Oslo - Stockholm - Utrecht - Brussels - Copenhagen - Helsinki

ni.com/nidays

NATIONAL INSTRUMENTS

HOW TO CHOOSE THE BEST INSTRUMENT CONTROL BUS FOR YOUR APPLICATION

National Instruments

Agenda

- Instrument Control Basics
- Bus Characteristics
  - GPIB, USB, PCI, PCI Express, Ethernet/LAN/LXI
- Head-to-Head Comparison
  - Setup
  - Bandwidth
  - Latency
  - Distributed/Remote Systems
  - Physical Ruggedness
- Hybrid Systems

Selecting an Instrument Control Bus

Fast Ethernet

PCI

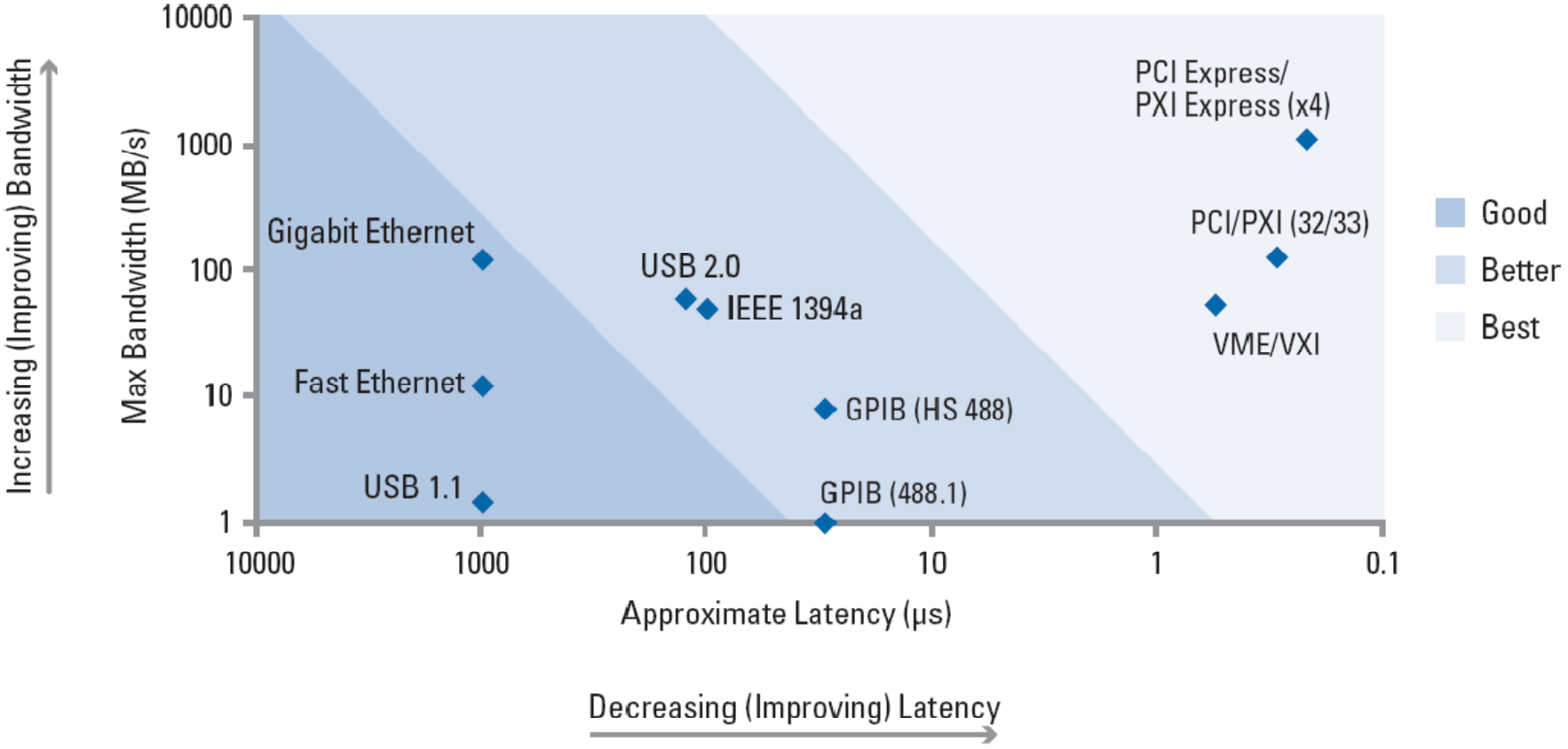
GPIB

Gigabit Ethernet

VMEbus

CompactPCI®

Latency versus Bandwidth



GPIB/IEEE-488

HS488 Max Bandwidth: 8 MB/s

488.1 Max Bandwidth: 1.8 MB/s

Bandwidth Distribution: Shared

Bandwidth Rating: Good

Latency Rating: Better

- More than 30 years of compatibility
- Robust and reliable
- Widest industry adoption
- Largest installed base of instruments

- Ideal for:
  - Automating existing equipment
  - Hybrid systems
  - Systems requiring highly specialized instruments

USB

Max Bandwidth: 60 MB/s (Hi-Speed USB)

Bandwidth Distribution: Shared across all ports

Bandwidth Rating: Better

Latency Rating: Better

- PC ubiquity
- Simplest plug-and-play connectivity (autodetection)

- Ideal for:
  - Portable desktop and benchtop applications
  - Small, low-cost systems

Ethernet/LXI

1000BaseT Max Bandwidth: 125 MB/s
(Gigabit Ethernet)
100BaseT Max Bandwidth: 12.5 MB/s
(Fast Ethernet)
Bandwidth Distribution: Shared across network
Bandwidth Rating: Better
Latency Rating: Good

