Safety Considerations for Configuring LXI-based ATE Systems
When IP Addresses Become Logical Addresses

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Abstract – ***LXI has become an increasingly popular instrumentation platform that is being used in many ATE system designs. It provides a simplified programming interface, a convenient LAN-based hardware architecture, and the precision synchronization and triggering required by many test applications. When multiple copies of an LXI instrument are used in a system, however, potential issues can arise if the instruments are swapped during troubleshooting. Technicians must manually reconfigure the instruments or update the system configuration file. Due to time constraints and shift changes, the technician may configure the system incorrectly, which can cause damage to the unit under test (UUT), especially if the instruments are power supplies. This paper will discuss an automated method for reconfiguring systems that significantly reduces the risk of UUT damage or risk to the operator.***

INTRODUCTION

Prime manufacturers of complex systems such as satellites, avionics and military weapons are finding it necessary to reduce the cost of test to remain competitive, without sacrificing the integrity of their products. Many of these primes are achieving this goal by consolidating their test assets into a 'common-core' that can be reused in different configurations capable of testing a diverse set of subassemblies. When assembling instrumentation into a test system, it is desirable to minimize operator intervention during the test process, which can introduce the element of human error and increased test cycle time. In response to this need, test equipment vendors have been implementing various communication busses on instruments for years (e.g, GPIB, VXI, PC-based) and integrating intelligent, software-based control of their products to facilitate the automation of test.

Intelligent instruments in an automated test environment offer the benefits of shorter test times and increased production throughput. However instrument busses produce a unique set of configuration and maintenance challenges that can produce hazardous conditions for system operators who lack detailed knowledge of the system design and implementation This is particularly evident when automated test equipment (ATE) is fielded in an environment such as a repair depot where system debug procedures consist of swapping instrument assets in order to isolate defective hardware and quickly return the system to operational status. If test assets are not properly configured in the course of debugging a system problem, damage to the test station, the unit under test (UUT) or even the test operator can result. If, for example, two power supplies are swapped and their logical addresses are not properly configured, catastrophic failure can occur on the UUT causing parts to 'fly' from the resulting explosion. Thus it is imperative to make sure that maintenance processes are as failsafe as reasonably possible.

HISTORY

In the past, ATE consisted of a lot of custom parts which relied on either custom interface busses, or IEEE-488 for controlling instruments from a remote PC. This has evolved over the years to incorporate more Commercial Off The Shelf (COTS) parts, which still mostly adhered to ATE specific interfaces such as IEEE-488, PCI-bus extensions or generic interfaces such as IEEE-1394. These bus structures required maintainers to manually set logical addresses that corresponded to specific locations in a test rack. This process was complex enough that extensive manuals and training systems were devised and implemented to maintain the ATE. This embedded a partial amount of safety in the system because of this complexity (and the need for instruction manuals). However, with the advent of more commercial interfaces such as LXI (based on the Ethernet standards) this is no longer the case. Now instruments can be replaced more easily (at least from a physical perspective) which can lead to the potential for errors that are not normally encountered in the consumer market where Ethernet is prevalent.

LXI INSTRUMENTS

The LXI instrumentation standard is a well thought out implementation of Ethernet communications for instruments. The specification defines a base 'core' specification, providing the necessary software and hardware infrastructure for ensuring multi-vendor interoperability that is critical to the success of ATE system design. Extended functions deliver standard mechanisms for precise inter-module synchronization and triggering, required by sophisticated ATE systems that are not available with generic Ethernet implementations. The LXI standard has become widely adopted with over 20 vendors supplying >1000 products that have achieved LXI-class compliance[1].

For the majority of test applications, the flexibility in setting up Ethernet-based devices makes LXI an attractive option as a communications interface between the host controller and the test instrumentation. Since each instrument has a unique IP address, there is a direct analogy to the familiar logical address schema that has been used with GPIB devices for years. However, there are various methods through which an LXI instrument acquires its IP (logical) address that present new challenges that were not present with GPIB system. Instead of dipswitches, IP addresses can be dynamically assigned through a DHCP server or automatically assigned based off a unique MAC address, or they can be statically set through a web-based software interface (see Figure 1) that can be accessed through standard browser utilities. These methods work very well, although a level of familiarity with Ethernet configuration is required that may not be considered common knowledge for ATE operators. Thus, additional training is required and specific procedures must be followed in order to properly maintain test system.

