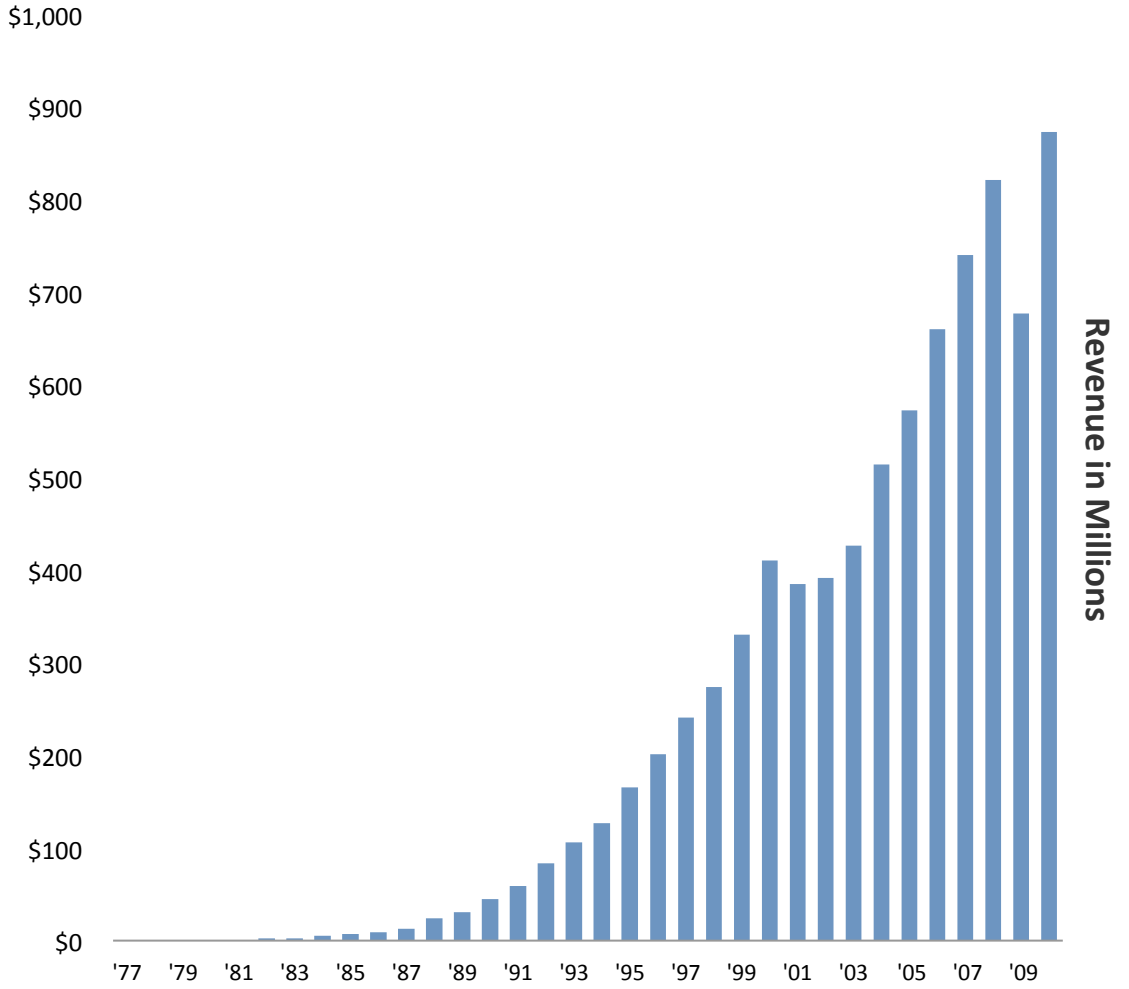

NATIONAL INSTRUMENTS
LabVIEW™

National Instruments

Leader in computer-based measurement and automation

- Long-term track record of growth and profitability
- $1B revenue in 2011
- More than 6,200 employees; operations in 45+ countries
- Sales to More than 30,000 companies
- No Industry >15% of Revenue
- *FORTUNE's* 100 Best Companies to Work For list for 13 consecutive years
- 16% or More Investment in R&D



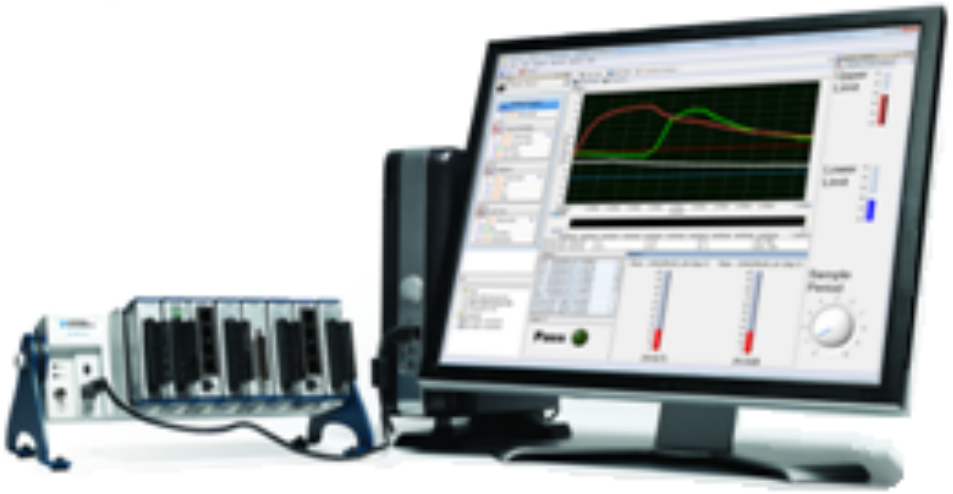
NATIONAL INSTRUMENTS

More than 30,000 companies

...including 90% of Fortune 500 manufacturing companies

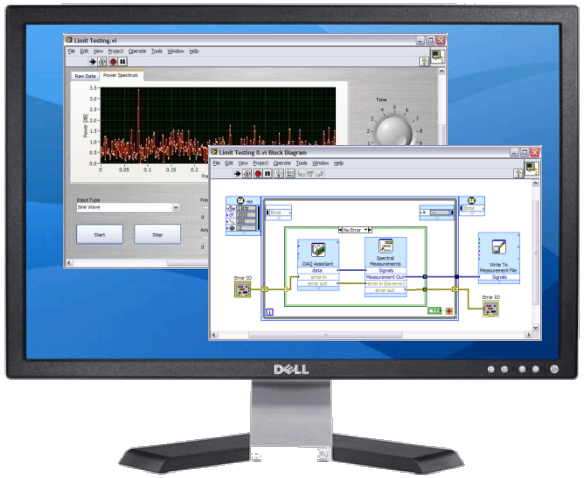
What You'll Do in the Lab

- Learn LabVIEW fundamentals
- Acquire temperature signal
- Output warning light based on alarm level
- Write data to file
- Challenge: AI and AO



Virtual Instrumentation with LabVIEW

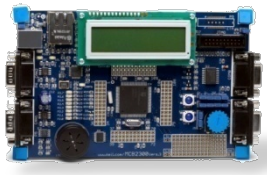
NATIONAL INSTRUMENTS LabVIEW™



Software-defined behavior

Test

Industrial



Embedded

Modular I/O

Virtual Instrumentation Case Study

BOEING®

Application

Boeing used LabVIEW and 70 PXI chassis to collect over 300 channels of acoustic data simultaneously in their research to decrease noise during takeoff

NI Products

LabVIEW, PXI

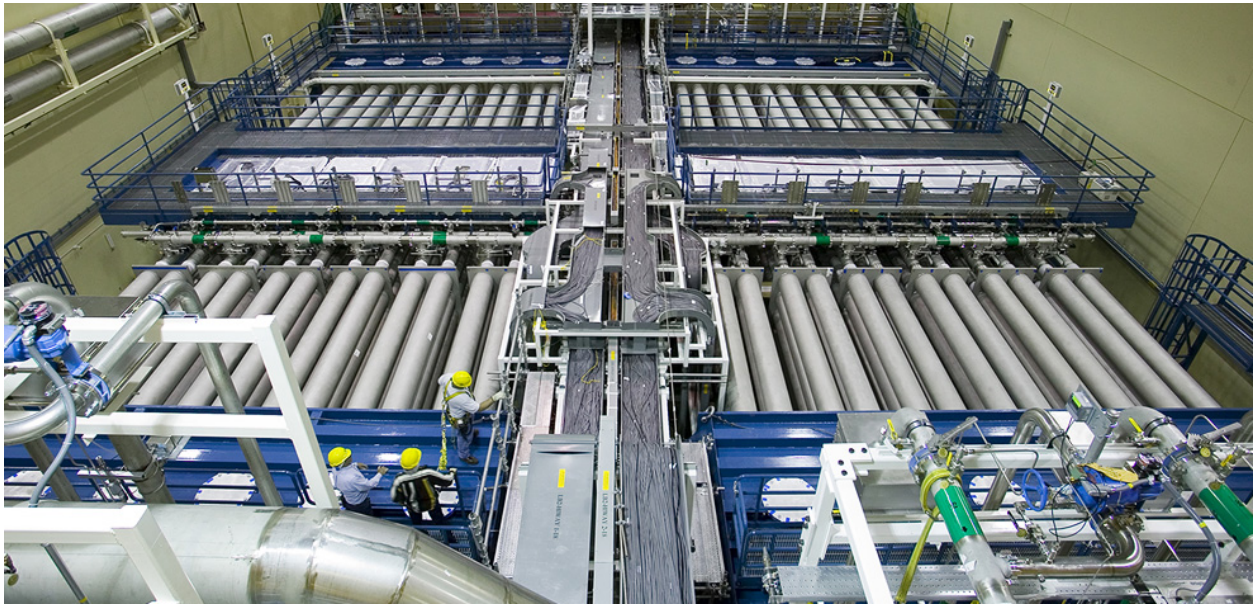
"Using NI software and hardware, we were able to create a high-end, low-cost system that could distribute the acquisition system across multiple chassis, tightly synchronize all channels, provide high channel count with full bandwidth on all channels simultaneously, and allow virtually unlimited channel-count expansion. "

-- James Underbrink, Boeing Aero/Noise/Propulsion Laboratory

Lawrence Livermore National Labs

Developed automated maintenance process for world's largest laser array at the National Ignition Facility using NI LabVIEW and PXI

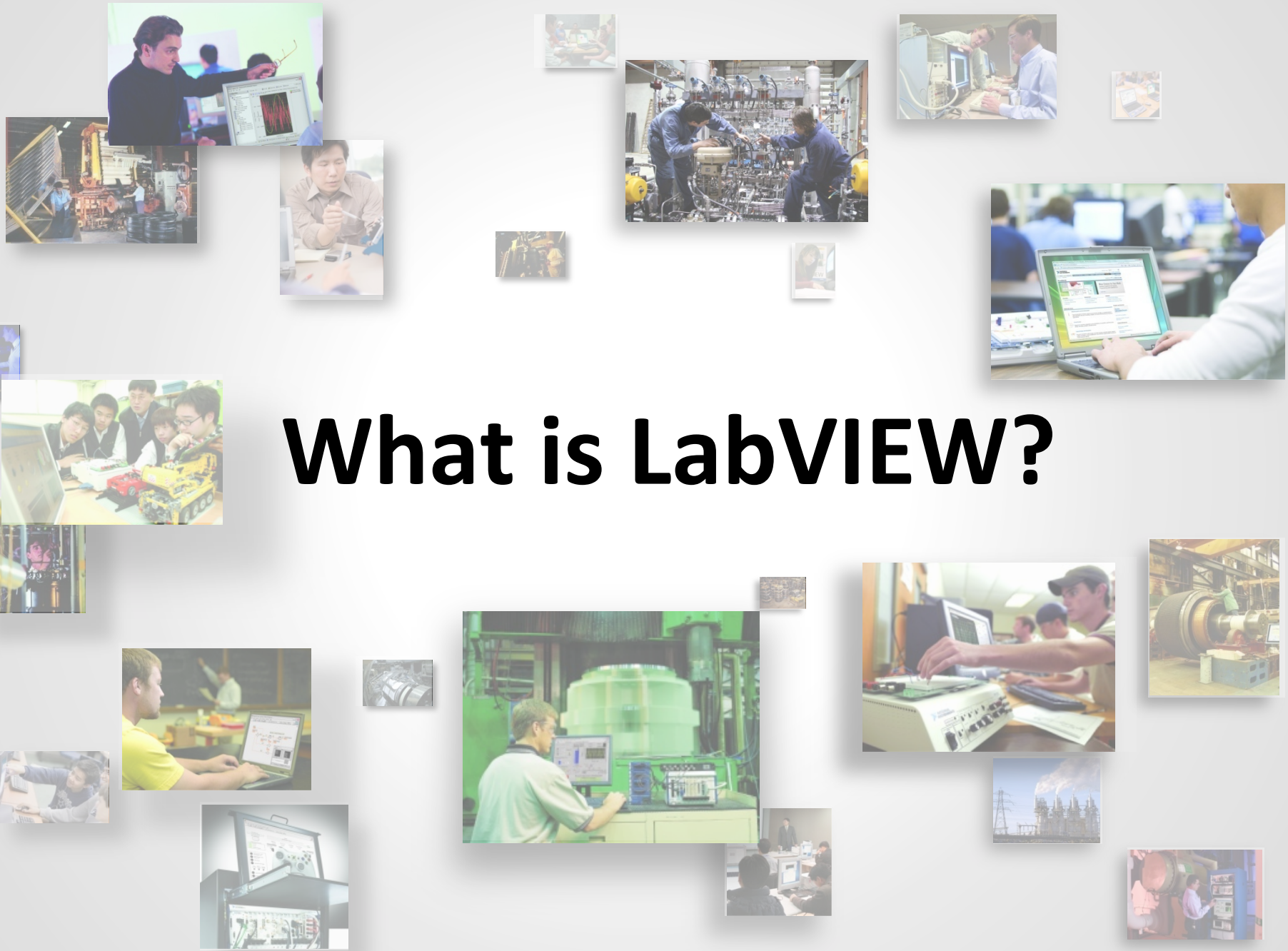
- LabVIEW increased productivity by 3X over Java and C++
- Developed complex application consisting of over 1,000 VIs



An overhead view of one of the main laser chambers

"The value in using the graphical dataflow language is the speed in which a team can deliver a robust solution while still using proper software engineering practices.

