environmentaltest

LXI Simplifies Satellite Environmental Testing

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Because satellites are subjected to large temperature extremes over very short times and distances, they present some interesting pre-flight environmental testing challenges. Parts of the satellite exposed to the sun will see very high temperatures while nearby sections that are shaded will see a very low temperature. This is due to the vacuum of space that prevents convection heating or cooling.

To accommodate these many conditions, the China Academy of Space Technology's Environmental Engineering Department recently began developing a project for environmental testing of spacecraft satellites.

A test chamber used for environmental testing of a satellite must subject it to the same conditions encountered in space. This requires the use of a vacuum chamber that also can, under programmatic control, heat and cool the satellite.

Implementing a Solution

Chamber cooling was accomplished using liquid cooling. For chamber heating, the equivalent of 240 precision heater control zones was required to accurately replicate the heating profiles that a spacecraft would experience in space.

To heat the chamber, halogen-type heater elements were used since they provide a highly efficient and relatively precise means to incrementally control the heating process. Each heating element needed 2 W to 600 W and operated from 0 to 150 V at 0 to 4 A, requiring a total of 144,000 W of power. For maximum flexibility, each element had to be independently programmable and monitored via a central controller, allowing precision operation of all power supplies and a response time of 100 ms for any one supply.

Besides the large mechanical size implied by the number of power supplies needed to supply 144 kW, providing the remote control and management of these power supplies offered an equally large integration challenge. The implementation had to consider the following issues:

- Cabling from unit to unit as well as interconnection to the remote controller.
- Setup and debugging of the system once assembled as well as ongoing maintenance/support tools.
- Interface control such as software and drivers.

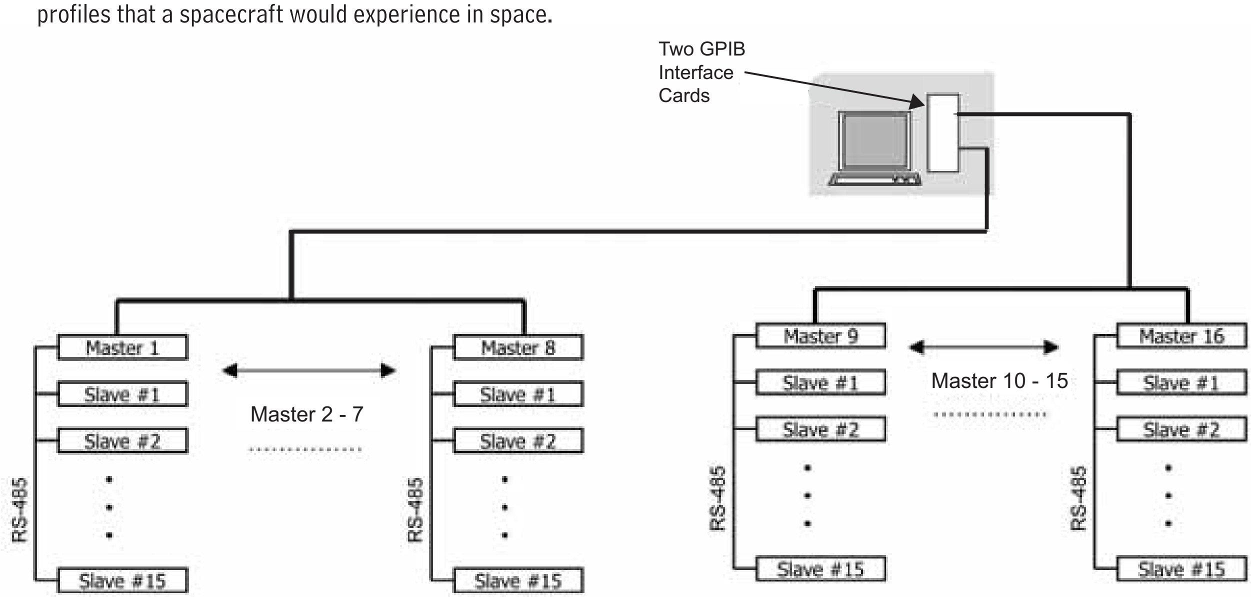

FIGURE 1. GPIB CONFIGURATION

• Interconnect infrastructure cost including cables, controllers, hubs, and switches.
• Distance from the system control computer to the power supply racks.

To meet the overall system requirements, 240 remote-controlled, 600-W power supplies would be needed. Based on Elgar's DLM power supply family, the implementation chosen consisted of 16 master units each driving 14 slave units. Additionally, each power supply or group of power supplies could be controlled by a GPIB or LXI interface.

