Introducing the Wired Trigger Bus

BY DAVID OWEN, PICKERING INTERFACES

The capability of instrumentation to respond to events or trigger commands to perform measurements is an important part of a test system. All instrumentation platforms have this feature, and not surprisingly, it also is an important part of the LXI standard. The importance of including trigger capabilities is demonstrated by how other instrumentation platforms evolved from the trigger standard defined in GPIB.

For GPIB systems, the standard includes a comprehensive model that supports trigger operation by commands over the GPIB interface. More deterministic trigger operation in these GPIB systems typically is provided by the use of vendor-specific hardware trigger signals between instruments using coaxial connections.

There is no uniform way in which these hardware triggers operate or how they are implemented. If you need to change the hardware trigger connectivity, it has to be done via switching. The integrator has to design this into the system and handle the differing characteristics of the devices.

Modular instrumentation, such as VXI and PXI, tackled hardware triggering by including a backplane trigger interface that interconnects the modular cards. The modules can exchange and route trigger signals on different physical channels. For both VXI and PXI, eight channels of independent trigger signals are provided.

The VXI standard uses open-collector drivers to connect to the trigger bus with a pull-up resistor to assert the logic high state. This arrangement has some considerable advantages since an open-collector arrangement supports a capability referred to as Wired OR.

In a Wired OR, several VXI devices can drive the trigger bus. If they all initially assert the bus to the low state, the line remains low until the last device releases the trigger bus line. This means the last device to be ready initiates events in all receiving devices.

Conversely, with all open collectors initially off, the first device to detect an event also initiates the receiving devices to act. The VXI trigger bus can be considered as a multipoint-to-multipoint bus. More than one device can drive the bus, and more than one can receive the signal.

The PXI trigger bus provides a point-to-multipoint trigger system. One device drives the bus, and many can receive it. It does not support the Wired OR trigger mode. However, it does have an additional capability referred to as a Star Trigger, which connects Slot 2 of the chassis to 13 slots on a point-to-point arrangement. This facility supports triggering actions with low timing skew between the modules by using matched transmission line lengths.

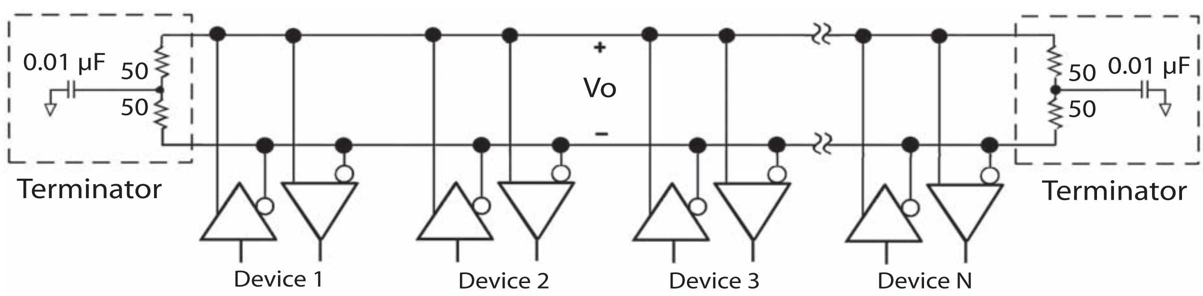

Figure 1. LXI Wired Trigger Bus Configuration

In each case, PXI and VXI support eight trigger bus channels. The VXI speed typically is limited to around 10-MHz clock rates. The PXI standard can go considerably faster since it uses active drivers rather than open-collector drivers.

Hardware Trigger Advantages

A trigger bus based primarily on hardware connectivity has significant advantages for some applications. The key benefits are the following:

Continued on page 16

• Low latency: When the trigger occurs, there is only hardware delay between the trigger occurring and action starting.
• Low jitter: The delays are more consistent between successive events so if there are any timing skews, it is easy to compensate for the delay.

These were important advantages recognized as the LXI standard was created. Just as the standard included innovation on LAN, programmatic, and IEEE 1588 triggers, there was a strong motivation to innovate in the area of hardware-based triggers.

Wired Trigger Bus

The LXI standard set an objective to emulate the characteristics of the VXI/PXI trigger bus and provide a more unified method of exchanging triggers between LXI devices, a facility not supported by bench instruments based on GPIB and other control interfaces. The Wired Trigger Bus (WTB) is complementary to the LAN-based triggers, providing additional functionality normally found in modular instrumentation.