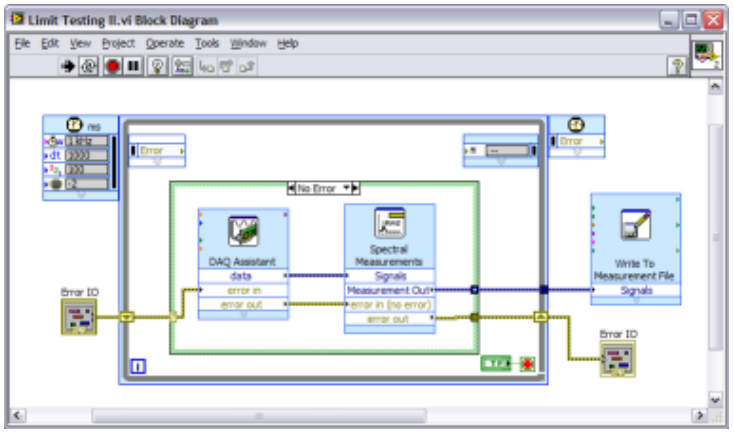
- Glenn Larkin, LLNL



What is LabVIEW?

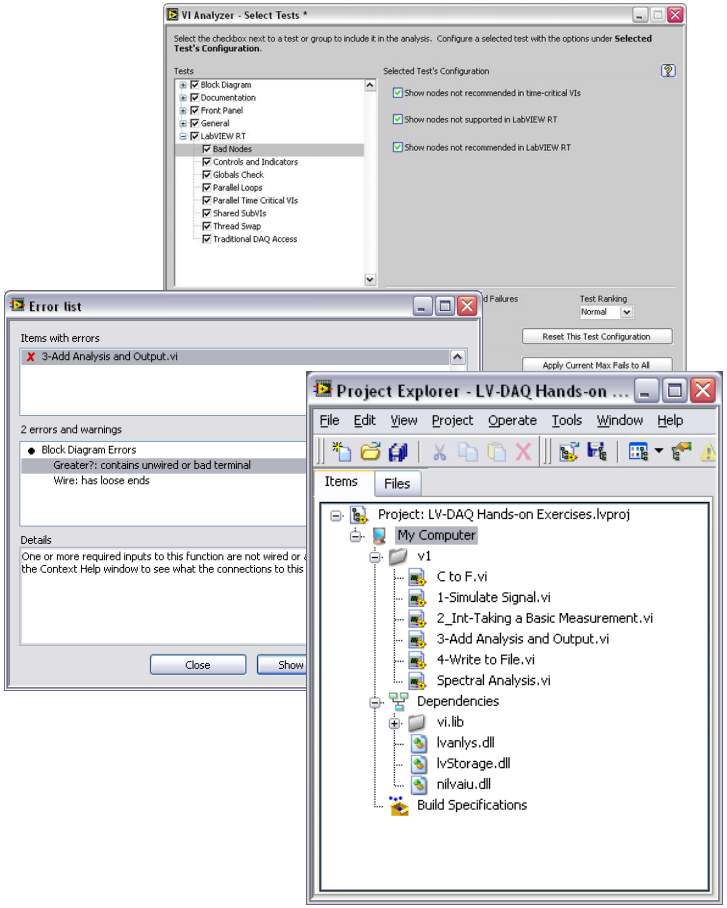
LabVIEW is a Programming Language

- Graphical Programming
  - Data types
  - Structures (i.e. loops, case, event handling)
  - Standard functions (i.e. File I/O)
- Reuse external code
- Compiles to machine code
- Automatic multithreading



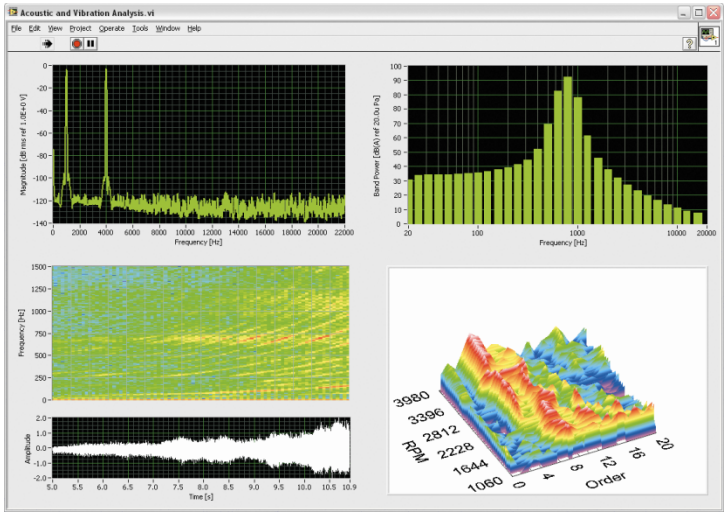
LabVIEW is a Development Environment

- Debugging tools
- Assistants
- Configurable functions
- I/O Finder
- Easy UI Development
- Software Engineering Tools
- Performance Tools



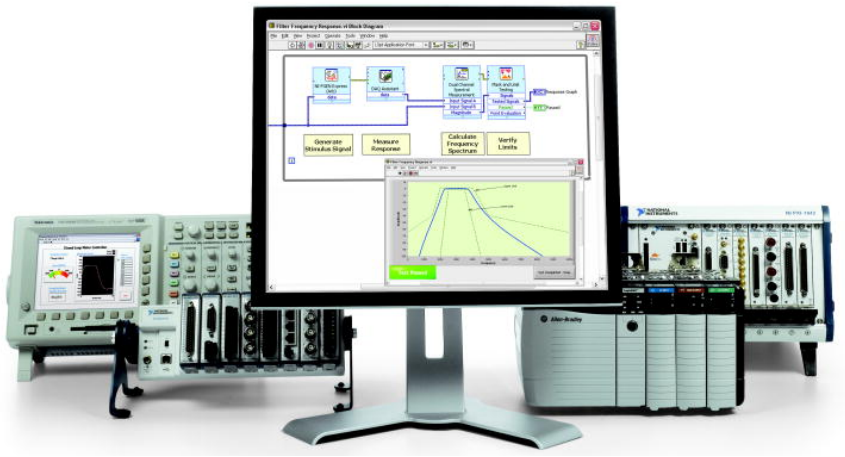
LabVIEW Has Built-in Engineering Libraries

- In-line and off-line analysis and control
  - Signal processing
  - Analysis and filtering
  - Complex math
  - PID
  - Vision
  - Motion



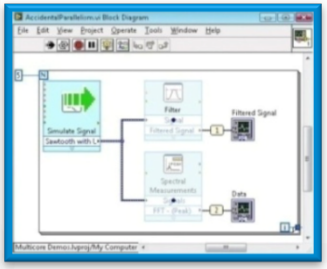
LabVIEW Easily Connects to Hardware I/O

- 6000+ instruments from over 250 vendors
- PCI, PCIe, PXI, USB, Ethernet, serial, GPIB, and CAN devices
- Modular data acquisition hardware from DC to the GHz range
- Motion control stages
- Cameras
- Hundreds of PLCs



LabVIEW Graphical System Design Platform

Dataflow

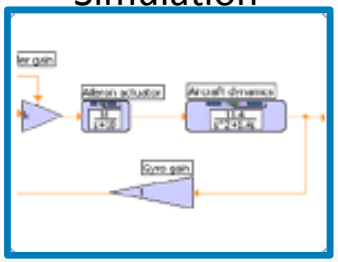


C Code

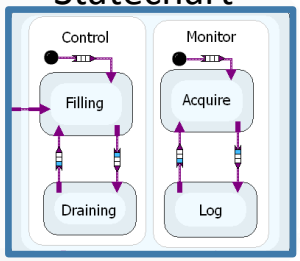
Textual Math

```
1 c = 0.285 + 0.013i;
2 [X Y] = meshgrid(x, y);
3 z = X + i*Y;
4 for k=1:30
5    z = z.^2 + c;
6 end
```

