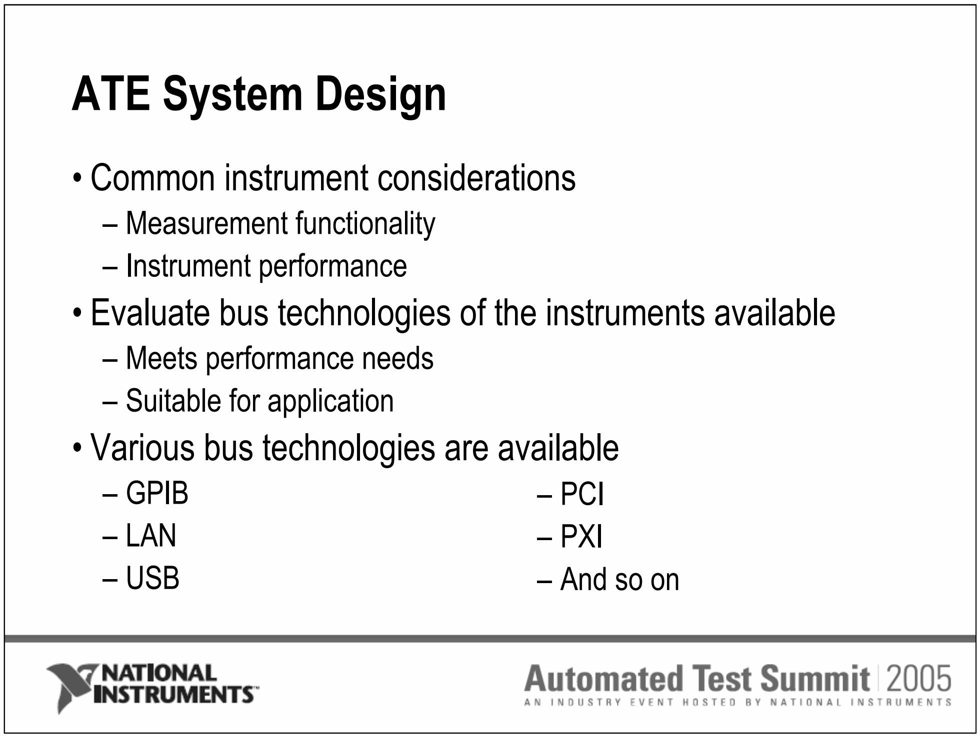
3.1 Choosing the Right Bus Technology: LAN, USB, GPIB, PCI/PXI

Evaluating Platforms for Performance and Reusability



When designing a system and determining hardware for an ATE system, the common consideration is first instrument/measurement focused. Can it provide the measurements and data that I need?

From there, the developer needs to carefully evaluate the bus technologies that offer the types of instruments needed. You should consider many factors to determine if the bus is appropriate for the specific application and if it meets performance needs.

There are a variety of bus technologies available. Some of the more popular ones include GPIB, LAN, USB, PCI, and PXI.

Bus Technology Considerations

- Key bus factors that affect instrument performance
  - Latency
  - Bandwidth
- Other considerations
  - Timing and synchronization
  - Distributed networks and remote monitoring
  - Standard software frameworks

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When considering the instruments for a system, people often evaluate buses based on the instruments that are available—looking for their measurement needs to be met. Does the bus provide instruments with the sampling rate, bandwidth, and so on, that is needed for the test system. When addressing these concerns, however, it is important to factor in the capabilities of the instrumentation bus itself as this affects the performance of the instruments you choose and their ability to work together to give you useful measurements. Factors like latency and bandwidth of the bus will affect the performance of the instrument.

Timing and synchronization vary by bus and should be evaluated as well since it affects the ability to communicate between instruments and tightly correlate signals.

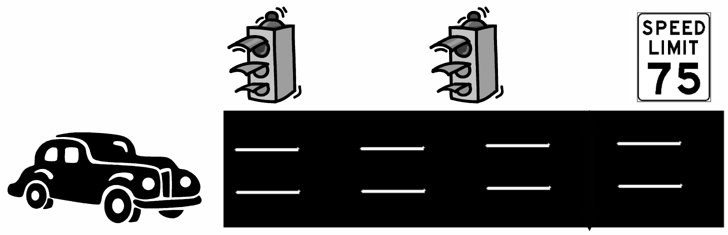
In addition, as you consider buses, you should also compare other factors

Distributed networks and remote monitoring: Some systems require either remote control of systems or distributed networks. Sometimes software can help in the deployment of these remote systems; however, some buses also simplify distribution.

