RIO for Test

Dr. Orbel Sevoyan

OLYMP Engineering LLC

R&D Manager

PXI Combines Standard Technologies

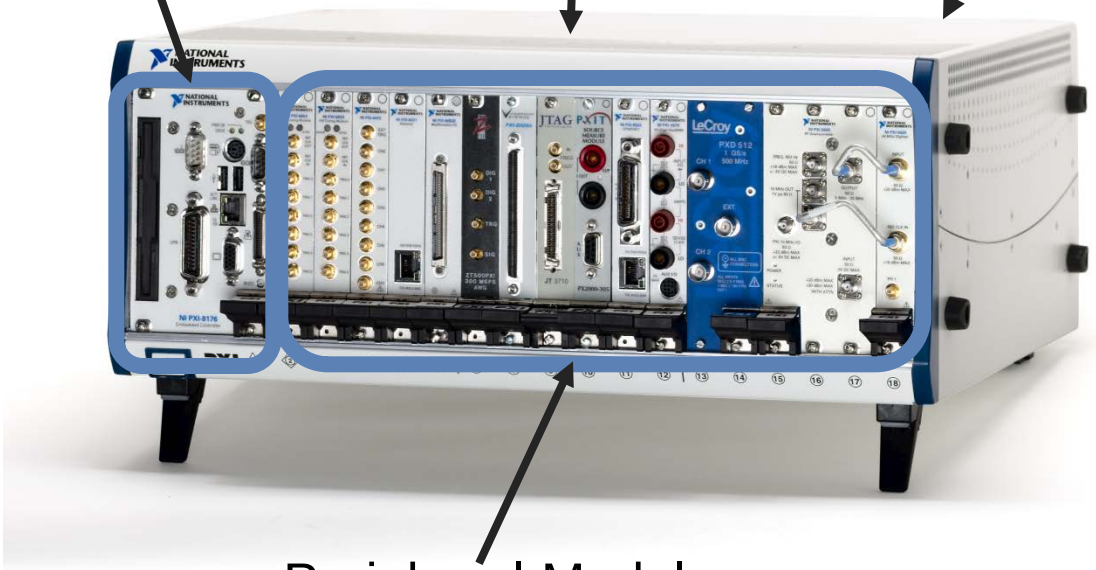
Controller

- Embedded PC or remote PC / laptop interface
- Runs all standard software

Chassis

PXI Backplane

- PCI and PCI Express buses
- Timing and Synchronization



Peripheral Modules

NI FlexRIO FPGA Modules for PXI

- Virtex-5, Kintex-7 FPGA
  - LX30, LX50, LX85, LX110
- Direct access to FPGA I/O lines
  - Full I/O pin performance
- Adapter module required

NI FlexRIO System Architecture

NI FlexRIO Adapter Module

- Interchangeable I/O
- Analog or digital
- NI FlexRIO Adapter Module Development Kit (MDK)

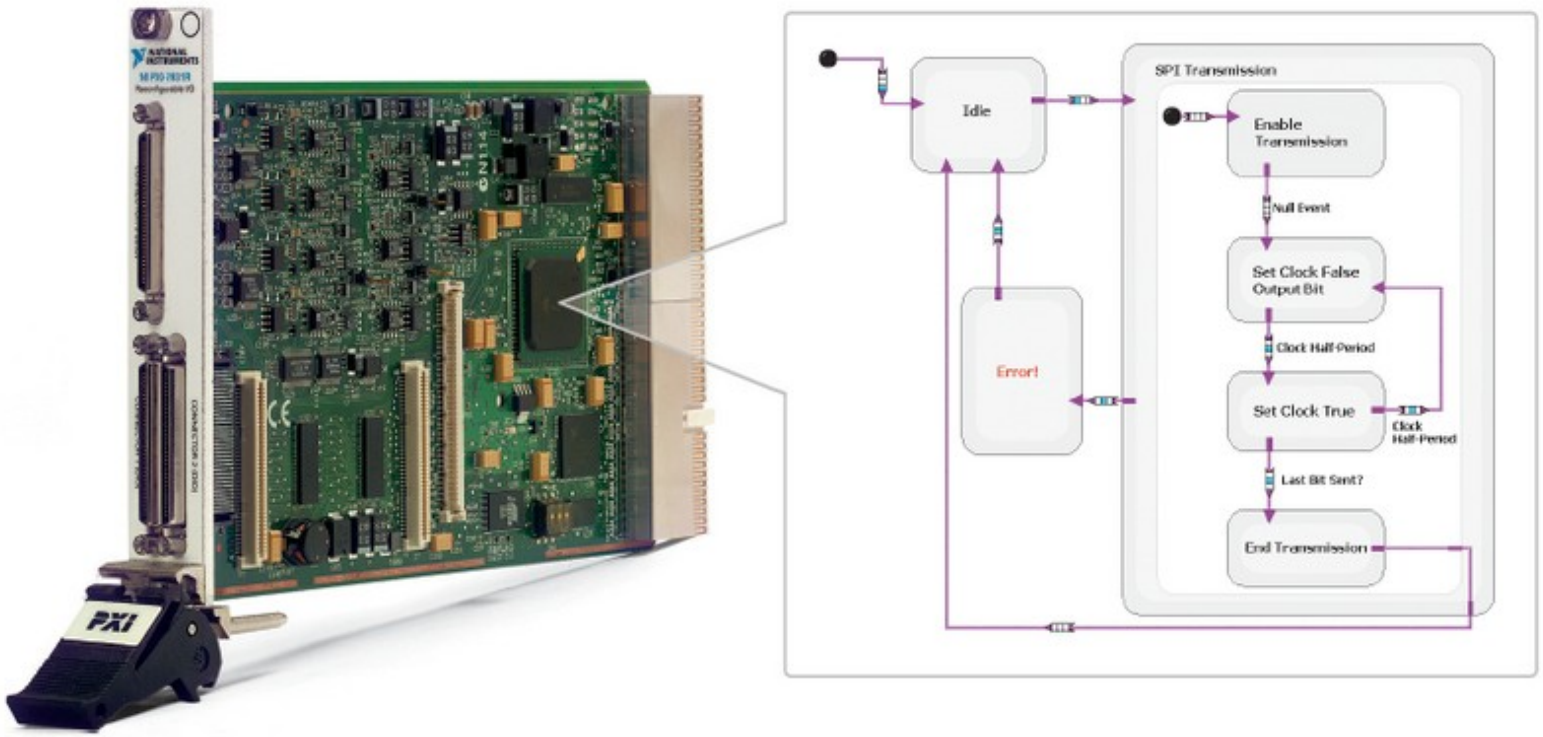
NI FlexRIO FPGA Module

- Virtex-5 FPGA
- 132 digital I/O lines
- Up to 512 MB of DRAM

PXI Platform

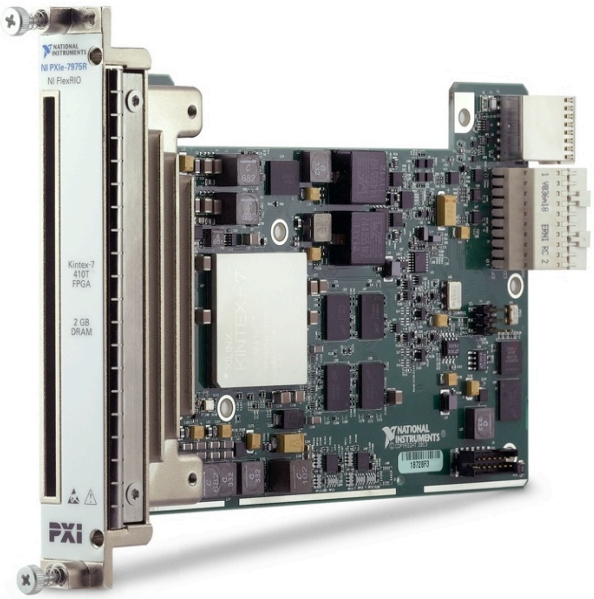
- Synchronization
- Clocking/triggers
- Power/cooling
- Data streaming

LabVIEW FPGA and RIO Hardware



7 Series FPGA Module

NI PXIe-7975



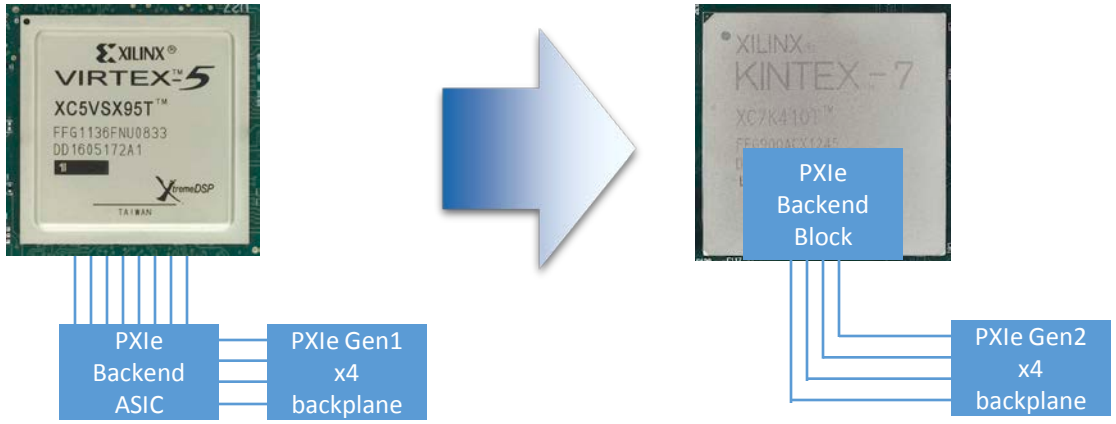
2x PCIe Bandwidth

4x On-board RAM

2x Digital Signal Processing

	PXIe-7966R	PXIe-7975R
FPGA	Xilinx Virtex-5	Xilinx Kintex-7
DRAM Size	512 MB	2 GB
DRAM Theoretical Bandwidth	3.2 GB/s	10.6 GB/s
PXI Express Bandwidth (bi-directional)	800 MB/s (700 MB/s)	1.6 GB/s (800+ MB/s)

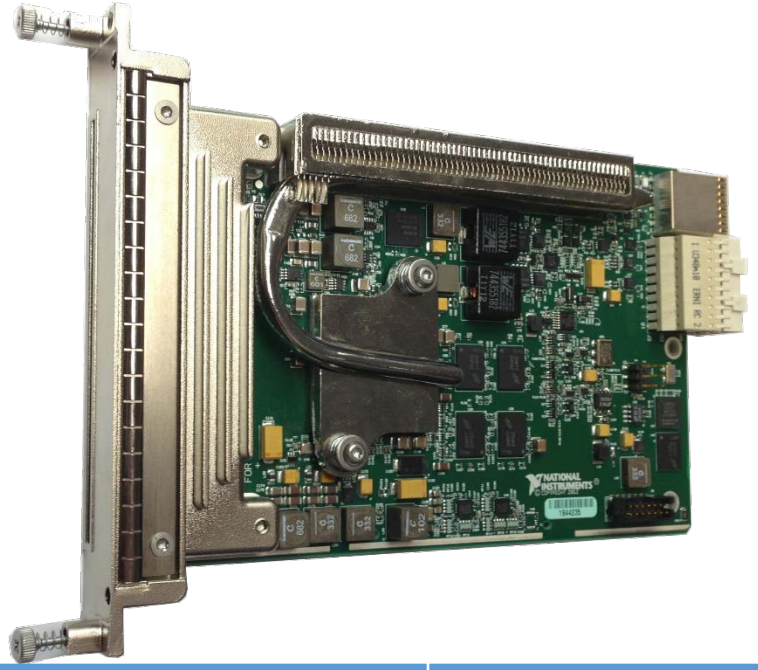
Implications of a larger FPGA and new backend

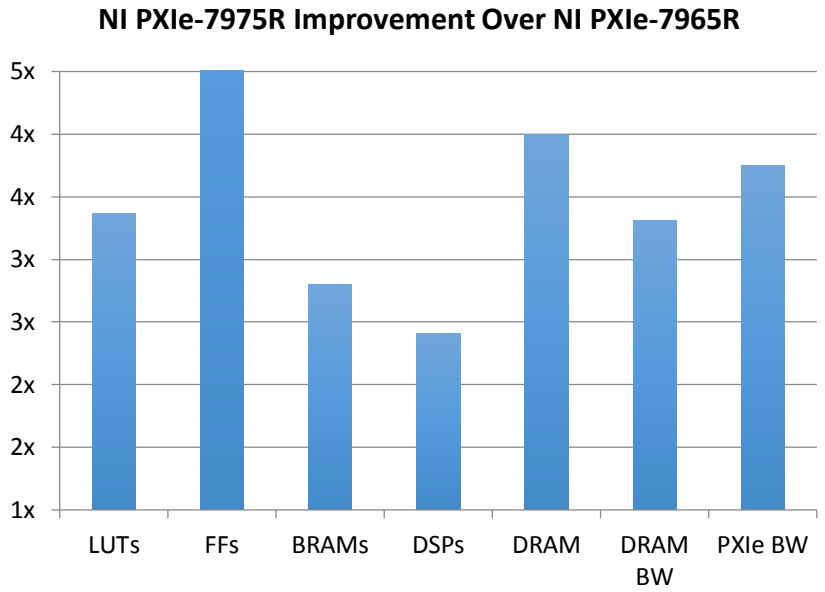


- Much larger FPGA
- New PXIe backend implemented on FPGA, not NI ASIC
- More complex and time-intensive compilations
- Better compilation experience coming in LV 2014!