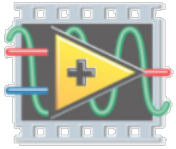
Simulation



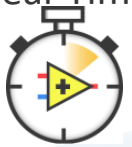
Statechart



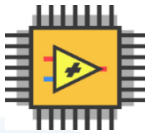
LabVIEW



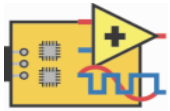
Real-Time



FPGA



Microprocessors



PC

PXI Systems

CompactRIO

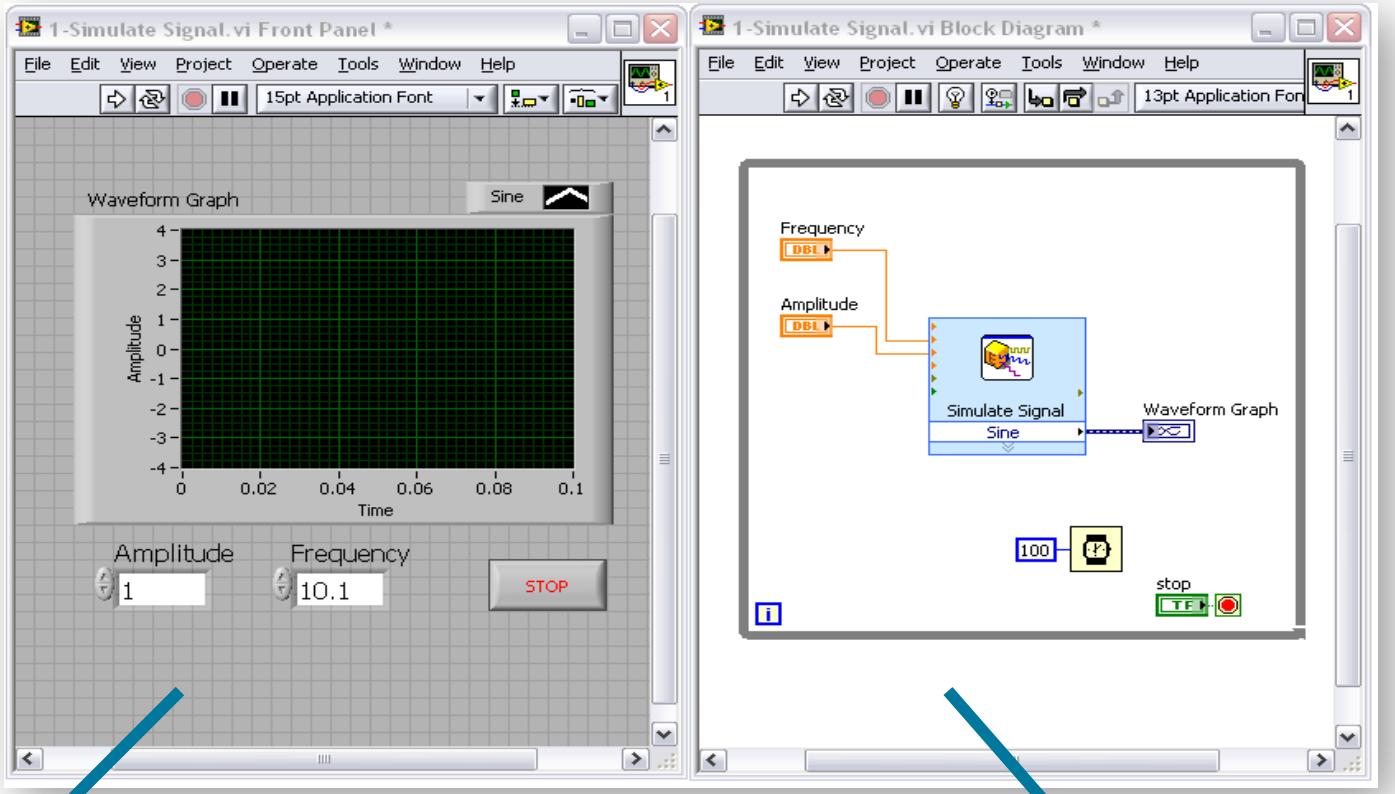
SB RIO

Custom Design

LabVIEW Fundamentals

The LabVIEW Environment

"VI" = program or function



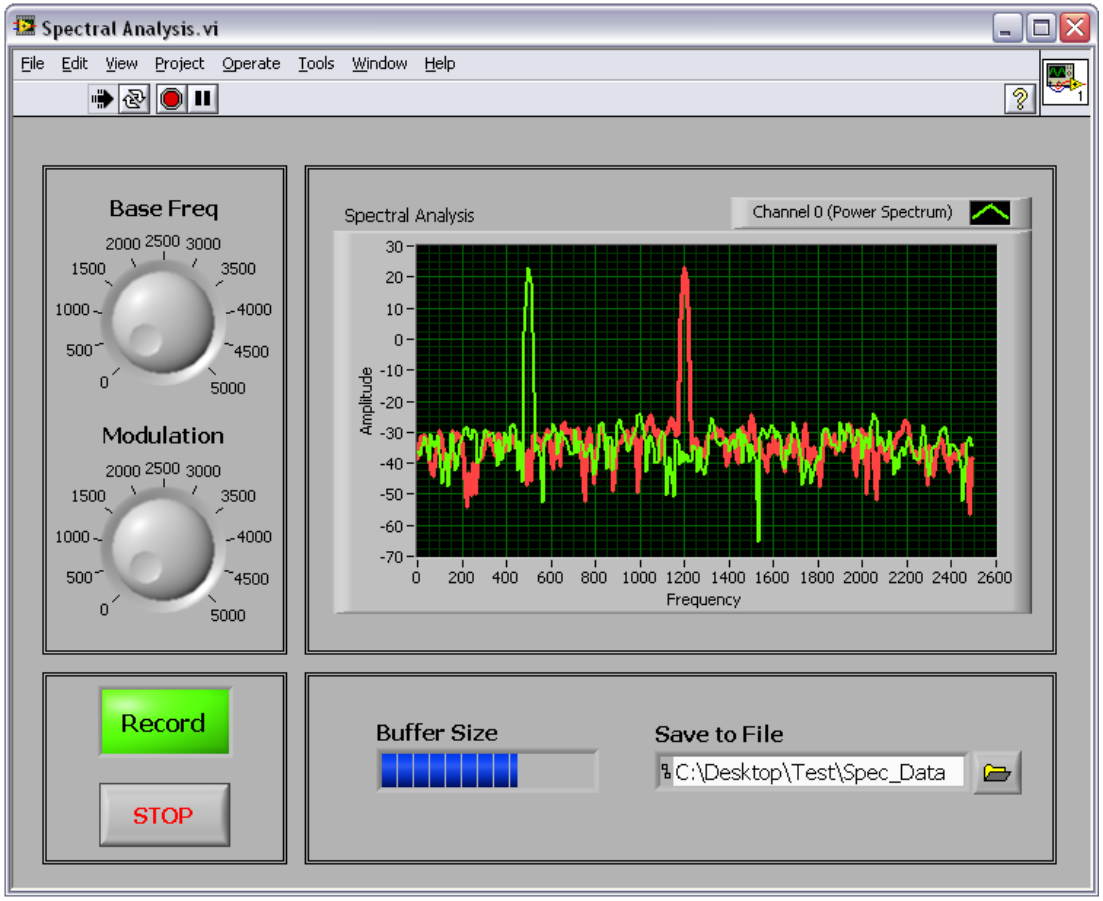
"Front Panel" = user interface

"Block Diagram" = code

Controls & Indicators

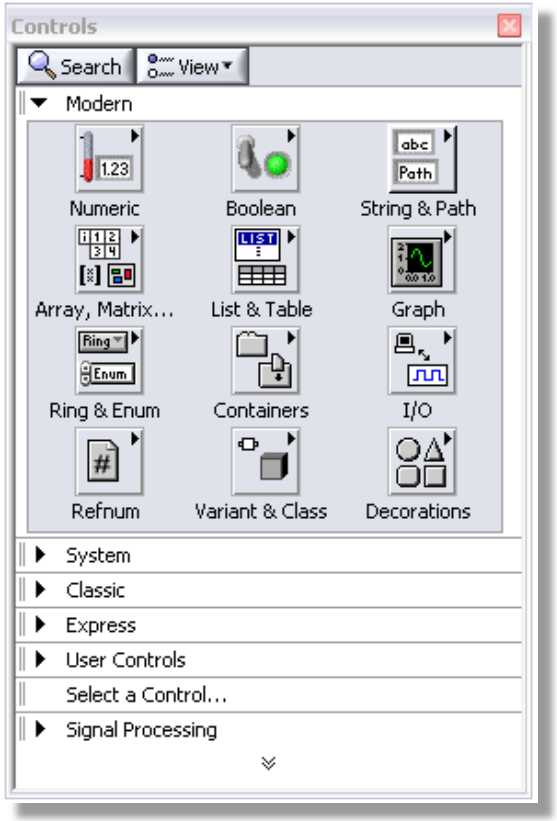
Front Panel

- Knobs/Dials
- Graphs/Charts
- Buttons
- Digital Displays
- Sliders
- Thermometers
- Customize and create your own



