Increase Your Test Capabilities with Reconfigurable FPGA Technology

CTEA Electronics Symposium

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FPGA Technology for Test
National Instruments
Graphical System Design
A Platform-Based Approach for Measurement and Control

Test
Monitor
Embedded
Control
Cyber Physical

NATIONAL INSTRUMENTS
LabVIEW™

Desktops and PC-Based DAQ
PXI and Modular Instruments
RIO and Custom Designs
Open Connectivity With Third-Party I/O
System Design Software

**Project Explorer**
Manage and organize all system resources, including I/O and deployment targets.

**Deployment Targets**
Deploy LabVIEW code to the leading desktop, real-time, and FPGA hardware targets.

**Instant Compilation**
See the state of your application at all times, instantly.

**Front Panel**
Create event-driven user interfaces to control systems and display measurements.

**Models of Computation**
Combine and reuse .m files, C code, and HDL with graphical code.

**Hardware Connectivity**
Bring real-world signals into LabVIEW from any I/O on any instrument.

**Parallel Programming**
Create independent loops that automatically execute in parallel.

**Block Diagram**
Define and customize the behavior of your system using graphical programming.

**Analysis Libraries**
Use high-performance analysis libraries designed for engineering and science.

**Timing**
Define explicit execution order and timing with sequential data flow.

**Accelerates Your Success**
By abstracting low-level complexity and integrating all of the tools you need to build any measurement or control system.
**PXI - The Industry-leading Platform for Test, Measurement and Control**

**PXI Modules**
>1,500 options from over 70 PXI vendors

**PXI Chassis**
Options ranging from low-cost, 4-slot desktop to high-performance 18-slot rack-mount

**PXI Controllers**
Performance embedded - Windows or RT OS
Remote control via desktop or laptop

**Software**
Flexible driver APIs, example code, soft front panels and configuration
Stay Ahead with the Latest PC Technologies

LabVIEW brings multicore processors and FPGAs into your test system, in the same software environment, giving you access to all the latest tools to do your job.
Test System Architecture

Host
Desktop or Real-Time

FPGA
Analog I/O
Digital I/O
Analog I/O
Digital I/O
Motion I/O
Custom I/O

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FPGA Technology

Field-Programmable Gate Array

Logic Blocks

Programmable Interconnects

I/O Blocks
FPGA Logic Implementation

Implementing Logic on an FPGA: \( F = \{(A+B)CD\} \oplus E \)

LabVIEW FPGA Code

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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

Protocol Emulation

Closed-Loop and Dynamic 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
FPGA-Based Test Benefits

- Real-Time, Continuous Measurements
  - Higher test throughput
  - Reduced cost
  - More complete test coverage
  - Higher measurement confidence

- Custom Triggering and Acquisition
- Closed-Loop and Dynamic Test
- Protocol Emulation
FPGA-Based Test Benefits

Real-Time, Continuous Measurements

- Multi-site test
- Reduce / eliminate custom hardware
- User-customizable
- Implement tests previously too complex / costly

Custom Triggering and Acquisition

Closed-Loop and Dynamic Test

Protocol Emulation
FPGA-Based Test Benefits

Real-Time, Continuous Measurements

Custom Triggering and Acquisition

Closed-Loop and Dynamic Test

Protocol Emulation

DUT / protocol-aware test
Reduce need to design for test
Reduce / eliminate custom hardware
FPGA-Based Test Benefits

Real-Time, Continuous Measurements

Custom Triggering and Acquisition

Reduce need to design for test
Test in real-world operating conditions
Implement tests previously too complex / costly

Protocol Emulation
Simple Example: PDM Microphone

Traditional Approach

- Vector-based approach is *useless*: **must** interpret data!
  - Capture and transfer data
  - Filtering and processing in host
  - Analyze data for pass/fail criteria
Simple Example: PDM Microphone

Protocol-Aware Approach

- Intelligence built into the tester
  - In-line processing of data
  - Analyze SNR, sensitivity, frequency-response *in Hardware*
More complex: Gyroscope / Accelerometer

