Extending the IEEE 488 Bus

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Overview

The general-purpose interface bus (GPIB) was developed to connect programmable instruments to digital controllers. Becaus of its high transfer rates of more than 1 MB/s, this interface bus maintains its popularity. In 1975, the Institute of Electrical and Electronic Engineers (IEEE) published the ANSI/IEEE Standard 488-1975, which contains the electrical, mechanical, and functional specifications for the GPIB. This standard evolved into the ANSI/IEEE 488.1-1987. With the IEEE 488 standard, different manufacturers can design products that reliably communicate with each other.

This document further introduces you to the IEEE 488 standard, and describes your options for expanding or extending your IEEE 488 bus.

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1. Introduction

The IEEE 488 standard places requirements on the configuration of a GPIB system to ensure proper operation. High-speed operation of the GPIB may contain additional restrictions. The standard places the following limitations on the physical distance between devices and the number of devices on the bus:

- A maximum of 15 devices.
- A maximum total cable length of 20 m or 2 m times the number of devices, whichever is less.
- A recommended separation of less than 4 m between any two devices.

These limitations do not affect most GPIB systems. However, if your system requires more devices or greater cable length than the standard states, expanders and extenders can solve your problem.

2. Expanding the GPIB

Using a bus expander, you can exceed the 15 device limit set by the IEEE 488.1 standard. An expander has two GPIB ports. When you connect these two ports to two GPIB systems, the expander buffers and repeats the signals from one bus to the other, and vice versa. Because each GPIB port of the expander can control as many as 14 devices through your computer, th additional port expands your system to control up to 28 devices. You can also use expanders to connect devices that are mor than 4 m apart, or to extend the maximum cabling distance limitation set by the IEEE 488 standard from 20 to 40 m, if there is a device load for every 2 m of bus cable.

Factors to Consider When Choosing an Expander

The following sections describe the factors you should consider before adding an expander to your GPIB system.

Transparency

If you can add or remove a device from a system without affecting the behavior of the system, the device is transparent. Ideally, an expander should be transparent to the application software when you add it to a bus system so that you do not have to make additional changes. That is, with a transparent expander, devices are installed in two separate physical GPIB networks that function as one logical GPIB network.

Figure 1 shows the physical configuration of a typical GPIB expander system.

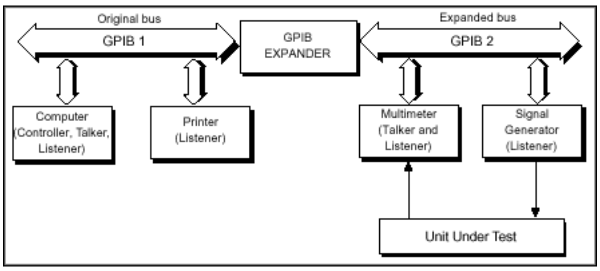

Figure 1. Typical GPIB Expander System (Physical Configuration)

Figure 2 shows the logical configuration of the typical GPIB expander system and represents how messages and signals transparently pass from one bus to another.

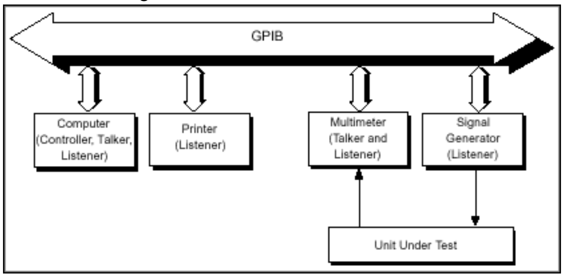

Figure 2. Typical GPIB Expander System (Logical Configuration)

All devices in the expander system communicate with each other as if the expander were not on the bus. Because the expander does not act as a logical device, you do not need to address it for the expanded bus system to work properly. Add it to your system as you would any device. Some expanders are not fully transparent because integrating them into the bus system forces you to change the device addresses. Once you change the device addresses, you must also change your application software.

Configuration
A well-designed expander system does not require any configuration. Both the system hardware and software should remain the same when you add an expander. You can install a Controller on either side of the expander without restricting the addresses you can use for the devices in your system. Additionally, you can add or remove devices from either side of the expander without having to reconfigure it or the addresses of the devices. These features are not common to all expanders. With some expanders, you can only install a Controller on one side of the expander and the devices on the expanded bus must be within a pre-defined address range. If you are not careful when choosing your expander, you might have to reconfigure and readdress the devices in your system whenever you add the expander.

Speed
Ideally, an expander should not affect system performance. When you add an expander to your system, you should not experience speed degradation for transfers between devices on the same side of the expander. However, because of signal propagation delays through the expander, data transfers between devices on different sides of the expander are slower than transfers between devices on the same side of the expander. While these propagation delays are inherent to all expanders, the length of the delay varies according to the quality of the expander. You should choose an expander that has minimal propagation delays for your data transfers to execute as quickly and efficiently as possible.

