification
- Software driver development
- User test program set code development
- Bill of Material generation
- Assembly instruction generation

A typical common core kernel development can be seen in VTI's RFIU LXI-based Class A communications and control interface. The two main components of the kernel are a digital communications board which is the main interface to the host controller, and an open-collector component driver board to generate the control signals for the microwave relays.

The primary objectives behind this design are flexibility, scalability and reusability. This design can be scaled to provide drive control in 72 channel increments, and expanded to a maximum of 576 channels. Additionally, the digital control board also contains non-volatile memory to store system documentation and a device configuration file. This information is used to automatically generate a custom web-based graphical user interface and is the basis for IVI path level switch programming. These features significantly reduce development and debug time for systems engineers.

This approach also allows modular and custom designs to benefit from an industry standards. For example the IEEE-1588 protocol enables tight synchronization and deterministic triggering mechanisms, over the wire, as part of the LXI standard. These capabilities are even further expanded to include hardware triggering capabilities in LXI Class A devices.

DEVELOPMENT PROCESS

The VTI Custom Microwave Configurator greatly simplifies the entire development process through a number of automated tools. RFIU design typically includes research and selection of components that meet the application requirements. Preferred vendor lists are commonly used in the industry to maintain a manageable pool of sourced components. The flexibility of the internet was leveraged to develop a searchable online components database that is automatically integrated within the development process. The interface has been developed to include key specifications, that can be entered via pull down lists, to quickly display a subset of parts that meet design criteria (see Figure 3).

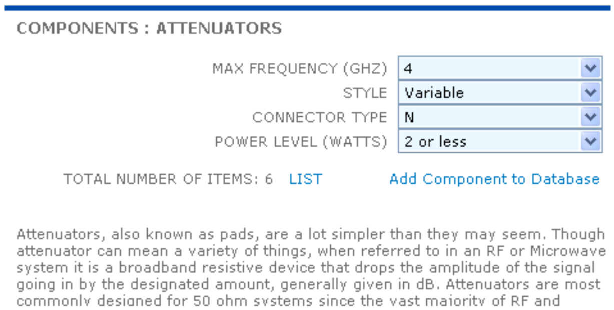

Fig. 3: Online Utility for Component Selection

The database also provides direct links to data sheets, numerous technical notes intended to educate new engineers, current pricing and lead time information. Once selected, components are added to a configuration list and the details are stored online. All the pertinent information relative to the RFIU design (i.e, component model numbers and quantities) is included. Saved configurations can be easily accessed and made available to all team members. This online component selection utility not only reduces design hours, but also provides the framework for expediting subsequent processes in the development cycle.

Since the LXI digital interface is 'Ethernet-enabled', the system configuration information is uploaded directly through an automated process that is part of the online configuration utility. The configuration data from an SQL database is converted to Extensible Markup Language (XML) data which is uploaded directly to the interface.

XML is not necessarily intuitive for a software engineer who is looking to develop test program application code. Therefore, a Java-based applet has been embedded on the interface board and allows further customization of the assembly in a point-and-click environment. An XML file is then automatically generated that will be targeted by the application software.

SCHEMATIC REPRESENTATION

Once the component list has been uploaded in XML format to the digital board, the wiring process can begin using a graphical design wizard resident on the digital board. Path definitions and connections can be easily assigned. Figure 4 shows a 2 x 6 matrix schematic that uses 8 relays and 20 wires. The goal is to translate the schematic into an XML file that will virtually define the assembly's wiring.

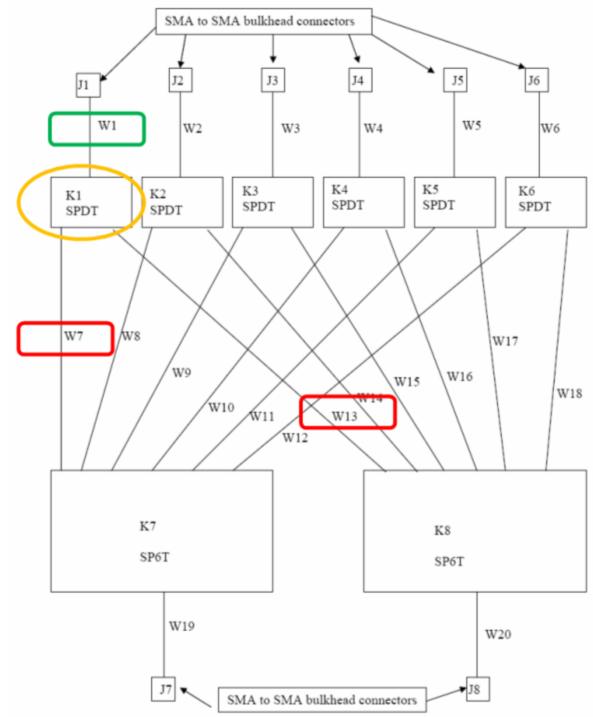

Fig. 4: Top-level Schematic of 2 x 6

Each component within the configuration file can be quickly assigned a logical name and virtually connected to other components using the design wizard. Figure 5 illustrates a panel within the design wizard that details component K1.