Series 7 FPGA Modules

NI PXIe-797xR



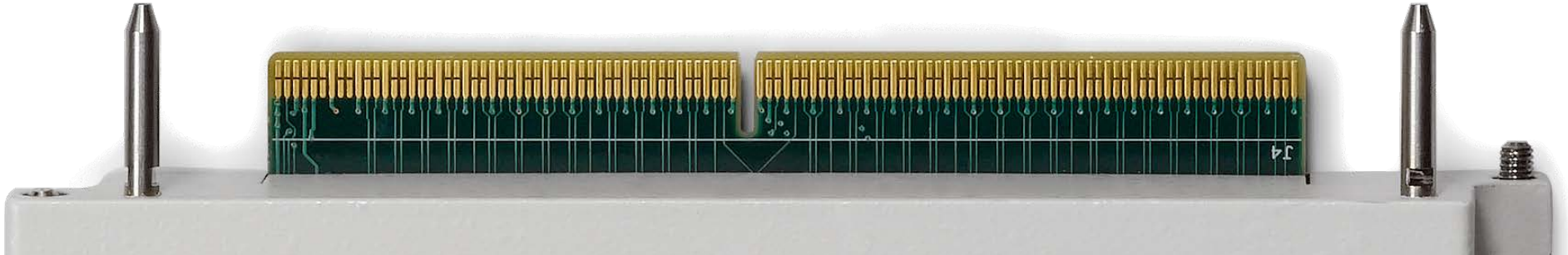


	PXIe-7965R	PXIe-7975R
FPGA	Xilinx Virtex-5 SX95T	Xilinx Kintex-7 LX410T
DRAM Size	512 MB	2 GB
DRAM Theoretical Bandwidth	3.2 GB/s	10.6 GB/s
PXI Express Bandwidth (bi-directional)	800 MB/s (700 MB/s)	3 GB/s (1.5 GB/s)

NI FlexRIO Adapter Module

- 132 single-ended lines @ 400 Mbps (200 MHz DDR) – or – 66 differential lines at 1 Gbps (500 MHz DDR) – or – any combination thereof
- 6 W power – electrical and thermal limit
- 3.3 V (1 A) and 12 V (200 mA) rails
- 2 logic supply reference voltages connected to 2 FPGA I/O banks apiece
- I^2C EEPROM for module identification and user-defined storage
- NI mechanical enclosures

	1.2 V	1.5 V	1.8 V	2.5 V	3.3 V
LVTTL					x
LVCMOS	x	x	x	x	x
LVDCI		x	x	x	x
LVDS				x	



NI FlexRIO Partner Modules

100 MHz PPMU

Camera Link and GigE

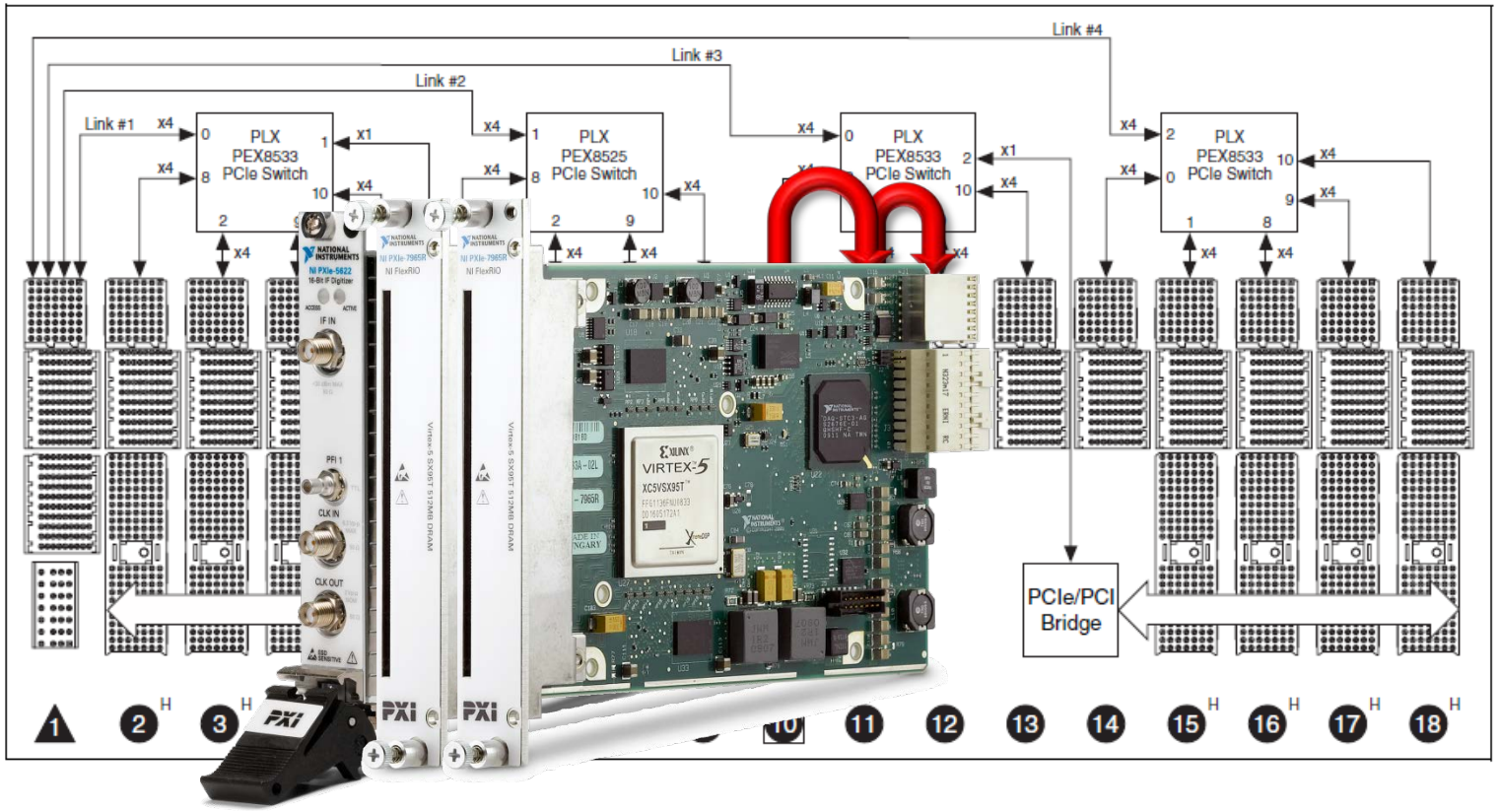
Multi-gigabit optical

Dual gigabit Ethernet

Video and Automotive

NI FlexRIO Peer-to-Peer Architecture

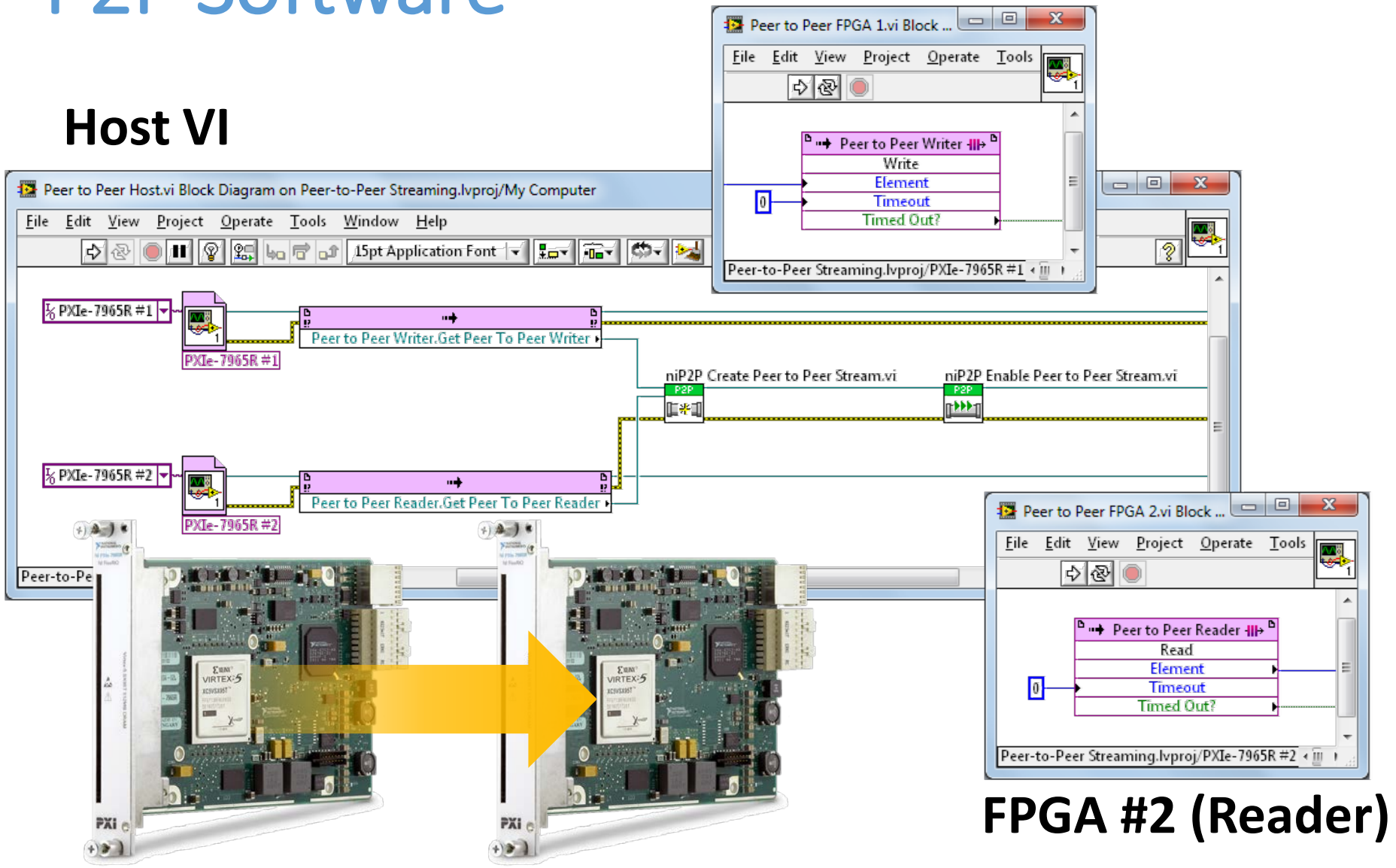
- **>800 MB/s one-way**
- **>700 MB/s both ways**
- **~10 us latency**
- **Up to 16 streams per FPGA**



P2P Software

FPGA #1 (Writer)

Host VI



FPGA #2 (Reader)

P2P Streaming Instruments – Input

PXIe-5122 Digitizer
- Dual-channel
- 14-bit, 100 MS/s
- 100 MHz bandwidth
- 400 MB/s P2P streaming

PXIe-5663/E VSA
- 10 MHz to 6.6 GHz
- 16-bit, 150 MS/s
- 50 MHz bandwidth
- 250 MB/s P2P streaming

PXIe-5622 IF Digitizer
- 16-bit, 150 MS/s
- 3-250 MHz bandwidth
- 60 MHz bandwidth DDC
- 300 MB/s P2P streaming
- I/Q or time domain

P2P Streaming Instruments – Input

PXIe-5665 VSA

- 20 Hz to 14 GHz
- 16-bit, 150 MS/s
- 50 MHz bandwidth
- 250 MB/s P2P streaming

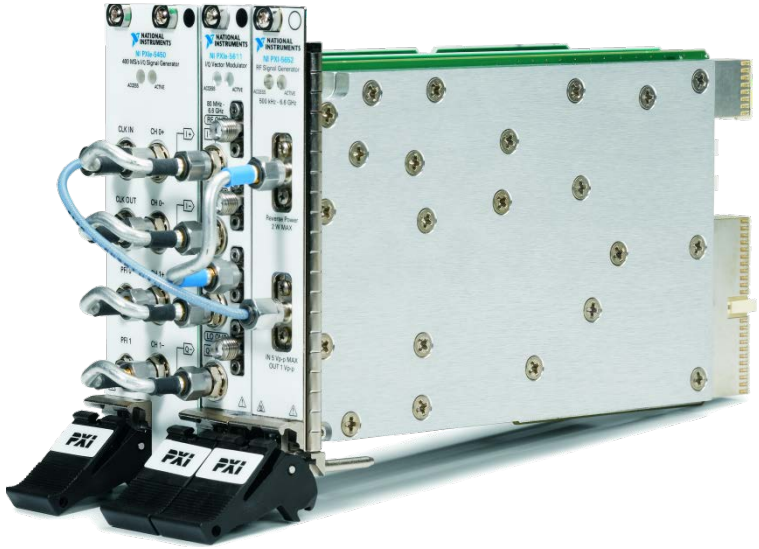
26.5 GHz Phase Matrix VSA

- 10 MHz to 26.5 GHz
- Frequency extension to PXIe-5663E
- 16-bit, 150 MS/s
- 50 MHz bandwidth
- 250 MB/s P2P streaming

P2P Streaming Instruments – Output

PXIe-5450/51 Arb

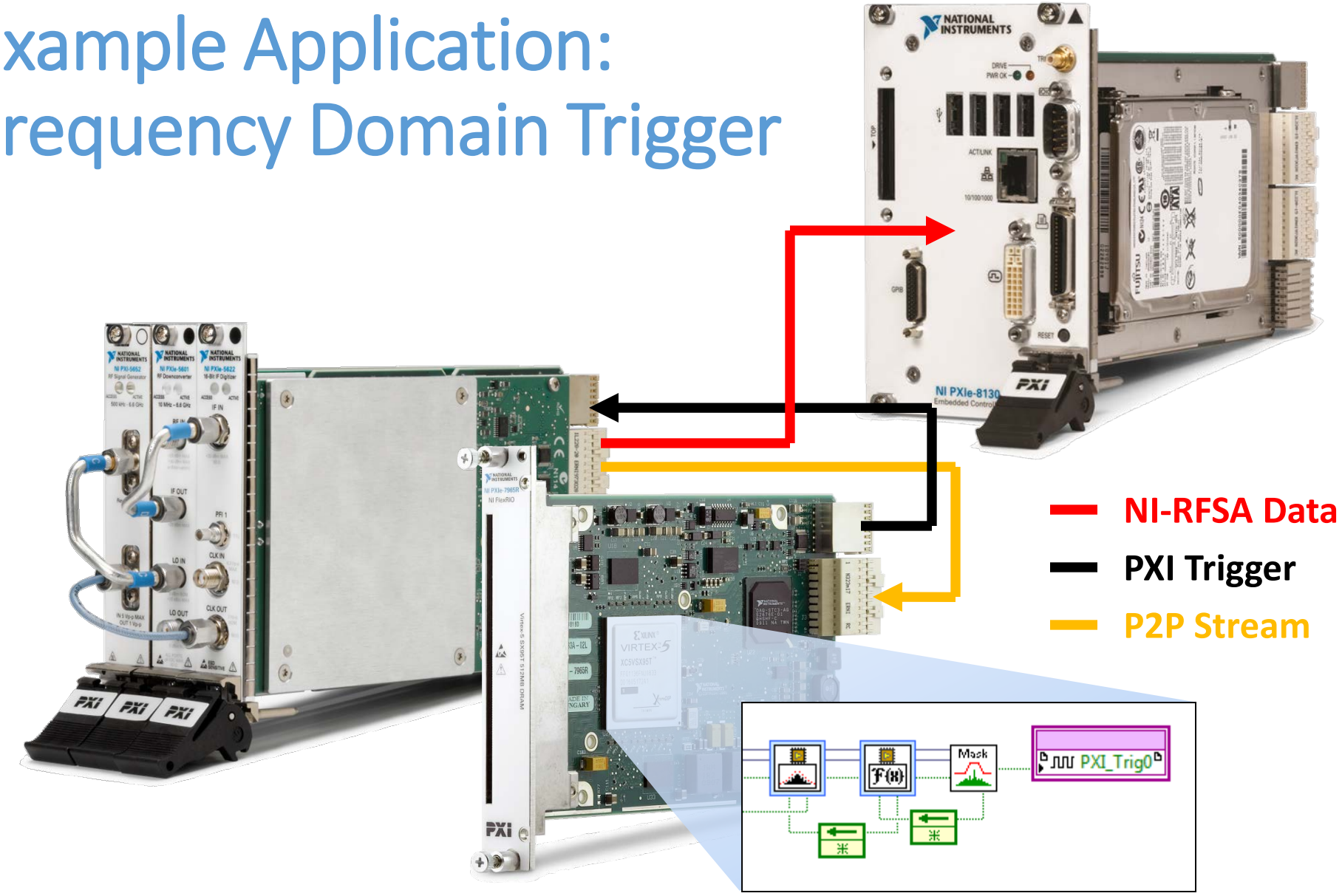
- Dual-channel
- 16-bit, 400 MS/s
- 145 MHz bandwidth
- 800 MB/s P2P streaming