Finding Front Panel Objects

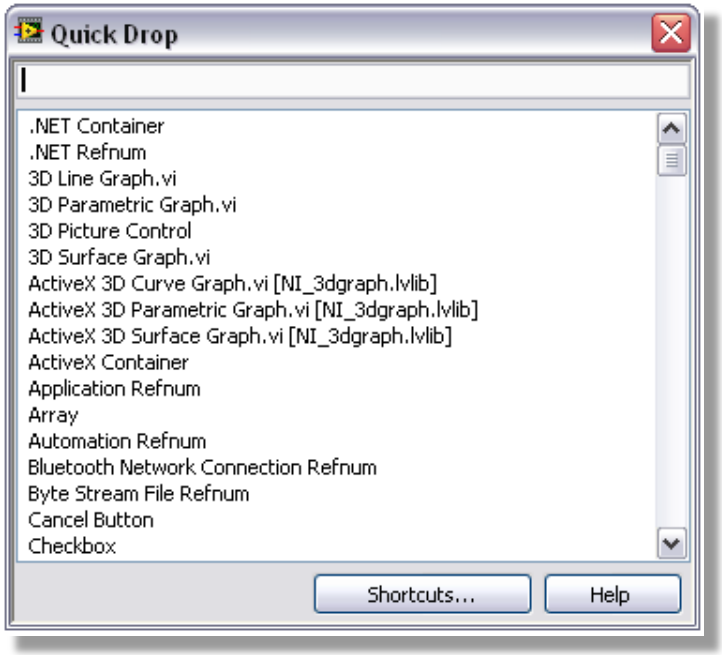
Controls Palette



- Right-click on Front Panel
- Browse by object hierarchy

or

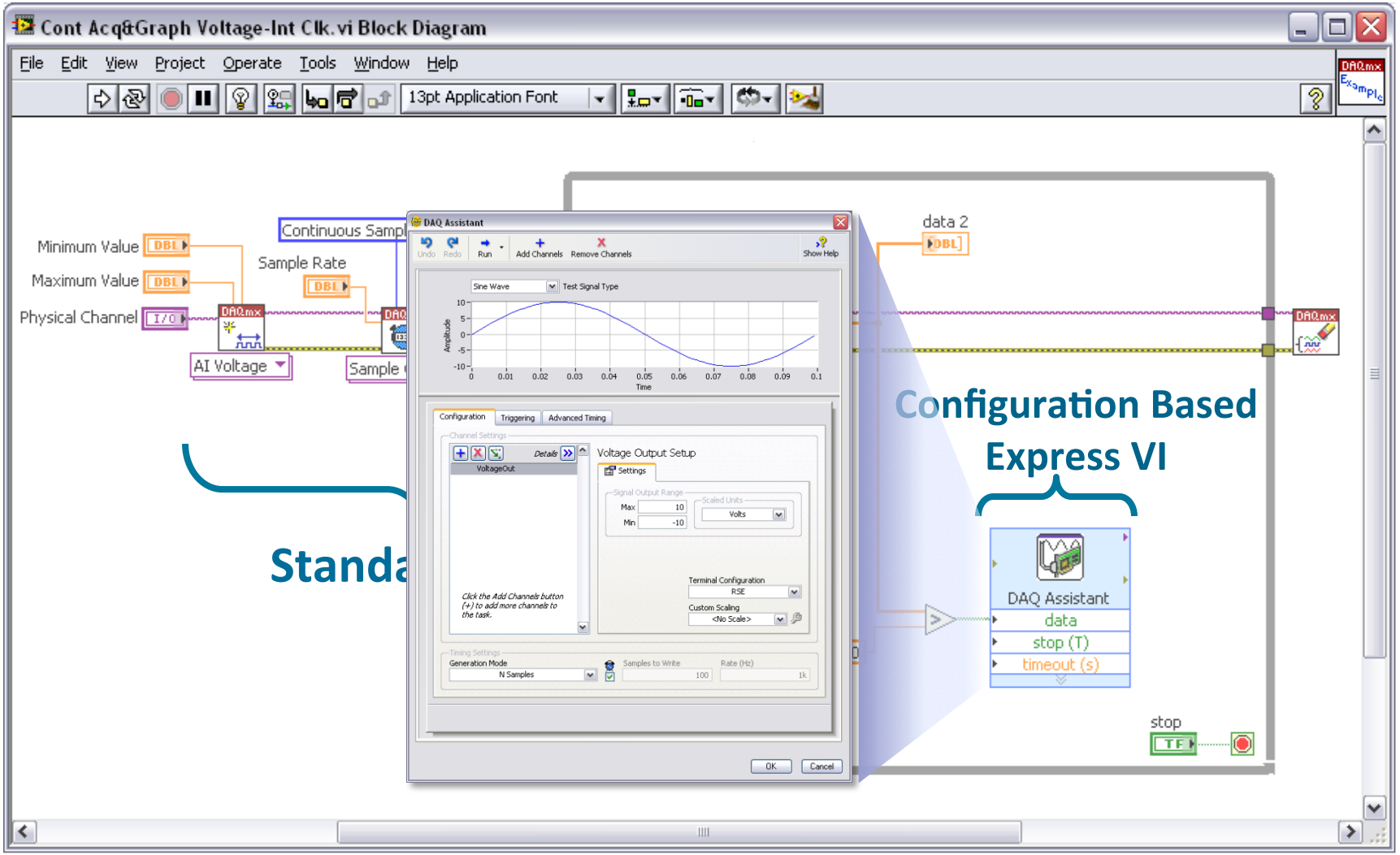
Controls Quick Drop



- Press <ctrl + space> to bring up
- Search by object name

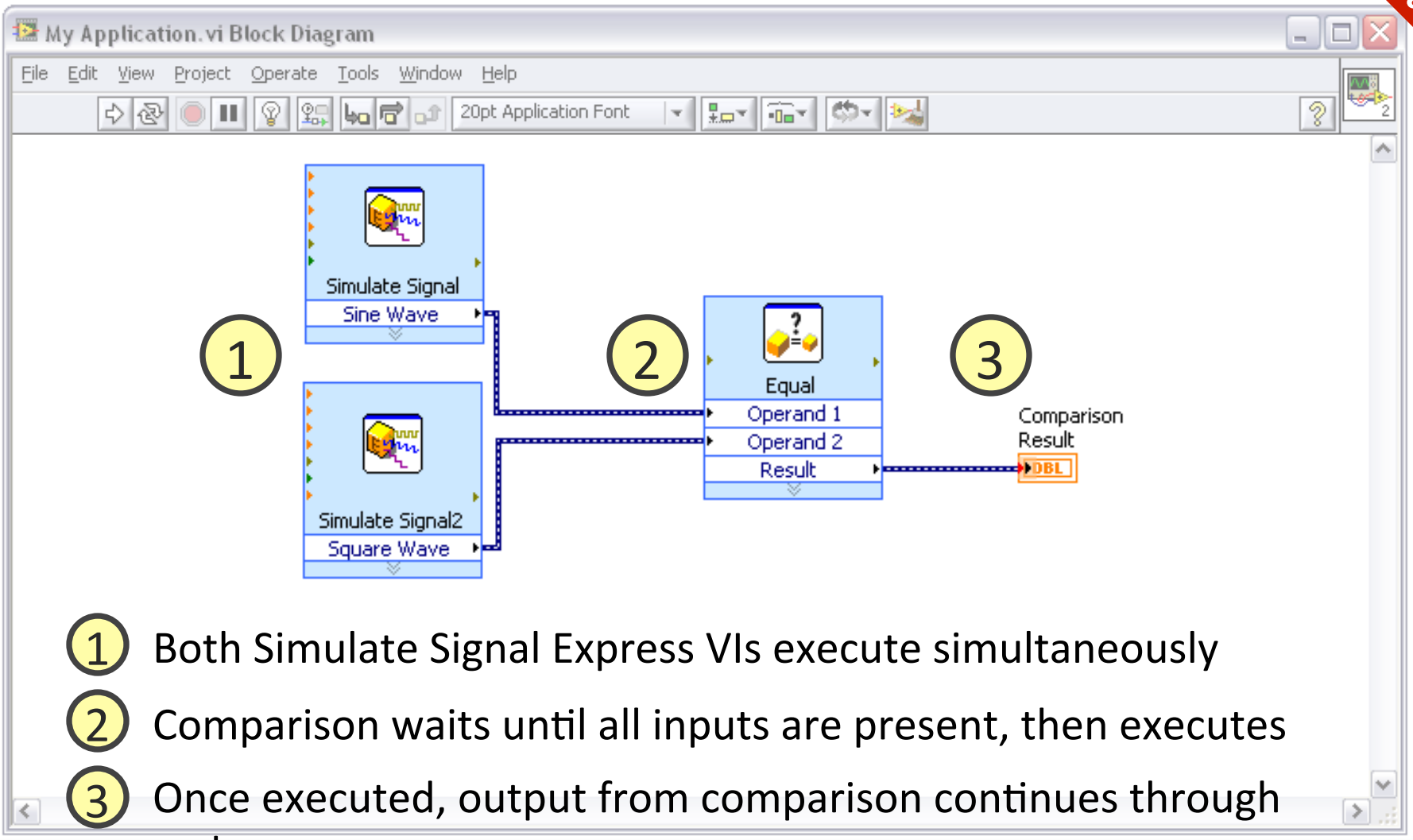
Functions and Express VIs

Block Diagram



Dataflow Programming

Block Diagram



1. Both Simulate Signal Express VIs execute simultaneously
2. Comparison waits until all inputs are present, then executes
3. Once executed, output from comparison continues through code

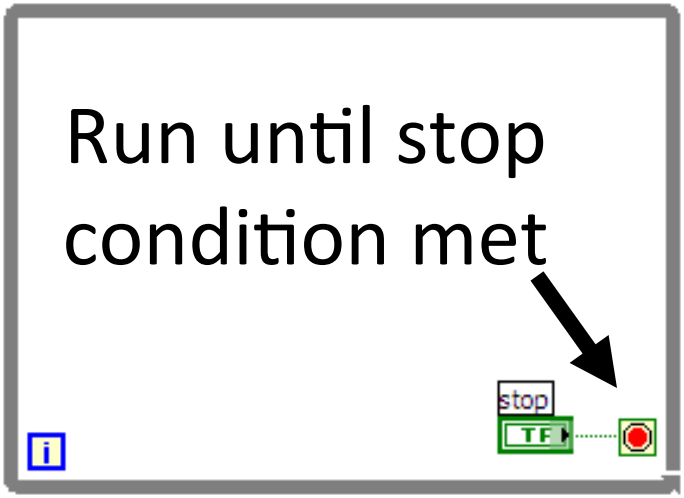
Wires and Data Types

- Transfer data between block diagram objects through wires
- Wires are different colors, styles, and thicknesses, depending on their data types
- A broken wire appears as a dashed black line with a red X in the middle

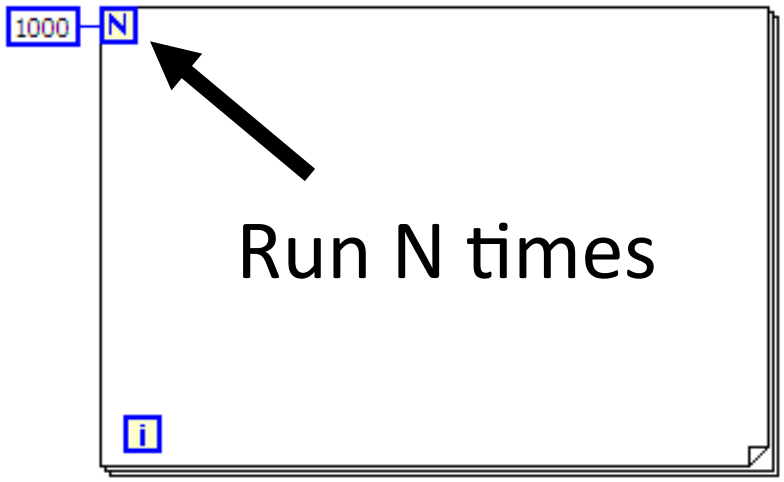
	DBL Numeric	Integer Numeric	String
Scalar			
1D Array			
2D Array			

Execution Control Structures

While Loop



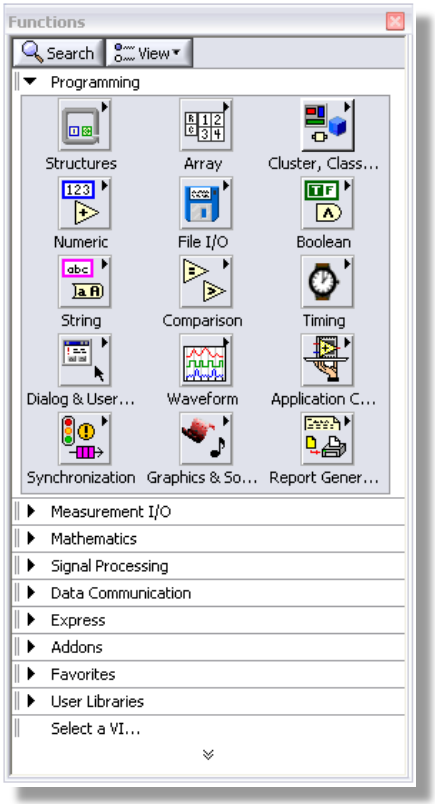
For Loop



- Allow same piece of code to run multiple times
- Exit conditions different for each

Finding Block Diagram Functions

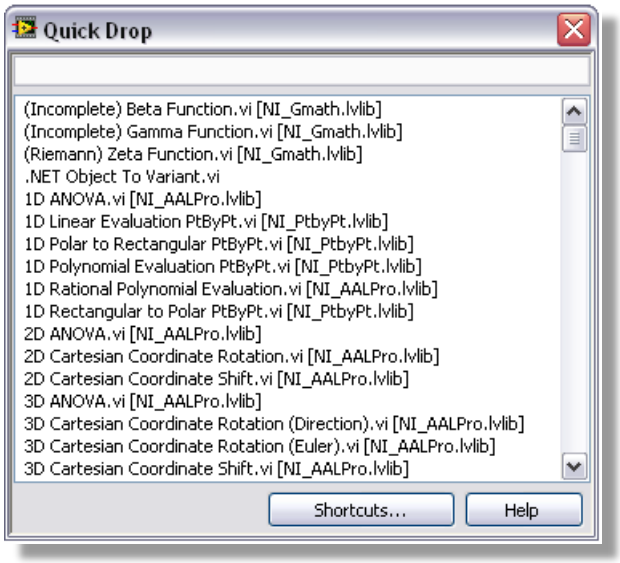
Functions Palette



- Right-click on Block Diagram
- Browse by object hierarchy

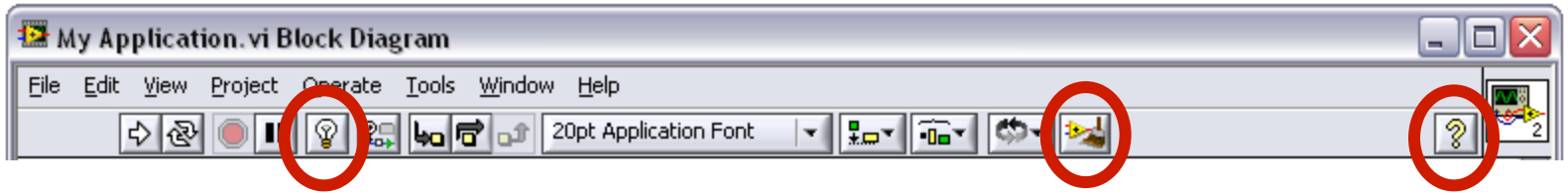
or

Functions Quick Drop



- Press “ctrl + space” to bring up
- Search by object name

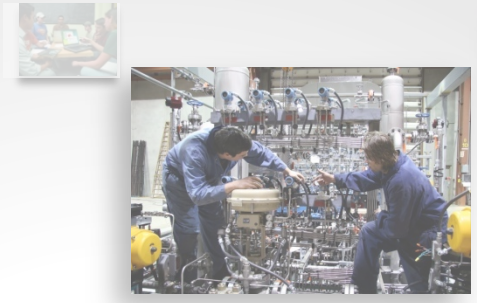
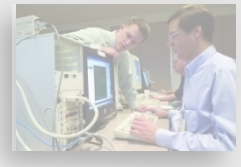
Built-in Programming Assistance

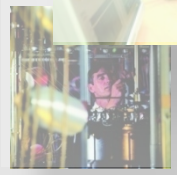


Highlight Execution

Block Diagram Cleanup

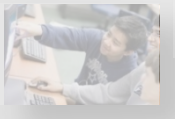
Context Help

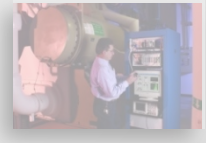






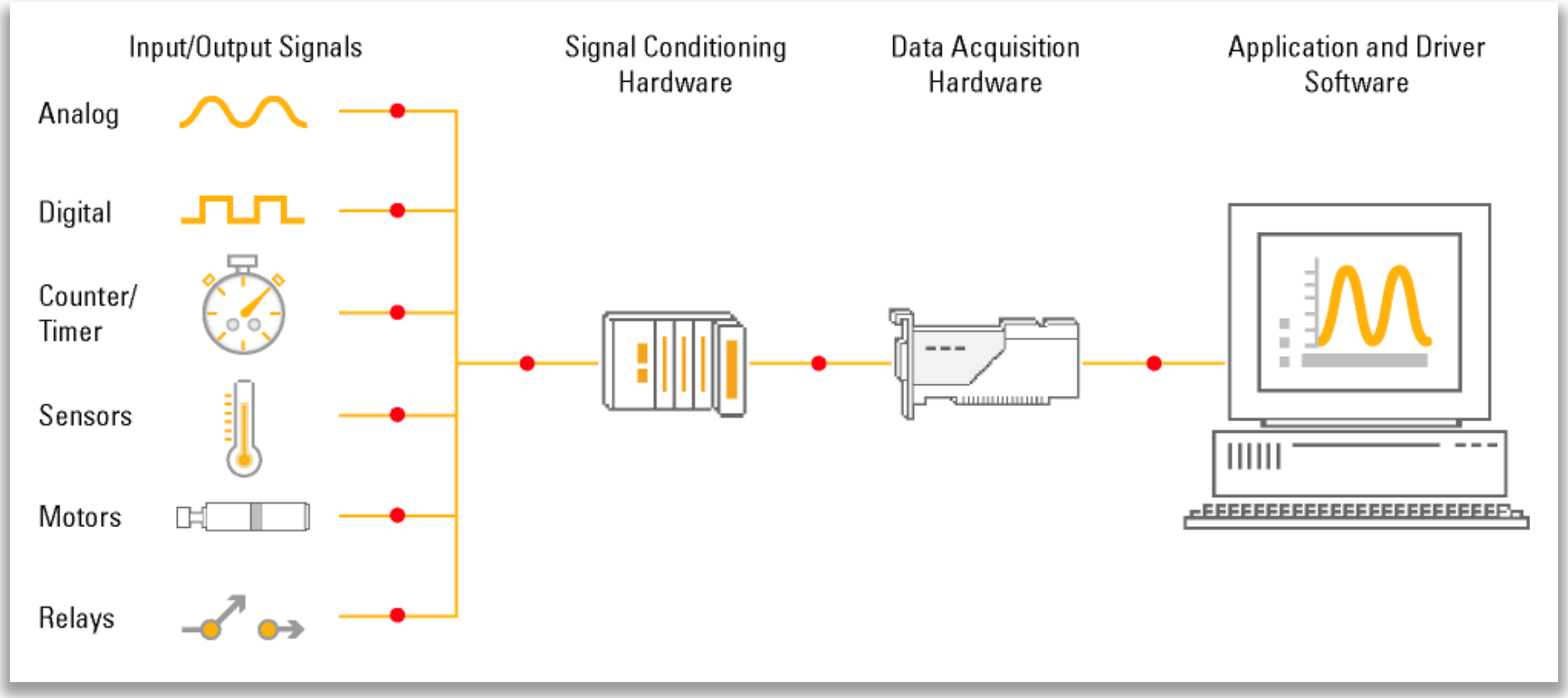




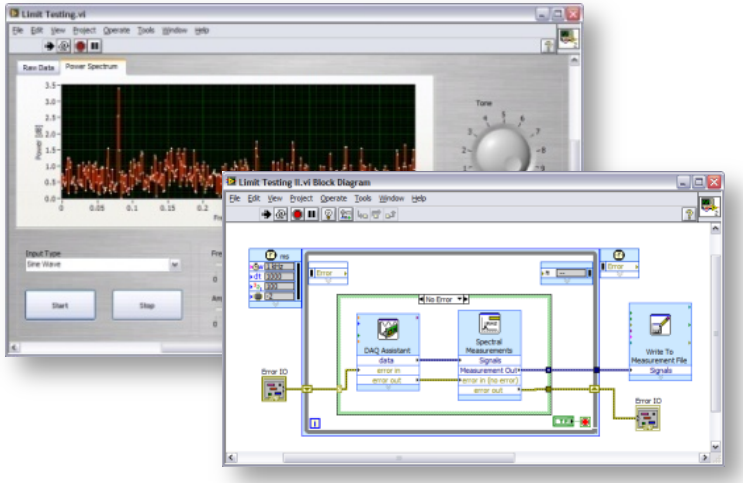


Data Acquisition (Diagnostics & Control) with LabVIEW

PC-Based Data Acquisition (DAQ)



