National Instruments
Automotive Seminar
Stephen Plumb
NI South Africa
Agenda

• Introduction to NI

• End-of-line Automotive Component Testing
  • Infotainment Testing
  • Cluster Inspection

• Test Cell Data Acquisition & Control

• Engine Control Research (RCP Platforms)

• In Vehicle Data Logging
Our Mission

We equip engineers and scientists with systems that accelerate productivity, innovation, and discovery.
Graphical System Design

A platform-based approach for test, measurement and control

LabVIEW

Desksops and PC-Based DAQ

PXI and Modular Instruments

CompactRIO and Custom Designs

NI Single Board RIO
Key Applications

Test and Measurement

Embedded DAQ and Control
NI’s Platform-Based Approach to Automated Test

Traditional Instruments vs. PXI Modular Instruments
Qualcomm Atheros reduced test time by more than 200X with NI solutions—compared to traditional instrumentation.
Subaru reduced overall test time by 94% with NI solutions—compared to manual testing.
NI’s Platform-Based Approach to Embedded System Design

Traditional Design Approach vs. Flexible Off-The-Shelf Solution

- Application Software
- Driver API
- Device Drivers
- Board Support Package
Airbus estimates it will reduce development time by 10X with NI solutions in their Factory of the Future.
National Grid deployed more than 110 networked CompactRIO systems to manage loads, optimize power quality, and plan for the future grid.
Our Customers

- Advanced Manufacturing
- Aerospace and Defense
- Consumer Electronics
- Wireless
- Energy
- Transportation
NI Supports Your Success
Through extensive services and Alliance Partner networks

Your Solution

Your Team
Engineering, Services, and More

Alliance Partners
Integration and Consulting

NI Services
Training, Calibration, Maintenance, and More

NI Products
Ecosystem
Users, IP, Add-Ons, and More
NI Company Overview

**Revenue:** $1.24 billion in 2014

**Global Operations:** Approximately 7,080 employees; operations in almost 50 countries

**Broad customer base:** More than 35,000 companies served annually

**Diversity:** No industry >15% of revenue

**Culture:** Ranked among top 25 companies to work for worldwide by the Great Places to Work Institute
NI in Automotive Industry

Hardware-in-the-loop Test
Infotainment Test
Test Cell DAQ & Control
End-of-line Test
Engine Control Research
In-vehicle data logging
Hardware-in-the-loop Testing for ECUs
Feature Explosion

- Active Suspension Control
- Parallel Parking Control
- Blind Spot Detection
- Power Seats/Doors Control
- Windshield Wiper Control
- Airbag Control
- Engine Control
- Transmission Control
- Electronic Brake Control
- Headlight Control
- Parallel Parking Control
- Power Seats/Doors Control
- Windshield Wiper Control
- Airbag Control
- Transmission Control
- Electronic Brake Control
- Headlight Control
Automotive System Development

Design

Prototyping

Physical Testing

HIL Validation

Code Gen Deployment

K_c - K_p

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Embedded Control Systems

Actuator Commands → Closed-Loop Interactions → Sensor Feedback

Electronic Control Unit
Hardware-in-the-Loop Test

Real-Time Simulation

Functional System Model

Electronic Control Unit

Real-World System
Hardware-in-the-loop Test System: I/O

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

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

**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
Versatility - I/O Interfaces

- General Purpose I/O
- FPGA-based I/O
- Instrument Grade I/O
- RF I/O
- Bus Interfaces
- Fault Insertion Units
- Image Acquisition
- Motion Controllers
Performance - Real-Time Multicore Processing
Scalability - Multi-Processor Systems
Openness - Open Hardware and Software Platform

- Support for 3\textsuperscript{rd} party hardware interfaces on the PXI platform

- Extensible software platform ensuring that your system can be adapted to your needs without waiting on vendor roadmaps

- Use a variety of 3\textsuperscript{rd}-party modeling environments as well as C/C++ code on real-time execution targets
Hardware-in-the-loop Test System: Software

Application Architecture

- Deterministic Model Execution
- Hardware I/O (Single Point)
- Closed-Loop Control
- Alarming

- Stimulus Generation
- Test Automation
- Data logging
- Calculated Channels
NI VeriStand™
Real-Time Testing and Simulation Software

- Deterministic Model Execution
- Hardware I/O (Single Point)
- Closed-Loop Control
- Alarming
- RT Stimulus Generation
- Test Automation
- Data logging
- Calculated Channels

Real Time PXI
CompactRIO
Real Time PC
What is NI VeriStand?

