LXI Networking Basics

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This is a summary presentation of Networking attempting to provide only as much information as is needed to understand the use of LXI Devices in a typical work environment. If you desire to learn more details about the concepts of Networking, you can use the terminology provided in this document to search the Internet for further information. Most terminology in this appendix is oriented towards IPv4. LXI Devices are required to support IPv4. The newer standard IPv6 is optional for LXI Devices and is not discussed much in this section. You may also want to refer to the document ***Glossary of Networking Terms***, found on the LXI Consortium website at: GuidesForUsingLXI.

A network is a group of devices, such as computers, printers, LXI Devices, etc., that are interconnected with each other. Each device usually contains a built-in LAN interface, but the LAN interface could also be a plug-in accessory. Figure 1 shows an LXI Device with multiple interfaces, including LAN. The LAN cable connects to the RJ45 connector of one LAN device to other LAN devices through a Hub, Switch, or Router.

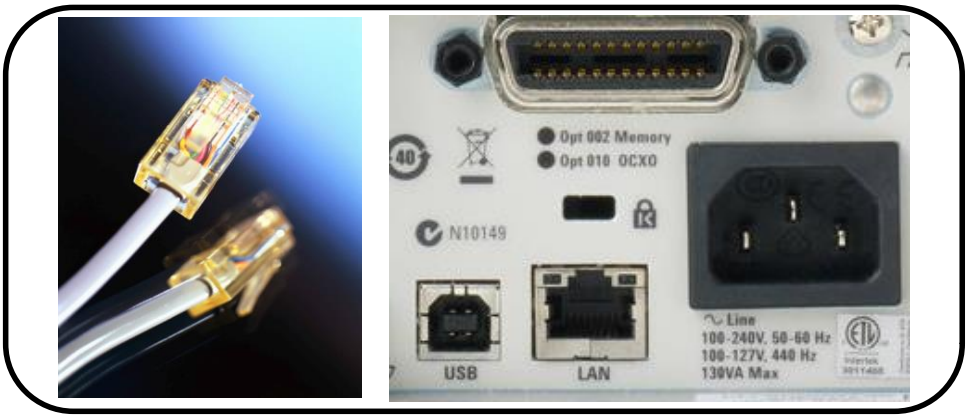

Figure 1. LAN Cable and RJ45 Connection

Most LXI Devices support 100Mbit or Gigabit LAN interfaces, and most modern computers have Gigabit LAN interfaces. Twisted pairs of wires form the LAN cable in order to reject electrical interference when running the cable near other electrical signals, such as power lines. At these bit rates, you need five twists per inch in each wire pair for reliable communication. The label CAT 5 refers to "categorizing" the LAN cable as five twists per inch. 100Mbit data rates require two pairs of twisted wires, and Gigabit data rates require four pairs.

Prior to the introduction of Gigabit LAN interfaces, the concept of a LAN crossover cable was prevalent, which is a cable that reverses TX (transmit) and RX (receive) pins on one end. Many LAN devices do not incorporate the feature called Auto-MDIX, which automatically configures itself for proper routing of TX and RX signal lines between LAN devices. Since Gigabit LAN interfaces are prevalent on modern computers and include Auto-MDIX, the use of a crossover cable is essentially unnecessary. Without Auto-MDIX on at least one of the LAN Devices, a crossover cable would be required for proper communication between the two devices. LXI Devices that do not incorporate Auto-MDIX must have a label stating so next to the LAN RJ45 connector.

Networking Layers

The ***Open Systems Interconnection*** model (**OSI**) helps you to think of networking in terms of abstraction layers. Different communication technologies with similar functions group into different logical layers on the OSI Model. Each layer of the OSI Model makes use of functions provided by the layers below it and provides functions used by the layers above it. It is helpful to understand the operation of the first three layers to understand the deployment of LXI Devices into your networking environment.

The LXI Specification focuses on Layers 1 – 3, as illustrated in Figure 2. The LAN Hub, Switch, and Router are the primary interconnecting LAN devices. These devices have multiple ports and allow multiple LAN Devices to be interconnected. The following sections will describe the LAN Hub, Switch, and Router and their impact on the deployment of LXI Devices into the LAN.