Standard software frameworks: does the bus specification implement a software framework? Software frameworks ensure that a user has a complete, multivendor system solution from the start and prevents market fragmentation due to competing standards from multiple vendors. This helps to ensure software interoperability.

Latency and Bandwidth

- Latency measures the delay of transmission of data across a bus
- Bandwidth measures the rate at which data is sent across the bus (typically MBytes/s)



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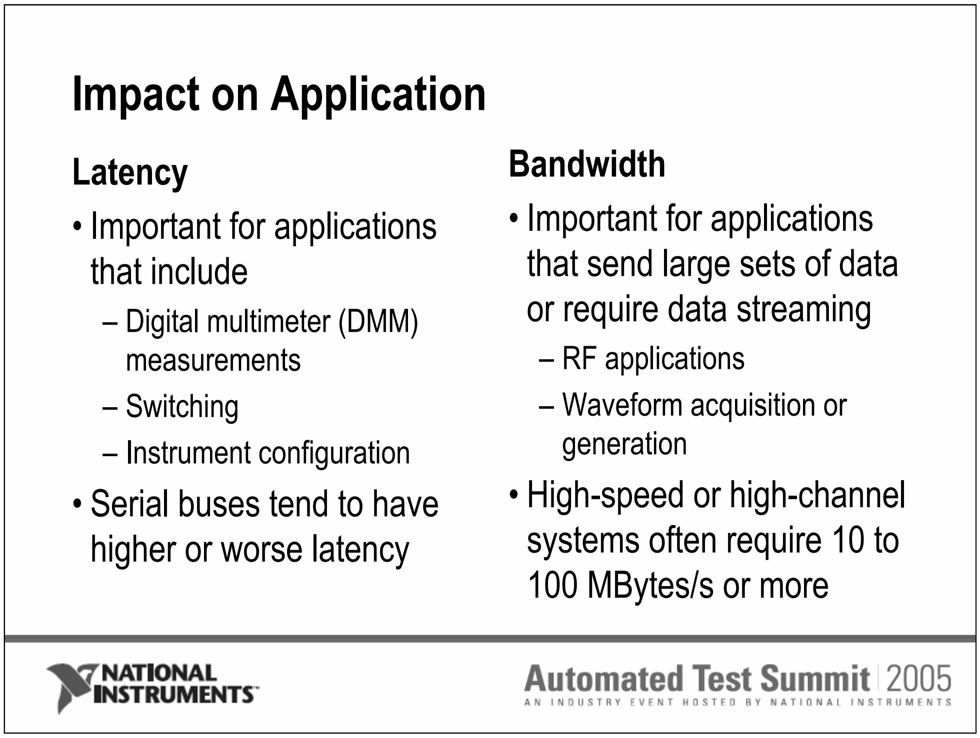
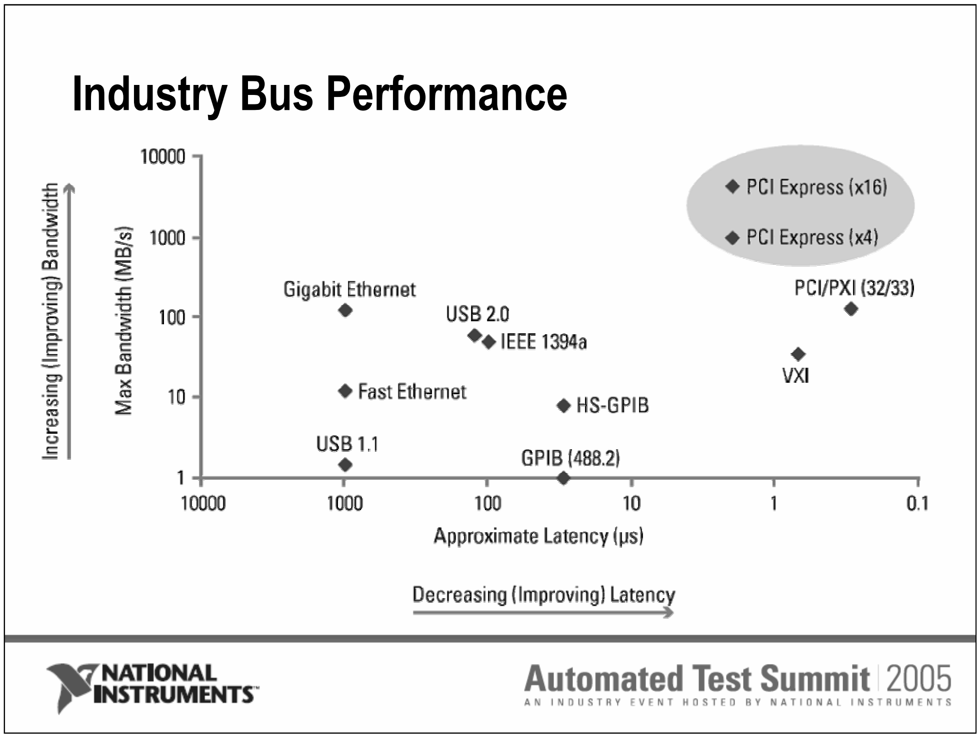
First we will address these key bus characteristics that affect instrument performance. Both latency and bandwidth impact the ability to support instrument performance, high-speed systems, and high-channel-count systems.