PXIe-5663/E VSG

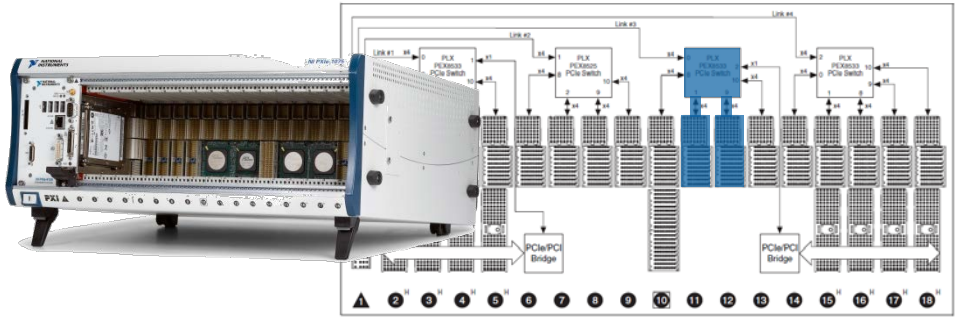
- 85 MHz to 6.6 GHz
- 16-bit, 400 MS/s
- >100 MHz bandwidth
- 800 MB/s P2P streaming

Example Application: Frequency Domain Trigger

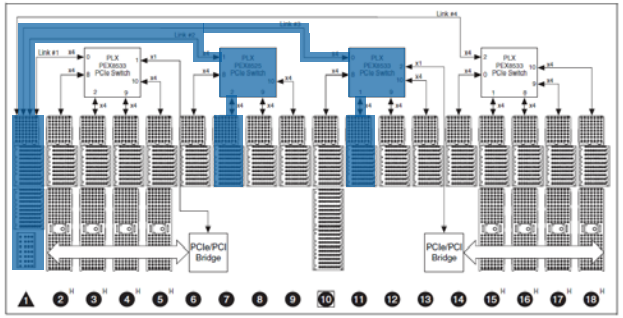


Peer-to-Peer Transfer Rates

- Dependent on chassis



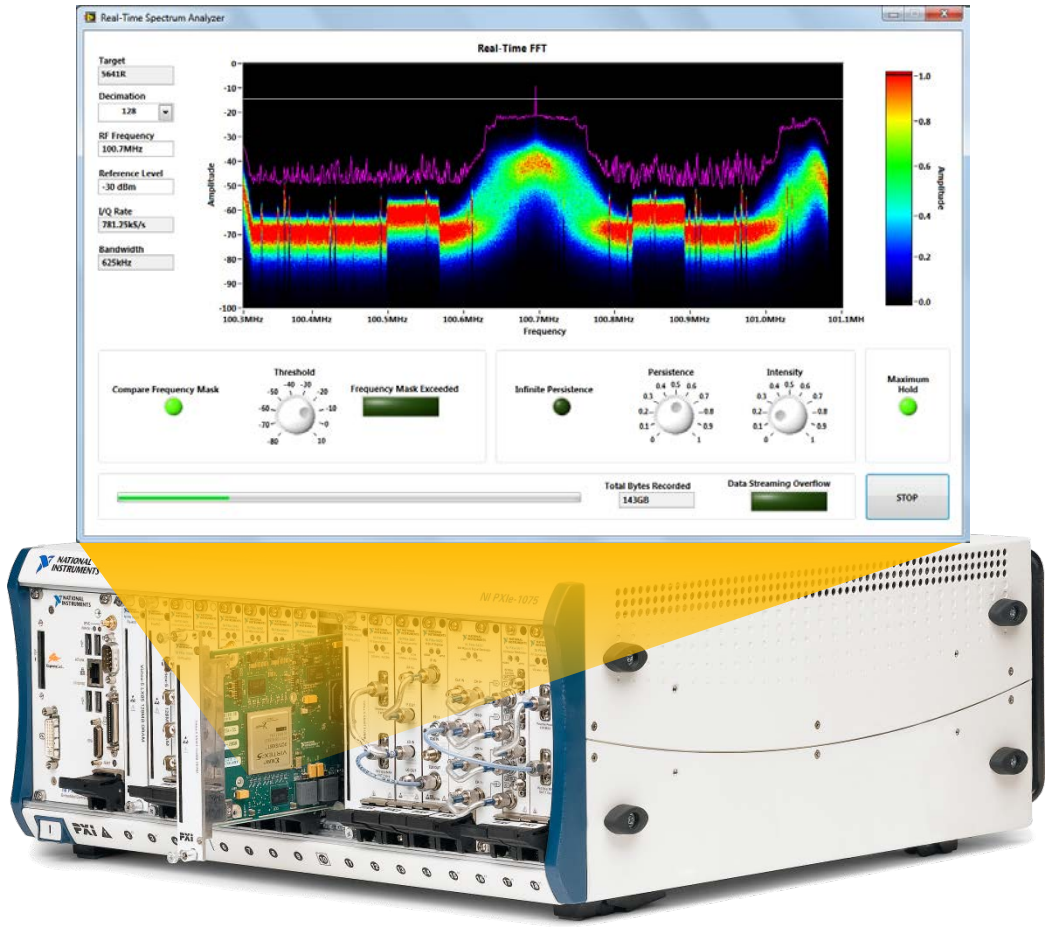
- Dependent on controller when traffic goes through it



- Transfer rate limited by lowest of:
  - PCIe switch (chassis)
  - Controller chipset / PCIe switch
  - Module limitations

NI FlexRIO Co-Processing

- Stream data at rates up to 800 MB/s from PXI Express modular instruments
- FPGA algorithms for real-time processing and measurements



The LabVIEW RIO Architecture in PXI Automated Test

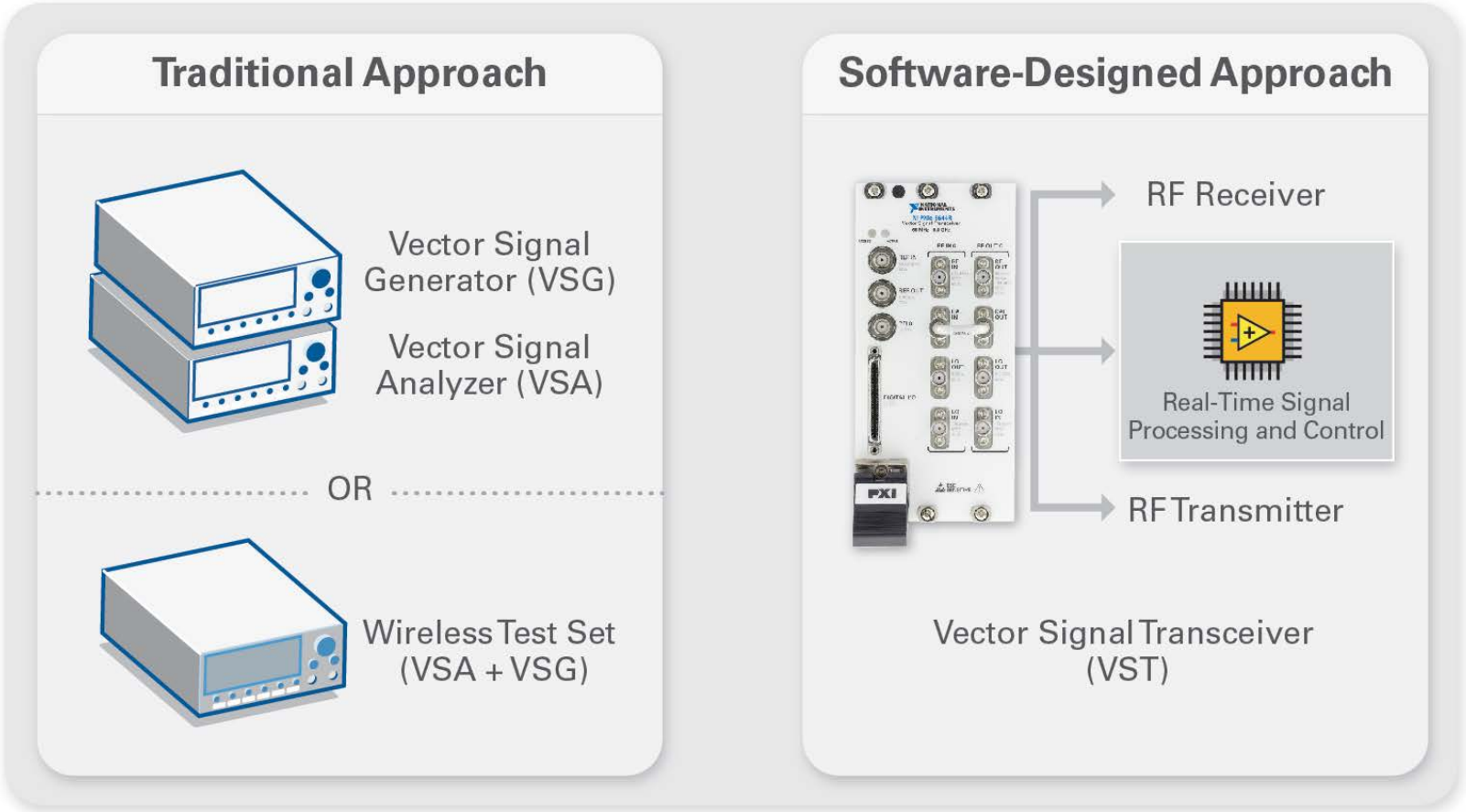
- aka -

“RIO for Test”

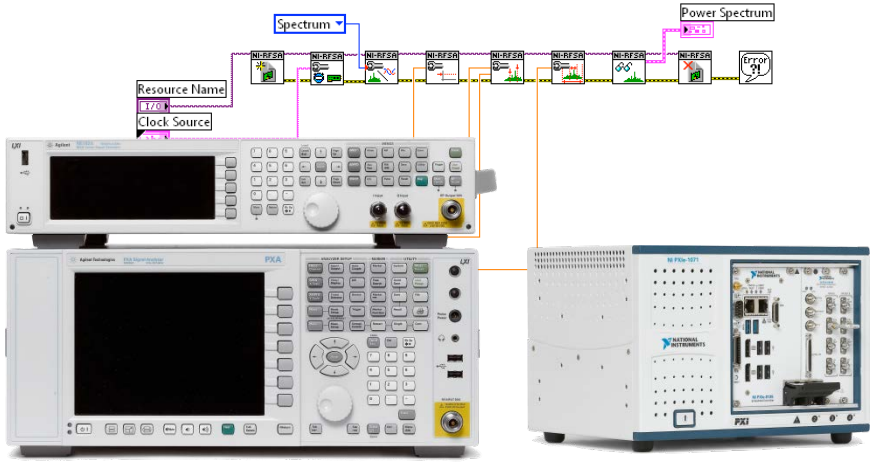
PXIe-5644R & 5645R 6 GHz Vector Signal Transceiver

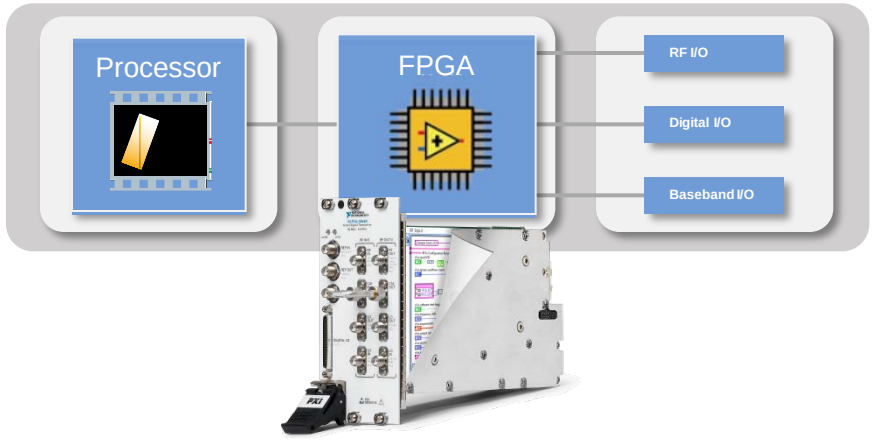
RF (PXIe-5644R/5645R)	
Configuration	VSA and VSG w/ independent LOs 24 DIO lines @ 250 Mbps
Frequency Range	65 MHz to 6 GHz
Bandwidth	80 MHz
Features	• Programmable FPGA w/ LabVIEW • Fast Tuning Mode: <400 µs
Baseband (PXIe-5645R only)	
Configuration	Differential Baseband I/Q Input & Output
Input/Output	16-bits @ 120 MS/s

Vector Signal Transceiver Advantages



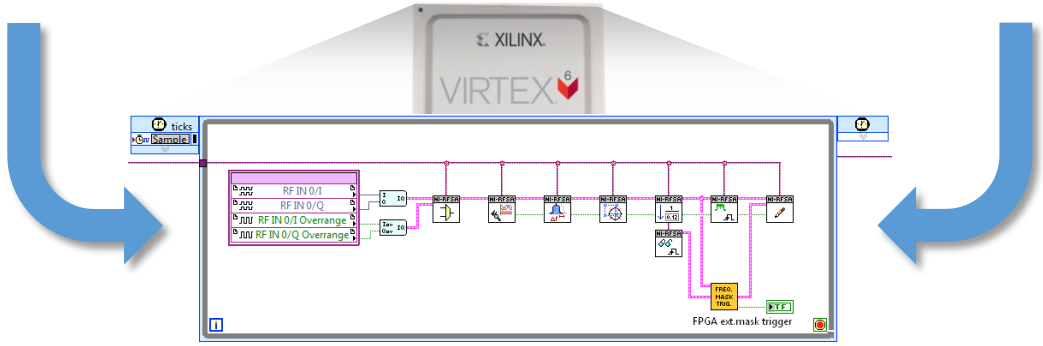
Instrument Driver *FPGA Extensions*





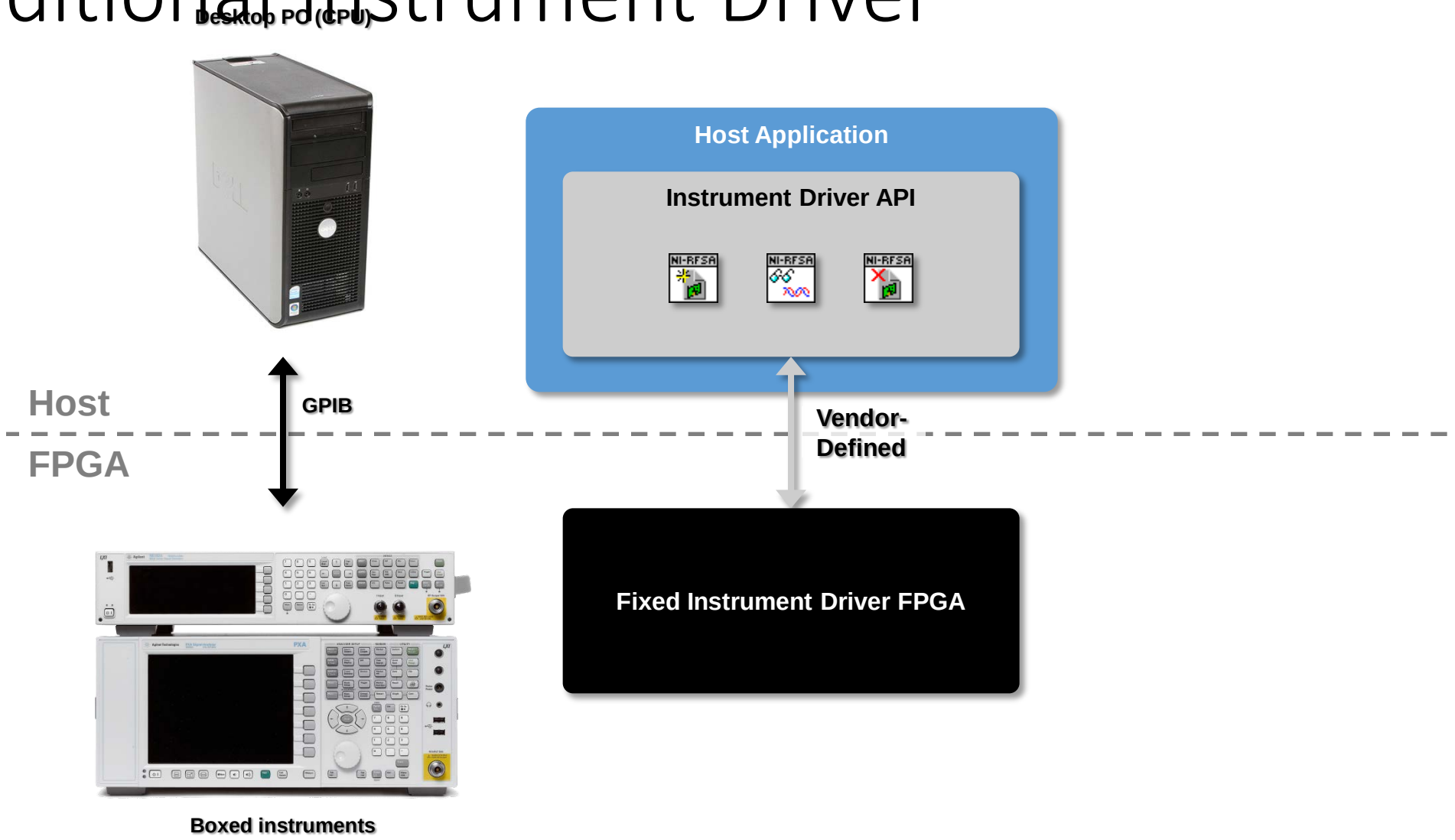
The *compatibility* of
industry-standard instrument drivers

