Strategies in Software Design, Development and Testing of RF and Wireless Communications Products

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RF and Wireless Communications
National Instruments
Agenda

• Wireless Trends
• Modular Test Architectures
• Software
• Technology – Multi-Core Processors
• Case Studies
• New Frontiers for Test
THE RF WORLD
Emergence of the Smartphone

1999

- Benfon: “esc!”
  First cell phone to include a GPS receiver

2000

- Ericsson: “T36”
  First cell phone with integrated Bluetooth

2002

- Nokia: “9500 communicator”
  First Nokia phone with integrated Wi-Fi

2004

- HTC: “EVO”
  First WiMAX phone in the US

2006

- LG CU50
  First HSDPA handset in US

2010

- Nokia 6200
  First EDGE phone

- HTC EVO
  First WiMAX phone in the US
Emergence of the Multi-Radio SOC

Broadcom BCM4317
First single-chip Wi-Fi solution (802.11b)

Aug-2006

Marvell 88W8688
First Bluetooth + Wi-Fi single chip

Sep-2003

TI WiLink 6.0
First integrated A-GPS + Bluetooth + FM

Mar-2008

GCT GDM7215
First integrated Wi-Fi + WiMAX chip

 Broadcom BCM4325
First integrated WLAN + FM + Bluetooth chip

Dec-2008

Broadcom BCM4317
First single-chip Wi-Fi solution (802.11b)

Feb-2010

TI WiLink 7.0
First integrated 802.11a/b/g/n + FM + Bluetooth + GPS Chip

Apr-2008

Sep-2003

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New Long Tail Applications

- Wireless Smart Meters
- RFID Toll ways
- GPS + Glonass Receivers
MODULAR TEST ARCHITECTURES
New Demands on RF Test

• Expanded Test Coverage
  ▪ New wireless standards
  ▪ Future wireless standards

• Better Instrument Performance
  ▪ Better RF measurement accuracy
  ▪ Faster measurement speed

Single-Band
  GSM

Dual-Band
  GSM/EDGE

Multi-band &
  Multi-mode
Virtual Instrumentation

Traditional Instrumentation

- Lower cost
- Higher performance
- Smaller size
- Flexibility
- Easy upgrades
- User-defined

GSM Tester
WLAN Tester
Spectrum
Radio Tester
Power Meter
RFID Tester
Multi-Protocol UUT

All in one PXI platform!
PCI eXtensions for Instrumentation (PXI)

- Open specification governed by the PXI Systems Alliance (www.PXISA.org)
- Introduced in 1997
- PC-based platform optimized for test, measurement, and control
- Advanced timing and synchronization features
- Standard Windows software
- Over 65 Companies in the PXI Systems Alliance
- Over 1150 PXI Modules available
Data Acquisition and Control
- Multifunction I/O
- Analog Input/Output
- Digital I/O
- Counter/Timer
- FPGA/Reconfigurable I/O
- Machine Vision
- Motion Control
- Signal Conditioning
- Temperature
- Strain/Pressure/Force/Load
- Synchro/Resolver
- LVDT/RVDT
- Many More...

Modular Instrumentation
- Digital Waveform Generator
- Digital Waveform Analyzer
- Digital Multimeter
- LCR Meter
- Oscilloscope/Digitizer
- Source/Signal Generator
- Switching
- RF Signal Generator
- RF Signal Analyzer
- RF Power Meter
- Frequency Counter
- Programmable Power Supply
- Many More...

Bus Interfaces
- Ethernet, USB, FireWire
- SATA, ATA/IDE, SCSI
- GPIB
- CAN, DeviceNet
- Serial RS-232, RS-485
- VXI/VME
- Boundary Scan/JTAG
- MIL-STD-1553, ARINC
- PCMCIA/CardBus
- PMC
- Profibus
- LIN
- Many More...

Others
- IRIG-B, GPS
- Direct-to-Disk
- Reflective Memory
- DSP
- Optical
- Resistance Simulator
- Fault Insertion
- Prototyping/Breadboard
- Graphics
- Audio
- Many More...

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SOFTWARE
The Need for Flexible SW

- Wireless standards evolve
  - Cellular
    - GSM/EDGE → WCDMA → HSPA+ → LTE → LTE Adv.
  - Wireless Connectivity
    - 802.11a/b → 802.11g → 802.11n → 802.11k?
- New standards can be addressed with Software
LabVIEW Graphical Development System

- Graphical programming environment
- Compiles code for multiple OS and devices
- Useful in a broad range of applications
Software Defined RF & Communications Platform

NI Modulation Toolkit
- Generate Bits
- Source Coding
- Channel Coding
- Modulation
- Impairments
- Upconversion
- Pulse Shaping

PXI RF Vector Signal Generator

NI Modulation Toolkit
- Downconversion
- Demodulation
- Equalization
- Channel Decoding
- BER Measurement
- Matched Filter

PXI RF Vector Signal Analyzer

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Modulation Analysis Demo
Other Applications for the PXI Platform

- Broadcast
- MIMO/OFDM
- WiMAX
- Cellular
- Streaming
- GPS
- WLAN
An Observation Becomes “The Law”

Moore's law describes a trend in the history of computer hardware: that the number of transistors that can be inexpensively placed on an integrated circuit is increasing exponentially, doubling approximately every two years. This observation was first made by Intel co-founder Gordon Moore in a 1965 paper. The trend has continued for more than half a century and is not expected to stop for another decade at least and perhaps much longer.

Intel QX6700 Quad Core Processor
• 4 processors (pair of Core 2 dies)
• 2*291 million transistors
• 2.66 GHz clock speed
Multi-Core Programming

“Multi-core programming is heck of a lot more difficult”

“LabVIEW technology makes it a heck of a lot easier”

Jonhathan Luse. Intel
NI Week 2008
“One Holy Grail of computer science research has been finding a way to let a compiler take care of parallelization.”