- Remote capabilities
- PC ubiquity
- LXI adds optional timing and triggering
  - Synchronization through IEEE 1588 (Class B)
  - Triggering support (Class A)

- Ideal for:
  - Distributed systems
  - Remote monitoring

PCI and PCI Express

PCI Express Bandwidth: (x1) 250 MB/s – (x16) 4000 MB/s

PCI Express Bandwidth Distribution: Dedicated per device

PCI Max Bandwidth: 132 MB/s

PCI Bandwidth Distribution: Shared

Bandwidth Rating: Best

Latency Rating: Best

- Best bandwidth and latency
- PC ubiquity
- Enables lower instrument cost

- Ideal for:
  - High-performance systems
  - Data-intensive systems

PXI and PXI Express

PXI Express Bandwidth: (x1) 250 MB/s – (x8) 2000 MB/s

PXI Express Bandwidth Distribution: Dedicated per device

PXI Max Bandwidth: 132 MB/s

PXI Bandwidth Distribution: Shared

Bandwidth Rating: Best

Latency Rating: Best

- Best bandwidth and latency
- Based on rugged CompactPCI physical standard
- Adds timing and synchronization to CompactPCI
  - Trigger bus
  - Star trigger
  - 10 or 100 MHz shared system clock

Ideal for:

- High-performance systems
- Integration of several types of instruments
- Timing and synchronization

Head-to-Head Comparison

- Setup
- Bandwidth
- Latency
- Distributed/Remote Systems
- Physical Ruggedness

1. Setup

Bus	Setup	Notes
Ethernet/LXI	Good	Configure IP address and subnet
GPIB	Better	Search bus for instrument
PCI	Better	Power down first; then Windows autodetects, autoconfigures
PCI Express	Better	Power down first; then Windows autodetects, autoconfigures
USB	Best	Instrument autodetects, autoconfigures

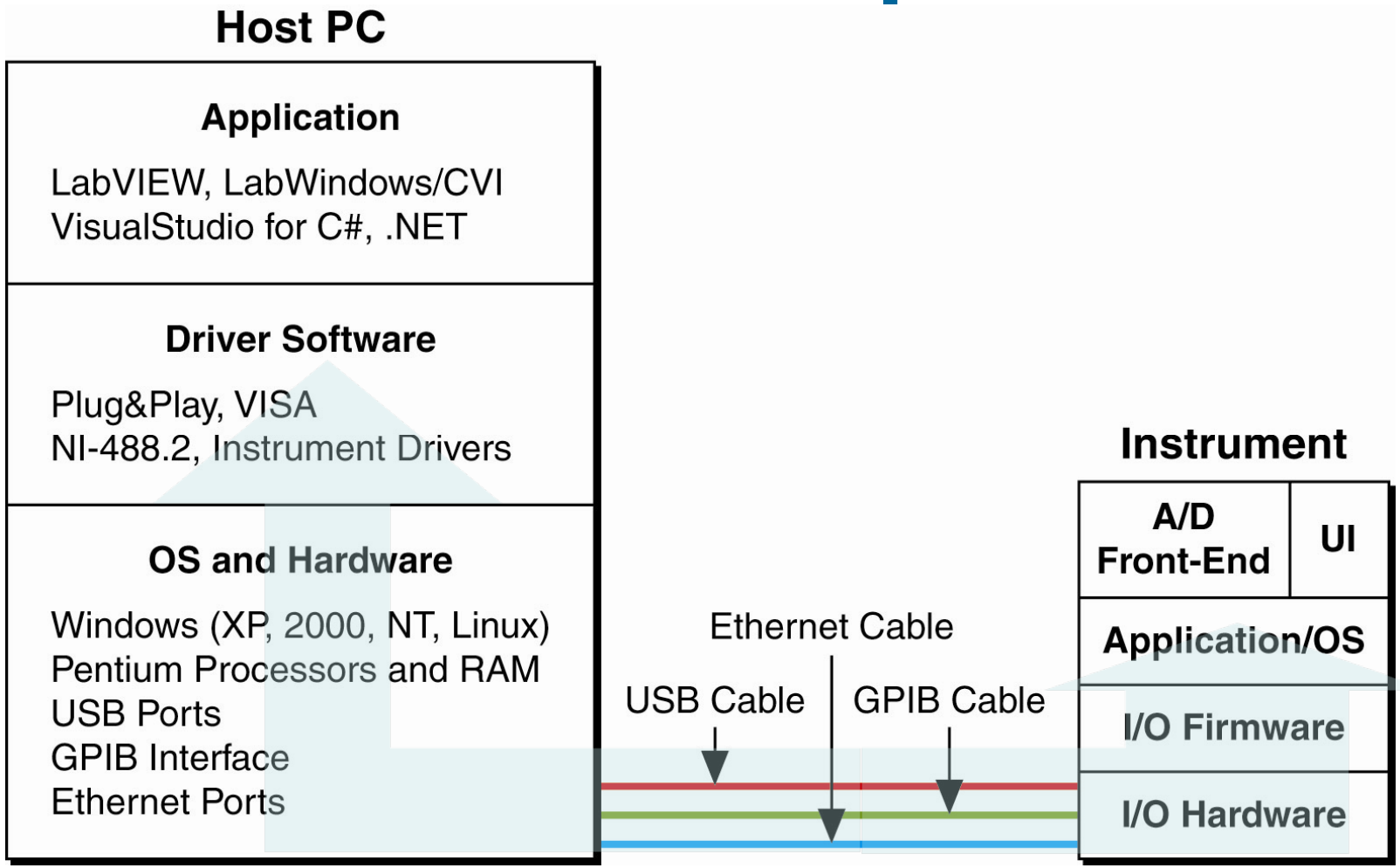
Many Factors Affect Performance

- **Offloading:** Performing computation on PC rather than the instrument
- **Transfer size:** The number of bytes in each transfer
- **Data format:** Waveform transfers support different formats: ASCII, binary
- **Synchronous versus asynchronous operations:** Synchronous call often better for small transfers, depending on the number of parallel tasks