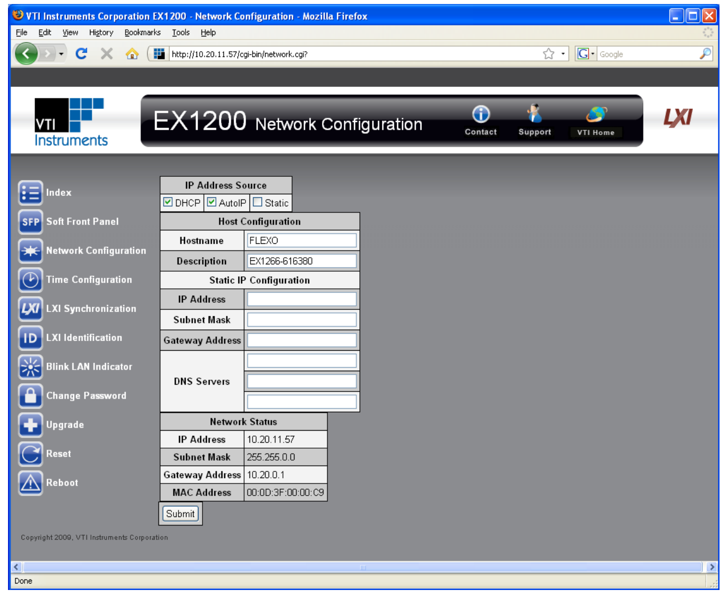

Figure 1: Web-based Network Configuration Panel

COMPATIBILITY REQUIREMENTS

Hardware

The large majority of computers available on the market today are equipped with Ethernet interfaces which can be used to send/receive test instrumentation commands and data. Therefore, unlike GPIB, no additional bus communication cards are required since instruments can connect directly to the Ethernet port on the PC. Ancillary hardware is commonly available resulting in a relatively inexpensive communications bus infrastructure adding to LXI's appeal. Standard cables with RJ45 connectors, and a generic Ethernet mult-port switch are all that is required to interface a host controller to multiple LXI devices. This interface simply requires the user to insert a cable into the instrument interface and ensure that the locking tab has engaged.

In addition to the system side interface, the LXI instrument will commonly have a cable interface to the devices under test (UUT). Modern cable routing can usually ensure these cables are connected to the proper interface. Cable markers and tie downs to control cable positioning also help to ensure that cables are connected properly.

Software

The LXI specification defines the Interchangeable Virtual Instrument (IVI) standard as the required framework for instrument drivers that are delivered with LXI-compliant devices[2]. IVI defines "specifications for programming test instruments that simplify interchangeability, provide better performance, and reduce the cost of program development and maintenance."[3] Some LXI vendors, particularly those that are migrating products from the GPIB platform, will offer additional interfaces and protocols such as Telnet or VXI-11 which provides a means for passing text-based commands (similar to SCPI) by directly opening up TCP/IP sockets to the instrument. It is important to note that all forms of LXI-based communications share the common thread of using the Ethernet bus as the interface between the host PC and the instrument. These protocols can be implemented in the instrument at a fairly low cost, providing a great deal of flexibility to the application developer.

The Challenge – Allocating IP Addresses

Large ATE systems often have multiple instruments that share a common communications bus. Instruments are assigned unique identifiers, typically logical addresses that are statically configured through the use of dipswitches. Thus, physical location of a device is irrelevant as it relates to identifying an instrument on the bus. For example, programming Power Supply #1 which it configured at a logical address 40 will be successful regardless of whether the power supply is in rack 1 or rack 2 of a test system.

However, physical location is extremely relevant in complex ATE systems because instrument input/output pinmaps are well defined and not expected to change. The power supply at logical address 40 has output pins that are assumed to reside at specific pins on the interface to the UUT. When the test application code sends a command to the power supply at logical address 40 to output 250 volts, it is understood that the voltage will appear at those pins (and nowhere else). If in the process of system debug, two identical power supplies are swapped and their logical addresses are not changed to reflect the swap, programming power supply 1 will result in voltage being present at different pin locations than what was expected which can lead to potentially hazardous consequences. Test technicians are generally well-trained and accustomed to modifying dipswitches during maintenance routines and these situations