GPIB Implementation

To implement the overall system configuration using GPIB control, several key technical factors had to be considered. The GPIB bus architecture only supports up to 15 devices on one network with a maximum total cable length of 20 meters and a maximum separation of 2 meters allowed between devices. Consequently, to control 16 master power supplies, two IEEE controllers would be needed, with each master unit controlling multiple slave power supplies.

As shown in **Figure 1**, a GPIB-controlled system could be configured by using a combination of master and slave units, with each slave unit controlled by a daisy-chained RS-485 interface. Up to 30 slave units can be controlled by a master unit, although for this configuration, 16 masters with 15 slave units per master were proposed with control of the masters split between two GPIB control buses.

While technically feasible, the use of multiple IEEE controllers would create a complex and expensive implementation. With two controllers and multiple instruments located on each bus, there was the additional concern that significant time might be needed to debug a complex GPIB configuration such as this one.

For example, if one or more instruments on the same bus were set to the same GPIB address, the control bus could lock up. There is very little the user could do to debug the problem aside from methodically checking and testing each device to verify operation and address assignment. This is a very slow and time-consuming process, particularly when you have multiple devices interspersed across four racks with limited accessibility to any one unit.

Interconnecting GPIB devices, which requires the use of expensive, shielded 24-conductor cables, also can present limitations when configuring such a large system. Overall cable length for a GPIB bus is limited to 20 meters with individual devices connected via a linear, star, or linear/star configuration.

This bus-length limitation was seen as a potential problem for this application since the controller might easily be located more than 20 meters from the chamber. Additionally, with the number of cables needed to interface to each device and the need for two GPIB bus networks from the controller to the racks, cable management and the expense of outfitting the complete system with GPIB cables were perceived to be problematic.

LXI Implementation

While it might be possible to implement this application based on GPIB control, significant setup and debug time would be required to make the system operational, and the requirement of having the control room close to the power supply was not desirable. However, because the selected power supplies supported both an LXI interface and the master/slave configuration, it was decided that a LAN-based control environment might be preferable.

Unlike a GPIB implementation, the LXI implementation removed any concern regarding the location of the power supply racks relative to the control-room location. A LAN-based implementation also eliminated any special communications cabling requirements, allowing the user to simply connect the test system to an existing LAN network without installing special cabling between the racks and system controller.

Implementing this system configuration with LXI-controlled power supplies meant using an Ethernet network or LAN to control and monitor all devices. As part of the system configuration and design, an overall LAN topology and IP address management scheme had to be established.

The LAN topology for this configuration was based on the creation of a sub network (subnet) that consisted of a PC with a dedicated LAN port and a switch/router that provided four LAN connections, one to each of the four racks. Within each rack, a seven-port switch was co-located to provide a LAN connection to each LXI device.

Creating a subnet or private network for all the LXI devices guaranteed that device control would not be compromised by other non-test system LAN traffic. Additionally, a subnet provided protec-

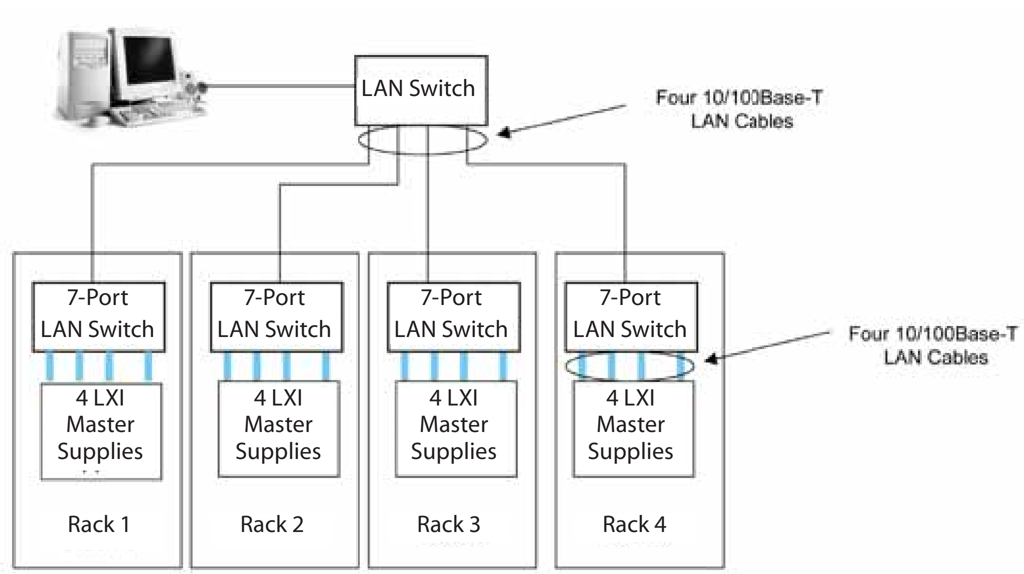

Figure 2. Network Configuration

tion against network viruses or worms by isolating the test system from the corporate intranet or Internet. **Figure 2** details the overall LAN configuration for the system.