The *flexibility* of
the LabVIEW RIO Architecture

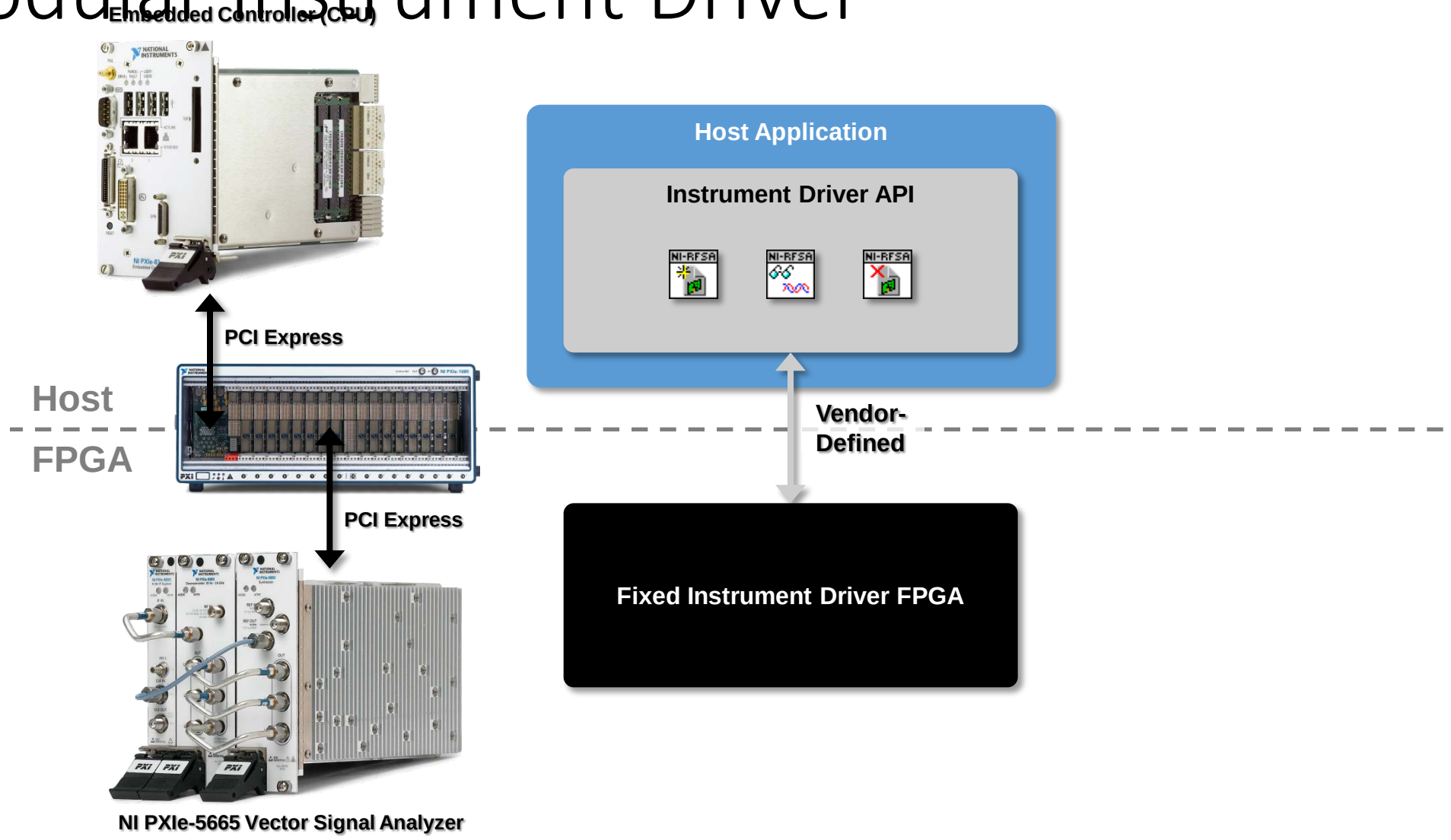


Instrument Driver *FPGA Extensions*

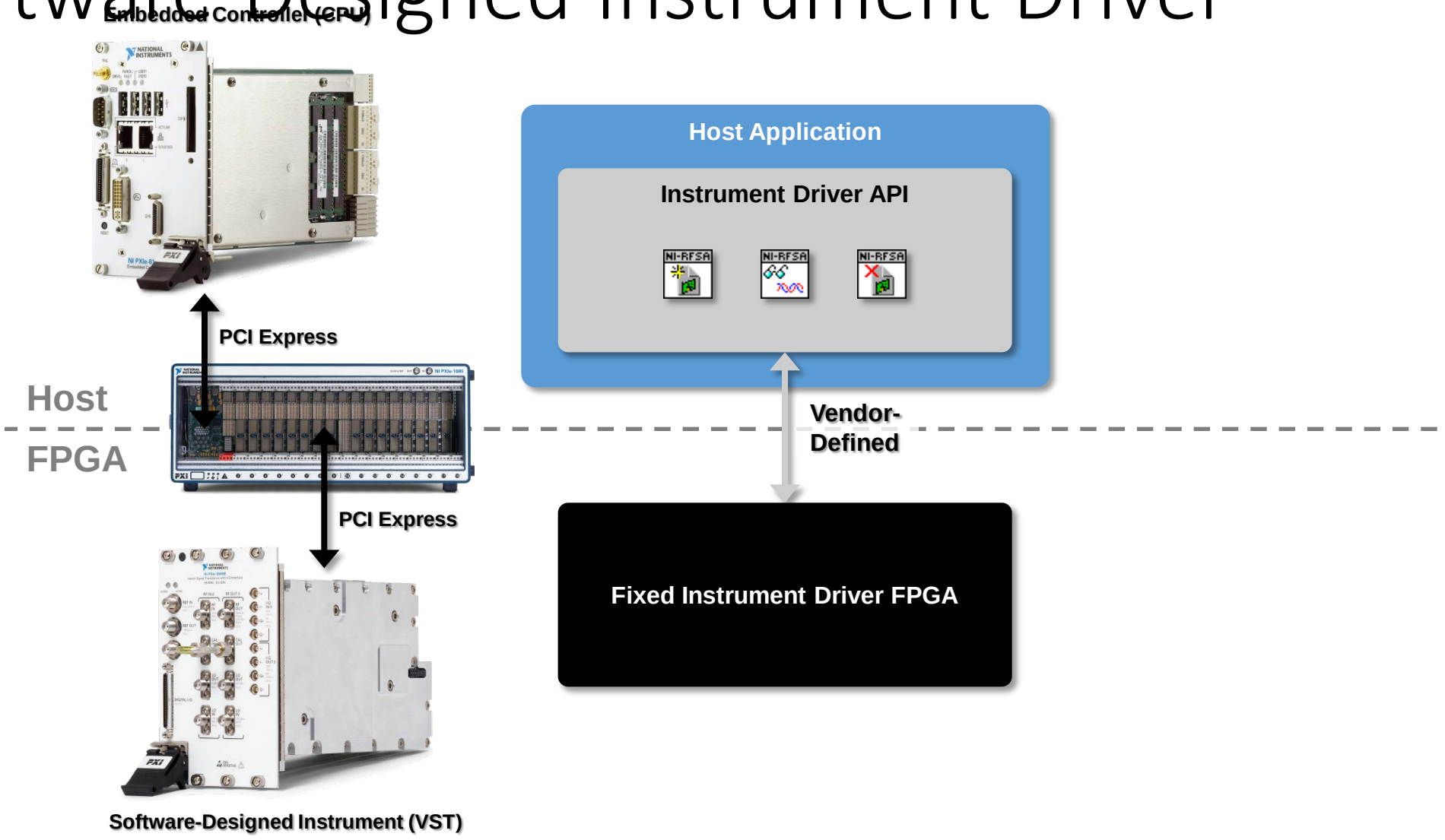
Traditional Instrument Driver



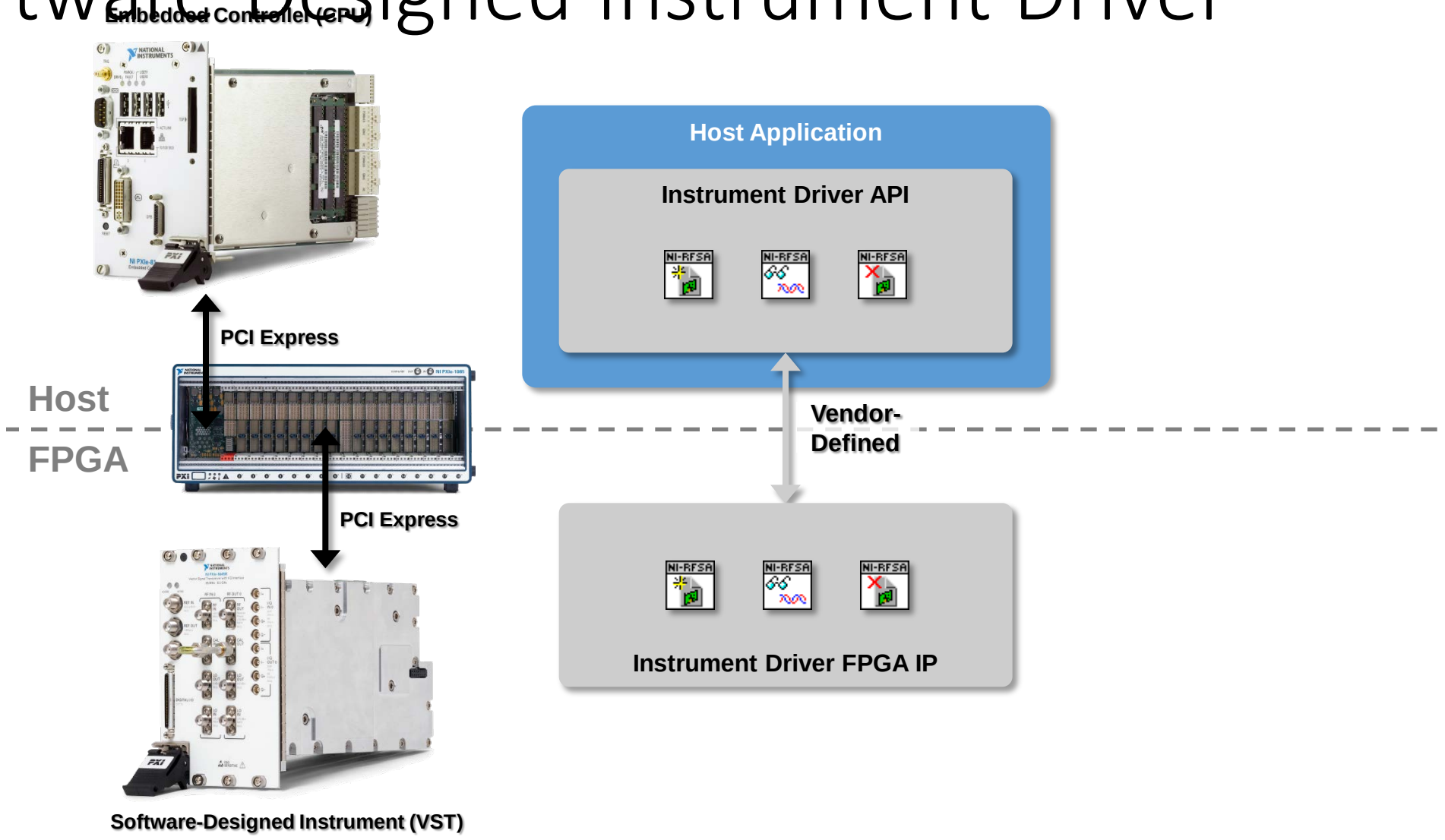
Modular Instrument Driver



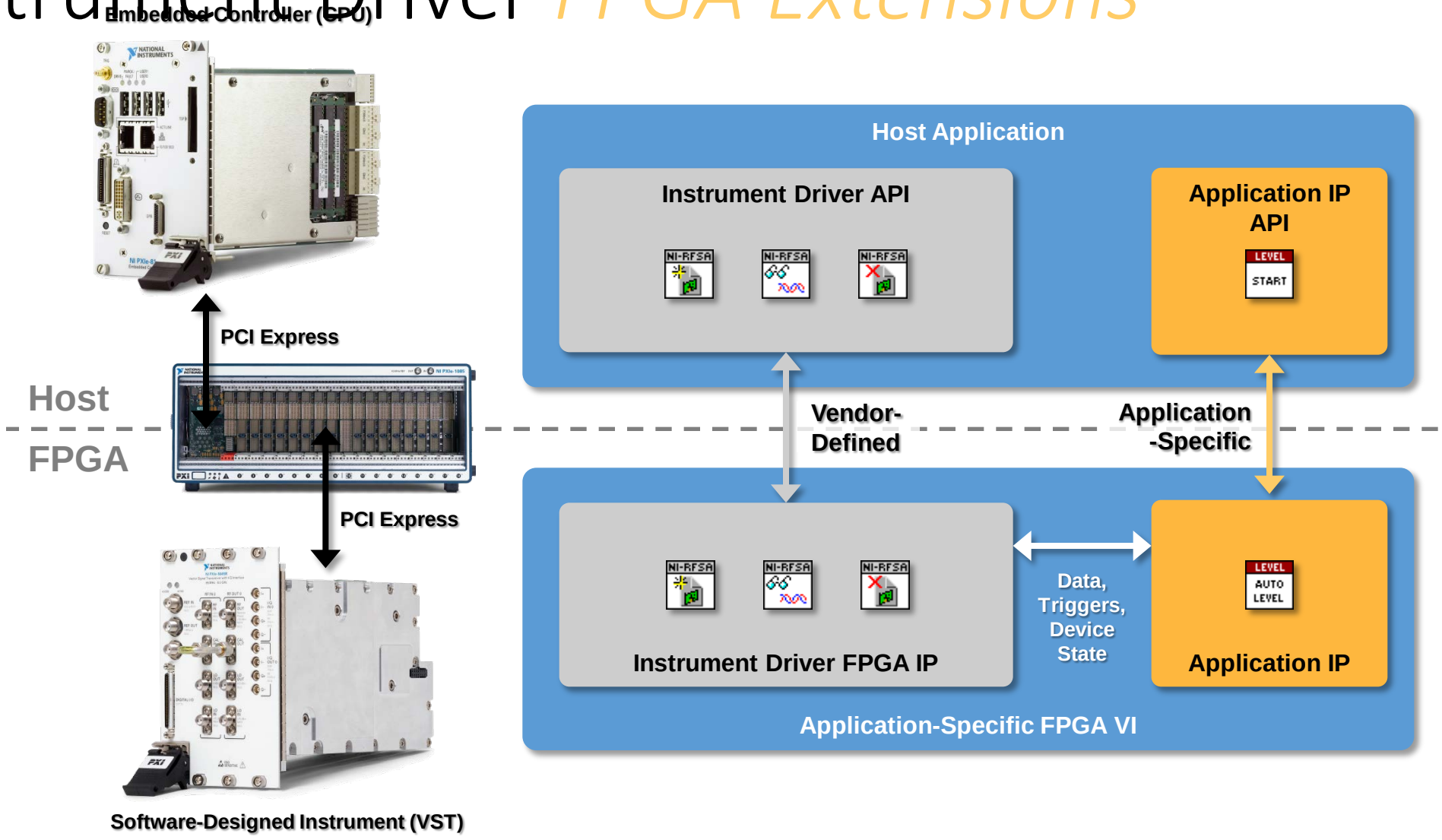
Software-Designed Instrument Driver



Software-Designed Instrument Driver



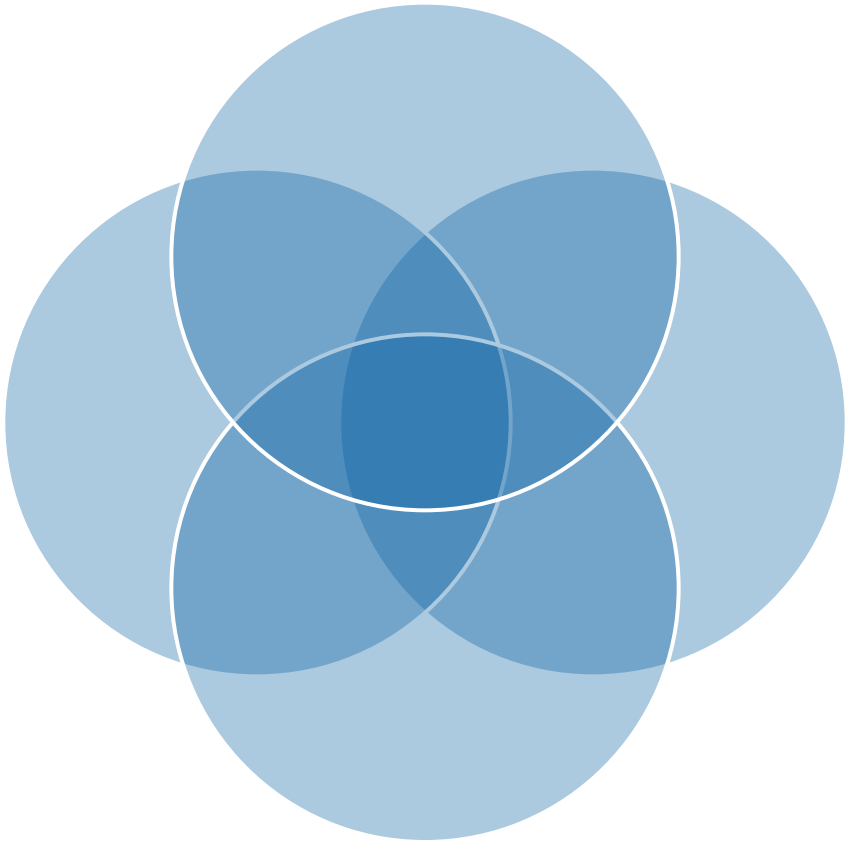
Instrument Driver *FPGA Extensions*



Electrical Test Today