Since LXI is not a card-cage-based solution, a hardware trigger facility needed to be based on cables and connectors that provide the interconnection between LXI devices. The selected electrical specification is based on the Multipoint Low-Voltage Differential Signaling (M-LVDS) standard defined in TIA/EIA-899-M-LVDS. Choosing to adapt an existing standard has ensured that the chip sets are commercially available.

LVDS was selected because it can be carried over long distances using simple twisted-pair transmission lines. The differential signaling ensures that the signals have low emissions and high immunity, and the controlled rise and fall times of LVDS devices minimize high-frequency emissions.

The use of the multipoint variant enables multipoint-to-multipoint operation, which permits a Wired OR operation of the trigger bus. It also allows the bus to operate even when at least one or more of the LXI devices connected together is switched off.

There are eight separate trigger channels, and LXI devices should be able to route their trigger signals onto any of the channels. The trigger bus channel count matches the channel count used in VXI/PXI trigger backplanes and meets the anticipated application requirements.

The LXI LAN and programmatic triggers also use a logical model of eight trigger channels, permitting an easy equivalence model between them and the WTB. This also allows hardware trigger events to be timed by IEEE 1588 via suitable signal routing on Class A devices.

WTB Transmission Line

The WTB uses a terminated transmission line to direct signals from one device to another.

As shown in **Figure 1**, each LXI device includes M-LVDS drivers, which drive a transmission line, and M-LVDS receivers that respond to the signals on the transmission line. The transmission line is a twisted pair with impedance of approximately 110 Ω. The signal from any driver is immediately split into two paths, one going left and one going right.

At the end of each transmission line is a differential termination load of 100 Ω. Any common-mode disturbance is terminated by the two 50-Ω resistors connected to AC ground via a 0.01-µF capacitor. The M-LVDS drivers must support a differential load impedance of 50 Ω.

To maintain the transmission-line characteristics, it is important that stubs and other parasitic components be minimized. Reflections on the transmission line could cause false trigger events or timing jitter. This imposes some constraints on the WTB connector arrangement. The bus has to use an input and an output connector wired together within the LXI device by a differential transmission line that has minimal parasitic stubs.

The transmission line is shown in **Figure 2**. Each LXI device has two connectors for cabling to adjacent LXI devices. The connectors are interchangeable so they require no additional identification. Stacking connectors could not be used because they would have created significant transmission-line stubs.

The connectors chosen for the WTB are the commercial version of the 25-conductor Micro D connector. They are physically small, minimizing the space occupied on the panel and providing a reasonable transmission-line match for the WTB. The screw locks ensure the cable is secure when fitted into an ATE system.

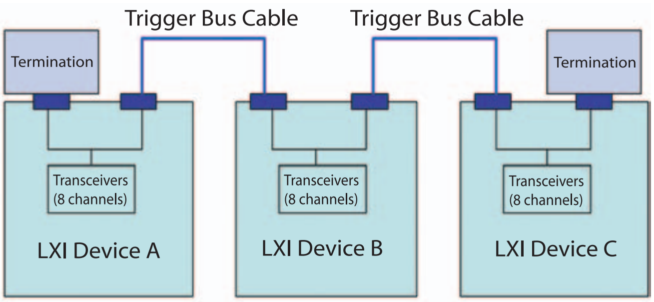

Figure 2. LXI Wired Trigger Bus Connection Scheme

Transmission-Line Cable and Termination

The cable that connects LXI devices with the WTB is critically important for correct operation of the system. It contains eight twisted pairs for the eight channels, each of which has a shield around it to minimize crosstalk between channels. Without the shield, the crosstalk between the channels has the potential to cause timing jitter.

To connect LXI devices over reasonable distances, it is essential that the cable have low loss since at high frequencies the skin effect and wire diameter have a significant impact on overall performance. Increasing wire gauge makes the cable stiffer and eventually impossible to use with the selected connector, so the usual engineering compromises were applied. The wire chosen uses a silver finish to ensure the best surface conductivity and achieves the best transmission distance with the largest useable wire gauge.

The cable characteristics are carefully controlled and specified in the document "LXI Trigger Bus Cables and Terminators." The terminators are simple devices that provide the termination for all eight channels at the end of each segment.

Cable assemblies and terminators can carry the LXI logo if they conform to the full specification and are available commercially. Tests at the LXI PlugFests have shown that compliant cables can support 10-ns wide pulses over a distance of 10 meters

Driving the WTB

It is not obvious from Figure 1 how the WTB can support more than one LXI device driving a particular channel, but it is clear that one device can be used to assert the logical state of the LVDS interface if no other device is attempting to drive it. When this is the case, the mode is referred to as the Driven mode. It is a point-to-multipoint connection method similar to PXI backplane triggers. A single driver is used to set the channel to its low or high state.