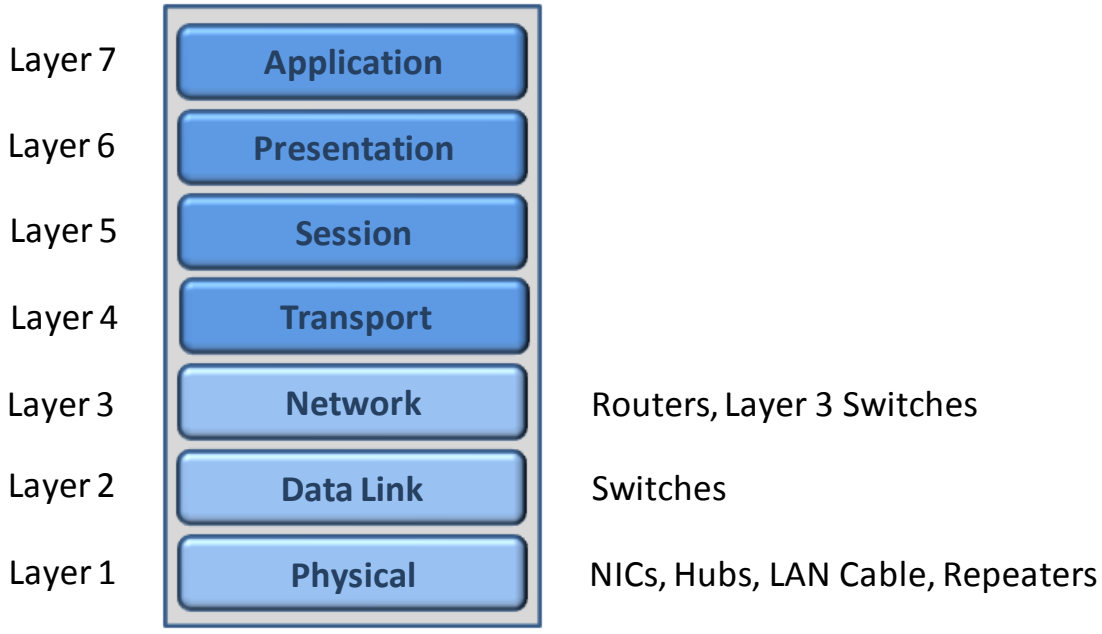

Figure 2. OSI Model - Network Layers and Components

LAN Hub and Switch

The Hub and Switch look identical, but they are quite different. The LAN Hub is a Layer 1 device, which means it is involved with the electrical signals sent over the LAN cable, also a part of Layer 1. The Hub sends the signals from one LAN port to all its other ports. Every LAN Device connected to a Hub sees the traffic from every other LAN Device. See Figure 3. This causes collisions and slows down communication, since every device on the Hub must share access to the same signal path. LAN handles collisions using a method referred to as 802.3 CSMA/CD (See Glossary for description), where each LAN Device must detect collisions and withdraw access for a random time before retrying. Adding more devices to a Hub simply increases the chance of collisions on the LAN.

The LAN Switch operates at the Layer 2 level, where it keeps track of which LAN Device connects to each port by noting its MAC address during initial communication from the devices. The MAC address is a 12-digit hexadecimal number used to create a unique hardware address for a LAN Device (MM:MM:MM:SS:SS:SS). The first half of the address represents the manufacturer of the device.

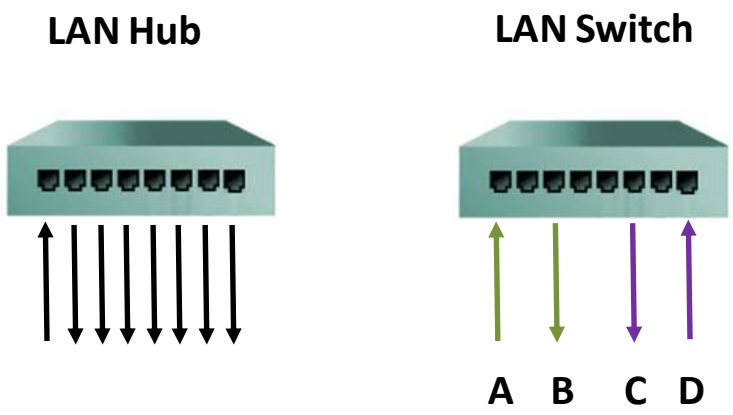

Figure 3. LAN Hub and Switch

Device A in Figure 3 wants to send information to Device B, and the LAN Switch knows which ports A and B are connected. Simultaneously, Devices C and D may be communicating. The LAN Switch isolates traffic so devices A and B never see traffic from devices C and D, and vice versa. Therefore, the LAN Switch maintains the maximum available bit rate between two devices. The limiting factor is the bit rate of the LAN Switch, which should be the same rate or faster than the fastest bit rate LAN Device connected.