Practical Implementation of the Bus

- Theoretical numbers on throughput are rarely achieved
- Bottlenecks occur
  - When a faster bus is routed through a slower bus
  - In poorly implemented communication firmware
- There can be very apparent performance differences between different vendors' implementations

Performance Comparison



Test System for Comparison

Application

- LabVIEW 8.20
- Identical IVI function calls

OS and Hardware

- Windows XP
- Pentium processor
- Hi-Speed USB ports
- GPIB interface
- Ethernet via Gigabit switch

PCI (PXI)

Ethernet (100BaseT)

Hi-Speed USB

GPIB (488.1)

NI Arbitrary Waveform Generator

NI PXI Digitizer

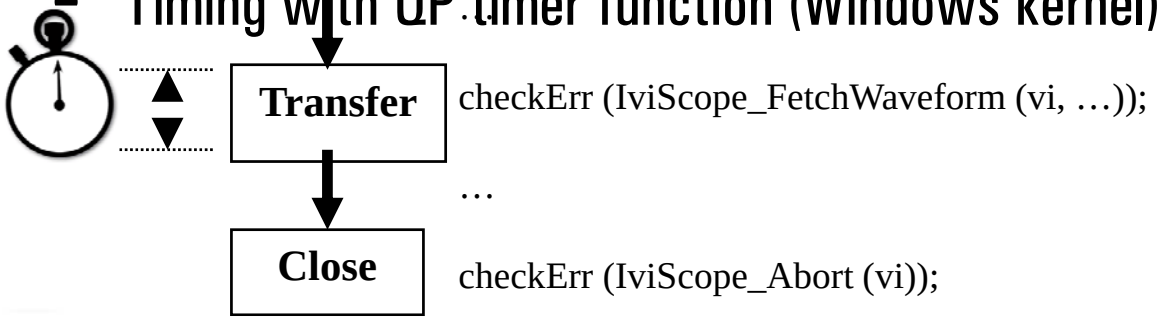
Agilent Oscilloscope

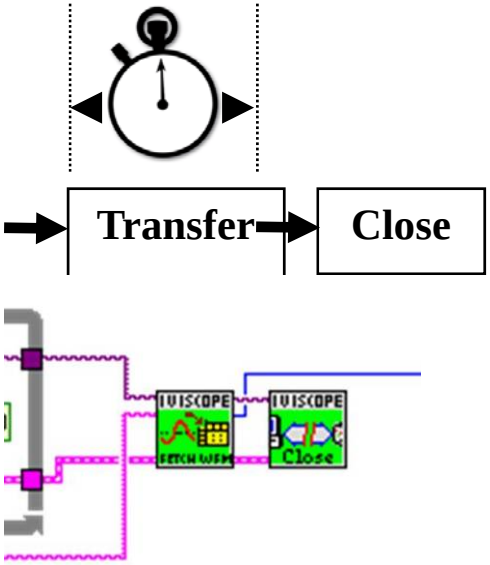
2. Bandwidth

Bus	Ideal Bandwidth (MB/s)	Distribution
GPIB	1.8 (488.1) 8 (HS488)	Shared
USB	60 (Hi-Speed USB)	Shared
Ethernet/LXI	12.5 (Fast) 125 (Gigabit)	Shared
PCI	132	Shared
PCI Express	250 (x1) 4000 (x16)	Dedicated per device, per direction