- NI VeriStand is a software written in NI LabVIEW
- NI VeriStand is an out-of-the-box software environment for configuring real-time testing applications
  - Host side GUI and configuration tool
  - Execution engine that can run on both Windows and Real Time OS
NI VeriStand Helps You…

- **Reduce development time without reducing flexibility**
  
  Architecture design, implementation, debugging, documentation of real-time application, host interface, and communication between them

- **Reduce maintenance costs**
  
  Operating System and Hardware I/O support, feature and performance innovation, continuous quality improvement
Supported Modeling Environments

**Supported**
- The MathWorks, Inc. Simulink® software
- LabVIEW
- LabVIEW Control Design and Simulation Module
- MapleSim models from Maplesoft
- SimulationX from ITI
- GT-POWER engine models from Gamma Technologies Inc.
- Tesis DYNAWare models
- NI MATRIXx SystemBuild
- Esterel SCADE Suite
- C/C++/FORTRAN/Ada

**In Work**
- CarSim from Mechanical Simulation
- AVL BOOST/Cruise
- WaveRT from Ricardo
- AMESim models from LMS
- Models from VI-grade
- Dymola models from Dynasim
- Easy5

Simulink® is a registered trademark of The MathWorks, Inc. All other trademarks are the property of their respective owners.
HIL Demo

Simulated Plant – NI PXI

NI VeriStand Real-Time Engine

ECU

PXI Modules

System Model

Stimulus Profile

Data Logging

Data Table

- fuel
- spark
- position
- speed
- load

UI Communication

User Interface, Analysis, Reports
Body Control Unit Testing

“The real-time stimulus profile tools work the way that a test engineer thinks and does not require knowledge of additional programming languages to utilize them. With this capability, our engineers are able to focus on their jobs – identifying potential module failures – which ultimately results in more issues identified and resolved.”

– Jason Bauman, Lear Corp.
Engine Control Unit Testing

Compact Desktop HIL Systems!!
Desktop ECU Tester
Desktop ECU Tester

- Low-cost Compact Desktop HIL

- Automotive Engine Simulation support, with FPGA

- In-built Automotive specific Signal Conditioning
  1. Ratiometric Analog I/O
  2. Reference based Digital I/O
  3. High current Fault Insertion
  4. Load simulation
  5. VR Sensor Simulation
Desktop ECU Tester

- Load Simulation example specification:

<table>
<thead>
<tr>
<th>Input / Output Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Channels</strong></td>
</tr>
<tr>
<td><strong>Connection</strong></td>
</tr>
<tr>
<td><strong>Resistor Type</strong></td>
</tr>
<tr>
<td><strong>Inductor Type</strong></td>
</tr>
<tr>
<td><strong>Configuration Method</strong></td>
</tr>
<tr>
<td><strong>Input</strong></td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
</tr>
<tr>
<td><strong>Current</strong></td>
</tr>
<tr>
<td><strong>Number of High Reference voltages</strong></td>
</tr>
<tr>
<td><strong>Physical Characteristics</strong></td>
</tr>
<tr>
<td><strong>Size</strong></td>
</tr>
</tbody>
</table>
Electric Motor Controller Testing
Overview

Power electronics + Motor Simulation

Real-Time Power Simulation
(Cracked ECU or Full Power Simulator)

Physical Control Board

- Battery Stack, Management System
- Inverter/Drive
- DC, DC, AC

Control System

- Power System
- Inverter/Converter/Drive
- Motor/Generator
Overview

Simple Inverter Topology – 6-Switch Bridge

[Diagram showing a simple inverter topology with a motor drive simulator, controller under test, and a 6-switch bridge configuration.]
Overview

Pulse Width Modulation

![Graph showing pulse width modulation](image)
Simulation Requirements - Speed

When simulating switch-mode power systems, speed matters!
Simulation Requirements – Non-linearities

- Complex geometry
- Magnetic materials
- Permanent magnets
- Nonlinear inductance
- Saturation effects
- Coil winding
- Copper and iron losses
- Efficiency

These phenomenon can be simulated, but only by non-linear models developed using Finite Element Analysis.
Simulation Requirements – Non-linearities
## Simulation Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>NI Solution</th>
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</thead>
<tbody>
<tr>
<td>High-speed model execution</td>
<td>FPGA-based simulation</td>
</tr>
<tr>
<td>High speed I/O (10x model speed)</td>
<td>Custom FlexRIO front-end adapter module (FAM)</td>
</tr>
<tr>
<td>High fidelity models</td>
<td>Electric Motor Simulation Toolkit</td>
</tr>
</tbody>
</table>
  - Non-linear |
  - Time varying |
NI Solution – FPGA Based Simulation