NI DAQ Platforms



One application, multiple targets

USB

PCI

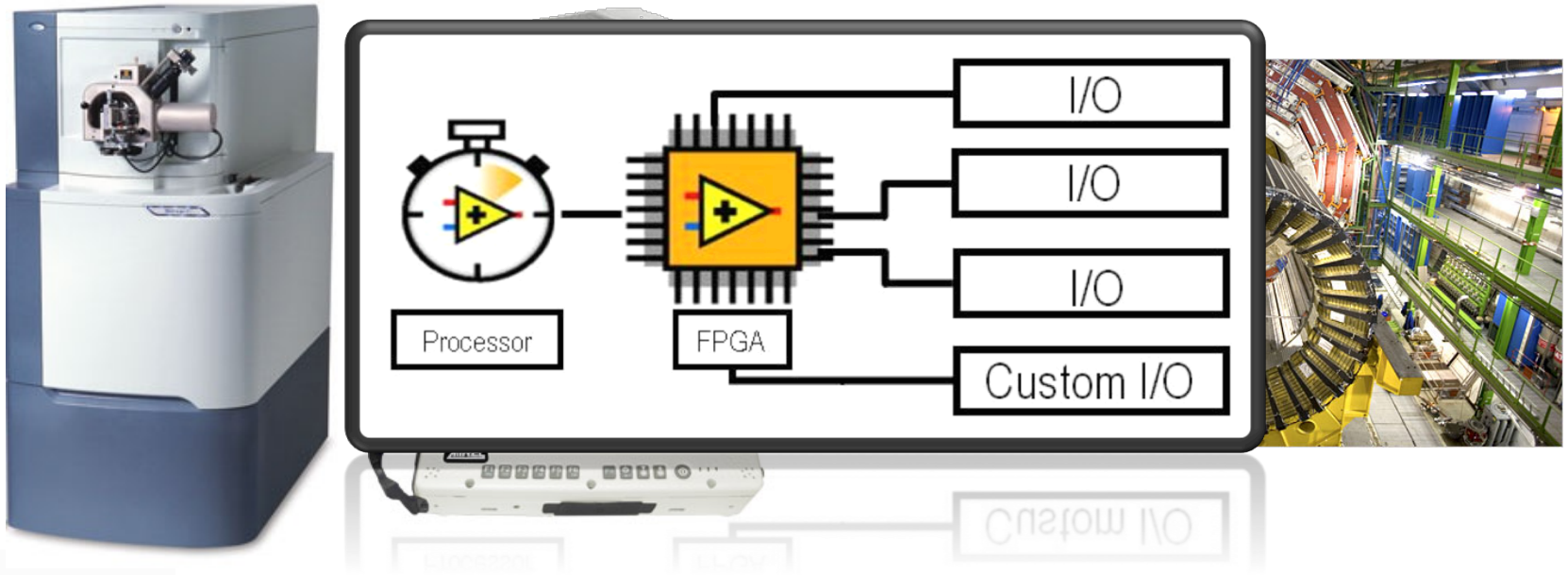
CompactDAQ

PXI

Wireless

Design Approaches

COTS Reconfigurable I/O Custom



NI RIO Technology Platform

Processor

- Enet
- USB
- RTOS
- Analysis
- Multicore
- Logging
- Comm

FPGA

- Analysis IP
- Control IP
- Timing IP
- Comm IP
- IPNet
- 3rd party IP

I/O

- Analog I/O
- Digital I/O
- Comm I/O
- Motion I/O
- 3rd party I/O

NATIONAL INSTRUMENTS LabVIEW™

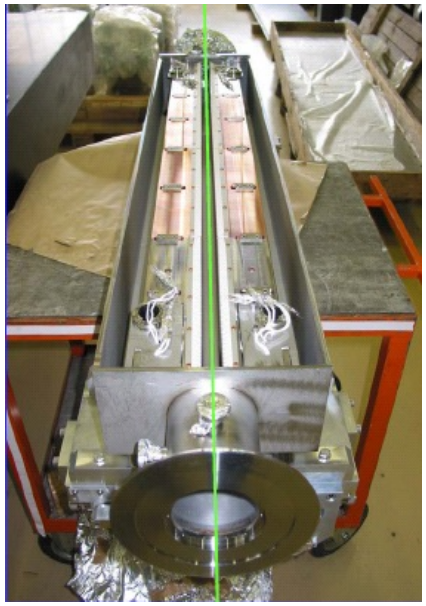
NI RIO Hardware

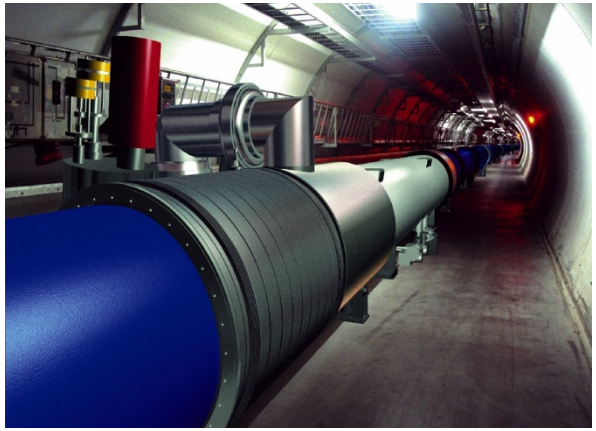
Packaged

Board-Level

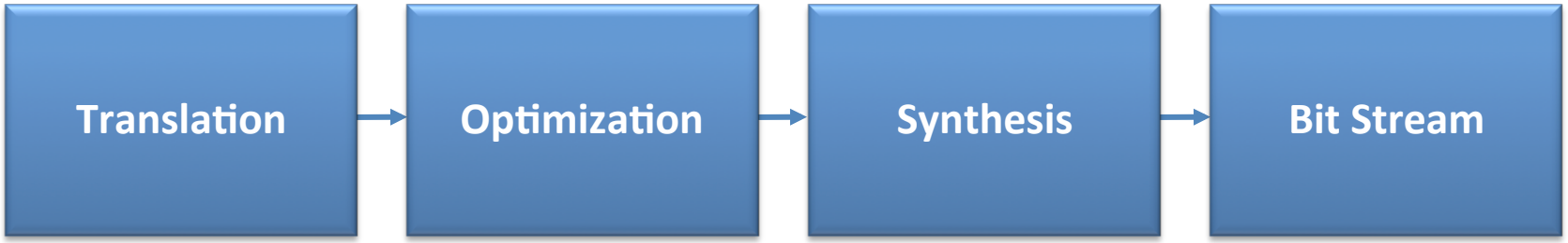
CERN Collimator Alignment

- 550+ axes of motion
- Across 27 km distance
- The jaws have to be positioned with an accuracy which is a fraction of the beam size (200µm)
- Synchronized to
  - < 5ms drift over 15 minutes
  - Maximum jitter in µs