Acquire, Transfer, Post-Process Paradigm

Fixed-Functionality Triggers and Records



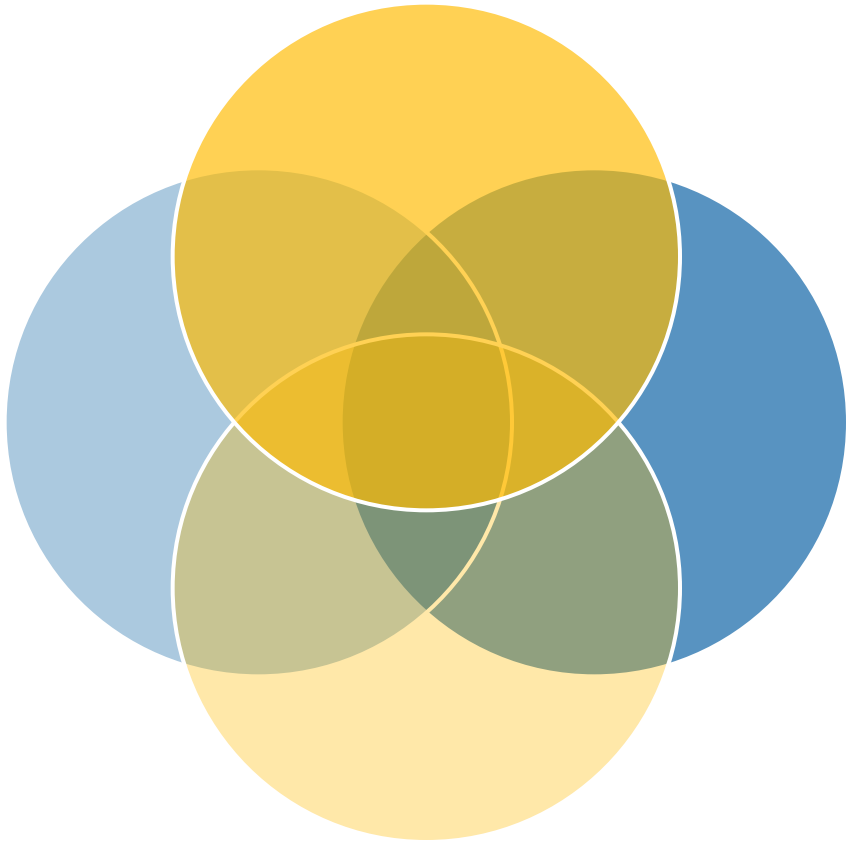
Open-Loop, Stimulus-Response Data

Test Vector and Waveform Synthesis and Analysis Tools

FPGA-Based Test Methods

Real-Time, Continuous Measurements

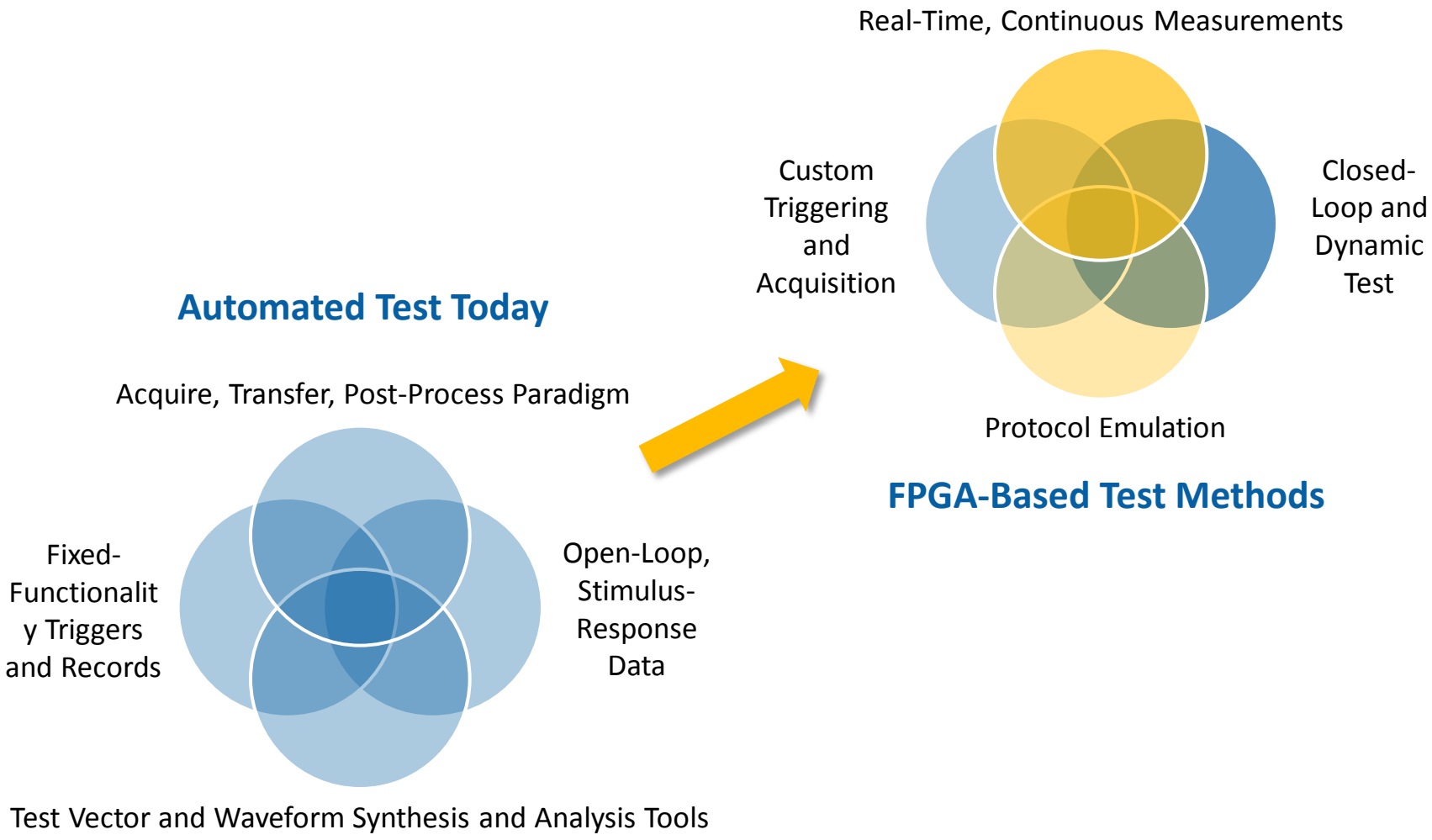
Custom Triggering and Acquisition



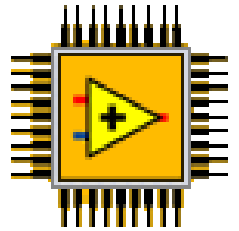
Closed-Loop and Dynamic Test

Protocol Emulation

RIO for Automated Test

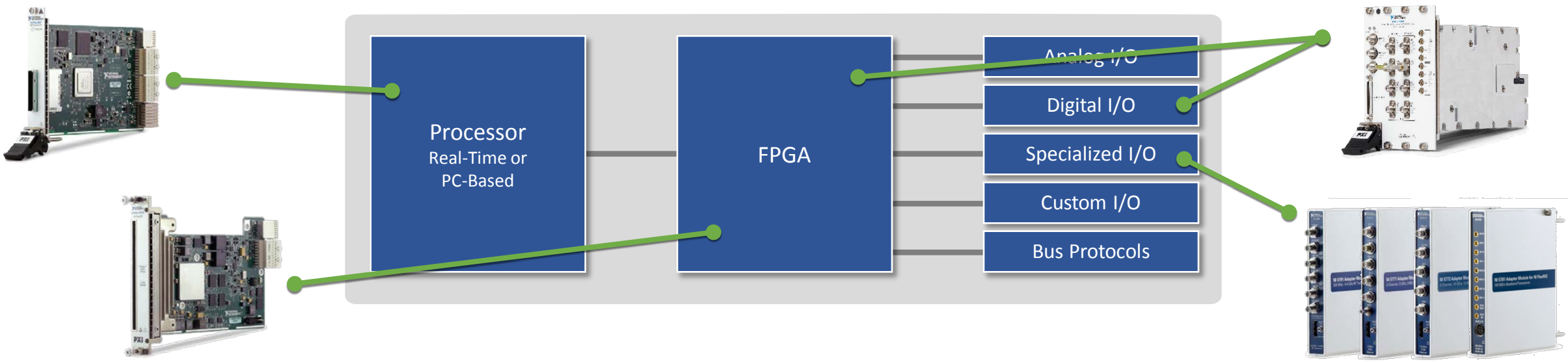


Why are FPGAs useful?