The Wired OR mode takes advantage of the fact that LVDS drivers actually are current source drivers rather than voltage source drivers. This feature also helps manage common-mode voltage sources between LXI devices without introducing errors.

In the Wired OR mode, two drivers are used in parallel and have two states, either disabled or enabled when positive current from the two drivers is forced into the WTB channel. A Wired OR bias device is used to bias the channel with the negative current from one driver. If all the LXI devices on one channel are disabled, the net current in the channel is negative by one driver's current.

The first LXI device to turn its driver from disabled to enabled (two drivers worth of positive current) overcomes the bias device and sets a high state, precisely the functionality required for Wired OR operation. As with the VXI open-collector arrangement, setting the starting condition with all the drivers enabled and changing state to disabled can implement the last-device-ready scenario.

The Wired OR bias device can be either not participating or participating in the trigger event. In the latter case, the Wired OR bias device is set to the Driven mode so that when its trigger event is low it provides one unit of negative current. If this device is the first to go high, it forces one unit of positive current into the channels.

In the Wired OR mode, more than one device could be setting the channel high, causing a larger voltage to appear across the LVDS receivers. This, however, has no impact on the WTB since the receivers and drivers are designed to handle such conditions.

With the Wired OR mode, the LVDS drivers do not operate as quickly to/from the enabled/disabled conditions as they do in the Driven mode. As a rough guideline, the minimum pulse width for trigger operation has to be doubled in the Wired OR compared to the Driven mode; consequently, the standard supports both modes.

The M-LVDS standard recommends that only 32 devices be connected on a bus. Since the LXI WTB has two drivers per LXI device, 16 LXI devices can be connected together on a single WTB segment.

Daisy Chaining and Star Connections

Some applications may require more LXI devices to be connected together than the 16 recommended for a daisy chain. Other applications could need access to more independent trigger channels with connectivity between them. In some cases, an application may demand that the delays to each LXI device be equalized in a way similar to the PXI Star Trigger bus. For these applications, the standard has defined the Star Hub.

A Star Hub can support a number of ports that are electrically buffered from each other. They can be set up so that a particular channel on one port can be connected to a channel on another port in a defined direction.

With the addition of the Star Hub, the WTB can be connected as a Star network, a daisy-chain network, or a combination of each. If a Star Network uses equal length cables, then delays will be nominally the same for each path from the Star Hub.

WTB Adaptors

Devices that do not support the LXI WTB can be made compatible through the use of simple adaptors. These adaptors allow external triggers to be converted to the WTB or WTB signals to be converted to single-ended triggers, enabling easy integration of older trigger standards into the LXI trigger system.

WTB Capability

The key capabilities of WTB are the following:

- Eight independent channels.
- All LXI devices supporting the WTB have a uniform wired interface.
- The WTB freely exchanges signals with the LAN and programmatic triggers since they use the same model.
- A total of 16 LXI devices can be connected as a single WTB chain. Functionality is preserved even if some of the LXI devices connected to the WTB are not powered.
- A trigger function provides low latency and low jitter.
- In the Driven mode, LXI devices can exchange 10-ns wide trigger signals over a distance of 10 meters.
- The Wired OR mode is a simple and effective way of providing a last device ready or first device to initiate an event without programmatic intervention.
- Extension of the WTB through the use of a Star Hub is defined to provide solutions for larger systems.
- Simple inclusion of triggers to and from other sources via adaptors provides a means to interoperate with LAN-based triggers.

The result is that the LXI WTB is a powerful addition to the LXI standard. And with its integration with LAN, IEEE 1588, and programmatic triggers, the WTB can emulate and exceed the ad hoc trigger mechanisms found on bench instruments. Users of LXI systems have a comprehensive suite of trigger functions that allows them to address even the most demanding applications.

About the Author

David Owen is the business development manager for Pickering Interfaces. Over the last 30 years, he has held key engineering, product management, and strategic marketing positions with Marconi Instruments, then IFR. Mr. Owen, the innovator of more than 10 patents in the field of RF signal generation and analysis, currently is involved in the PXI and LXI standards and serves as deputy chair of the LXI Compliance Working Group. Pickering Interfaces, Stephenson Rd., Clacton-on-Sea, Essex, CO15 4NL U.K., 011 44 1255-687900, e-mail: david.owen@pickeringtest.com