LAN Hubs are rare but still available and used for monitoring the traffic between devices when debugging or analyzing LAN traffic. A typical Layer 2 Switch does not allow this capability since it isolates traffic between ports. However, commercial-grade LAN Switches do provide a concept called Port Mirroring to allow a LAN analyzer to monitor the traffic of any port.

LAN analyzers can be a stand-alone product or software running on a computer using the computer's LAN interface. The LXI Consortium members often use a network protocol analyzer called **Wireshark** (www.wireshark.org), a software program that consists of the contributions of many network experts from across the globe. **Wireshark** is one of the principle tools used to verify an LXI Device is conformant to the LXI Specification. The LAN Analyzer captures the communication packets that travel over the LAN connection. As information travels from Layer 1 all the way up the chain to Layer 7, encapsulation of the packets of information occurs according to the protocol of communication expected at the next layer. Likewise, when traveling down from Layer 7 to Layer 1, the packets are unwrapped for the next layer below. The LAN analyzer helps the development engineer understand what is happening to communication at the various levels.
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IP Addressing and Hostnames

The MAC address is the hardware address of a LAN Device, and LAN Switches keep track of MAC addresses to reduce LAN traffic. For many test system developers, the IP (Internet Protocol) Address is the primary means of communication. The IP address comes from a DHCP Server, automatically generated by the LAN Device itself (AutoIP), or it can be a static number manually configured by the User.

The IP Address can also be associated with a Hostname. Hostnames are human-readable nicknames that correspond to the IP Address of a device connected to a network: "ConradsDMM" or "Lab1SpecAnalyzer". Every LXI Device is required to have a Hostname, and when it connects to the LAN, it will acquire an IP Address associated with that Hostname.

The IP Address may change when moving the LXI Device from office to office, but the Hostname remains the same. When writing test programs for a test system, Hostnames are more descriptive of the device than

using an IP Address, and if the DHCP Server remaps a LAN Device to a different IP Address, your program will still execute properly by using the Hostname.

The Hostname should be a text string consisting of the letters A through Z (upper or lower case), digits 0 through 9, the minus sign (-), and the period (.). No spaces permitted as part of a name. The first character must be an alphabetic character and the last character must not be a minus sign or period. Hostname limited to 15 characters.

The translation from Hostname to IP Address or vice-versa can occur in several ways: DNS (Domain Name System) Server, mDNS (Multicast DNS), and WINS (Windows Internet Name Service).

In the Open Configuration discussed in ***Section 3***, the computer and LXI Device connect to the LAN through a LAN Switch (or Hub). Figure 4 illustrates the typical configuration where a DHCP Server on the company LAN hands out IP Addresses to devices joining the network.

If configured to request an IP address at power-ON, a LAN Device (Computer or LXI Device) will begin broadcasting its need for an IP address to join the network. The DHCP Server sees the request and gives the LAN Device an IP Address, Subnet Mask, and Gateway IP Address, among other information. It is the job of the DHCP Server to hand out unique IP Addresses to avoid duplication on the network. Once acquired, the LAN Device establishes itself on the LAN and becomes available for communication with other devices.

Addresses handed out by the DHCP Server can be just about anything and decided upon by the Network Administrator. An IPv4 address has the form of four decimal numbers separated by dots, such as **156.140.92.106**. Newer computers and LXI Devices also support IPv6 addressing made of eight groups of four hexadecimal digits separated by colons: **ABCD:EF12:0:0:0:0:0:3456**, which has a short-form of **ABCD:EF12::3456**.