Protocol-Aware Approach

- Intelligence built into the tester
  - Direct register interaction
  - Ability to process received data and make pass/fail decisions
- Test with high-level commands
  - Real-world scenarios
  - Inherently easier to program
SPI Digital Interface

Real-Time, Continuous Measurements

Custom Triggering and Acquisition

Closed-Loop and Dynamic Test

Protocol Emulation

DUT Interface / Control
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

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NI FlexRIO Adapter Modules

**Digital**
- 100 Mbps SE DIO
- 300 Mbps SE/LVDS DIO
- 300 Mbps SE/LVDS DIO
- Camera Link
- RS-485/422

**Analog**
- 100 MHz BW, 4.4 GHz RF I/O
- 2 ch. 3 GS/s, 8-bit AI
- 2 ch. 1.6 GS/s, 12-bit AI
- 2 ch. 100 MS/s, 14-bit AI/16-bit AO
- 2 ch. 250 MS/s, 14-bit AI/16-bit AO

- 2 ch. 250 MS/s, 14-bit AI
- 2 ch. 250 MS/s, 16-bit AI
- 2 ch. 100 MS/s, 16-bit AI
- 2 ch. 1.25 GS/s, 14-bit AO

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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
Frequency Domain Trigger

Swept Spectrum

Real-Time FFT
Example Application: Frequency Domain Trigger
Frequency-Domain Trigger

Real-Time, Continuous Measurements

Custom Triggering and Acquisition

Frequency-Domain Trigger

Closed-Loop and Dynamic Test

Protocol Emulation

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# PXIe-5644R 6 GHz Vector Signal Transceiver

<table>
<thead>
<tr>
<th>PXIe-5644R</th>
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<tbody>
<tr>
<td><strong>Configuration</strong></td>
<td>VSA and VSG w/ independent LOs 24 DIO lines @ 250 Mbps</td>
</tr>
<tr>
<td><strong>Frequency Range</strong></td>
<td>65 MHz to 6 GHz</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>80 MHz</td>
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| **Features** | • Programmable FPGA w/ LabVIEW  
• Fast Tuning Mode: <400 μs  
• Small footprint (3 PXIe slots)  
• Support for the latest wireless standards (802.11ac and LTE)  
• Industry-leading test speed and performance for testing 802.11ac |
Vector Signal Transceiver Advantages

**Traditional Approach**
- Vector Signal Generator (VSG)
- Vector Signal Analyzer (VSA)

**Software-Designed Approach**
- RF Receiver
- Real-Time Signal Processing and Control
- RF Transmitter
- Vector Signal Transceiver (VST)

OR

- Wireless Test Set (VSA + VSG)
The vector signal transceiver is ready to run out of the box, but the driver is written entirely in LabVIEW, giving you direct access to the instrument’s I/O.
Software-Designed Instrumentation

- DUT Control
- Power Level Servoing
- Protocol Aware ATE
- Noise Correction
- Vector Signal Analyzer
- Software Defined Radio
- Frequency Triggering
- Channel Emulation
- Test Sequencing
- Vector Signal Generator
- Frequency Domain Averaging

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Traditional RF Power Amplifier Servoing Application

Servoing Time = 4-5 seconds
PA Settling Time – Traditional Instruments

Power Amplifier Output Power versus Time

- Output Power (dBm)
- Time (s)

FPGA-Based vs Traditional Instrument
FPGA-based RF PA Servoing Application

Servoing Time = <5 milliseconds; Over 800x faster!

NI PXIe-5644R Vector Signal Transceiver

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PA Settling Time – Vector Signal Transceiver
Frequency-Domain Trigger

Real-Time, Continuous Measurements

Custom Triggering and Acquisition

Closed-Loop and Dynamic Test

Protocol Emulation

RF Power Amplifier Servoing
Instrument Customization

Real-Time, Continuous Measurements

- Spectral Measurements
- Inline Filtering
- Event Classification
- Frequency Domain Averaging

Custom Triggering and Acquisition

- Frequency-Domain Trigger
- Boolean Combinatorial Trigger
- Time-Domain Window

Protocol Emulation

Closed-Loop and Dynamic Test

- DUT Control
- Dynamic RF Modulation
- Dynamic Digital Protocol
- Hardware Test Sequencer

DUT Interface

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