Using a highway analogy, you can think of a bus as the highway. The latency measures the delay of transmission of data, so you can think of it as corresponding to the number of stoplights in the road. The bandwidth measures the rate at which data is sent across the bus, and thus corresponds to the width of the road and speed of travel.

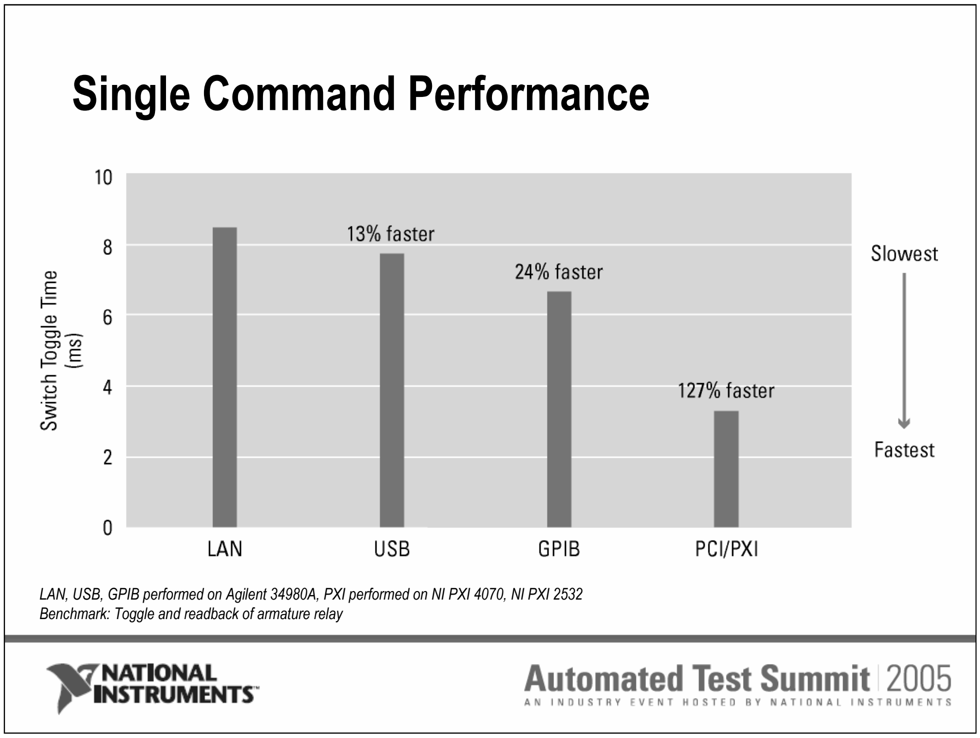


Why do latency and bandwidth matter? They help determine whether you can actually perform the measurements needed. Since latency is the delay of transmission of data, it is important to use a bus with lower latency in applications like DMM measurements, switching, or instrument configuration. Typically you will find that serial buses have a higher latency. (Exception to this is PCI Express which is serial, but packetizes data and has an extremely fast data link at 2.5 Gbps so that the typical latency is very low).

For applications that transfer large sets of data or require data streaming common to applications like RF and waveform acquisition and generation, you will need a bus with higher bandwidth. In addition, high-speed and/or high-channel systems require 10 to 100 Mbytes/s or greater bandwidth.



This chart provides a reference for comparing the buses in terms of latency and bandwidth. Notice that PCI Express is highlighted because it is an emerging technology, which we will be discussing later. A few points to note with the chart, decreasing or improving latency moves to the right and note that both scales are logarithmic. From the chart, you can see the tradeoffs between latency and bandwidth for the various buses. As noted earlier, you can see that the serial buses tend to have higher latency (with the exception of PCI Express). You will notice that PCI/PXI provides both the best latency and bandwidth for measurements making it ideal for many applications.