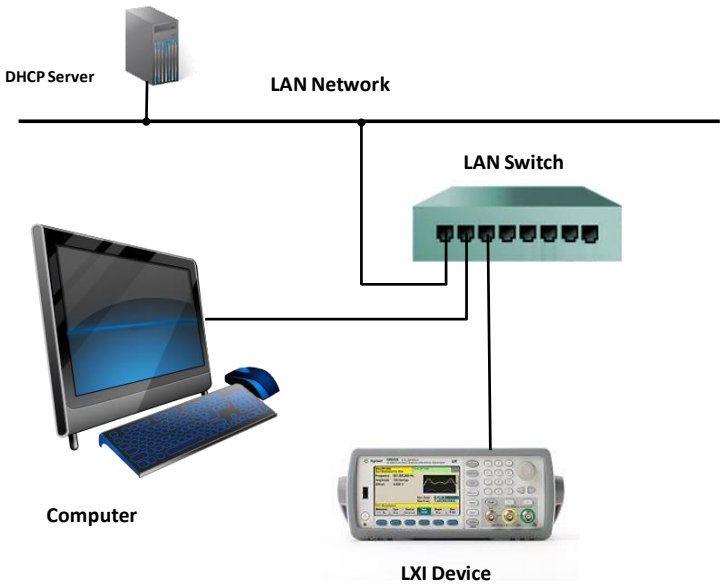

Figure 4. DHCP Server on LAN

A Subnet Mask is a number that defines a range of IP addresses used in a network. Subnet masks designate sub-networks, or subnets. LAN Devices within the same subnet can communicate directly with each other, while systems on different subnets must communicate through a Router using a Gateway IP Address.

Subnet masks have to be contiguous 1's followed by contiguous 0's. The

IP Address 192.168.1.1 11000000 10101000 00000001 00000001
Subnet 255.255.255.128 11111111 11111111 11111111 10000000

Example:

LAN Device 1 = 192.168.0.1
LAN Device 2 = 192.168.0.2
LAN Device 3 = 192.168.0.140
Subnet Mask = 255.255.255.128

LAN Device 3 is not in the same subnet as 1 and 2, because **192.168.0.140** is greater than **192.168.0.128**.

The Gateway IP Address is the location to send communication packets when the IP Address destination is not a member of the subnet of the Source IP Address. This means the desired LAN Device is elsewhere on the LAN or even out on the Internet somewhere.

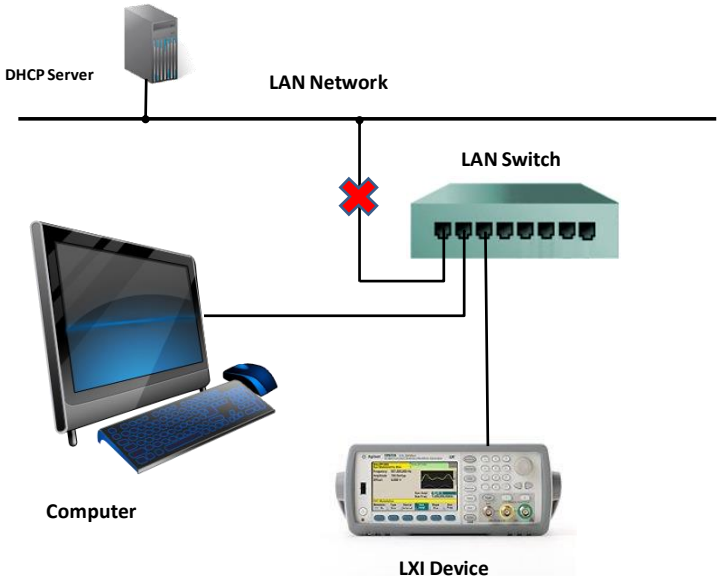

Figure 5. No DHCP Server

Figure 5 illustrates what happens when the connection to the LAN is broken. The Computer and LXI Device automatically ask for an IP address. However, the DHCP Server does not see their requests because of the broken connection to the company LAN. Since the LAN Devices connect to the LAN Switch, there actually is a "LAN" connection, and they will wait about 2 minutes before taking things into their own hands. At that point, they will begin broadcasting an AutoIP address (**169.254.x.x** for an IPv4 address). If an IP address is already in use, the inquiring LXI Device will pick another IP address until it finds a unique one.

If a LAN Device has no connection to another LAN Device, it will recognize no connection and automatically come up with an IP Address of **0.0.0.0**, and indicate with an LED or a message on its Front Panel display that no LAN connection exists, which refers to a LAN Status Fault in the LXI Specification. Note that the same AutoIP process occurs if you directly connect one LAN Device to another. For example, you could directly connect the Computer to the LXI Device, and both will settle on some

169.254.x.x address after about 2 minutes. If either LAN Device has Auto-MDIX or a Gigabit interface, there is no need for a crossover cable to switch TX and RX lines for proper communication.