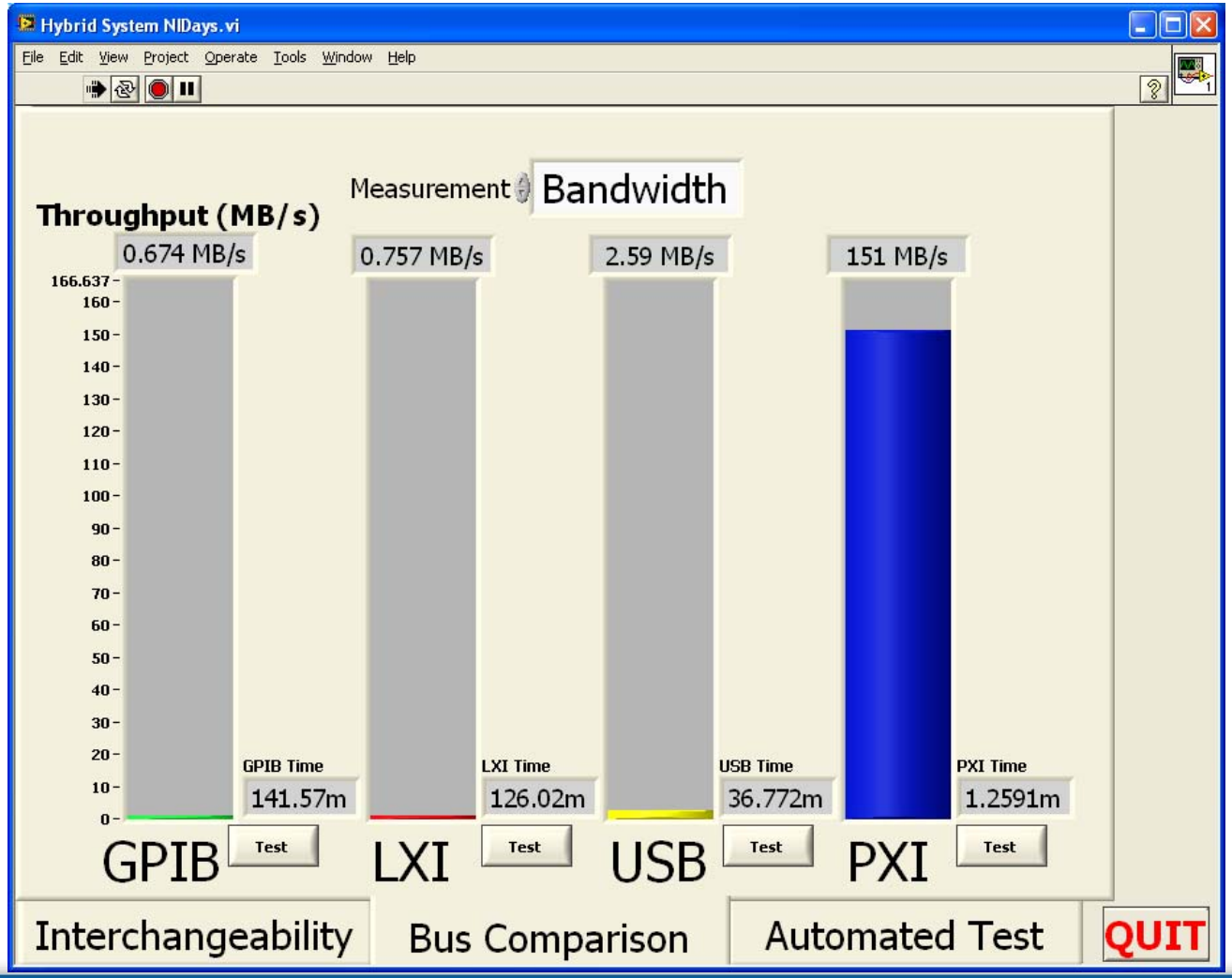
2. Bandwidth Experiment

- Using identical IVI function for each bus
- Transferring 100,000 samples
- Averaging 100 trials for each bus
- Measuring data transfer only
- Timing with QP timer function (Windows kernel)





Bandwidth Experiment Results

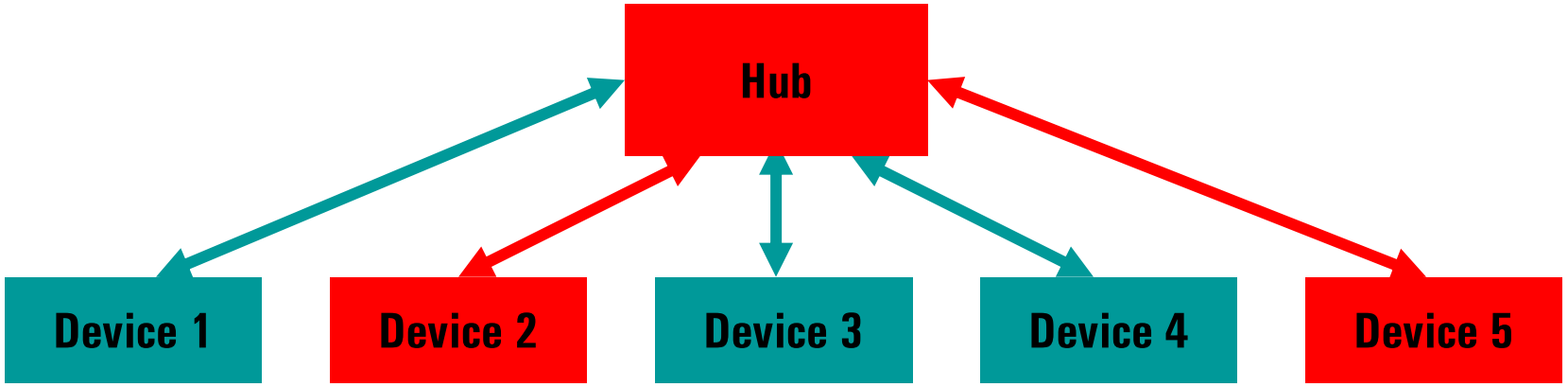


3. Latency

Bus	Latency (microseconds)
Ethernet/LAN/LXI	1000 (Fast) 1000 (Gigabit)
USB	1000 (USB 1.1) 125 (Hi-Speed USB)
GPIB	30
PCI	0.7
PCI Express	0.7 (x1) 0.7 (x4)

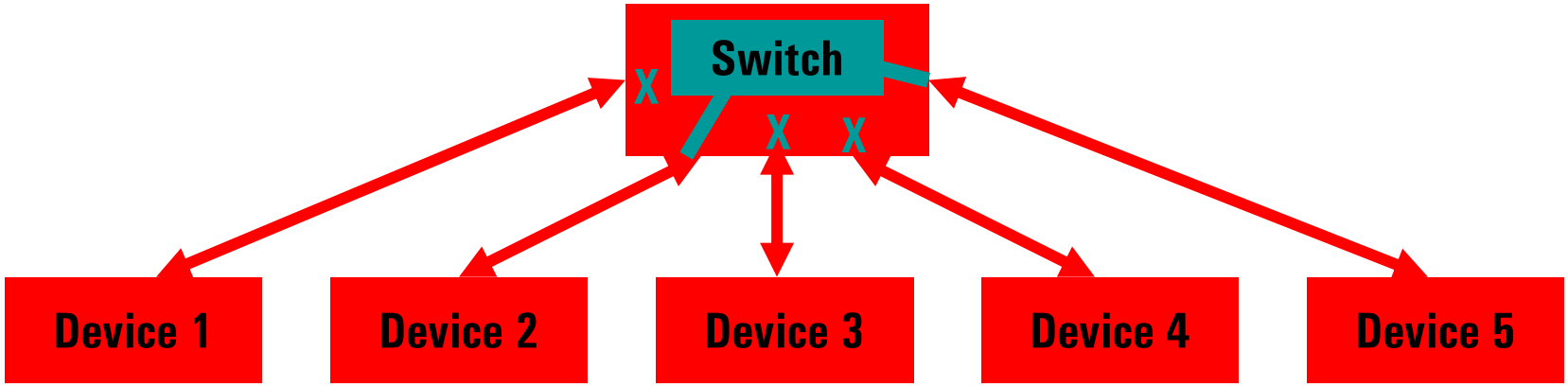
Source: Bus specifications and 2005 NI benchmark testing