Here you can see the impact of latency in an application. We benchmarked the performance of instruments in response to a single command; the performance of this type of communication is directly impacted by latency. The performance for this application directly maps back to the previous slide with the bus latency and bandwidth chart (flip back to previous slide). You can see the improvement in system performance with a lower latency bus. PCI/PXI is 127% faster than LAN in this application.

Timing and Synchronization

- Used for handling synchronous events
  - For example, Starting signal generator and digitizer at same time
- Used for performing asynchronous events
  - For example, Handshaking with switch and DMM, Arb, and so on
- Backplane buses provide most direct and accurate method of synchronization (PXI and VXI)
- IEEE 1588 protocol provides external synchronization (LAN)
- Input and output triggers available for GPIB, USB, and 1394

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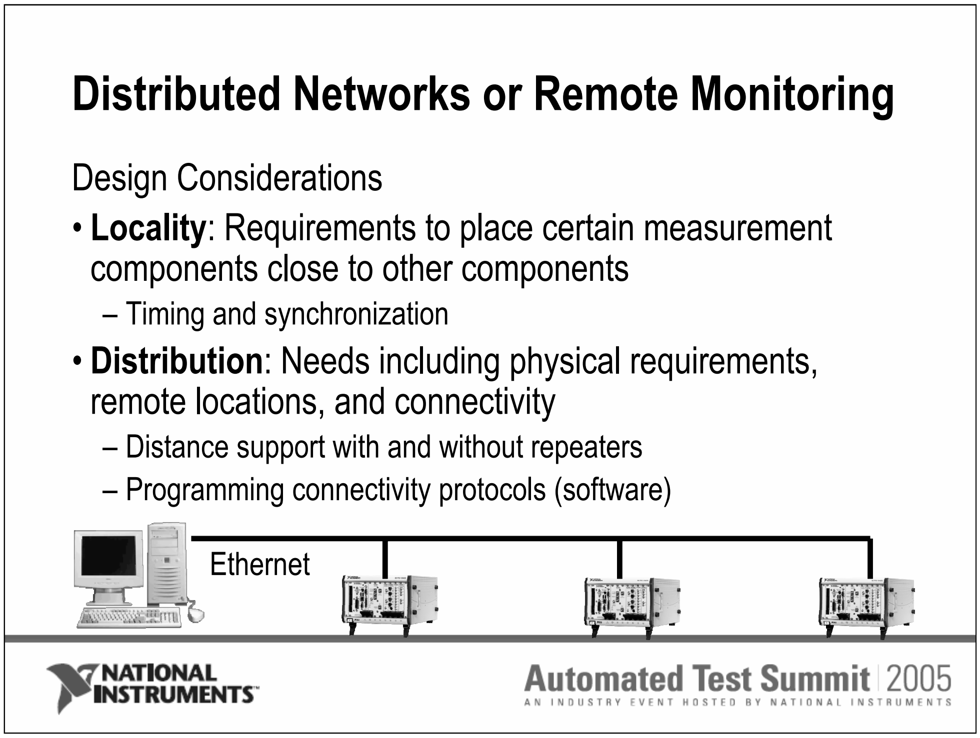
Timing and synchronization is an important factor to consider and will be discussed more in depth in another session. It enables the communication between the instruments in your system which is very important for correlating all of the data taken for one device under test. Timing and synchronization impacts your ability to handle both synchronous and asynchronous events. The various buses provides different levels of synchronization. Backplane buses provide the easiest and most direct connection between instruments as well as the most accurate synchronization. 1588 protocol provides a method for synchronizing over large areas using LAN. GPIB, USB, and 1394 provide the most basic level of synchronization with input and output triggers.

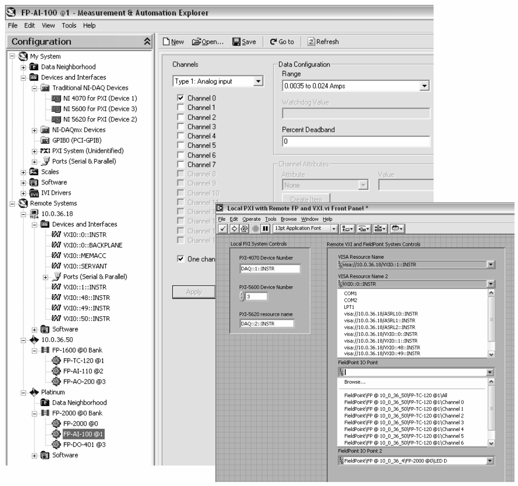


Some systems like jet engines, generators, antenna ranges, or process plants require distributed measurement applications. With other systems it's necessary to remotely monitor the system.