From LabVIEW to Hardware



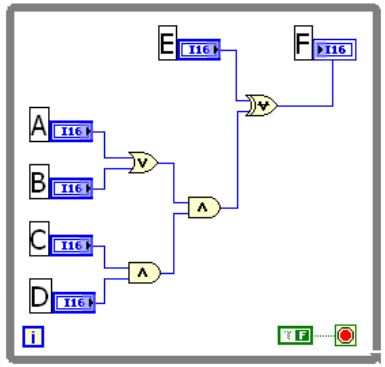
VHDL Generation

Analysis
Logic Reduction

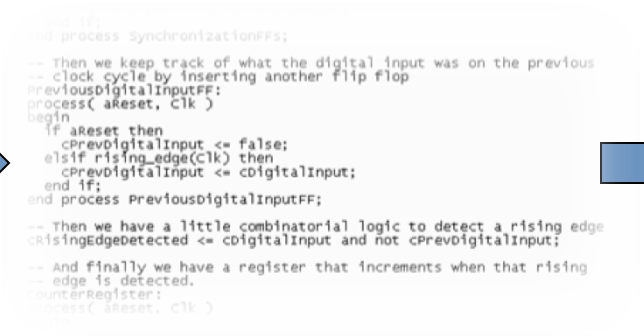
Place and Route
Timing Verification

Generation
Download/Run

LabVIEW FPGA Code

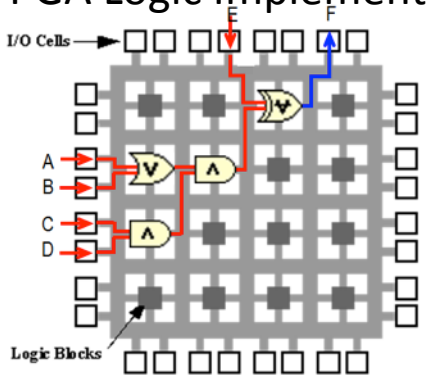


Compile VHDL through Xilinx

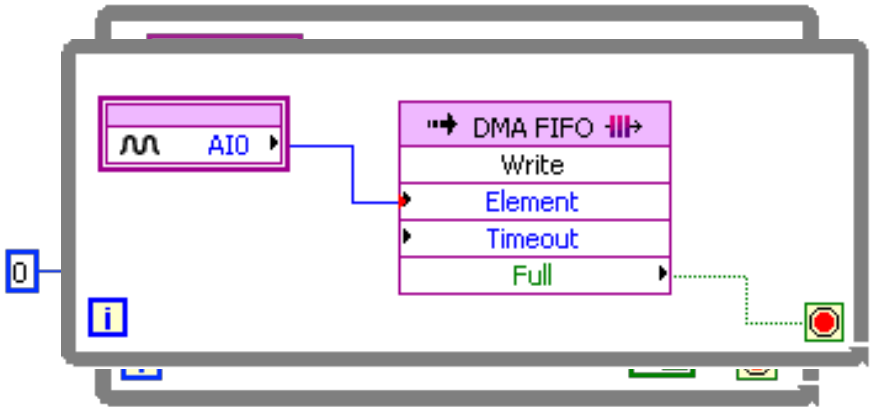


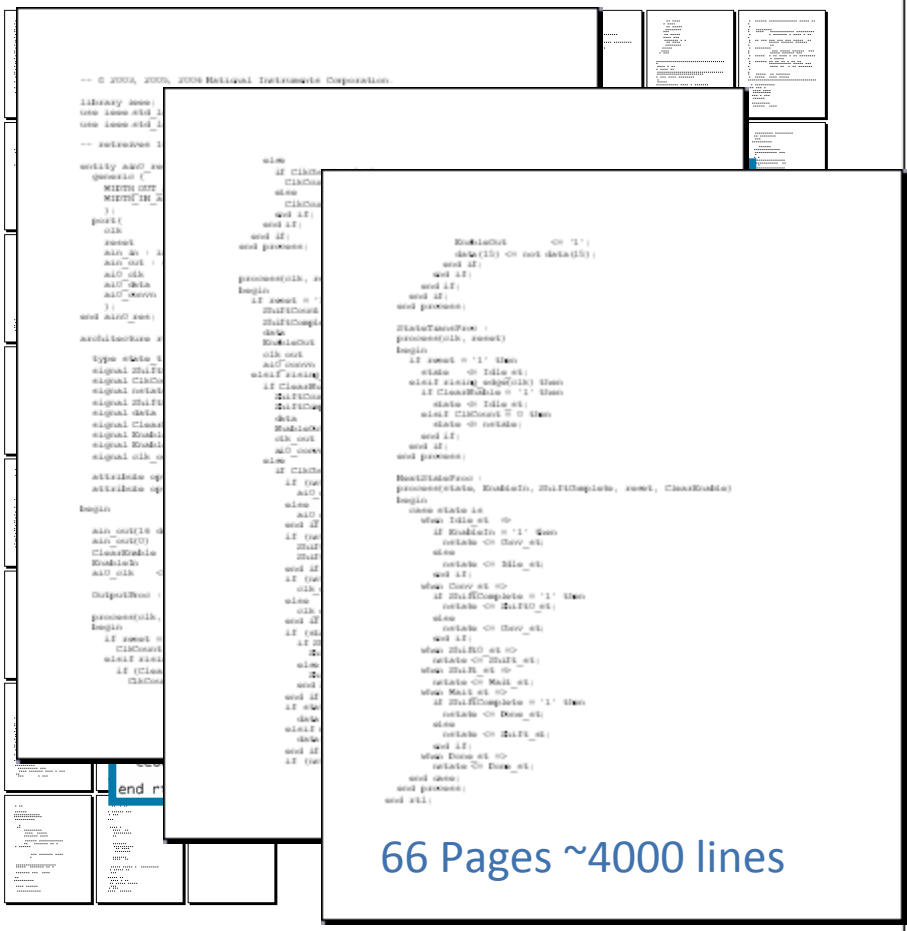
```
process SynchronizationFFs;

-- Then we keep track of what the digital input was on the previous
-- clock cycle by inserting another flip flop
PreviousDigitalInputFF:
process( aReset, Clk )
begin
  if aReset then
    cPrevDigitalInput <= false;
  elsif rising_edge(Clk) then
    cPrevDigitalInput <= cDigitalInput;
  end if;
end process PreviousDigitalInputFF;

-- Then we have a little combinatorial logic to detect a rising edge
cRisingEdgeDetected <= cDigitalInput and not cPrevDigitalInput;

-- And finally we have a register that increments when that rising
-- edge is detected.
CounterRegister:
process( aReset, Clk )
```

FPGA Logic Implementation



LabVIEW FPGA vs. VHDL





Counter

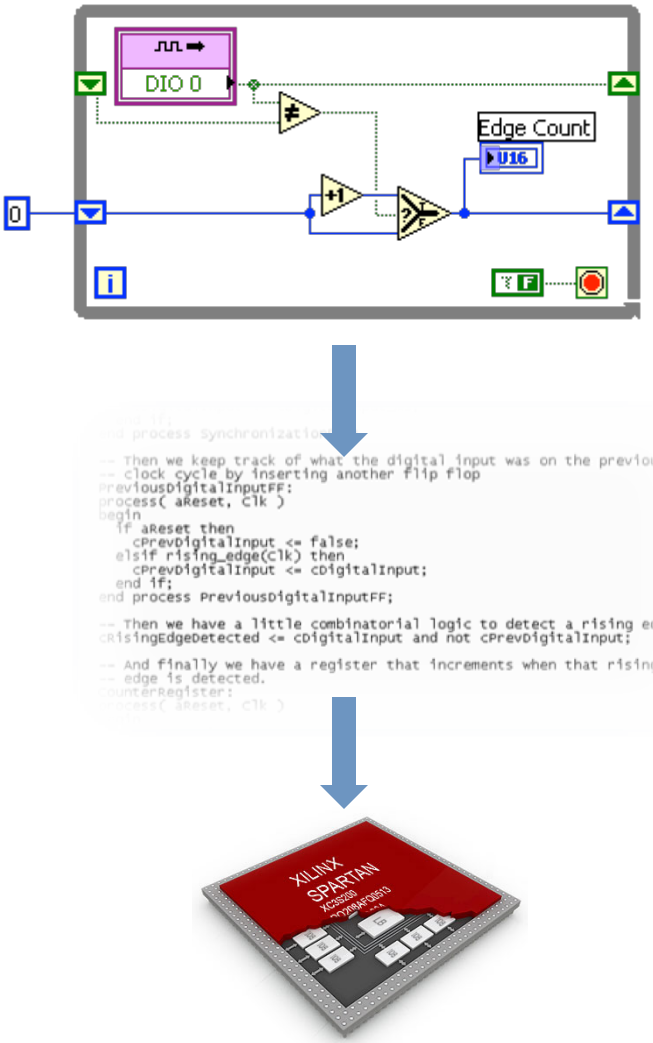
Analog I/O

I/O with DMA

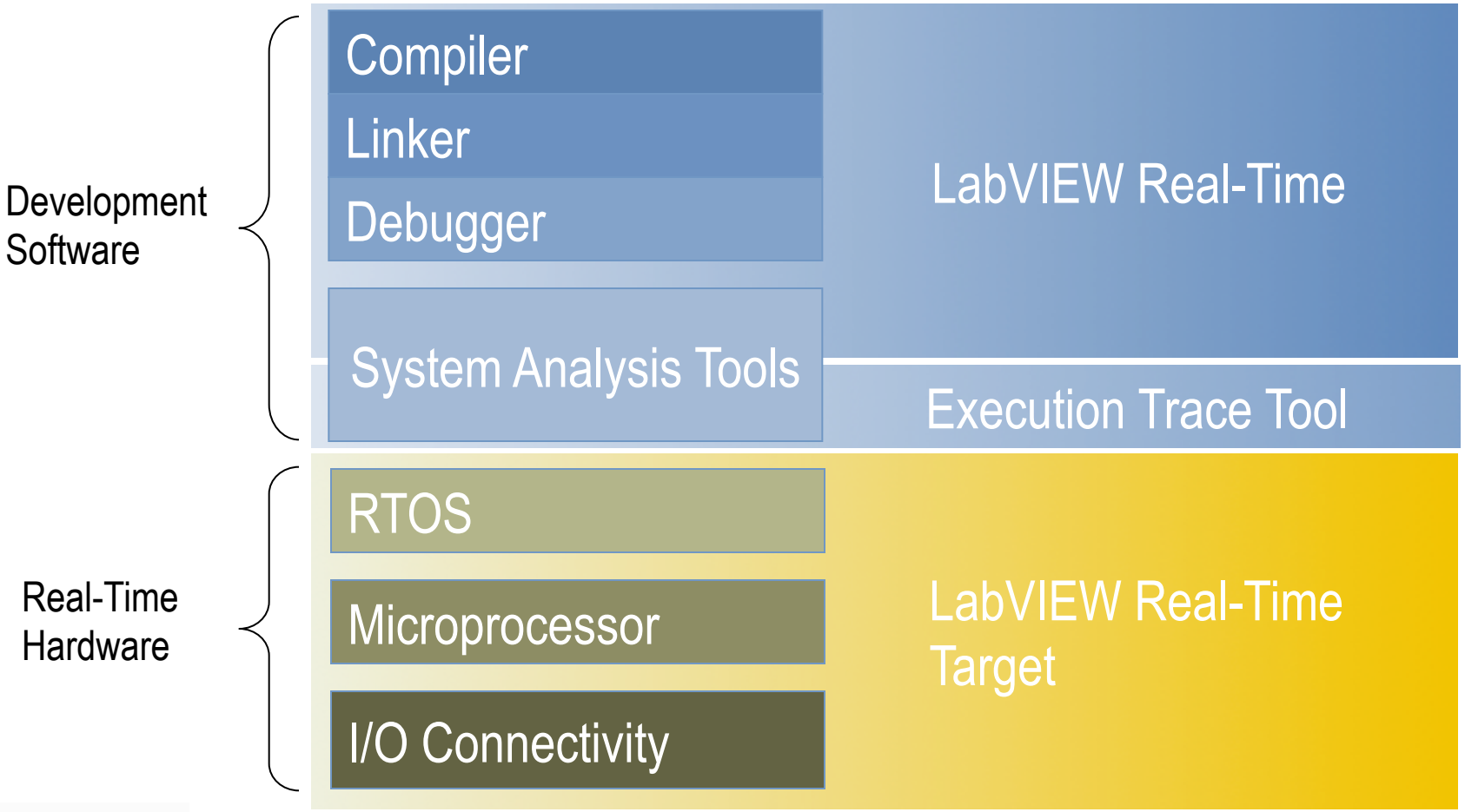
NATIONAL INSTRUMENTS

How Does LabVIEW FPGA Work?

1. Same graphical programming
2. Generate VHDL
3. Compile VHDL through Xilinx
4. Generate downloadable bit file

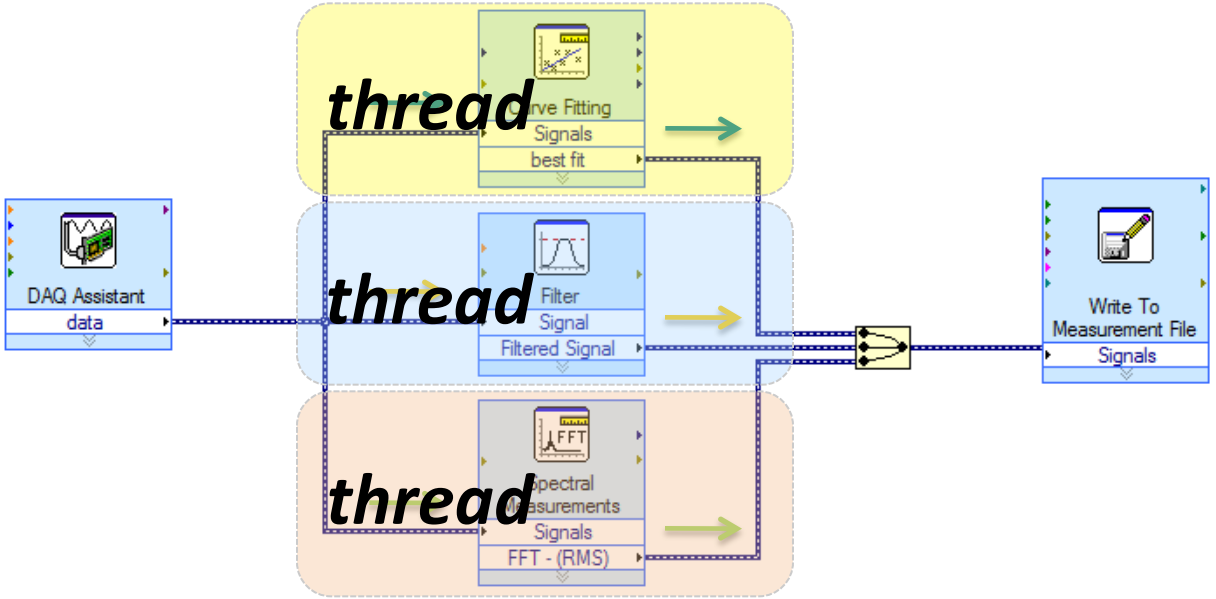


Real-Time Development Tools



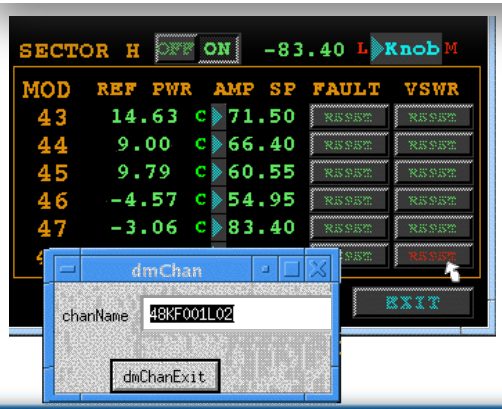
Automatic Multithreading in LabVIEW

- LabVIEW automatically divides each application into multiple execution threads (introduced in 1998 with LabVIEW 5.0)
- Parallel code paths will execute in unique threads

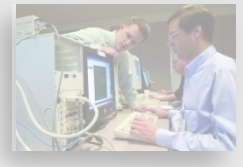


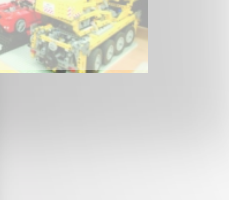
Los Alamos LANSCE – R Upgrade

- Refurbishment of LINAC
  - Remote instrumentation and data acquisition
  - Industrial control
- Ongoing migration to NI CompactRIO system with embedded EPICS
  - LabVIEW for beam diagnostic
  - EPICS for industrial control