Shared Ethernet Using a Hub



- Only one Ethernet network
- Only bus master can transfer data
- Collisions are resolved by random delays before next request

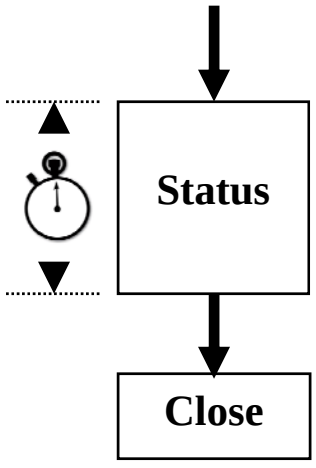
Point-to-Point Ethernet Using a Switch



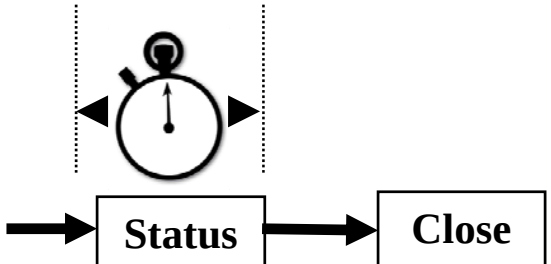
- Multiple point-to-point Ethernet networks
- Each device shares bus master with switch port on local link
- Collisions are resolved by queuing delays and jitter in switch

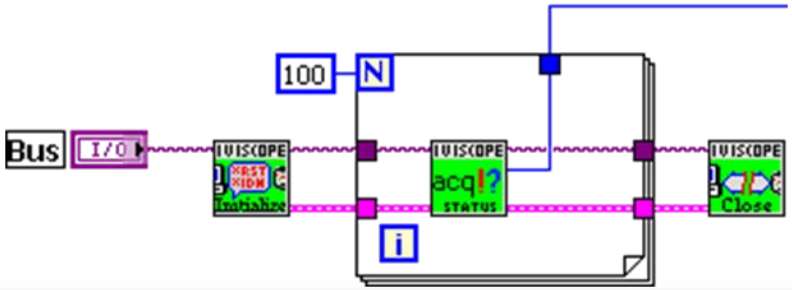
4. Latency Experiment

- Using identical IVI function for each bus
- Querying for acquisition status 100 times
- Timing with QP timer function (Windows kernel)

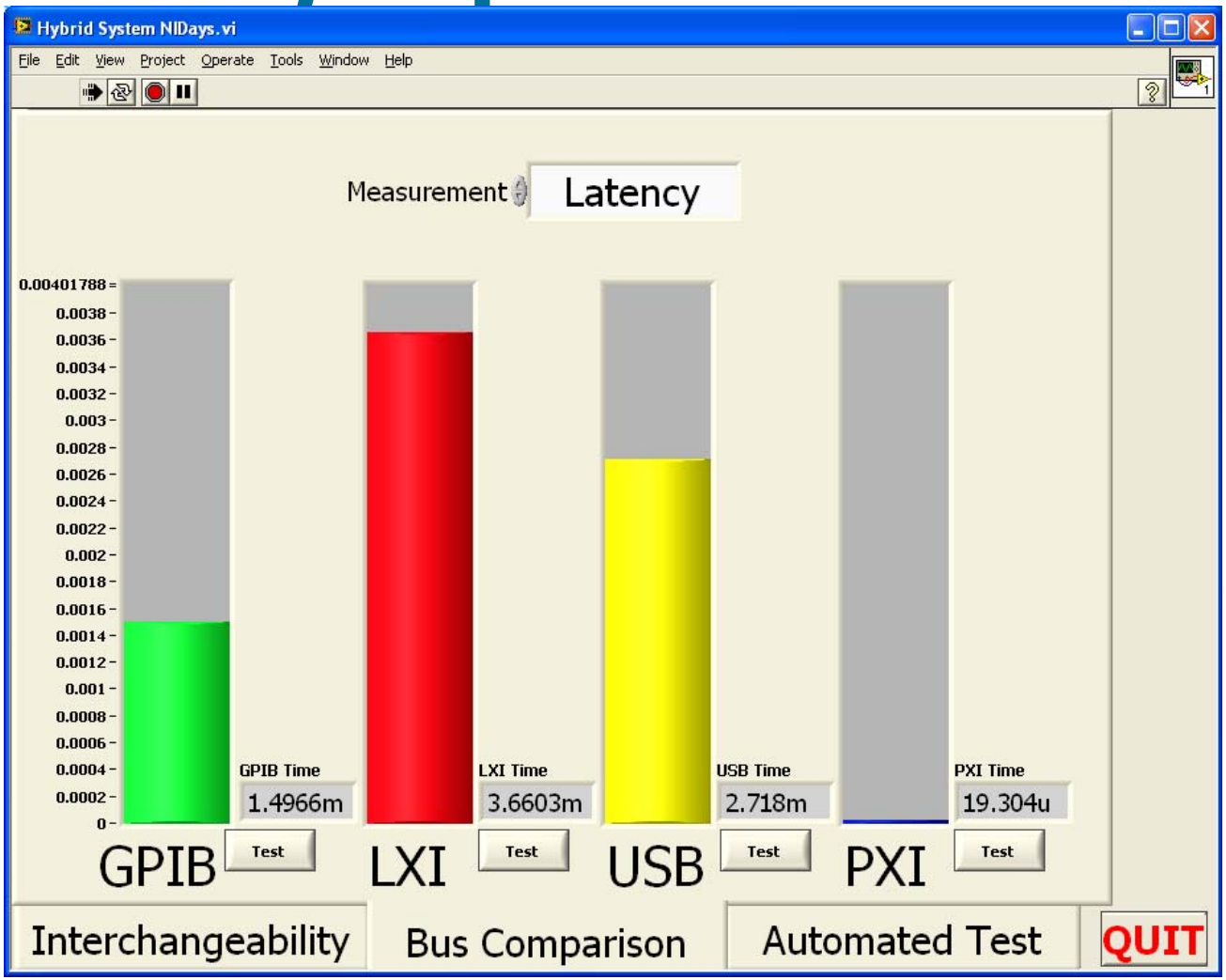



```
…

for (i = 1; i <= numOfMeasurements; i++)
    {
     checkErr (IviScope_AcquisitionStatus (vi, …));
     }
…

Error:
        return error;
…
```