Isolation
Voltage isolation between the two GPIB ports of an expander is another important feature. The expander physically separates your GPIB systems so you can place sensitive devices on one side of the expander while placing noisy devices on the other side. Devices in the expander system, while physically separate, are logically part of the same system. If the ports are adequately isolated, you can improve the integrity and the reliability of your GPIB system by separating devices that are at different power potentials, eliminating ground loop noise, RF noise, and voltage spikes, and isolating devices that place high-frequency noise on their GPIB interface signals. You can also isolate computing equipment from noise-sensitive instruments that are measuring very low-level signals to reduce possible noise interference. If you plan on using sensitive devices in your system, you should choose an expander that has these isolation capabilities. Figure 3 shows how to configure your system so that a sensitive device is isolated from a high voltage device.

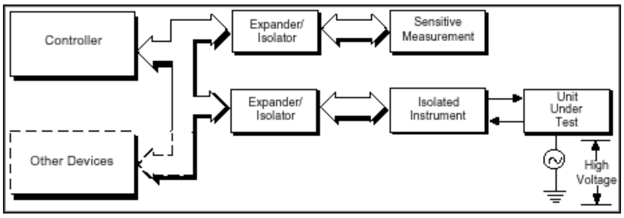

Figure 3. A GPIB System Designed to Isolate an Instrument

Cascading
If your system requires more than the 28 device limit with one expander, you can consider cascading expanders. By adding more than one expander to your system, it is possible to add more than 28 devices. Figure 4 shows a system containing 41 GPIB devices integrated into one logical network by cascading two expanders.

Be sure that the expander you choose can be cascaded. Not all expanders can be cascaded, and those that can often have restrictions on how many expanders can be cascaded.

Cascading expanders is also an easy way to connect devices that are more than 8 m apart. When you add an expander to your system, you get another GPIB system and an additional 4 m of cable. With this extra cable, you can connect a device that is more than 8 m away. Again, remember to select an expander that does not have any cascading restrictions.

Remember that the transfer rates between devices on opposite sides of the expanders decrease. The transfer rates continue to decrease with each level of cascading. Another way to include more devices in your system and still sustain the most efficient transfer rates is to configure your devices in a star configuration. Figure 5 shows how you can set up the GPIB network in a star configuration to minimize the propagation delays between the cascading levels.

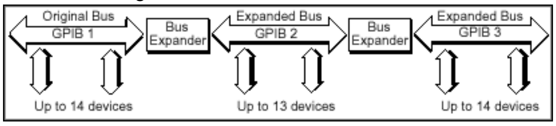

Figure 4. Cascading Expanders to Add More Devices

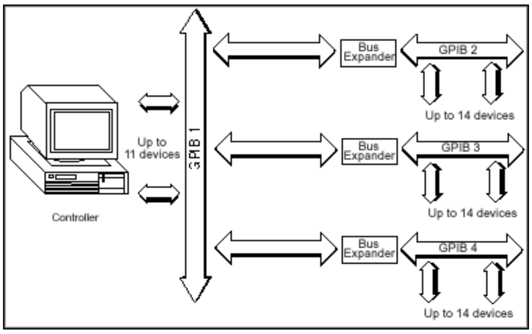

Figure 5. Cascading Expanders in Star Configuration

Multirack Systems
Expanders can also be used in multirack systems. The expanders prevent circulating ground loops between any two racks. In addition, you do not need to worry about the total device count being over the limit in the IEEE 488.1 standard as long as eacl rack holds less than 14 devices. Figure 6 shows how you can configure your system using expanders in a multirack system.

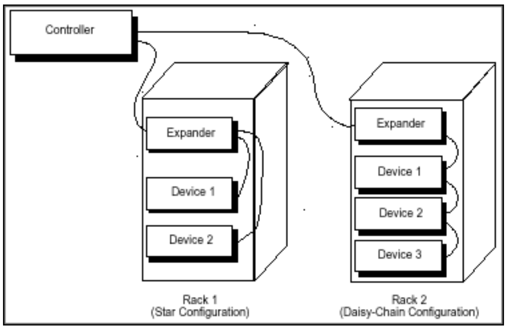

Figure 6. A GPIB System Designed for Multirack Use

The National Instruments GPIB-120A Expander
The National Instruments GPIB-120A expander electrically buffers and repeats GPIB signals, increasing the maximum numbe of devices you can connect to a GPIB system from 15 to 28. The GPIB-120A is also useful in test and measurement systems that require electrical isolation between devices. Using opto-isolators and an insulated GPIB connector on the back panel, the GPIB-120A provides 1,600 V of electrical isolation between its two GPIB ports.