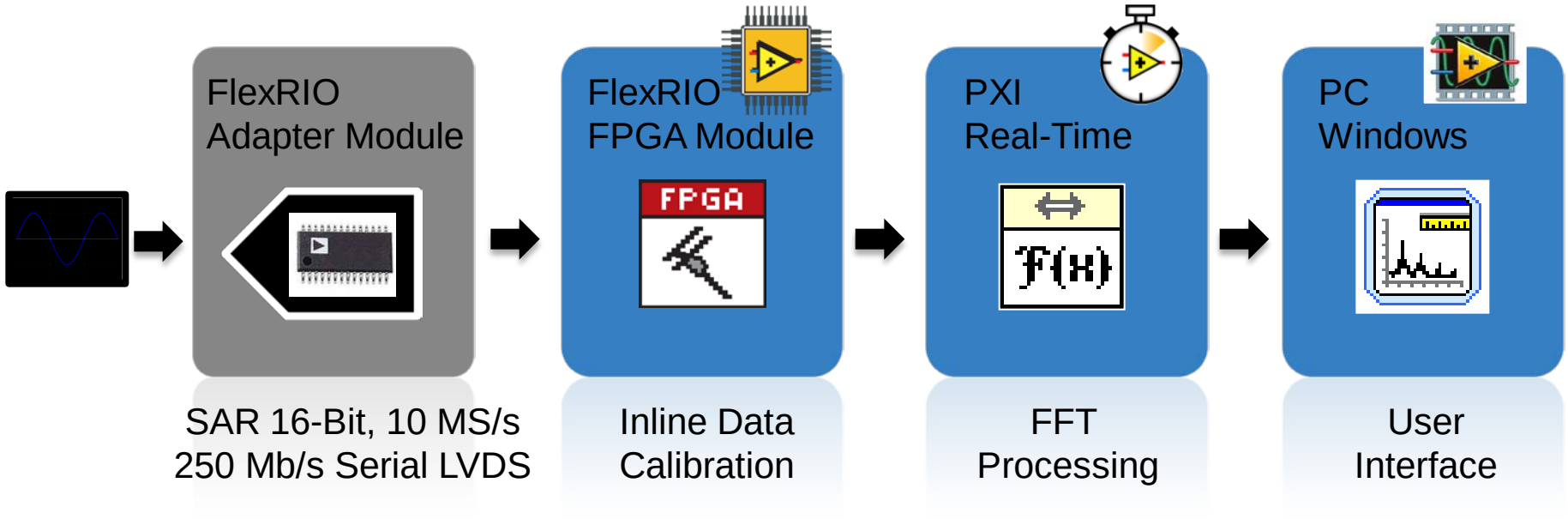


- ***High Reliability*** – Designs implemented in hardware
- ***High Performance*** – Computational abilities open new possibilities for measurement and data processing speed
- ***True Parallelism*** – Enables parallel tasks and pipelining, reducing test times
- ***Low Latency*** – Run algorithms at deterministic rates down to 5 ns
- ***Reconfigurable*** – Create DUT / application-specific personalities

The LabVIEW RIO Architecture for Automated Test

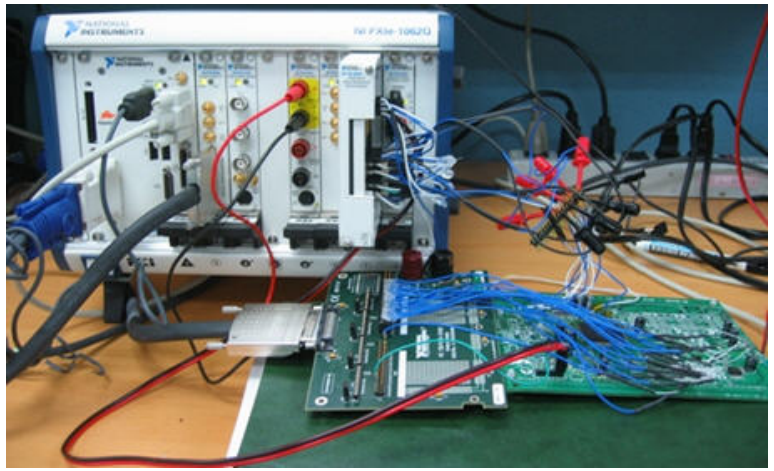


ADC Characterization with NI FlexRIO



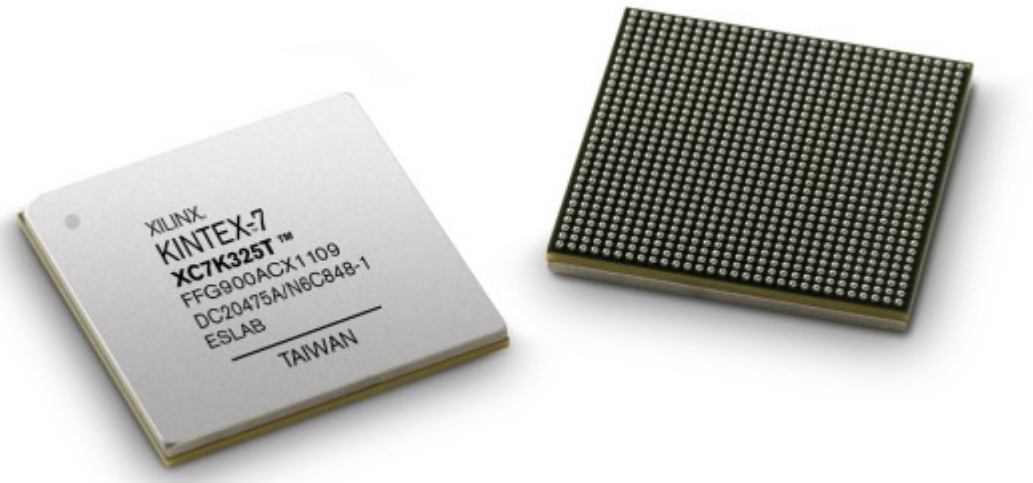
Chip Validation

- Chips on adapter modules can be characterized with PXI
  - Variety of Power, Digital & Mixed-Signal Instrumentation
  - Automate tests with LabVIEW
- Flexibility
  - Reuse test system and test code for multiple chips
  - Create custom adapter modules for unique test requirements

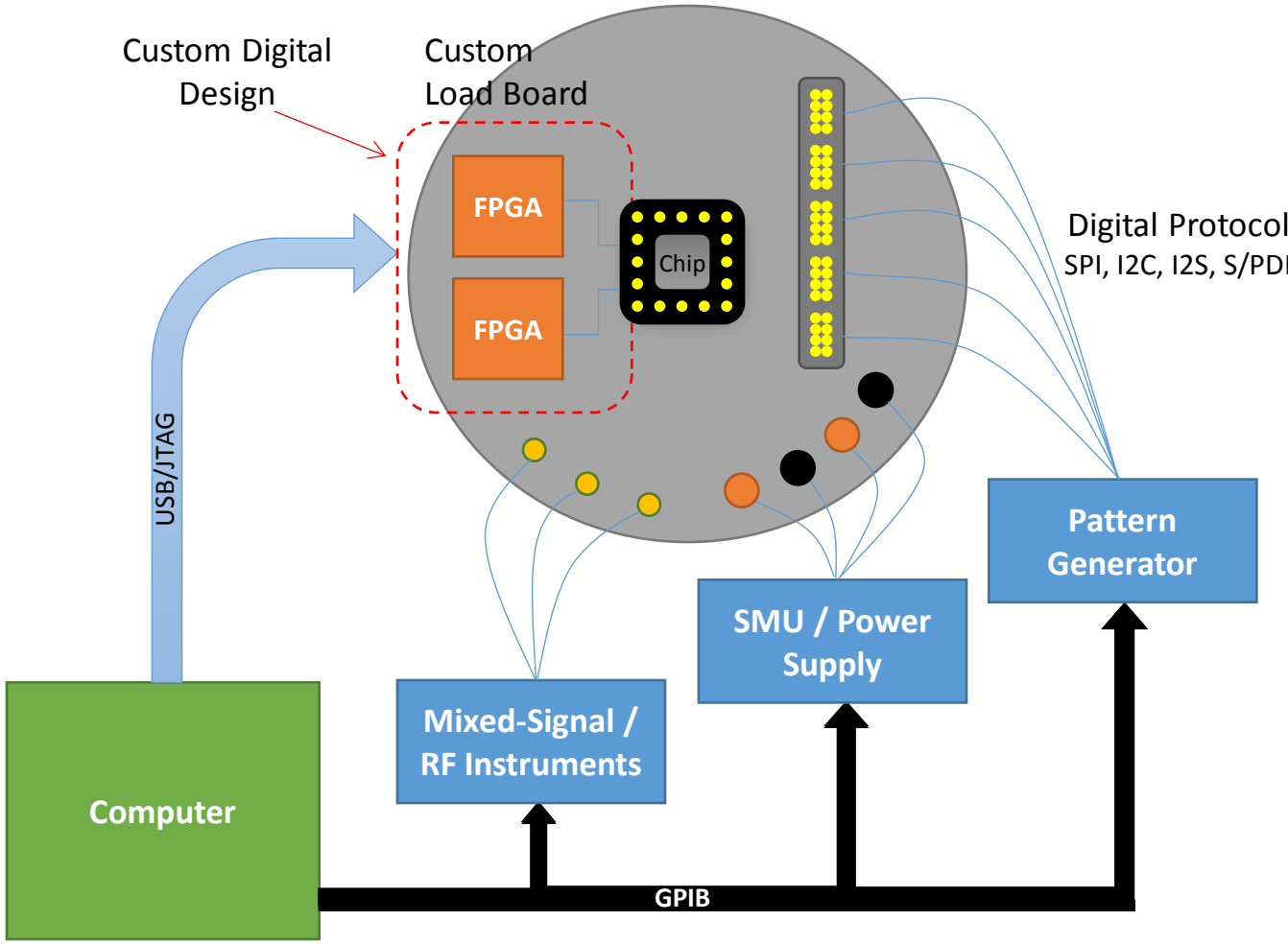


Validation

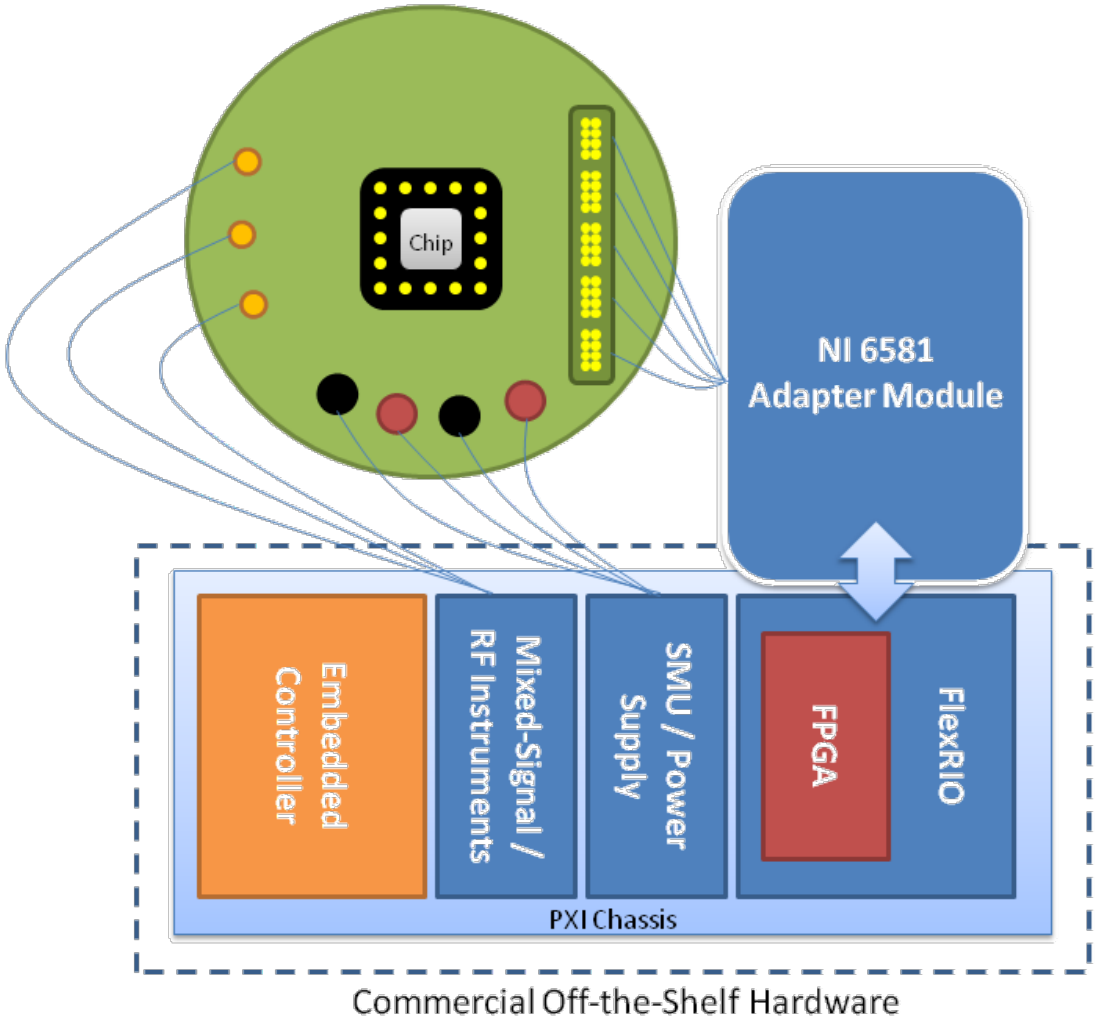
- Why use FPGAs?
  - Custom Digital Protocols
  - Emulation
  - Data Processing