Latency Experiment Results



Test System for Comparison

Application
- LabVIEW 8.20
- Identical IVI function calls

OS and Hardware
- Windows XP
- Pentium processor
- Hi-Speed USB ports
- GPIB interface
- Ethernet via Gigabit switch

PCI (PXI)

LXI

Hi-Speed USB

GPIB (488.1)

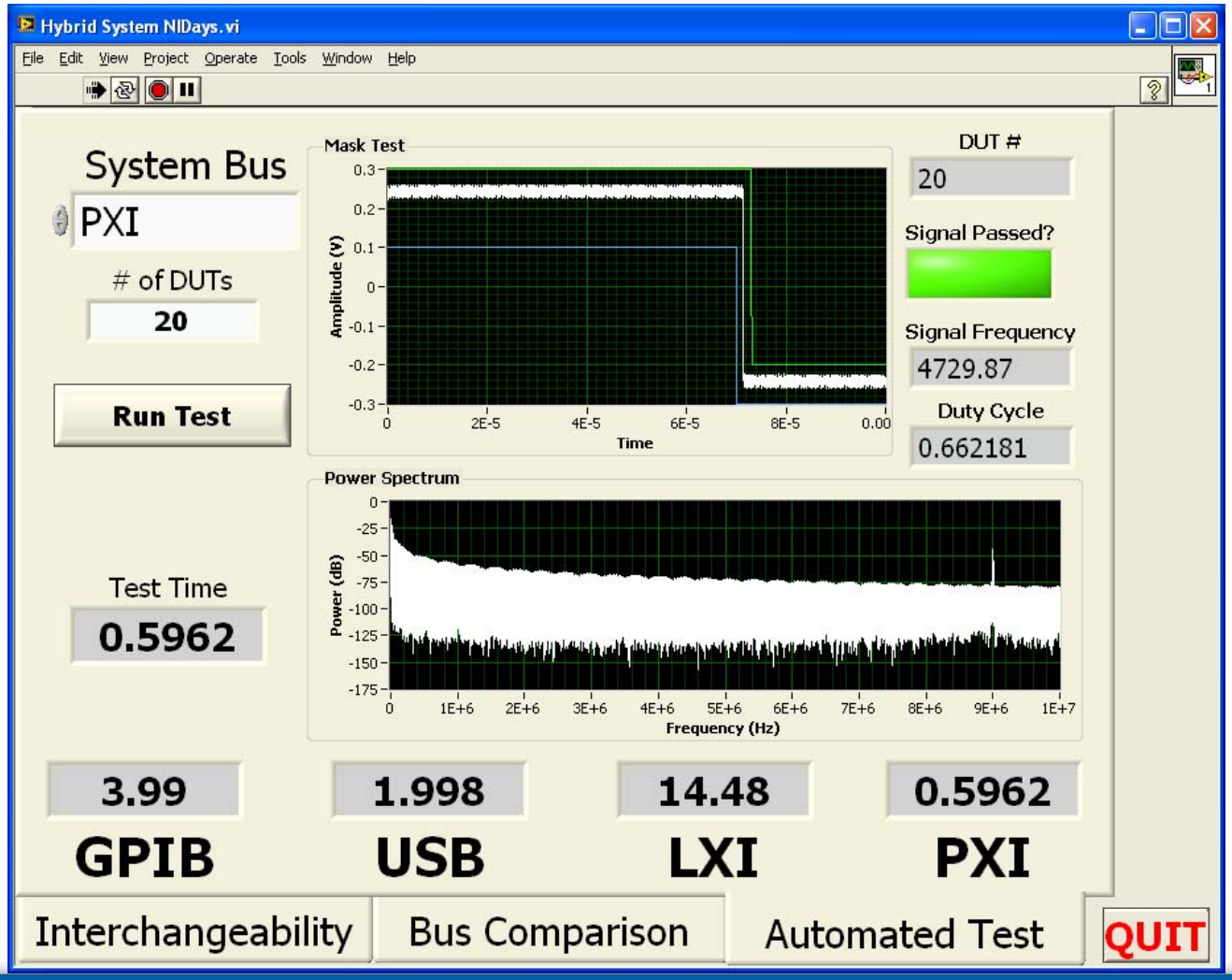
NI Arbitrary Waveform Generator

NI PXI Digitizer

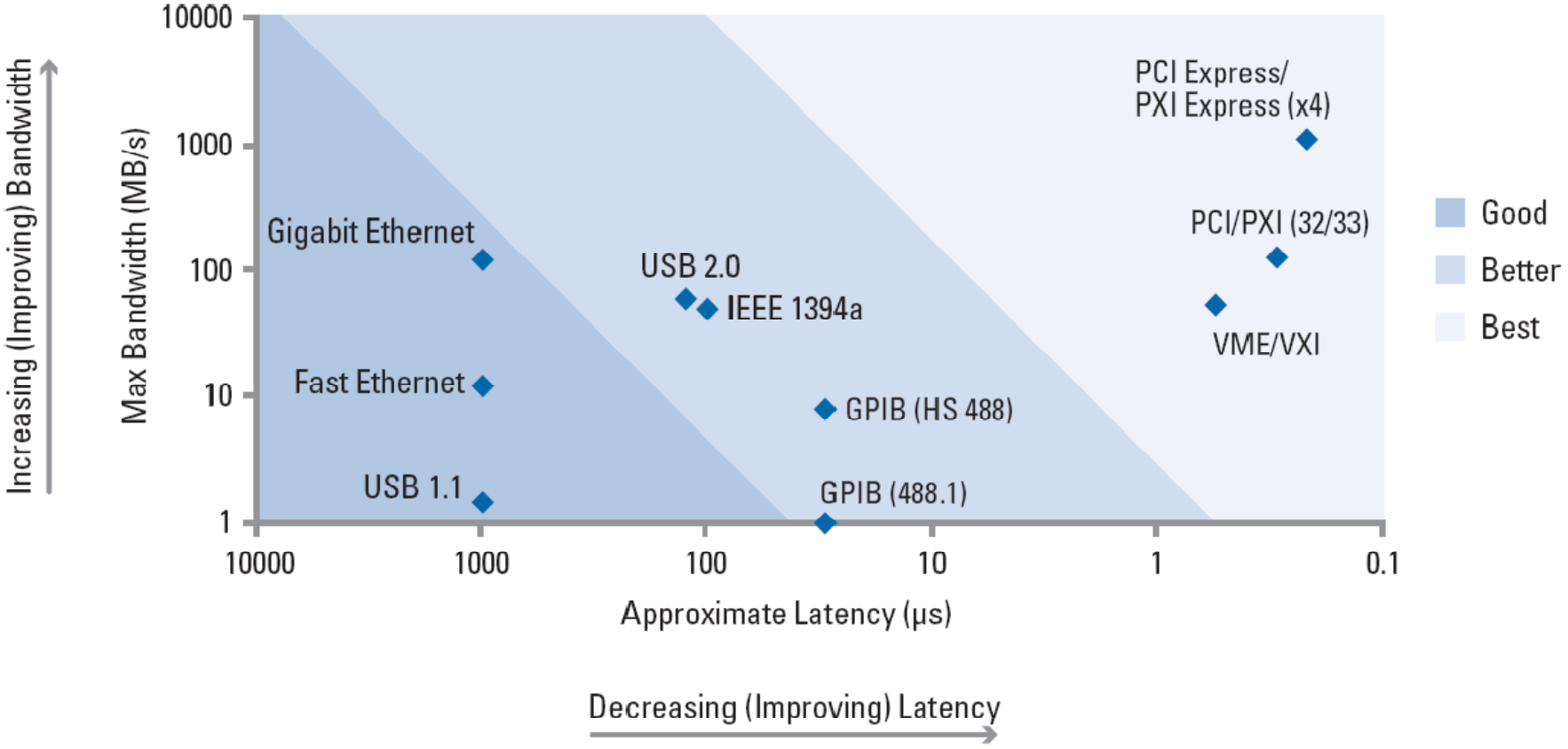