You can readily add the GPIB-120A into your system without any configuration. It is uniquely constructed for GPIB protocol transparency. Also, you do not have to rewrite your application software when a GPIB-120A is added to the system. The GPIB-120A has very short propagation delays and data transfer rates can exceed 1 MB/s. There is no limit on the number of GPIB-120As that you can cascade together. The GPIB-120A meets United States and European product safety standards (UI and EN listed), is a class A certified device under U.S. Federal Communications Commission (FCC) part 15 subpart J, and is suitable for any industrial or commercial use.

3. Extending the GPIB

You can use GPIB extenders to overcome the device separation limitations of the IEEE 488 standard. Extenders connect two separate buses via a transmission medium, such as coaxial cables, fiber-optic cables, or multi-conductor cables, to increase the distance between devices. Extenders work in pairs transmitting signals back and forth from a local GPIB system to a remote GPIB system. Each extender has one GPIB port and one or more transmission media ports. The extender translates the local GPIB signals into a different protocol that it can transmit and then sends the message or signals through the transmission link to another GPIB extender at a remote site. The remote extender converts messages from the transmission media back to GPIB signals on its GPIB port. In the same way, the remote expander translates GPIB signals on its GPIB port into the same protocol and sends it across the transmission link to the local GPIB extender which converts it back to GPIB signals on the local GPIB. By integrating extenders into your system, you can increase the distance between two GPIB devices to several kilometers. Because you can attach 14 GPIB devices to the GPIB port of each extender, you can also expand the GPIB to 28 devices while remaining within the constraints of the IEEE 488.1 standard.

Factors to Consider When Choosing an Extender
The following sections discuss some of the important issues to consider before using extenders in your GPIB system.

Transparency
Each extender transmits the encoded signals from a local GPIB system to a remote system, or decodes the signals received from the remote system and recreates them on the local GPIB. In an ideal situation extenders, like expanders, are transparen

to application software. That is, you should be able to add or to remove the extenders from your system without affecting the system behavior. Figure 7 shows the physical configuration of a typical GPIB extender system.

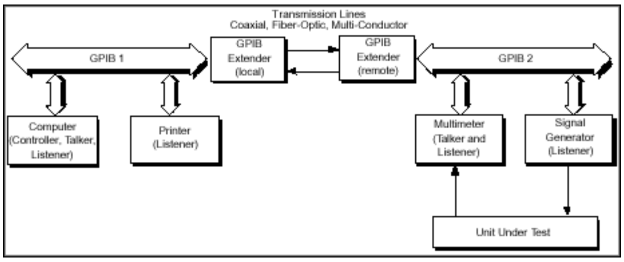

Figure 7. Typical GPIB Extender System (Physical Configuration)

Figure 8 shows the logical configuration of the typical GPIB expander system and represents how messages and signals transparently pass from one bus to another.

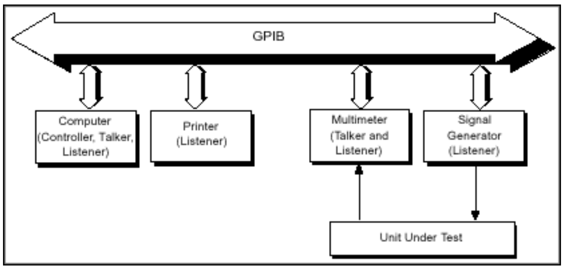

Figure 8. Typical GPIB Extender System (Logical Configuration)

Configuration
When choosing an extender, be sure to select one that does not require complicated configuration to work in your GPIB system. As with expanders, the best extenders are integrated with your GPIB systems without having to modify the hardware or software. This feature offers you the convenience of not having to change the system hardware and software each time yo add or remove devices from either side of the extender.

Speed
Every GPIB extender degrades normal system performance. The presence of an extender in the system and the distance between the extenders cause propagation delays, which in turn cause speed degradation. As the distance between the extenders increases, the propagation delay introduced by the cable increases. Some extenders use FIFOs to buffer data and reduce the effects of long propagation delays. When choosing an extender, you should select one that minimizes these propagation delays so your system will work optimally.

Figure 9 shows how you can use two GPIB extenders to link a computer to a scanner 100 m away.

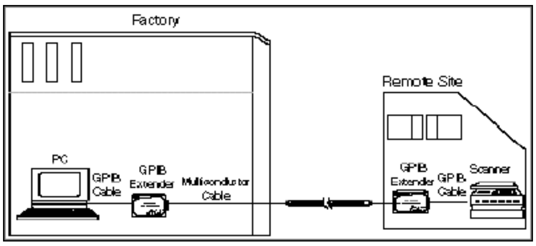

Figure 9. Use of Extenders to Maximize Speed

Medium
There are three common types of extender cables: multiconductor, coaxial or twisted pair, and fiber-optic. Each type of cable has characteristics that may make it more suitable than other cables for use in your system. Consider these specific system requirements when deciding which cables to use. In general, multi-conductor cables are the most expensive, but they have th fastest transfer rate over short distances. Coaxial or twisted pair cables are the least expensive, but their susceptibility to nois interference and long propagation delays make them unsuitable for long distance applications, except in cases where speed i not a critical factor.