The overall system layout consisted of multiple racks of power supplies, with each rack subsystem being controlled by an Ethernet connection. Like the proposed GPIB configuration, each rack contained 60 power supplies with four of them configured as LXI device masters. In turn, each of these masters controlled 14 slave units via RS-485 connections.

Each rack included an inexpensive, off-the-shelf LAN switch that connected each LXI device along with simple off-the-shelf Cat 5 cabling to each group of master/slave power supplies. **Figure 3** depicts an overall layout of the power supply rack system.

LXI Device Configuration

To set up or configure LXI devices, each device requires its own IP address. Since all LXI devices must support TCP/IP, communications to other network devices are done via IP addresses that can be set statically or dynamically depending on the device's capabilities and whether the network supports the dynamic host configuration protocol (DHCP) dynamic IP assignment. For this system configuration, all devices were assigned static IP addresses.

Static addressing allowed for the orderly numbering of preassigned IP addresses throughout the power supply rack. For example, IP address xxx.xx.xx.101 corresponded to the unit in the upper left rack location and IP address xxx.xx.xx.117 to the unit in bottom right rack location.

To configure each device's IP address assignment and the TCP/IP address mode, the user can access the LXI device's web page, a feature that all LXI devices support. Accessing the instrument's home page requires entering the device's IP address if statically configured by the manufacturer. If the device's IP address has been dynamically assigned and the network supports the domain naming system (DNS), you can enter the device's default host name, which is specified in the manufacturer's product manual.

Accessing the LXI device's web home page and configuration page provided the following network information and control options:

- Host Name.
- MAC and TCP/IP Address.
- VISA Resource String.
- Configuring TCP/IP Mode: DHCP or static IP assignment; default will be DHCP if the device supports automatic IP assignment.
- Configuring Static IP Configuration, Set Values for IP Address, Subnet Mask, and Default Gateway.
- Enabling Dynamic DNS if the device supports this mode and Specifying DNS Server(s); default will be dynamic DNS enabled.