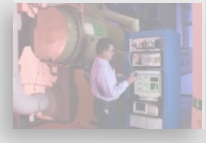









Analysis and
Signal Processing

LabVIEW Signal Processing, Analysis and Math

- **Signal Processing & Analysis**
  - Waveform Generation
  - Waveform Conditioning
  - Waveform Monitoring
  - Waveform Measurements
  - Signal Generation
  - Signal Operations
  - Windows
  - Digital Filters
  - Spectral Analysis
  - Transforms
  - Point-by-Point

- **Mathematics**
  - Numeric
  - Elementary and Special Functions
  - BLAS/LAPAC-based Linear Algebra
  - Curve Fitting
  - Interpolation / Extrapolation
  - Probability and Statistics
  - Optimization
  - Ordinary Differential Equations
  - Geometry
  - Polynomial
  - Formula Parsing
  - 1D & 2D Evaluation
  - Calculus

Using Analysis Functions

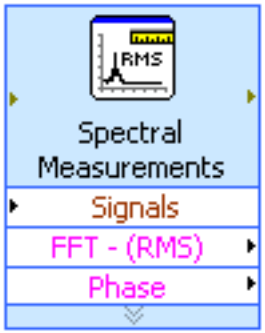
My Application.vi Block Diagram

File Edit View Project Operate Tools Window Help

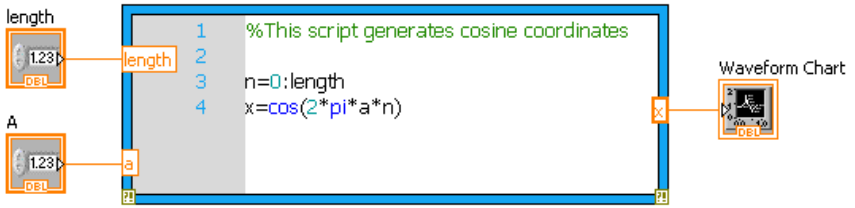
20pt Application Font

Programmatic, Low-Level VIs

Configuration Based Express VIs



Text-based MathScript Node



Advanced Analysis - Mind/Computer Interface

ambient

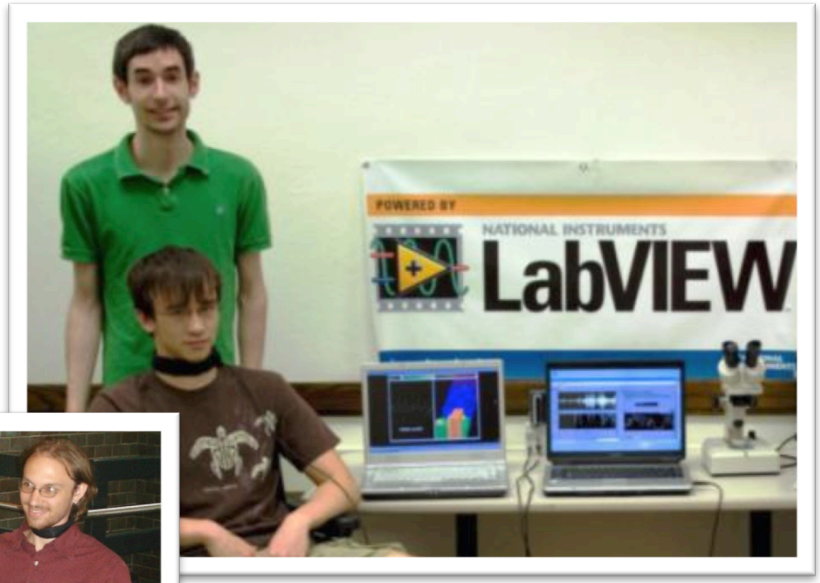
www.theaudeo.com

Application

University of Illinois engineering students worked with LabVIEW to develop a device that translates thought into control commands.

NI Products

Signal Processing in LabVIEW
USB DAQ

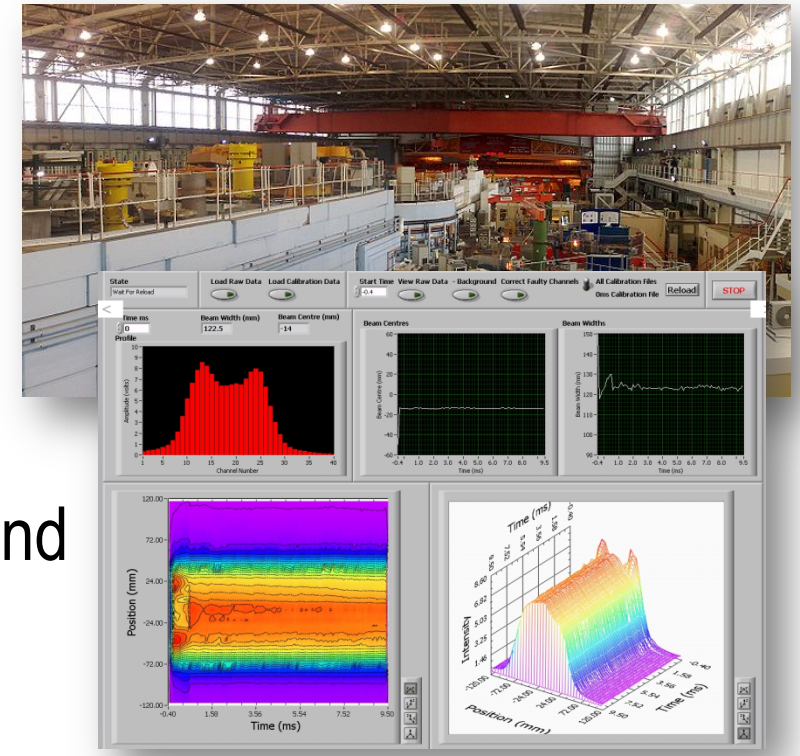


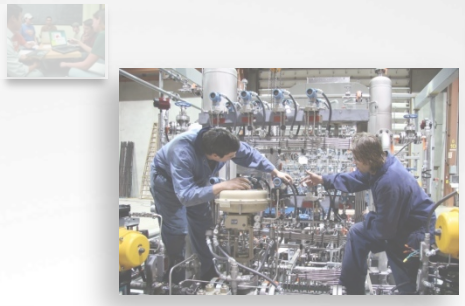
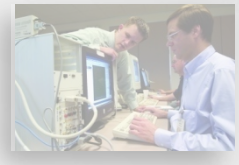
"LabVIEW simplifies development and encourages innovation by offering an intuitive graphical programming approach; you can focus on innovation rather than programming details."

- Michael Callahan, CEO, Ambient

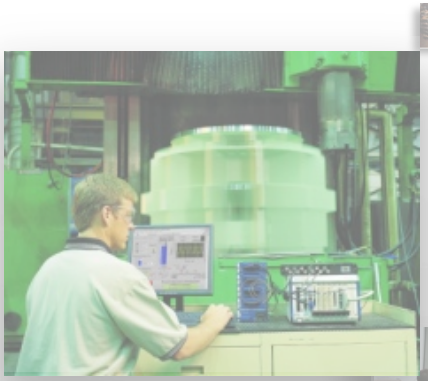
ISIS Synchrotron, Rutherford Appleton Labs

- Beam data acquisition and analysis
  - Beam loss monitoring
  - Beam position monitoring
  - Multichannel profile monitoring
- Hardware based on PXI platform
  - High speed digitizers
  - Timing and synchronization
- LabVIEW based control system and process display data

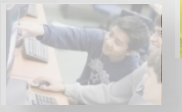


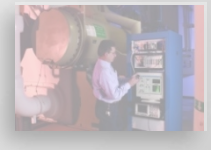













Reporting and Data Visualization

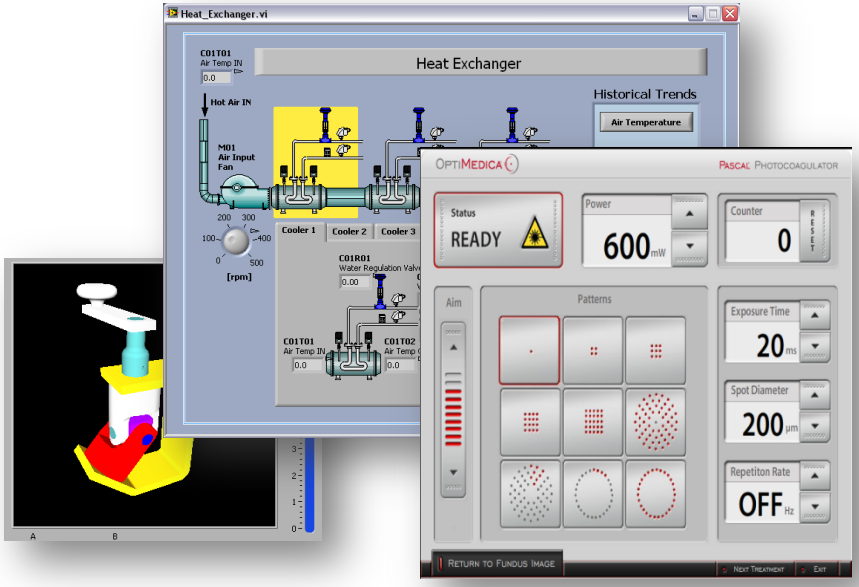
Data Visualization and Communication

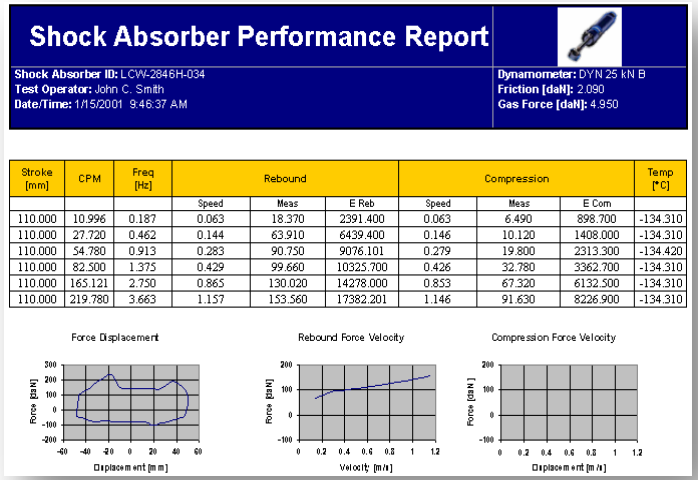
Visualization

- Built-in user interface objects
- Charting and graphing capabilities
- Remote application control

Reporting and Data Storage

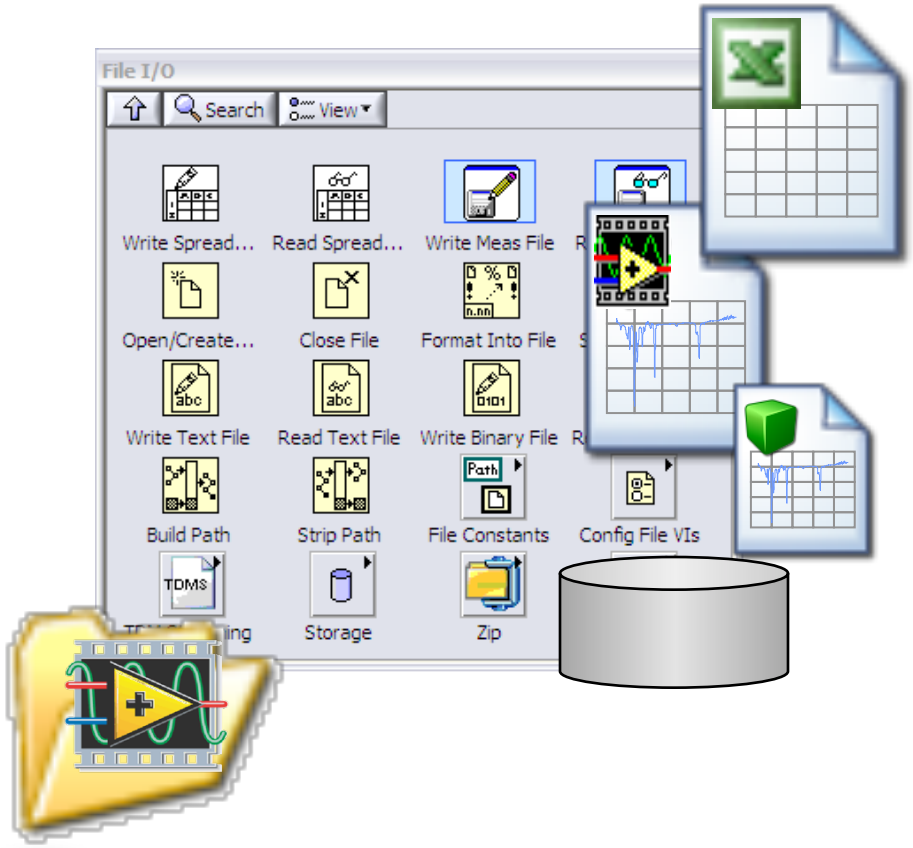
- File I/O functionality
- HTML reports for the Web
- Microsoft Word and Excel reports