Typical Validation Setup

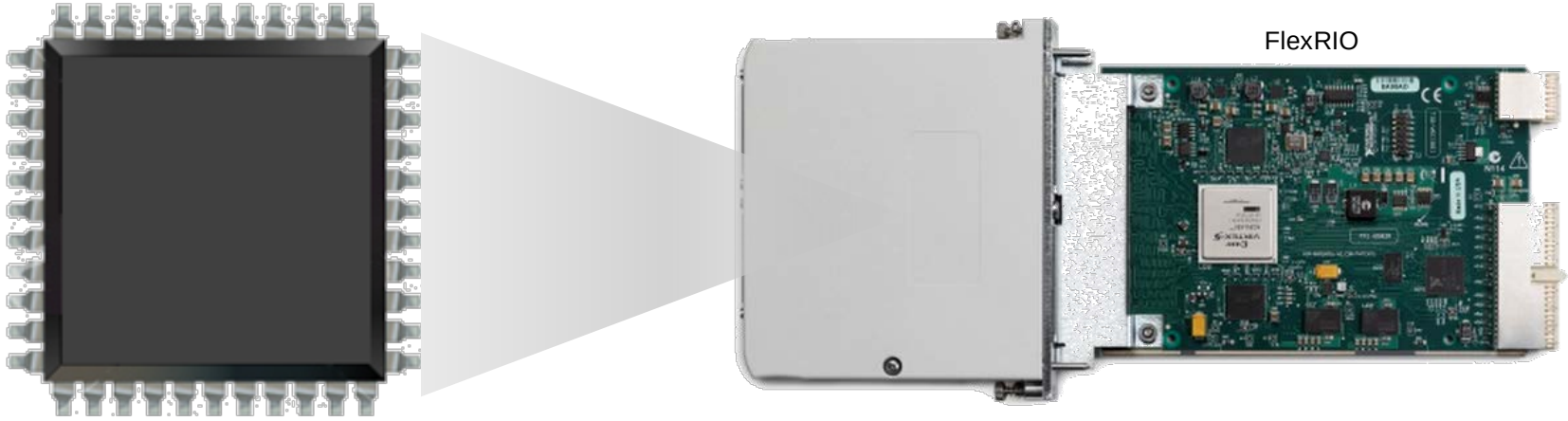


Validation on NI FlexRIO

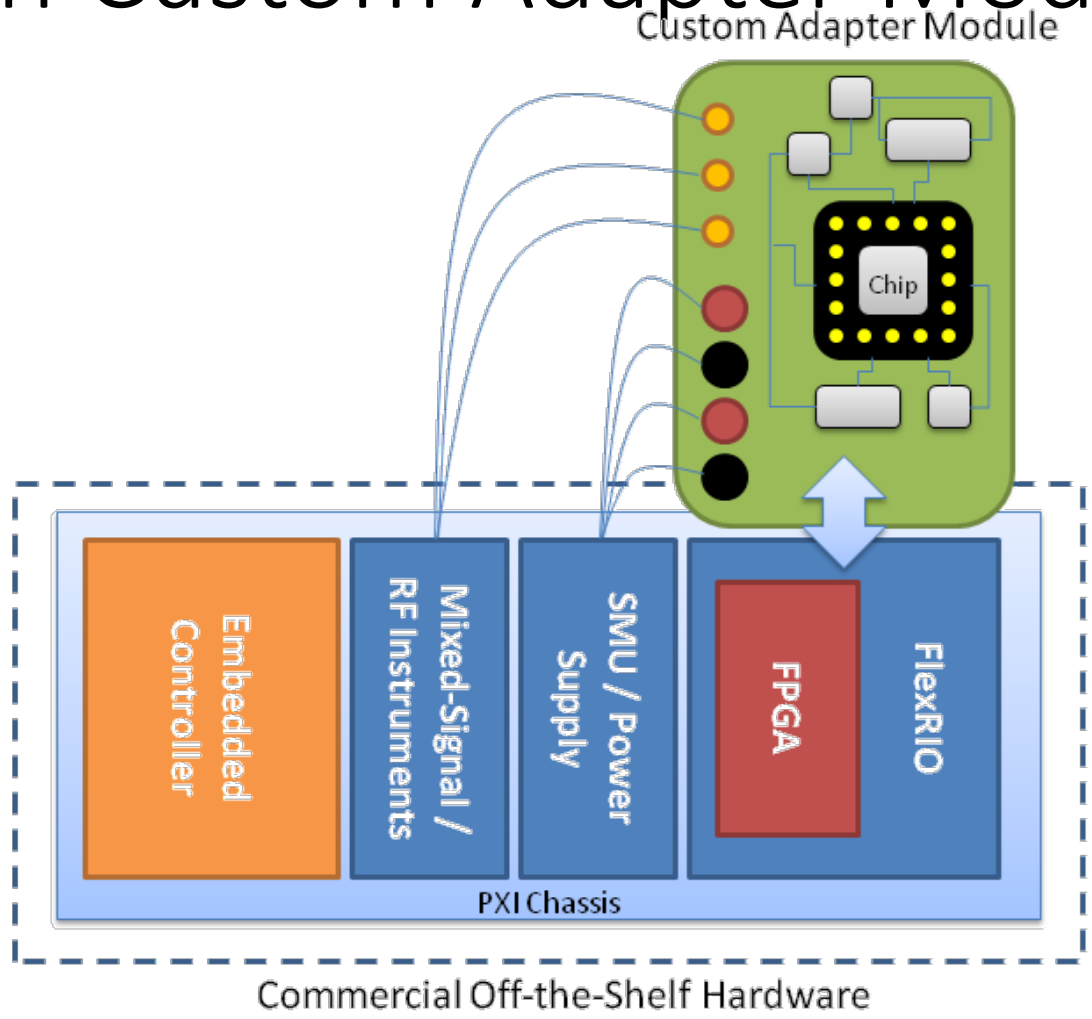


Adapter Module Implementation

- Chip Validation
- Customer Evaluation

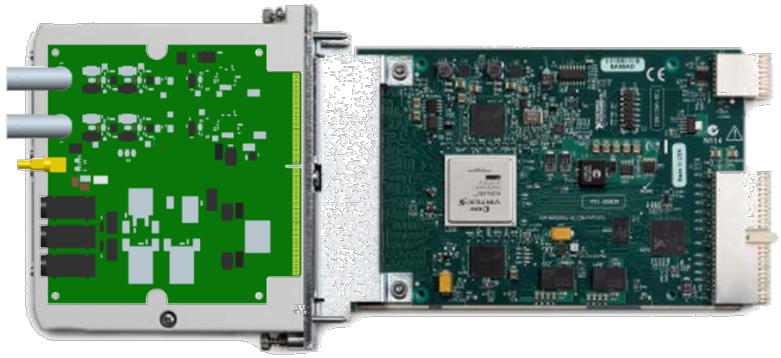


Validation on Custom Adapter Module

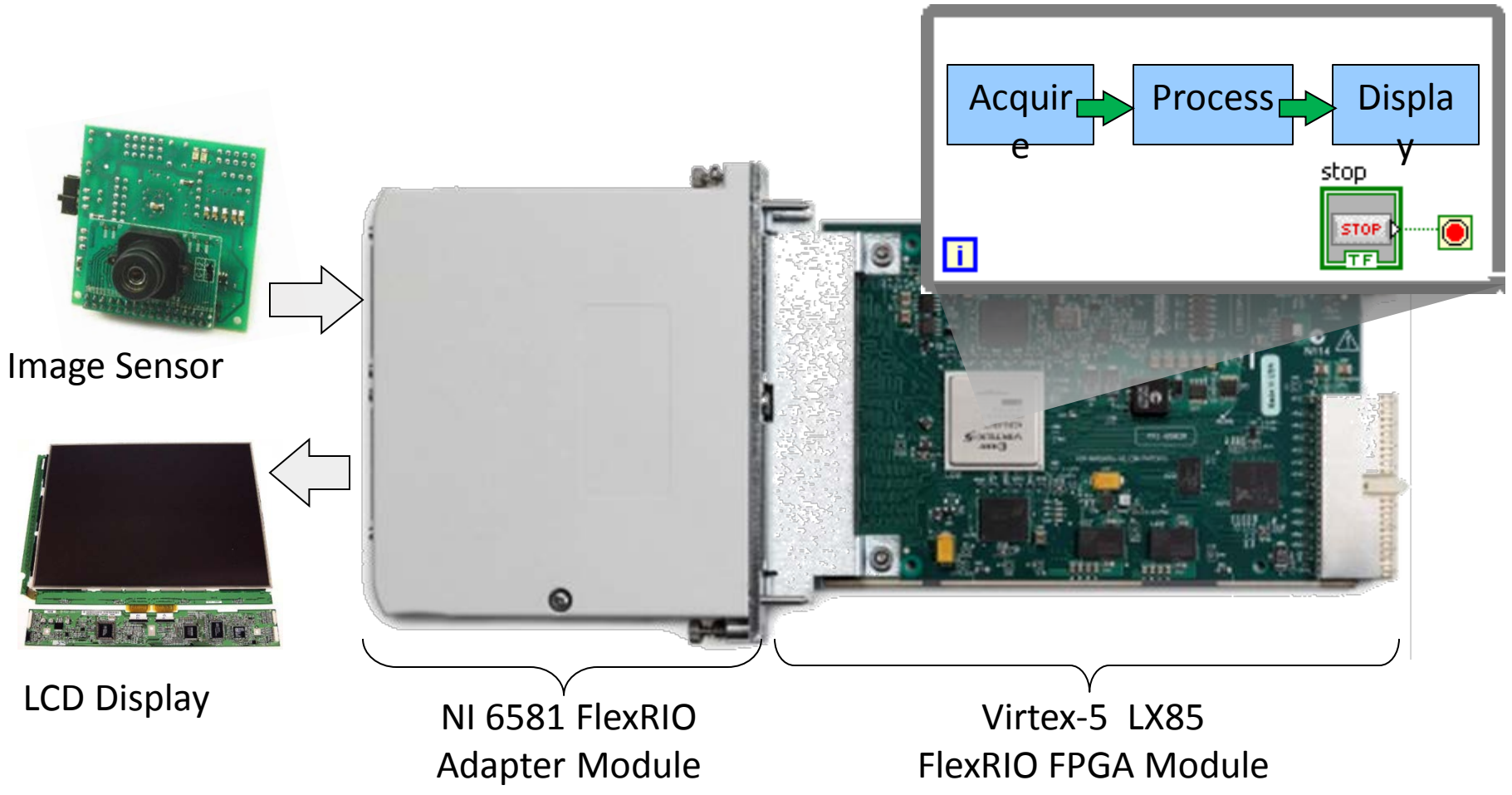


Flexible Evaluation Platform

- Complicated chips require flexible evaluation
- Automate tests with LabVIEW (dynamic datasheet)
- Prototype immediately on the same platform
  - Board level prototyping on adaptor modules
  - Digital design prototyping on FPGA
  - Reuse evaluation test code

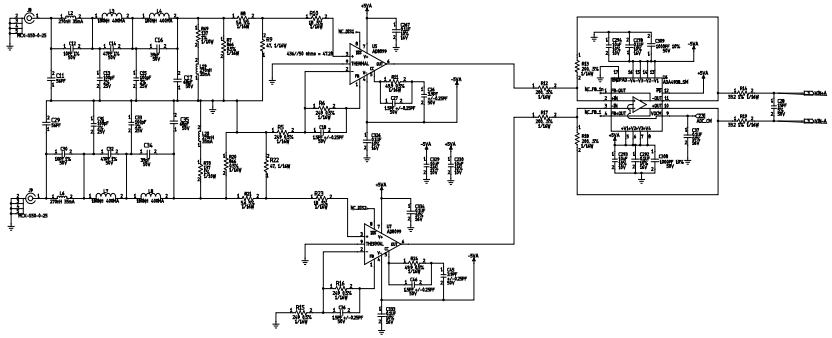


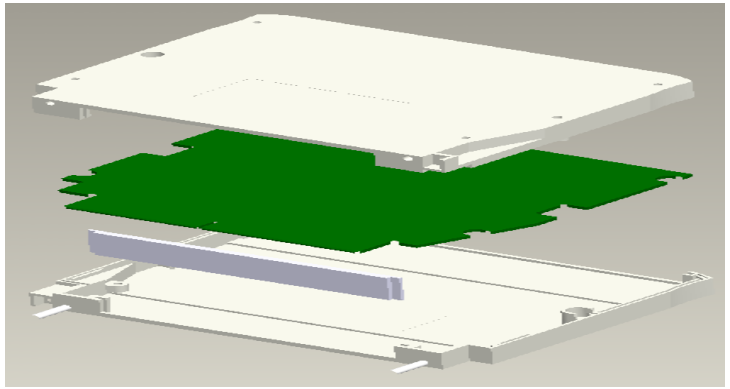
Onboard Processing

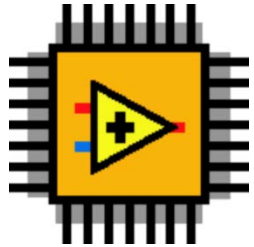


Custom Adaptor Modules

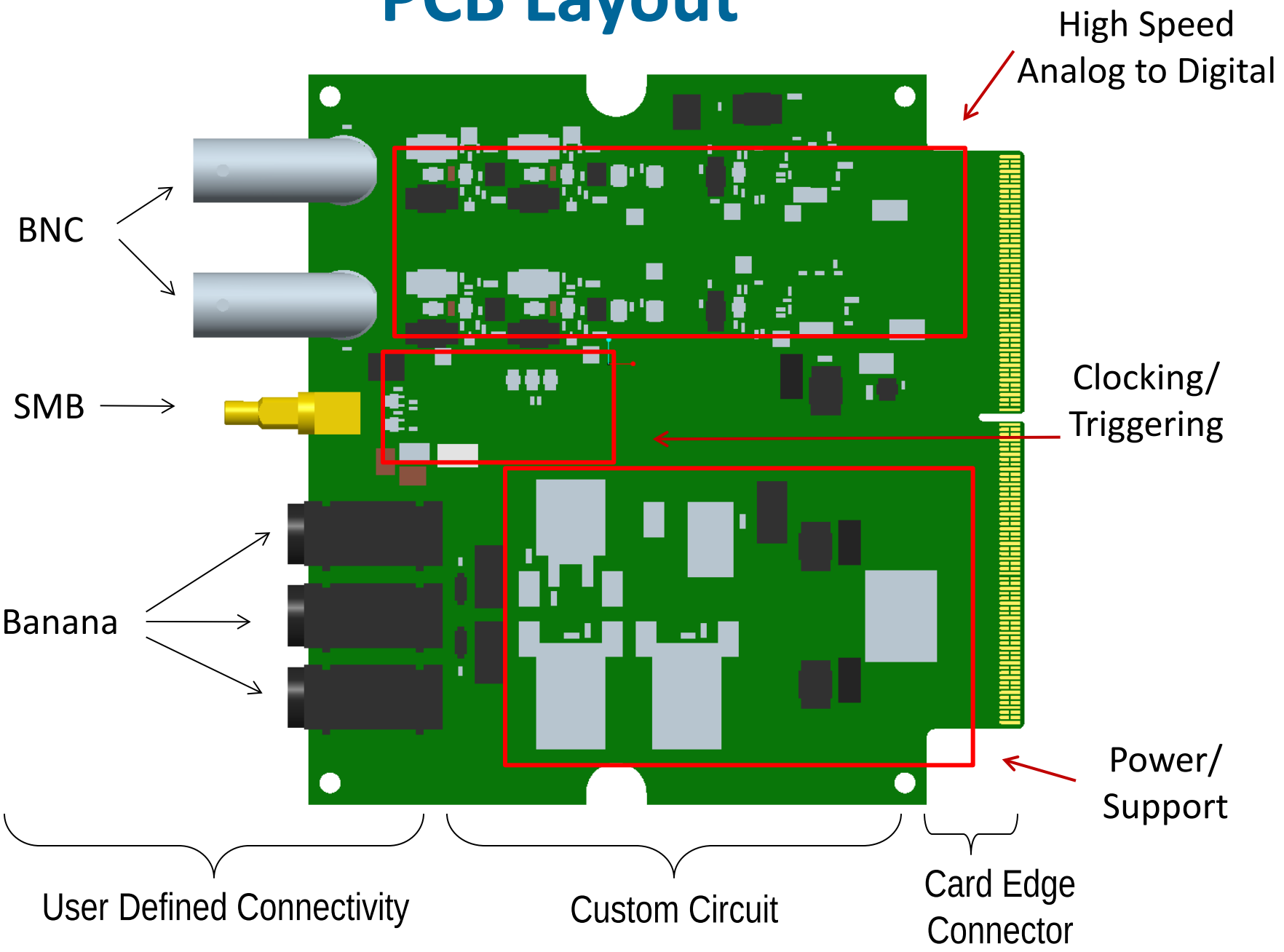
- Circuit Design & PCB Layout
- Mechanical Components and Enclosure
- VHDL to Socket Clip





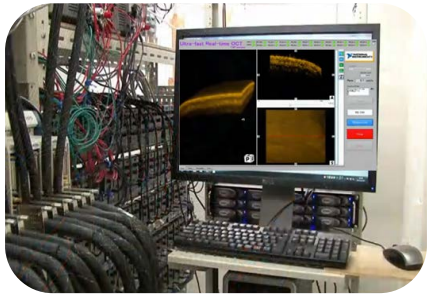


PCB Layout


High Speed
Analog to Digital
BNC
SMB
Clocking/
Triggering
Banana
Power/
Support
User Defined Connectivity
Custom Circuit
Card Edge
Connector

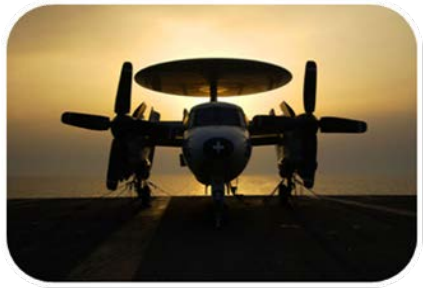
Top Application Areas Today

Digital Protocols
(esp. Mil / Aero)