When evaluating buses for these types of measurement systems, there are two major design considerations: locality and distribution. Locality refers to the requirements to place certain measurement components close to other components. For instance, for an RF application you need the downconverter and digitizer to be placed close to each other for your measurement. For locality, timing and synchronization and bandwidth needs are often the driving requirements. Distribution needs include physical requirements, remote locations, and connectivity. This is the wide area distances that need to be supported; thus, distance support provided by the bus and the programming protocols for connectivity are important.

You can maximize both of these needs by combining a PXI chassis to meet locality needs with Ethernet to meet distribution needs.

Software is Key



With proper software tools you can:

- Abstract system complexity
- Use instruments of various buses
- Integrate instruments into one system

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We have discussed many of the important bus factors to consider, but an important thing to remember is that software is key no matter which bus you choose. With the growing complexity of devices, you face growing complexity in the test system. There is inherent test system complexity and artificial complexity, introduced by the tools used. The right software allows you to reduce the artificial system complexity by providing tools to simplify taking measurements, performing analysis, and presenting data. With the right software tools, you can work with any mixture of bus technologies. This allows you to take instruments or various buses and integrate them into one system.

The screenshots show how easy it is to do this – the first screenshot shows Measurement & Automation Explorer (MAX), a configuration manager provided with NI drivers. It allows you to see all of your instruments and integrates the buses into one environment. Here you can see there are PXI, VXI, and FieldPoint instruments. MAX allows you to configure the instruments, ensure they are working properly, and create aliases and tasks for your system. LabVIEW, in the second screenshot, integrates the configurations made in MAX to simplify programming. In addition, LabVIEW simplifies user interface development and provides built-in analysis functions.

Software Standard Frameworks

- Impacts development and integration of the system:
  - Ease system integration tasks
  - Driver software eases programming
    - VISA
    - Plug and Play drivers
- PXI and VXI specify a standard driver framework
- Virtual Instrumentation Software Architecture (VISA) available for PXI,VXI, LAN, GPIB, USB, and 1394

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Software is important no matter what bus you use, but some buses outline a standard software framework for its instruments to help system integration and to ease programming. This typically includes things like specifying a driver should be provided, providing help documents, and using a standard like VISA. VISA provides the same application programming interface (API) to talk to instruments of a variety of bus types. Thus you can talk to PXI, GPIB, VXI, LAN, etc. instruments all with the same driver standard.

To help ensure that a user has a complete, multivendor system solution, PXI specifies that both system controller modules and PXI peripheral modules have to meet certain requirements for operating system and tool support. PXI requires that peripheral modules provide software for installing, configuring, and controlling the modules under Windows and recommends that instrumentation class PXI modules provide a user-level interface that is supported under the common development environments. PXI requires that system controller modules supply a VISA implementation that supports the PXI bus and also recommends that instrumentation class PXI peripheral modules should provide instrument drivers and soft front panels that are consistent with VXI*plug&play* instrument driver specifications.

For buses like LAN, GPIB, USB, and 1394 that do not specify a standard framework, you can still take advantage of the VISA open standard.

Bus Comparison

	GPIB	VXI	1394a	USB	TCP/IP Ethernet	Standard PCs	PXI
Latency (us)	◒	●	○	○	○	●	●
Bandwidth (Mbytes/s)	○	◒	○	○	◒	●	●
Timing and Synchronization	○	●	○	○	◒	○	●
Standard Software Frameworks	◒	●	◒	◒	◒	○	●
Measurement Availability	●	◒	○	○	○	◒	◒
High Channel Count	○	◒	○	○	◒	●	●
Data Streaming	◒	●	○	○	○	●	●
Distributed and Remote Systems	○	◒/●[1]	○	○	●	◒/●[1]	◒/●[1]

● Best
◒ Better
○ Good

[1] Achieved with Ethernet connection to controller

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We've discussed many factors for evaluating bus technologies. This chart provides a reference that you can come back to in the future. It summarizes the points discussed today and some of the main factors you should consider when evaluating bus technologies. To highlight a few points, PXI provides a best solution for latency, throughput, and timing and synchronization. As a result, it is a very good bus option for high channel count and data streaming applications.