- HARD CORE DSP SLICES
- PROGRAMMABLE LOGIC & COMMUNICATION
- EXTERNAL COMMUNICATION

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NI Solution – FPGA Based Simulation

FPGA-based State Space Simulator

Simulation loop rate of 3.57 MHz

> 3000X Acceleration vs. Processor
NI Solution – Custom IO Module for FPGA

FlexRIO IO Module

FlexRIO FPGA
## NI Solution – Custom IO Module for FPGA

<table>
<thead>
<tr>
<th>Channel Type</th>
<th>Analog Input</th>
<th>Analog Output</th>
<th>Digital Input</th>
<th>Digital Output</th>
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</thead>
<tbody>
<tr>
<td>Isolation Type</td>
<td></td>
<td>Non-Isolated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channels</td>
<td>12</td>
<td>12</td>
<td>16</td>
<td>16</td>
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<tr>
<td>Resolution</td>
<td>16bit</td>
<td>16bit</td>
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<tr>
<td>Sampling Rate</td>
<td>50MS/s (6ch), 25MS/s (12ch)</td>
<td>50MS/s</td>
<td>50MS/s</td>
<td>50MS/s</td>
</tr>
<tr>
<td>Settling Time</td>
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<td>20ns</td>
<td></td>
<td></td>
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<tr>
<td>Latency</td>
<td>70ns (6ch), 290ns (12ch)</td>
<td></td>
<td>8ns</td>
<td>8ns</td>
</tr>
<tr>
<td>Range</td>
<td>Differential ±12V</td>
<td>Single-ended ±12V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NI Solution – Electric Motor Simulation Toolkit

• LabVIEW toolkit

• Motor types (Linear and Non-linear)
  • Permanent magnet synchronous machine (PMSM)
  • Switched reluctance motor (SRM)
  • AC Induction Motor

• Simple inverter models

• Direct support for JMAG-RT via .rtt files (FEA modeling)
NI Solution – Electric Motor Simulation Toolkit

NI VeriStand Implementation

Custom Device Settings
- Name: PMSM FEA Model
- Description:
  Simulates a permanent magnet synchronous motor (PMSM) using the finite element analysis (FEA) model function.

PMSM FEA Model Settings
- RTT File:
  C:\Users\Public\Documents\National Instruments\NI VeriStand 2013\Custom Devices\EMSim\PMSM FEA Model\FPGA\JAG037P-PM-RT-02.rtt

Base Values
- Voltage Base [V]: 10
- Current Base [A]: 10
- Speed Base [RPM]: 95
- Resistance [Ohm]: -1

Mechanical Parameters
- Inertia [kgm²]: 1
- Friction Coefficient: 0.1
- DC Voltage [V]: 288
- dr [V]: 1.6E-9

Hardware Settings
- RIO Device: RIO0
- FPGA Bitfile:
  C:\Users\Public\Documents\National Instruments\NI VeriStand 2013\Custom Devices\EMSim\PMSM FEA Model\FPGA\PXIe-7965R PMSM FEA Model Simulator.bit
Case Studies
Renesas Electronics Corporation

The Challenge:
Developing higher level in-vehicle microcontrollers to address the demand of next-generation automobiles that use electrical power sources, such as electric vehicles (EVs) or hybrid-electric vehicles (HEVs).

The Solution:
Building an advanced hardware-in-the-loop simulation (HILS) system for HEVs and EVs using NI LabVIEW system design software and NI PXI modular hardware.

"We would like to be one step ahead of our users—the automobile and in-vehicle device manufacturers. We unearth the problems our users will face before they get there and would like to be the first to offer them solutions. To make this happen, it would be beneficial for automobile or in-vehicle device manufacturers to have a testing environment for microcontroller-mounted devices."

Hideki Kagawa, Renesas Electronics Corporation
Subaru XV Crosstrek Hybrid

The Challenge:
Using automated testing to develop a new verification system that satisfies the control quality level required for the motor electronic control unit (ECU) in Subaru’s first production model hybrid vehicle, Subaru XV Crosstrek Hybrid, and creating strenuous test conditions that are difficult to achieve using real machines.

The Solution:
By Building a verification system with the NI FlexRIO platform that makes automatic execution of all of the test patterns possible and replicates the most severe testing environments to ensure the highest level of safety to the user, while obtaining the required control rate and meeting critical timelines. By adopting FPGA-based simulation using the NI hardware and software platforms, we achieved the simulation speed and model fidelity required for verification of an electric motor ECU. We reduced test time to 1/20 of the estimated time for equivalent testing on a dynamometer.

Tomohiro Morita, FUJI Heavy Industries, Ltd.