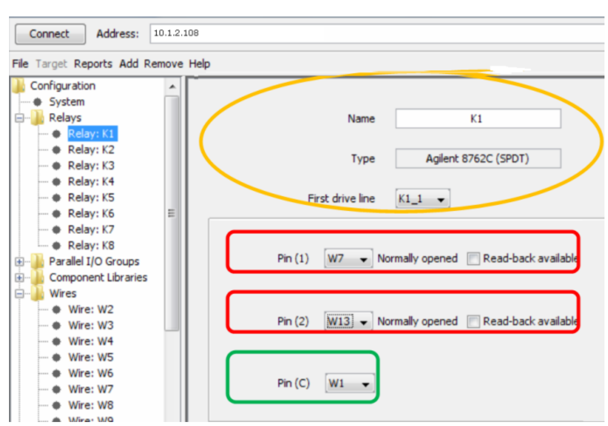

Fig. 5: GUI for Schematic Generation

Specifying a connection between two pins on two individual components, each pin is assigned the same wire name. For example, K1.2 and K8.1 are connected in the schematic, and are both assigned the label 'W13' by the design wizard, while K1.1 and K7.1 are assigned the label 'W7'. Once the schematic has been translated using this tool, the XML file can be loaded on the digital board; this effectively stores the unique personality of the subsystem in memory on the unit. This entire process utilizes an intuitive wizard to simplify the wiring task.

SOFTWARE DEVELOPMENT

Conformance to the LXI standard mandates industry-standard IVI drivers as a minimum requirement for an application programming interface (API)[2]. The IVISwitch driver is used to program the RFIU and provides an API that connects functional paths, as opposed to closing individual coils on relays.

The XML file (schematic) that was generated by the design wizard maintains a database of all the system interconnects, including the logical names of end points. The main advantage of this is software engineers are not required to delve into the internal details of the RFIU and architect software based on individual components nor do they need to generate a list of possible paths. The virtual schematic provides this information and the end-to-end connection statements can now be made to establish desired (see statement below).

driver->Path->Connect ("J8", "J1")

This command activates coils on two different relays (K1 and K8) with a single function call using an industry standard API. Software development time in greatly reduced because the IVI driver is common to all system designs. Further, the digital interface can be reconfigured on-the-fly to adapt to new system layouts by uploading a new XML file. This is particularly useful for applications that utilize modular building blocks and test adapters as part of the system architecture.

DESIGN DOCUMENTATION

Aggressive schedules, combined with custom or application specific requirements, typically mean delivering subsystems to the field as quickly as possible, and documentation is often an afterthought. However, comprehensive documentation is critical for long term support and maintenance, as well as ensuring a repeatable build process for future requirements.

VTI leverages a standard COTS communications interface, so documentation generation can be leveraged across multiple subsystem designs. Furthermore, because the IVISwitch driver is common to all modular and integrated subsystems, the documentation is readily available as part of an html file, and through the IVI Foundation[3]. The LXI Class A compliant digital interface simplifies synchronization with other LXI-based instruments with the LXIsync API used to invoke LAN events and triggers for.

The XML file also contains all of the individual component information, including OEM part numbers that can generate a comma delimited value-based (.csv) bill of materials though the design wizard. Wire lists also play an important role in providing the tools needed to maintain fielded subsystems. All interconnects have been captured, including those to passive components, as well as wire lengths, and types. The design wizard can also create a .csv based wire-list for manufacturing activities. Both .csv files can be easily edited and customized to meet changing requirements.

Finally, the XML file provides the information to generate a customized soft front panel accessible through a standard web browser. Simply enter the IP address in the address toolbar; no additional coding is necessary. Figure 6 shows an example of a soft front panel which allows immediate point and click monitor and control capability of the RFIU. The interface also includes detailed component information including model numbers, specifications and cycle counts.

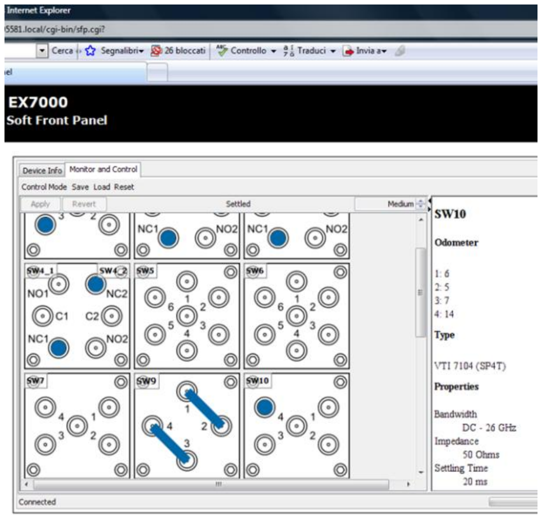

Figure 6: Monitor and Control GUI

These displays can be accessed from anywhere in the world through the LXI interface, turning a custom-designed solution into a product that is designed for supportability.

SUMMARY

Custom RF interface designs present many challenges that can result in excessive non-recurring engineering time, driving system cost and extending production cycles. However, it is possible to extract common core elements that are used in all designs. A standard infrastructure, based on a COTS toolset, can be reused in many different applications to minimize non-recurring engineering (NRE) costs.

Using industry standards, such as a core infrastructure based on the LXI Class A standard, provides a versatile communications interface that includes integrated graphical web-based configuration. Selecting common industry standards also ensures long term support and an edge against product obsolescence.

REFERENCES:

[1] W3C Website, www.w3c.org

[2] LXI Standard Revision 1.1

[3] IVI Foundation Website, www.ivifoundation.org