Agilent Arbitrary Waveform Generator

Agilent Oscilloscope

Automated Test Example



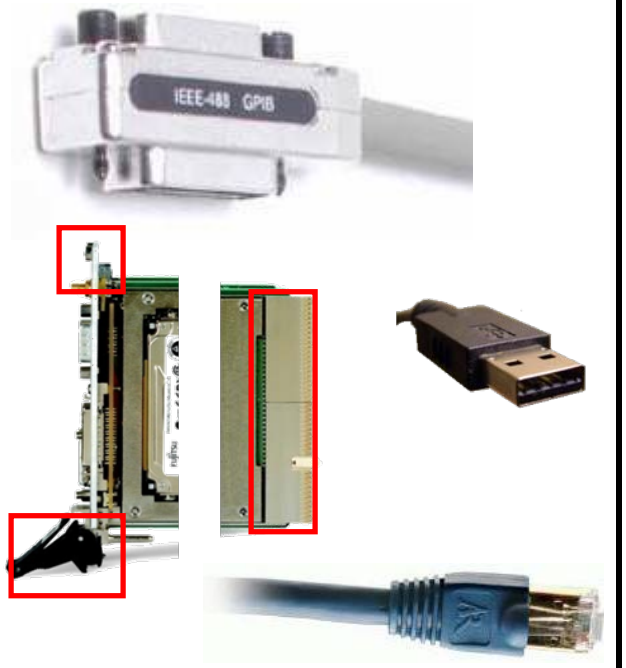
Latency versus Bandwidth



4. Distributed Capability

Bus	Max Length	Notes
PCI	Internal PC bus	Fiber-optic MXI extends to 200 m
PCI Express	Internal PC bus	MXI-Express extends
USB	5 m	Not easily extended
GPIB	20 m	Fiber-optic cables extend to 2 km
Ethernet/LXI	85 to 100 m	Fiber-optic cables extend to kilometers