Fiber-optic cables can extend a GPIB system over long distance with the least speed degradation. They also provide exceller noise immunity. These cables are especially useful in industrial applications where the cables are routed next to machinery or power lines. Because fiber-optic cable is nonconductive, it is well-suited for extending the GPIB outdoors where the cable might be exposed to electrical storms. Finally, fiber-optic cables enhance security. Because the cables transmit light instead o electric current, fiber-optic transmission provides a nonemitting signal path immune to unauthorized eavesdropping.

Figure 10 shows a system where extenders are used to connect a computer with a multimeter 2 km away. Because speed is not very important, coaxial cables are used to reduce cost.

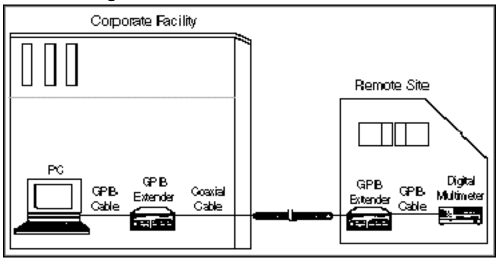

Figure 10. Use of Extenders to Reduce Cost

Figure 11 shows a system where GPIB extenders connected by fiber-optic cables, which are immune to electronic data decoding, can transmit data between two security buildings.

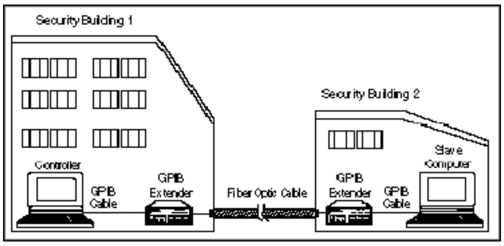

Figure 11. Use of Extenders to Maximize Security

Parallel Poll
Another feature to consider when choosing an extender is whether devices can still respond to a Parallel Poll Identify (IDY) message when you add that extender to your system. Because of propagation delays across the transmission cable in a normal extender system, devices on the remote side of the extender usually cannot respond to a parallel poll within the time designated by the IEEE 488 standard. You can overcome these problems by either using a Latched or Unlatched Parallel Pol Response (PPR) mode.

Many extender manufacturers include a Latched (or stored) PPR mode in their extenders. In this mode, the device immediately responds to the IDY message by outputting the contents of the PPR data register. This register contains the response of the previous poll. At the same time, a parallel poll message is sent to the remote bus. To obtain the most current response, the control program should execute two parallel polls back-to-back and use the second response. Another solution is to use the Unlatched PPR mode to extend the period of the parallel poll so that the current PPR response can flow through the extender to the Controller. Changing the period of the parallel poll may be more convenient because you do not have to change the application software.

National Instruments GPIB Extenders

GPIB-130
The National Instruments GPIB-130 extender uses multiconductor cables that can extend the distance limit to 300 m and the loading limit to 28 devices. It can transfer data at 900 kB/s. The GPIB-130 has two operating modes: unbuffered and buffered In unbuffered mode, the GPIB-130 maintains the IEEE 488 double-interlocked handshaking protocol. Each byte is held on the transmission cable until both the sender and the receiver confirm that it has been transmitted correctly. In buffered mode, the GPIB-130 uses FIFOs to buffer data between the remote and local units. The buffering, which is managed completely by the hardware, does not require you to modify your software.

GPIB-140A
The National Instruments GPIB-140A is ideal for extending the bus to longer distances. With fiber-optic cable, the GPIB-140A can extend the distance to 2 km. It also incorporates an error checking and recovery scheme to guarantee error-free data transmission. Like the GPIB-130 above, it can operate in a buffered or an unbuffered mode.

4. Conclusion

GPIB expanders and extenders overcome some of the limitations of the IEEE 488 standard. When selecting an expander or an extender, you should choose one that is best suited to your GPIB system. In particular, your expander and extender shoulc be as fast as necessary, easy to integrate, and transparent to your application software. The National Instruments GPIB expander and extender products meet these criteria and provide solutions to limitations of both cable length and the number c devices. The National Instruments GPIB expander and extender products augment the National Instruments GPIB product lin of plug-in controllers, external controllers, driver software, and external converters by providing flexible, easy-to-use solutions to users whose needs exceed the intrinsic capabilities of the IEEE 488 standard.