With the introduction of LXI to ATE platforms, instruments inherently have IP addresses that uniquely identify a device on a network. Assigning specific IP addresses to instruments involves more than setting dipswitches and can be a cumbersome process for the end user if they are not given some helpful tools. For instance, if the ATE system relies on static non-routable IP addresses, and does not have a DHCP server, the user must first assign the network interface to the same subnet as the instruments default before they can set the instrument to the desired address Because this process is less intuitive and not engrained in the test technicians usual maintenance process, the likelihood of swapping instruments and neglecting to change IP addresses increases. Assigning IP addresses through typical DHCP servers does not overcome this problem since the physical location of the device has no bearing on the IP address that is assigned to it; typically a DHCP server will reply to an address request with one that is either random, or based on the device's unique MAC address.[4] The potential for UUT damage or operator injury is severe enough to warrant consideration of preventative measures.

THE SOLUTION

In LXI-based systems, an Ethernet switch is used to connect multiple test instruments to the host controller. By default, the instrument will request an address from a DHCP server which dynamically assigns IP addresses to the devices that are connected to the switch. Ordinarily DHCP is rather simplistic in nature as it applies to instruments in ATE systems. In fact it can be counter-productive (since it will attempt to give an instrument its previously given address, even if it has been moved). In an ideal situation, the each port on the switch would be assigned a specific IP address that never changes. This would allow a system architect to assign a logical address to an instrument asset based on its physical location in a rack.

One mechanism that shows considerable potential for achieving this goal is a DHCP Relay Information Option known as RFC 3046 Option 82. This option, when enabled on a switch, can request a pre-defined set of IP addresses from the DHCP server and assign them to specific port locations on the switch. ATE systems that utilize this method for assigning IP addresses yield LXI-based designs that are simpler to maintain, especially when compared to GPIB equivalents where an awareness of logical address dipswitch settings is required. Thus, the goal of a system design which reduces potentially hazardous scenarios can be achieved.

RFC 3046 Option 82 explained

When a client instrument is configured to obtain an IP address through a DHCP server, the request typically gets routed through an Ethernet switch. In this case, the Ethernet switch simply passes through the request, the DHCP server subsequently returns an IP address that gets routed back to the requesting client instrument. As previously pointed out, the IP address is not guaranteed to be the same each time for each request. There are many switches on the market today that can be configured to support RFC 3046 Option 82. When a switch has this extended capability enabled, usually through a firmware configuration, it becomes more than a simple pass-through device. When a client instrument makes a request for its IP address through a switch with this capability, the switch edits the message, appends Option 82 information that gets sent to the DHCP server. The Option 82 information describes a specific port on the switch as well as the switch itself and when the DHCP server receives this request, it is able to identify the requesting port and switch, and assign it a pre-defined IP address that has been determined during the system design phase. However, it is important to note that most DHCP servers does not by default recognize Option 82 requests and must be configured explicitly to do so.

Modifying the DHCP Server

An LXI-based instrument need not be aware that it is receiving its IP address through the use of Option 82. Thus, it must be pointed out that **no modification is required to existing LXI-based instruments** to enable them to use this option. An instrument simply needs to be configured to retrieve an IP address from a DHCP server; the switch and the server can do the rest. The DHCP server is modified to reference a lookup table that associates a list of IP addresses with specific ports on specific switches. The lookup table is generally a one-time configuration that can reside as part of the ATE system files which can be read by the DHCP server during initialization.

The Results

What this option gives system designers is the capability to statically assign instrument IP addresses based on physical location in the test rack. The Ethernet switch which would generally be used to simply expand the number of instruments that can be attached to a single LAN interface is given the additional task of working in conjunction with a DHCP server to assign a specific IP address to a port location. Therefore, if proper cabling and labeling procedures are followed, any power supply plugged into port 12 of switch A would always be assigned the same IP (logical) address, and the application software will always communicate to any power supply of the same type that is plugged into that port (and slot in the rack). See Figure 2.