- Richard Wirt, Intel Senior Fellow
BENCHMARKS AND COMPARISONS
WLAN Measurement Speed Demo
PXIe-5663: WCDMA Benchmark

- Measurement speed is combination of:
  - Tuning time
  - Processing time
- Benchmark compares NI 5663 vs. RS FSG/FSQ
  - WCDMA Measurement algorithms by Amfax
  - Accounts for configure time + measurement time
  - Assumes instrument is not required to tune
- Compares measurement time vs. # of averages
  - NI 8353 Quad-Core was fastest
  - NI PXIe-8106 was second-fastest
  - NI solution 5x to 10x faster than traditional instrument

<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>Instrument A</th>
<th>Instrument B</th>
<th>PXIe-5663</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>9 kHz to 8 GHz</td>
<td>1 MHz to 8 GHz</td>
<td>10 MHz to 6.6 GHz</td>
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<tr>
<td>Release Date</td>
<td>2007</td>
<td>2006</td>
<td>2008</td>
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</table>

\(^1\)Instrument A is a Rhode and Schwartz FSG,
\(^2\)Instrument B is a Rhode and Schwartz FSQ
**PXIe-5663: ACLR (W-CDMA)**

- ACLR (Adjacent Channel Leakage Ratio) measures dynamic range
- NI is 13.2x to 13.9x faster (NI performs ACLR measurement in <7 ms)
- Typical NI ACLR results are -64 dBc (with 5673)

**ACLR Measurement Time vs. Number of Averages**

- PXIe-8130 Embedded
- PXIe-8106 Embedded
- NI 8353 Rackmount
- Traditional Instrument A

- 13.2x
- 13.9x
PXLe-5663: OBW (W-CDMA)

- Occupied bandwidth of 4.175 MHz
- NI is 30.8x to 24.7x faster than traditional instrument
PXIe-5663: EVM (W-CDMA)

- EVM measures modulation accuracy
- NI is 4.8x to 5.9x faster
- Both instruments report EVM results that are 0.7% to 0.8%

EVM Measurement Time vs. Number of Averages
NEW FRONTIERS FOR SOFTWARE DEFINED INSTRUMENTATION
## Open Source IP @ ni.com/ipnet

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P2P Architecture
Demo: Peer-to-Peer Streaming

NI 5673 Signal Generator

PXIe-5663 #1

PXIe-5663 #2

PXIe-7965R

Window FFT Scaling

Window FFT Scaling

DMA CH0

DMA CH1

Host

Control

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RF Record and Playback

**Traditional Instrument**

- Desktop PC
- LAN/GPIB (10 MB/s)
- Onboard Memory (RAM)
- Analog-to-Digital Converter
- RF Analog Front End
- RF

**PXI Express Instrumentation**

- PXI Controller
- PXI Express (1 GB/s)
- Onboard Memory (RAM)
- Analog-to-Digital Converter
- RF Analog Front End
- RF

- High-Speed RAID (650 MB/s)

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MIMO – Multiple Input Multiple Output

- Common Configurations are 2x2 and 4x4
- Used in 802.11n, WiMAX, LTE, and evolving standards
- Use of spatial domain yields higher data throughput
Four Channel Phase Coherent Acquisition

- Local Oscillator
- Downconverters
- Digitizers
- Shared LO
- Shared ADC Clock
CUSTOMER SOLUTIONS
Microsoft Uses NI LabVIEW and PXI Modular Instruments to Develop Production Test System for Xbox 360 Controllers

• **Products:**
  National Instruments Modular Instruments, LabVIEW, PXI/CompactPCI

• **The Challenge:**
  Developing a comprehensive, low-cost production test system for the Microsoft Xbox 360 wired and wireless controllers.

• **The Solution:**
  Using a flexible, automated test system based on Microsoft Windows XP, Microsoft SQL Server, National Instruments LabVIEW, and NI PXI modular instruments to test the functional performance of the Xbox 360 controller, both wired and wireless versions.

"Overall, LabVIEW helped us develop an optimized end-of-line production test system for the Xbox 360 controller with data storage to our Microsoft SQL Server, communication through TCP/IP, and programmatic interaction with ActiveX controls."

D.J. Mathias - Microsoft
Embedded Fire Suppression System

• Application
  ▪ Cargo aircraft in-flight fire suppression system

• Requirements
  ▪ Cost effective & reliable control system
  ▪ Aggressive deployment schedule
  ▪ Full autonomy/zero operator input
  ▪ Self-identify aircraft type
  ▪ FAA approval
Harris Decreases Test Cost by 74 Percent Using NI Software and PXI Hardware

Customer Profile
Harris Corporation is a $4 billion international communications and information technology company serving government and commercial markets in more than 150 countries. Harris provides best-in-class products for government communications, RF communications, broadcast communications, and wireless transmission network solutions.

- $1 billion division
- Falcon III radios
- High quality, low volume
- Parallel Testing for 4X Throughput Increase
- Maximized Resource Use with COTS Tools
- Standardized LabVIEW, TestStand and PXI
- Reduce the cost for test by 74%
- ROI 185% and a
- Payback 2.8 months.
Summary

• Use of wireless technology increasing
  ▪ Many New protocols
  ▪ Many New Industries and Markets
• Need for SW-Defined instrumentation
• Multi-Core is the industry trend
  ▪ LabVIEW has the facilities to exploit Multi-Core processing
  ▪ RF Testing time can be optimally reduced by using LabVIEW parallel strategies
• Breadth of PXI enables integrated test solutions
  ▪ Broad range of applications
  ▪ Coverage from GPS to WiMAX and between
  ▪ New possibilities Expanding with FPGA and RAID