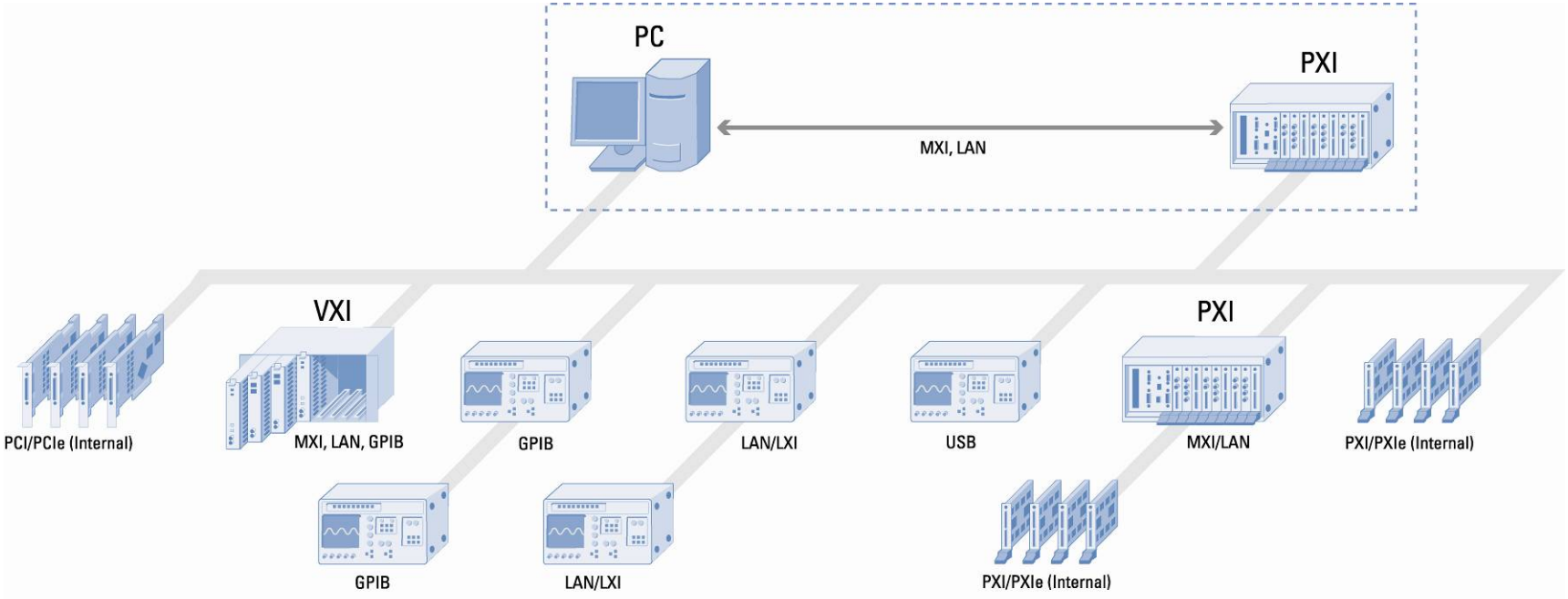
5. Ruggedness

Bus	Ruggedness	Connector
Ethernet/LXI	Good	
USB	Good	
PCI	Best (for PXI)	
PCI Express	Best (for PXI Express)	
GPIB	Best	

The Right Bus for Your Application

- No single bus technology solves all needs
  - GPIB → stand-alone instrument reuse, specialized instruments
  - PCI/PCI Express → best bandwidth and latency performance
  - PXI/PXI Express → best bandwidth and latency + timing and triggering
  - USB → autodetecting plug-and-play connectivity
  - Ethernet/LAN/LXI → distributed or remote systems
- Hybrid systems are often needed to integrate several technologies

Hybrid Systems Provide Flexibility



Layered Approach to Hybrid System

System Management

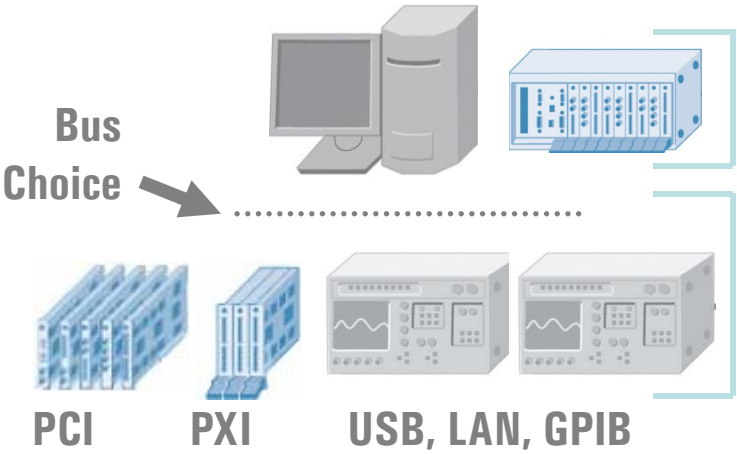
- NI TestStand, DIAdem

Application

- LabVIEW, LabWindows™/CVI, LabVIEW SignalExpress, VB, C, C++

Measurement and Control Services

- VISA, LabVIEW PnP, IVI, MAX, NI-DAQmx



Computing

- PXI, VXI, Desktop/Server/Laptop PC

Device I/O

- Instruments, Data Acquisition, Vision, Motion

http://ni.com/icfundamentals