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

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Agenda

• Wireless Trends
• Modular Test Architectures
• Software
• Technology – MultiCore Processors
• Case Studies
• New Frontiers for Test
THE RF WORLD
RF Development Challenges

1990
1995
2000
2005
2010

RFID

802.11
802.15.1
802.11a
802.11b
802.11i
802.11j
802.11k
802.11h
802.11g
802.11f
802.11e
802.11d
802.22
ZigBee
HSDPA
UMTS
cdma2000
802.20
802.16e
802.20

AMPS
IS95
IS136
IS54
GSM
TD-SCDMA
GPRS
EDGE
UWB

802.11u
802.11c
802.16
802.16-2004
802.11n
802.16-2004
802.11u
802.16-2004

Wireless Expands From Vertical To Horizontal
Converging Applications…

• Mobile phone content, such as music, gaming and video, is forecast to reach $43 billion worldwide by 2010, up from $5.2 billion in 2004.
  Source: iSuppli, 2006

• Global revenues from mobile games are forecast to increase from $2.6 billion in 2005 to $11.2 billion by 2010.
  Source: Informa Telecoms and Media, 2005

• Overall mobile video revenue will grow from under $550 Million in 2005 to over $14 Billion by 2010.
  Source: iSuppli, 2006

• U.S wireless mobile music users could surpass online music service users by 2010. Source: IDC, 2006
"Vendors are still unclear about the standards that are likely to gain favor in the communications sector. The proliferation of wireless technologies and standards has left the participants wary. Due to the number of existing technologies, it becomes necessary to implement multiple standards at the same time."

-Frost & Sullivan, December 29, 2006
MODULAR TEST ARCHITECTURES
Traditional Instrumentation vs. Virtual Instrumentation

Different Box for Each Protocol

- GSM Tester
- WLAN Tester
- Spectrum
- Radio Tester
- Power Meter
- Video Tester

All in one PXI platform!

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

Multi-Protocol UUT
PXI vs. GPIB

Reduce system size by 90% and increase wallet size by 100% with the NI modular instrumentation.

NI Solution: $39,545
0.67 ft³ (0.019 m³)

Traditional Solution: $82,972
6.12 ft³ (0.1734 m³)
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
PXI Products. . .Over 1,500 and Counting

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. . .

ni.com
New 6 GHz Analyzer and Generator

PXle-5663 VSA
- Single stage heterodyne downconverter
- 10 MHz to 6.6 GHz
- 50 MHz Instantaneous BW (3 dB)
- -112 dBc phase noise (10 kHz) at 1 GHz
- -158 dBm/Hz typical DANL at 1 GHz
- 80 dB SFDR

PXle-5673 VSG
- Direct (homodyne) RF upconversion
- 85 MHz to 6.6 GHz
- >100 MHz Instantaneous BW
- -112 dBc phase noise (10 kHz) at 1 GHz
- Up to +10 dBm RF output power
- Better than -60 dBc carrier and image
Converging Applications...

“Suddenly, the interface isn't fixed and rigid, it's fluid and molten. Software replaces hardware.”

-Time Magazine on the Apple iPhone
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

Constellation Plot

PXI RF Vector Signal Analyzer

ni.com

National Instruments Confidential
NI Modulation Toolkit for LabVIEW

**Bit Generation**
- PRBS (orders 5-31)
- User-defined

**Digital Modulation/Demodulation**
- 2, 4, 8, ..., ASK and PAM
- 4, 8, 16, 32, 64, 128, 256-QAM
- 2, 4, 8, 16-FSK
- MSK and GMSK
- 8, 16, 64-PSK
- BPSK, QPSK, OQPSK, DQPSK, p/4 DQPSK
- Adaptive (LMS) feedforward equalization for ASK, PAM, QAM, FSK
- Continuous phase modulation (CPM)

**Analog Modulation/Demodulation**
- AM/DSB, AM/SSB, AM/VSB
- FM
- PM

**Modulation Analysis Functions**
- \( r(\rho) \)
- DC offset
- Phase error
- Quadrature skew
- IQ gain imbalance
- Bit error rate (BER)
- Frequency deviation
- Burst timing measurements
- Modulation error ratio (MER)
- Error vector magnitude (EVM)

**Visualization and Analysis**
- Trellis diagrams
- Constellation plot
- 2D and 3D eye diagrams

**Channel Coding**
- Reed-Solomon
- Golay
- Hamming
- Convolutional
- BCH
- Low-density parity check (LDPC)

**Noise/Impairments**
- Multitone
- DC offset
- Fading profiles
- Frequency offset
- Quadrature skew
- IQ gain imbalance
- Additive white Gaussian noise (AWGN)
- Phase noise

**System Requirements**
- Windows XP/2000/NT
- LabVIEW 7.0 or later (Full or Pro)

**More than 100 Source Code Examples**
- Simulation
- Signal generation and acquisition
Other Applications for the PXI Platform

- Broadcast
- MIMO/OFDM
- Cellular
- WiMAX
- Streaming
- GPS
- WLAN
TECHNOLOGY
MULTICORE PROCESSORS
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
Intel’s Self-Fulfilling Prophecy

*Intel has a self-fulfilling prophecy to adhere to Moore’s Law. At the 2006 Intel Developer’s forum, Intel CEO Paul Otellini revealed an 80 core prototype and pledged the product’s timeline.*

“Intel pledges 80 cores in five years”
- Paul Otellini, CEO Intel at 2006 Developer’s Forum

*Intel's prototype uses 80 floating-point cores, each running at 3.16GHz, Justin Rattner, Intel's chief technology officer, said in a speech following Otellini's address. In order to move data in between individual cores and into memory, the company plans to use an on-chip interconnect fabric and stacked SRAM (static RAM) chips attached directly to the bottom of the chip, he said.*

- Tom Krazit, CNET News, 26-Sep-2006
Multi-Core Programming

“Multi-core programming is heck of a lot more difficult”
“LabVIEW technology makes it a heck of a lot easier”

Jonathan Luse. Intel
NI Week 2008
Multi-core Programming

“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
20 Years of Innovation

More than 20 years of parallel programming investment

Improved multicore capabilities for desktop and real-time developers in 2007

More than 10 years of multithreading investment
Parallel Programming with LabVIEW
Data Parallelism: Breaking the Dataset
Results: 3x Algorithm Execution Time

Elapsed, ms
37

Elapsed, ms
20

Elapsed, ms
12
CELLULAR
BENCHMARKS AND COMPARISONS
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 A¹</th>
<th>Instrument B²</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>
</tr>
<tr>
<td>Release Date</td>
<td>2007</td>
<td>2006</td>
<td>2008</td>
</tr>
</tbody>
</table>

¹Instrument A is a Rhode and Schwartz FSG,
²Instrument 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)
**PXIe-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
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
Business Impact Case Study: Harris Corporation

- $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

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.

Overview
Company
Harris is a $4 billion international communications and information technology company serving government and commercial markets.

Reduced Cost of Test
Payback 2.8 months.

ROI 185% and a

Increased Test Throughput
Reduced Cost of Test
Scalable Test Platform

ni.com

National Instruments Confidential
NEW FRONTIERS FOR TEST
The number of HDL-savvy designers is expected to reach 200,000 by 2010.

-Wally Rhines
Mentor Graphics CEO

VHDL 66 Pages ~4000 lines

LabVIEW FPGA
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