LAN Router

Rather than get into the complexities of how LAN Routers create subnets between groups of LAN Devices, the focus will be on using a Router connected to a LAN to isolate some LAN Devices from the rest of the LAN Devices on the LAN. Figure 6 represents the ***Isolated System Configuration***.

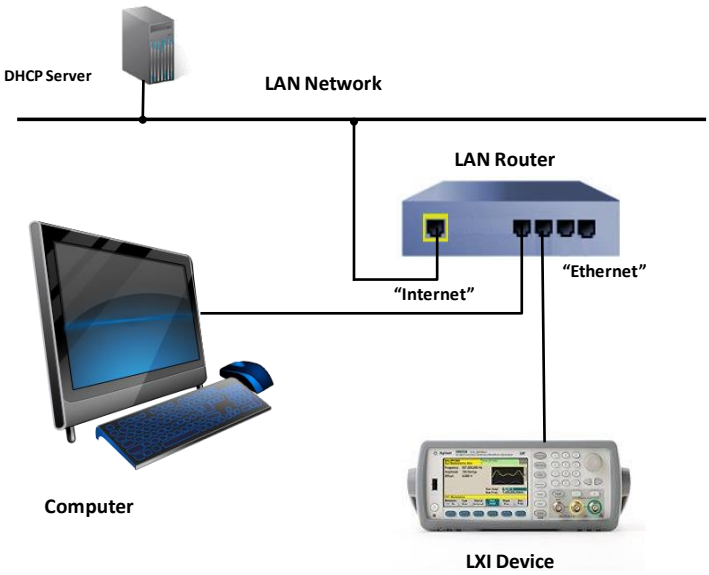

Figure 6. Isolated System Configuration using a LAN Router

The LAN Router gets its IP Address from the DHCP Server on the company LAN. This happens through the single port called "Internet". The Computer and LXI Device get their IP addresses from the LAN Router, which comes equipped with a DHCP Server built into the product. IP addresses are typically in the range of **192.168.1.x** from the LAN Router. The LAN Router's Configuration page permits changing this range of addresses.

The "Ethernet" side of the LAN Router is where the protected LAN Devices exist. They are isolated from the LAN, because other devices do not know they exist unless the devices on the "Ethernet" side communicate with them directly. For example, the Computer can access www.lxistandard.org with its Web Browser, and the Router will package up the request and send it out on the LAN as though the Router actually made the request. The response information returns to the Router's IP address, which then unpacks the information and delivers it to the Computer's IP address on the "Ethernet" side.

CAUTION: *Avoid connecting the "Ethernet" side of the router to the LAN, since doing so will place the Router's DHCP Server in direct conflict with the company DHCP Server.*

The Router establishes a Firewall. Firewalls allow connections started by "Ethernet" devices to devices on the broader LAN, but do not allow connections started by a device on the broader LAN to an "Ethernet" device. This is particularly important for developing Test Systems where it is not desirable for any other LAN traffic to interfere with the Computer controlling LXI Devices involved in a test sequence.

Even inexpensive Routers allow the User to bypass some of the protection of this Firewall by changing parameters in the Router's configuration pages. The Router's configuration page IP address is on the "Ethernet" side and is typically set to an address of **192.168.1.1**. The Router can actually make certain

LAN Devices on the "Ethernet" side visible to the LAN. The Router can also use the computer's MAC Address as its own. In both these cases, the LAN Device typically is the computer, so others can access its test system database or push software updates to the computer. Cloning the MAC Address of the computer also avoids the issue with a DHCP Server not permitting a Router to receive an IP Address, as discussed in the "***Allow all but Routers***" case of ***Section 4***. Find this topic and others with more detail in ***Building LXI-base Test Systems*** and ***Introducing LXI to your Network Administrator***.

Static IP Addresses

There are some test system configurations where it is desirable to preset each instrument to a specific IP address. The LXI Device's Configuration page makes this possible. To be conformant to the LXI Specification, each LXI Device ships with its Automatic IP address setting enabled. This means it normally requests an IP address from a DHCP Server when powering ON and resorts to assigning itself an IP address using the AutoIP mode if no DHCP Server responds.

You can access LXI Configuration pages through the Hostname or IP address of the LXI Device, as described in the ***Discover*** portion of ***Section 3***. The Manual IP setting can be set, and an associated Subnet Mask and Gateway IP address can be manually set for the device. On many LXI Devices with Front Panel interfaces, you can also enter a static IP address, subnet mask, etc.