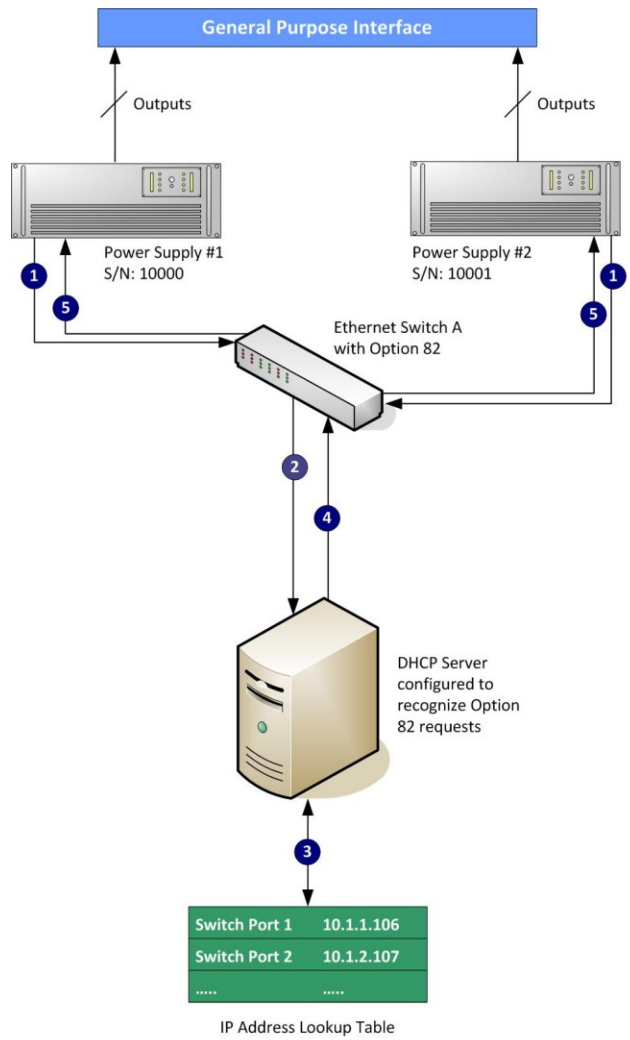

Figure 2: Option 82 Implementation

1.) Two power supplies request IP addresses via a request to a DHCP server that gets routed through an Ethernet switch.
2.) The enhanced capability switch appends Option 82 to the message
3.) The DHCP server (enabled to recognize Option 82 requests), references a lookup table and retrieves pre-defined IP addresses based on the port numbers of the requesting switch
4.) The IP addresses get routed through the switch back to the power supplies
5.) The power supplies are assigned location specific IP addresses. What this means is that PS1 and PS2 can be physically swapped, and the supplies will receive the new IP address upon initialization.

This simplified architecture creates an ATE system where the instruments each have a static IP Address which requires no additional effort by the Operator or Maintainer other than they follow some simple procedures during instrument installation or replacement (namely to insert the labeled

Ethernet cable into the described port). This is much more reliable (and easier) than requiring the Operator or Maintainer to manually use a tool to configure instruments after they are installed. In addition, when instruments are swapped during debugging of faults, the IP Addresses are automatically changed so that the potential for hazardous situations is reduced.

Additional Benefits

In addition to the simplified maintenance and safety created by using this methodology, there is an additional benefit that is realized. Now that all the instruments in the ATE have a very specific IP Address, and they are provided on initial startup of the system, configuration should be simplified. All of the common interfaces provided for instrument access require some sort of Resource Identification to access the proper instrument. For Ethernet based instruments this commonly includes the IP Address of the instrument itself. This Address is now a static number which can be utilized directly by the Test Program, or configured into the system. If the system is designed using a non-routable internal addressing scheme to communicate with the instruments, then this can be standardized. Thus the system software and configuration can remain the same across any number of similar (or same) systems. This provides a more reliable and less expensive process of system configuration.

CONCLUSIONS

The LXI specification was introduced in 2005 and defined an industry standard for LAN-based ATE instrumentation. In addition to the convenience of LAN-based communications, LXI brings powerful timing and synchronization capabilities that are required by demanding test and data acquisition applications. However, for large-scale ATE systems, the flexible configuration options that are inherent to Ethernet devices present new challenges as they relate to system maintenance. These challenges, if not addressed properly, can produce damaging results. RFC 3046 Option 82 has the potential to add a layer of protection to ATE systems by reducing the reliance on manual configuration to simplify maintenance procedures. Once a system type is configured, it may be replicated any number of times (if using internal non-routable addresses) with no additional configuration required. This process only requires the use of switches supporting RFC 3046 Option 82 and a DHCP server which can be configured using this technology. Both elements exist today in products which are widely available In fact, one could argue that for complex ATE it should be required in order to prevent issues and promote safety.

REFERENCES

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