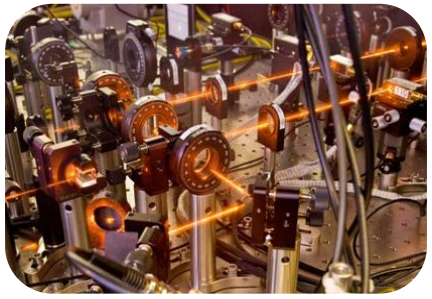


Medical Imaging

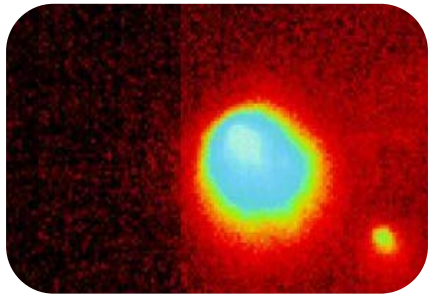
Signal
Intelligence



Software-
Defined Radio



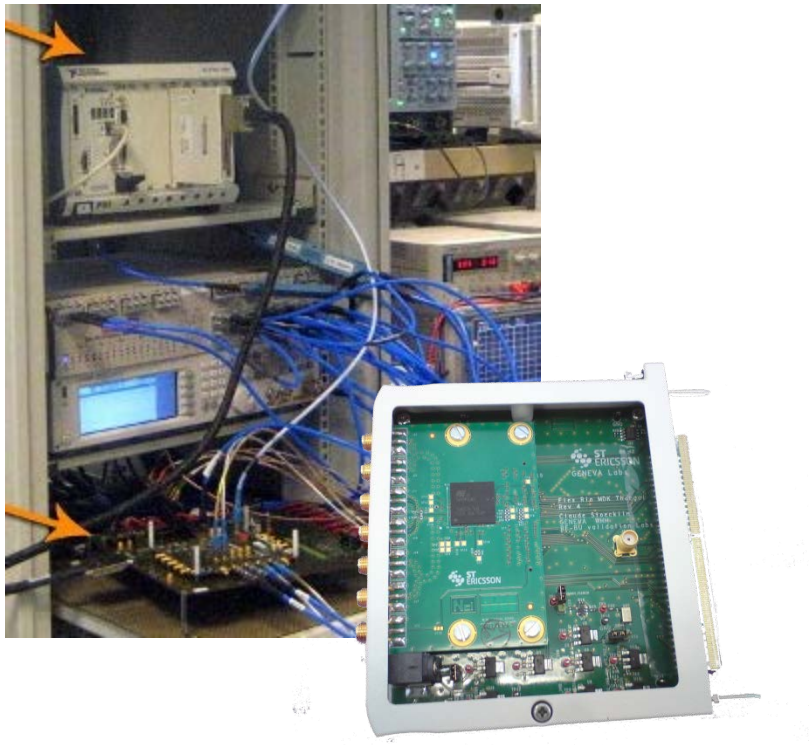
Scientific
Research



Vision

Testing Multiple Digital Protocols with a Single Instrument

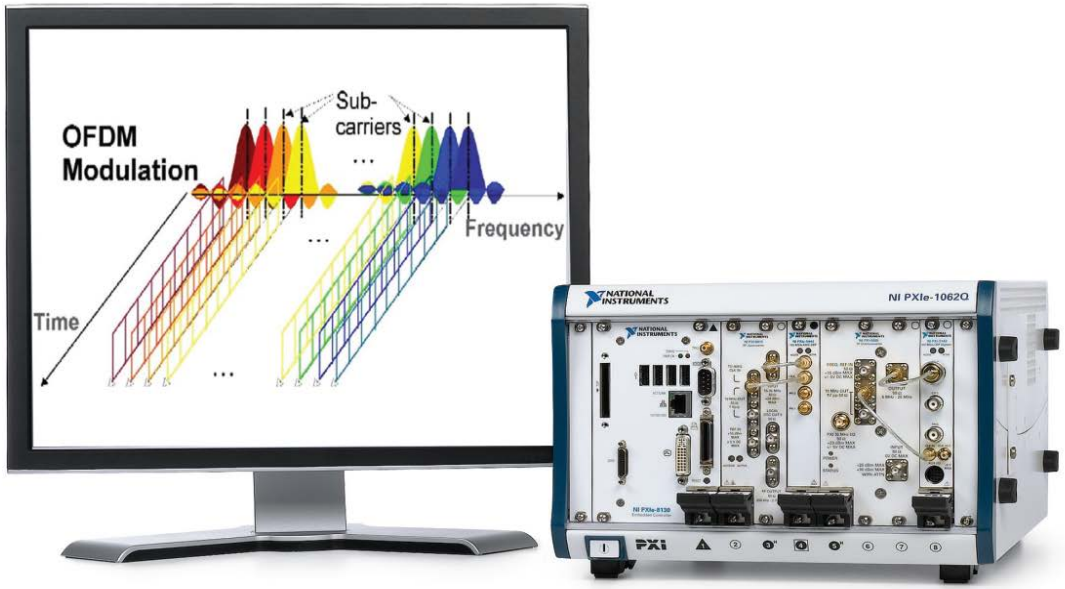
- Multiple digital protocols dynamically mapped to off-the-shelf I/O
- Quickly adapt to new ICs and test requirements
- Custom adapter module for specialized protocols



OFDM Modem implementation on NI FPGA Platform

ΩLYMP Σngineering

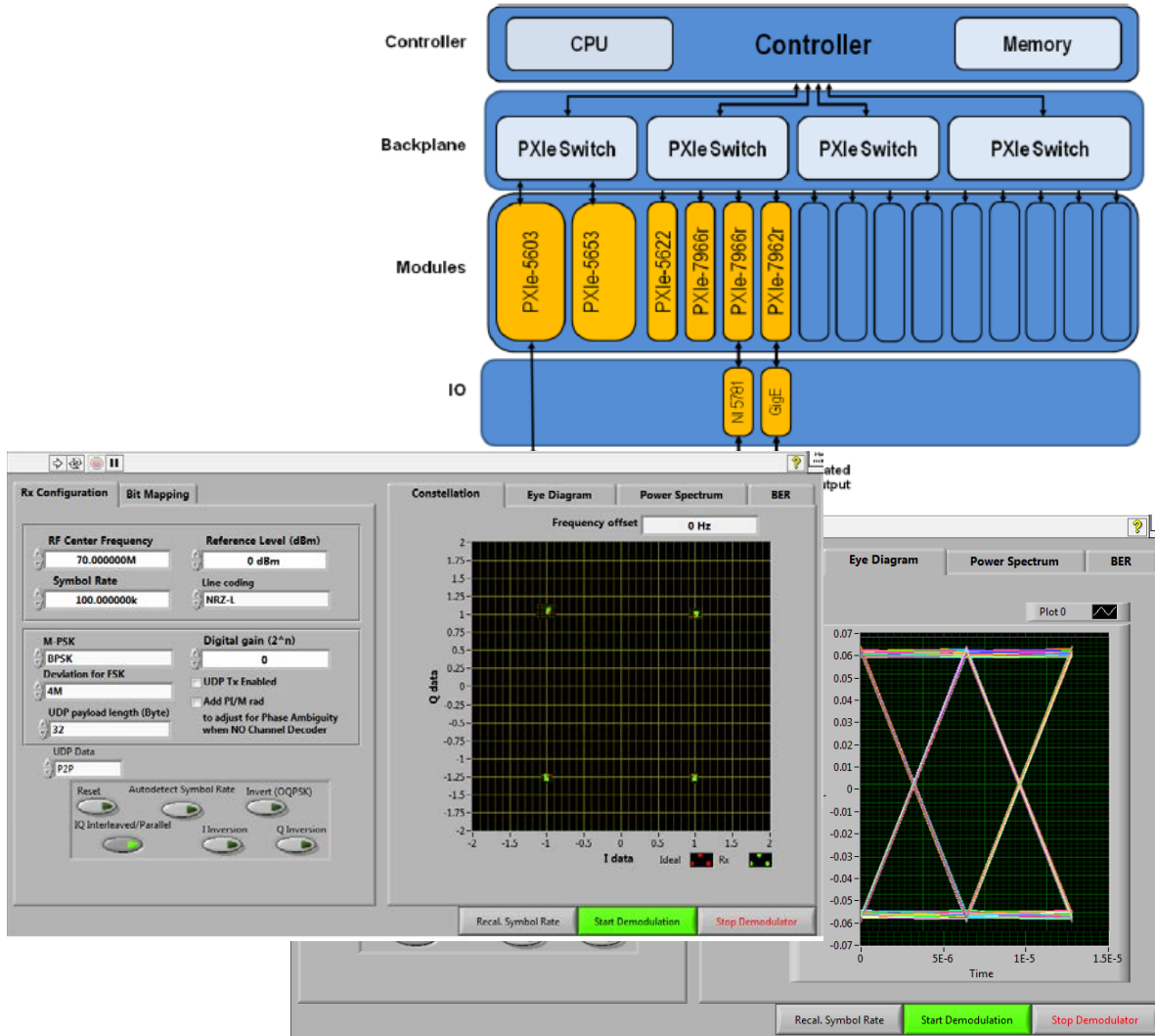
- Full implementation on NI FPGA
- Full duplex Tx/Rx on 2 FPGAs
- Up to 26 MHz bandwidth Tx/Rx
- Frequency hopping up to 400 hops per second (requires GPS synchronized pps)
- TDMA implementation for bandwidth efficient usage
- Supported modulation schemes PSK and QAM
- Automatic gain control
- Supported subcarriers 64, 128, 256, 512, 1024 and 2048
- Supported data throughput 16 Mb for BPSK and 96 Mb for 64QAM



Blind Demodulator

ΩLYMP Σngineering

- Demodulation for most complicated schemes
- Up to 140 Mb throughputs
- Possibility to add other schemes upon request
- Full implementation on NI FPGA
- Automatic symbol rate calculation
- ±5% frequency capture range
- Automatic gain control (AGC) for all supported schemes
- Supported Schemes: FSK, MSK, GMSK, PSK, QPSK, QAM, OQPSK.



Managing Avionics Bus Obsolescence

- Managing equipment with decades-long lifecycle
- Existing protocol interface cards go EOL
- Most protocols not standard in the first place, a pain to maintain built-in-house.
- Custom adapter module and hardware abstraction layers

Custom Protocol / HIL

- Using NI 6584 adapter module for custom protocol acquisition/generation over RS-485

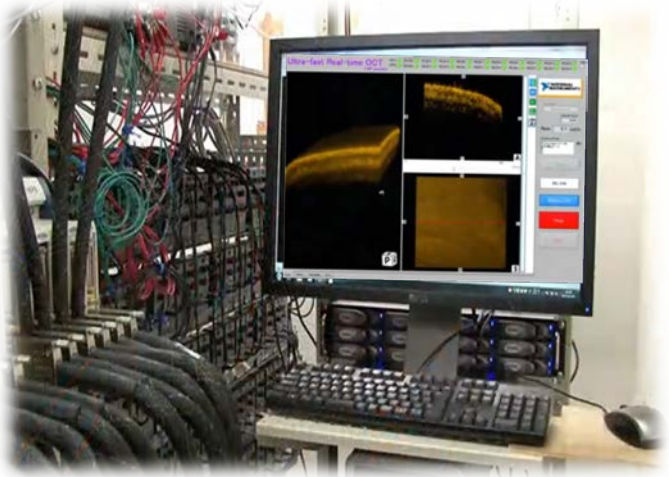
- Used FlexRIO to upgrade existing system
  - 10-15 protocols, all using RS-485 for transport layer
  - Moved filter and decode intelligence to FPGA, log data to host
  - Can easily add “network pollution” in the future

World's First Real-Time 3D OCT Imaging System

- Combining 320 simultaneous channels, 22 FPGAs, peer-to-peer streaming, and GPUs to achieve real-time 3D imaging

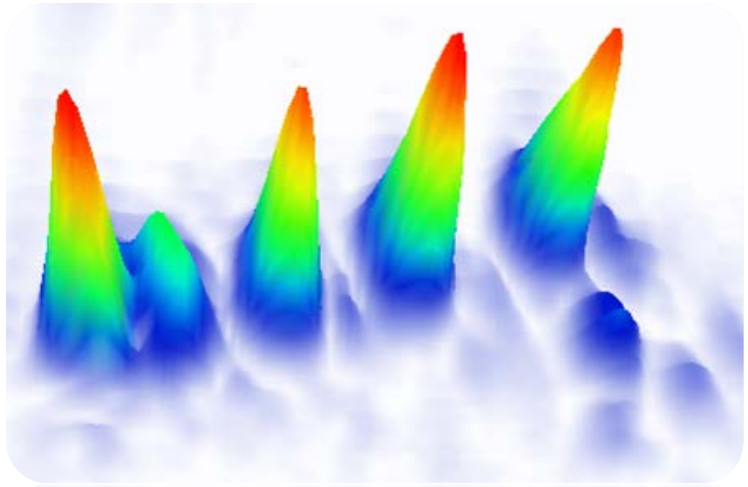
- LabVIEW, PXI, and FlexRIO for system design
  - LabVIEW for system integration and control
  - PXI for synchronization and data streaming
  - FlexRIO for FPGA processing (>700,000 FFTs per second)

"We leveraged the flexibility and scalability of the PXI platform and NI FlexRIO to develop the world's first real-time 3D OCT imaging system."



Rendered 3D fingerprint image

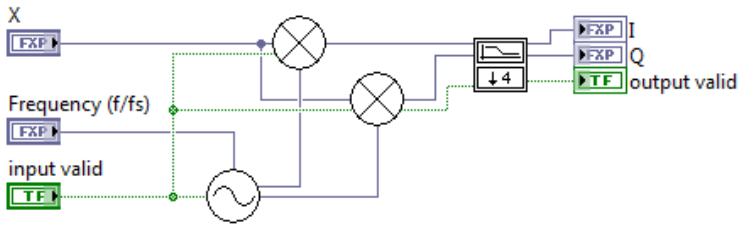
NI FlexRIO for Ultrasound and NDT



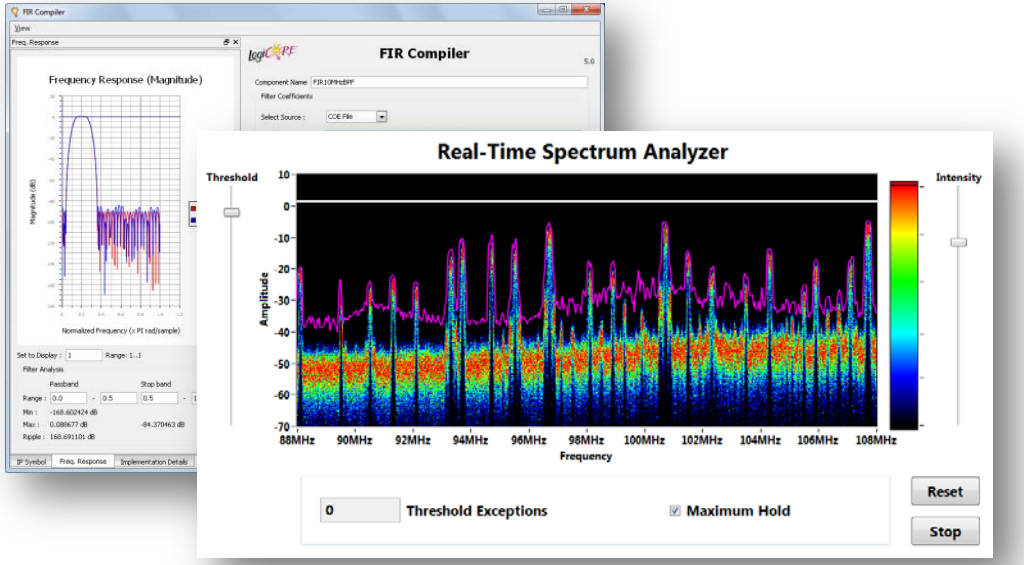
- Solution for ultrasonic imaging
- 128 element 3.5 MHz linear array acquired by NI 5752 adapter module
- Incorporates real-time FPGA signal processing

Diagnostic Sonar

NI FlexRIO for Signal Intelligence



- Modules for baseband and IF acquisition and generation
- DSP-focused FPGAs
- IP integration in LabVIEW FPGA



Conclusions

- NI FlexRIO enables increased capabilities and reduced development time for a variety of high-performance test and embedded applications

- LabVIEW FPGA is a powerful hardware programming paradigm for test and systems engineers

Thank you