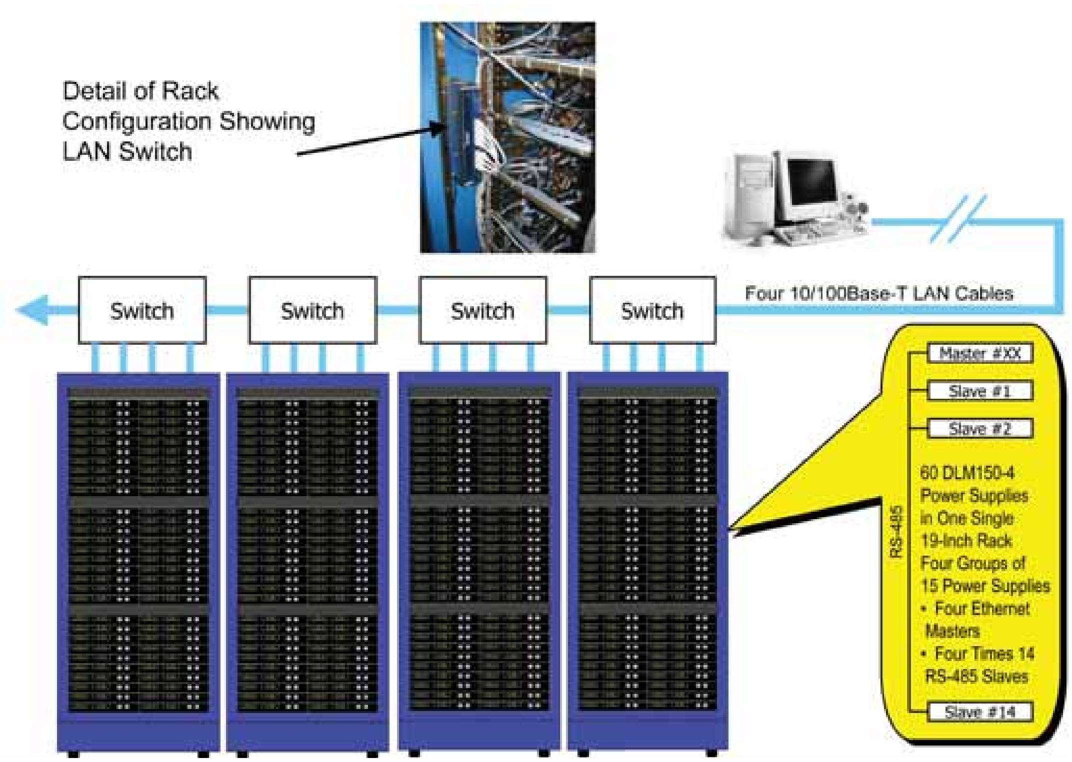

Figure 3. System Configuration

With the capability to access each device's web page via the LAN interface, configuration and maintenance of each device as well as overall system configuration were easily accomplished in spite of the large number of remote-controlled devices and complexity of the system.

There are other LXI features that helped to facilitate debugging and turn-up of the system. To aid in the discovery of devices located on a subnet, all LXI devices support the VXI-11 discovery protocol. The VXI-11 protocol in conjunction with software I/O libraries and a discovery tool provided the capability to identify all LXI devices located on the LAN subnet.

By invoking the discovery mechanism, each LXI device connected to the subnet provided identification information such as manufacturer, model number, serial number, and IP address. This information was used to access each instrument's web page as well as populate resource tables that were used by other applications and utilities.

LXI devices also support the use of the Internet control message protocol (ICMP) ping server functionality, which provides a diagnostic mechanism for verifying an LXI device's LAN connection. By sending a ping command to a device, the LXI instrument's LAN status indicator will indicate when a ping command has been received, providing a diagnostic mechanism for verifying an LXI device's LAN connection and physically identifying the location of the device within the rack. This functionality was very useful during system debug since it allowed the user to easily associate the physical location of an instrument with the device's IP address.

Controlling the LXI Devices

After connecting and configuring all LXI devices on the network, programming and control of each device required developing an application, which interfaced with the instruments' supplied drivers. For this application, a COM-based software development environment was selected with control of each LXI device.

All LXI devices are supplied with an IVI driver. For these user power supplies, an IviDCPwr class driver provided a standardized set of commands for monitoring and controlling all the LXI-controlled DC power supplies in the system. The IVI class driver with its standardized functions helped expedite integration and development of the application and offered the capability to easily incorporate or interchange other DC power supplies in the future.

Actual configuration of the IVI driver required only that the appropriate VISA resource string name be attached to each instrument driver:

TCPIP::10.0.41.6::INSTR or
TTCPIP::HOSTNAME::INSTR

where the value 10.0.41.6 is the device's IP address. For this configuration, since static IP address assignment was used, each instrument's IP address value was used to create each resource string name.

Conclusion

When compared to a GPIB-based solution, the use of LXI-compliant power supplies greatly reduced the challenges and risks associated with implementing a complex system configuration. System control and integration were made much easier by using IVI.COM drivers that easily interfaced to the system's application development software. Troubleshooting and debugging of the complete system also were streamlined by features such as the VXI-11 discovery mechanism, the use of ICMP (ping server) functionality, and web-page support for each LXI device.

Using an LXI solution also made the implementation of this system quicker, easier, and less expensive when compared to a comparable GPIB implementation. Significant savings and performance were realized by:

- Virtually unlimited flexibility in locating the controlling computer relative to the LXI instrument rack. The distance between the controller and the chamber was a nonissue by adopting an LXI-based implementation. The flexibility associated with being able to locate LXI instruments virtually anywhere relative to the system controller has become a key reason for adopting Ethernet-based instrumentation.
- Elimination of costly and bulky GPIB cables. Even though GPIB cabling was possible, cable management would have been much more difficult and complicated.
- Web-based control of power supplies providing support for diagnostics and lab testing. During the initial integration and debug phase of the project, the capability to easily connect a laptop computer to an instrument or portion of the subnet highlighted the benefits of using Ethernet in conjunction with a browser interface to control and troubleshoot system components. Unlike a GPIB implementation, no special interface cards or cables were needed to interconnect to a LAN device or switch.
- Simpler and less costly networking components. Cabling and control interfaces cost a fraction of an equivalent GPIB implementation.
- Simplified system integration and system turn-up by the customer. The combination of a simple discovery mechanism for identifying all LAN devices, coupled with the use of an IVI class driver, resulted in a very short integration time. The system was running almost immediately.

For a large system, using an LXI-based solution clearly provided a superior solution compared to an equivalent GPIB implementation. LXI's network-based communications, the web-based interface, and the standardized software features helped to create a high-performance, cost-effective, and technically sound solution for a complex test system.

About the Authors

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