Figure 7. Example Front Panel Configuration Page

Figure 7 illustrates an example of setting the Hostname, IP Address, Subnet Mask, mDNS Service Name, or mDNS Hostname. mDNS is a service used by printers on a LAN. You can create your own specified description of the LXI Device as well as giving it a specific Hostname. When others try to discover LXI Devices on the LAN, they can know whose device they are viewing.

When the LXI Device configured with a static IP address powers ON, it will attempt to use that IP address and Subnet Mask. Test System configurations replicated for production, for example, might want this type of operation. A DMM might be set to IP **169.254.1.2**, a Scope is set **169.254.1.3**, etc. This greatly simplifies test system software development and helps to debug a test system that has developed problems with communication. See Figure 8 for an example of a Web Page Configuration.

CAUTION: *For the Open System Configuration, you should never assign a Static IP address unless your Network Administrator has specifically given one to you. Otherwise, you could create a Duplicate IP address on the LAN, where one of the devices will have to disengage from the LAN to avoid the problem.*

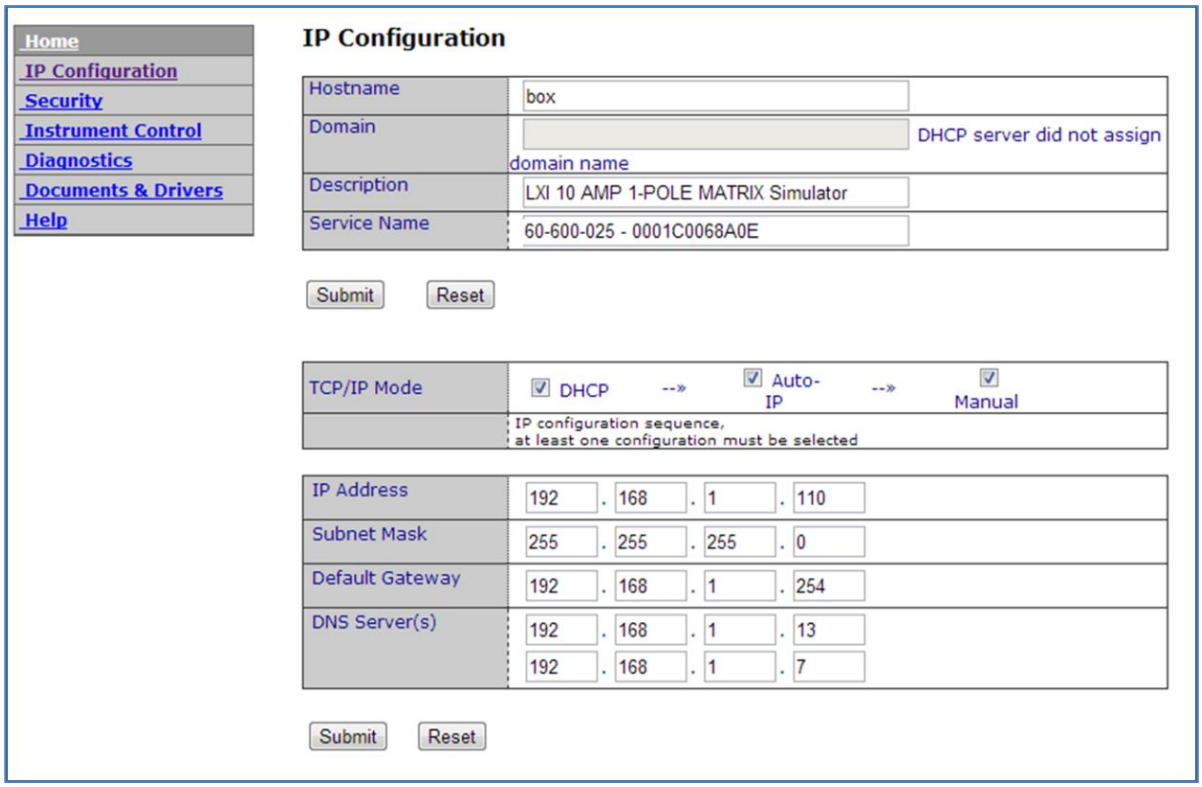

Figure 8. Example LAN Configuration Page