Stroke [mm]	CPM	Freq [Hz]	Rebound			Compression			Temp [°C]
			Speed	Meas	E Reb	Speed	Meas	E Com	
110.000	10.996	0.187	0.063	18.370	2391.400	0.063	6.490	898.700	-134.310
110.000	27.720	0.462	0.144	63.910	6439.400	0.146	10.120	1408.000	-134.310
110.000	54.780	0.913	0.283	90.750	9076.101	0.279	19.800	2313.300	-134.420
110.000	82.500	1.375	0.429	99.660	10325.700	0.426	32.780	3362.700	-134.310
110.000	165.121	2.750	0.865	130.020	14278.000	0.853	67.320	6132.500	-134.310
110.000	219.780	3.663	1.157	153.560	17382.201	1.146	91.630	8226.900	-134.310

LabVIEW Supported Storage Types



- ASCII
- Binary
- HTML
- XML
- LVM
- TDM(S) *
- Excel
- Word
- Datalog
- Databases

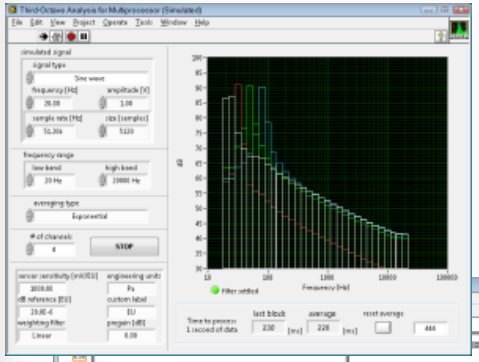
Graphical System Design

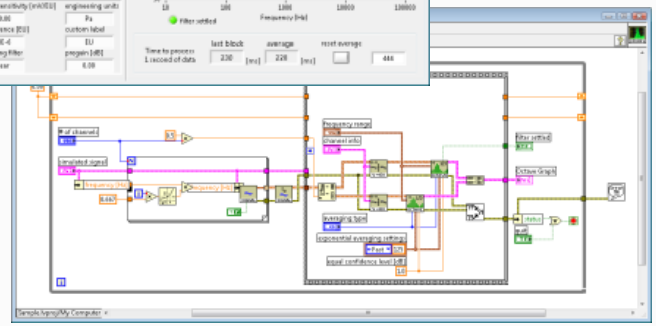
LEGO® MINDSTORMS® NXT

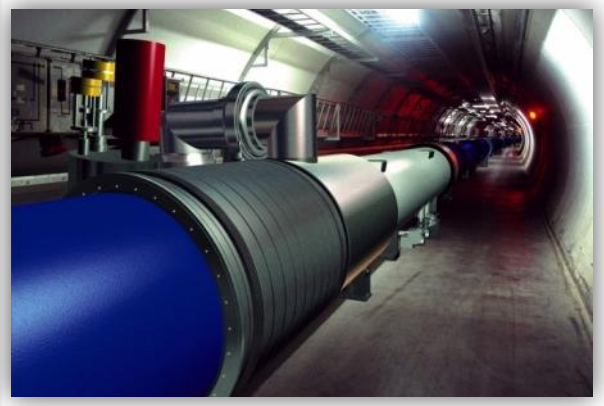
"the smartest, coolest toy of the year"

POWERED BY

NATIONAL INSTRUMENTS LabVIEW™







CERN Large Hadron Collider

"the most powerful instrument on earth"

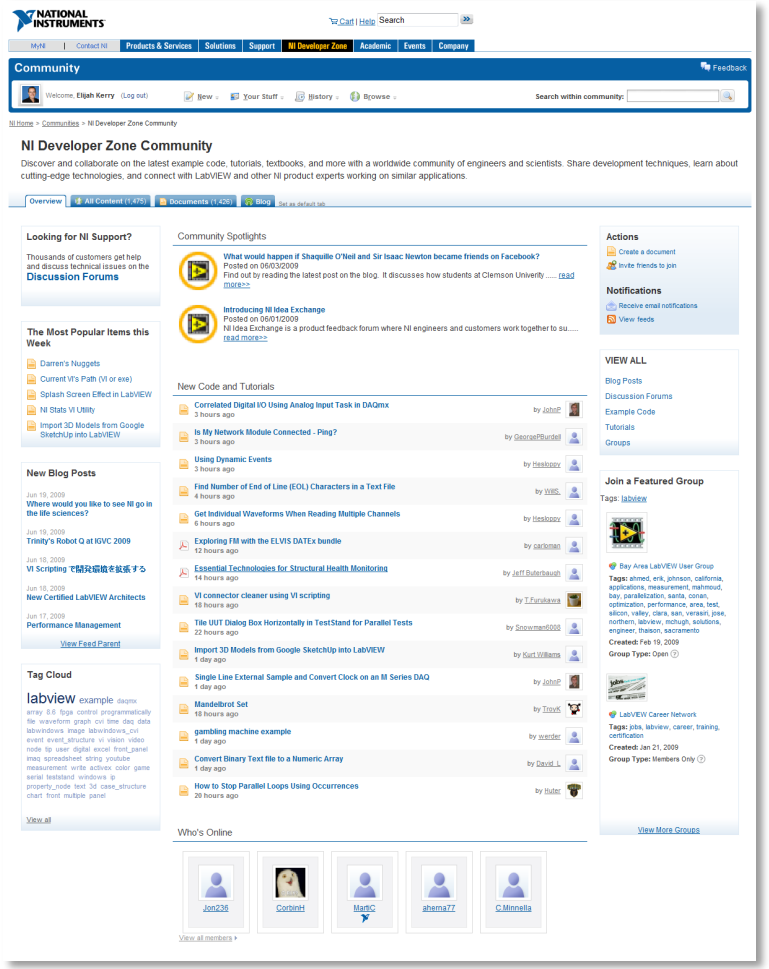
Summary

- LabVIEW is a graphical programming language
- Ability to program FPGA and real-time targets
- Widely used for measurement, diagnostics and control - both in industry and physics

Next Steps

Worldwide LabVIEW User Community

- Over 100,000 members on award-winning NI Discussion Forums
- NI and LabVIEW user-contributed examples, tutorials and blogs
- More than 100 LabVIEW User Groups
- Third-party community web sites in over 15 languages
- Hundreds of third-party add-on tools on the LabVIEW Tools Network



Learn More about NI LabVIEW and NI DAQ Systems

- Check out additional **LabVIEW** exercises for Automated Test, Industrial Measurement and Control and Embedded: www.ni.com/labview/whatis
- View DAQ product specs and demos: www.ni.com/daq

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Membership in a National Instruments software maintenance and support program allows you to:

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- Enjoy direct access to technical support from NI applications engineers
- Access special online software training modules that highlight features, application uses, and development best practices

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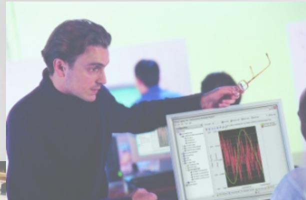
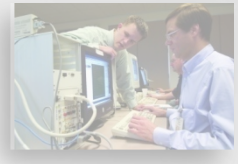
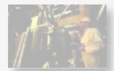
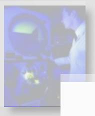
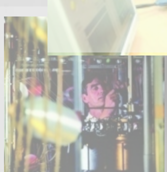
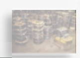


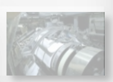


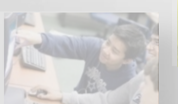



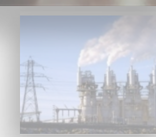
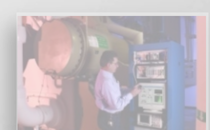
LabVIEW Modules and Toolkits



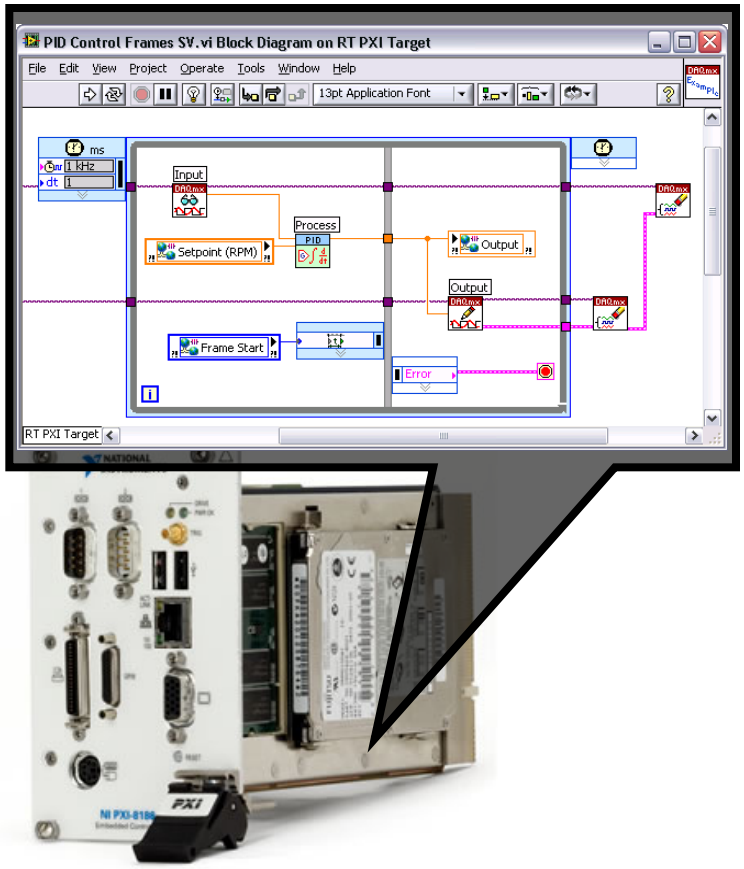




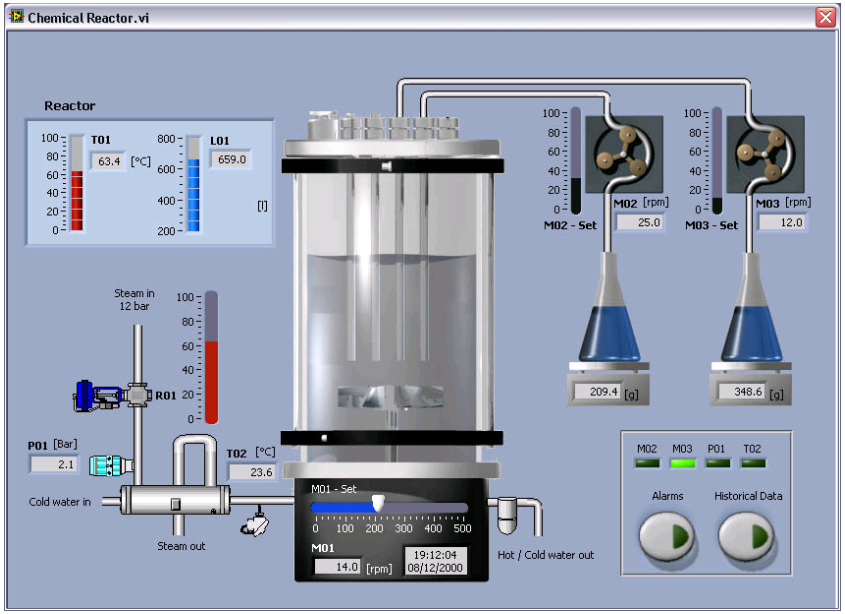
LabVIEW Real-Time Module

- Rapidly develop deterministic applications with graphical programming
- Easily architect distributed control and monitoring systems
- Eliminate time spent integrating diverse I/O



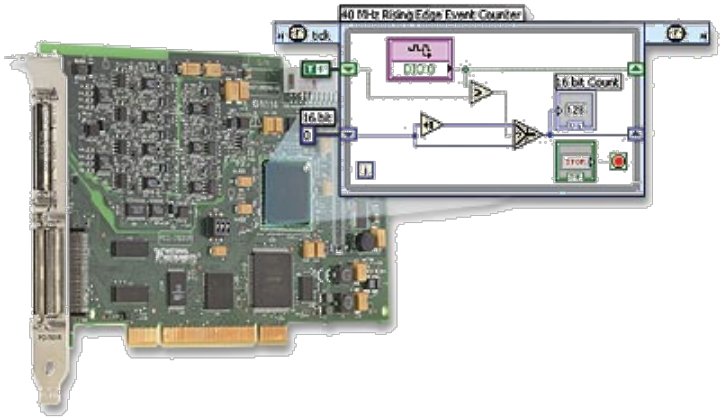
LabVIEW Datalogging and Supervisory Control Module

- Graphical development for distributed monitoring and control systems
- Trend real-time and historical data
- Log data from any networked I/O to a historical database
- Monitor and log alarms and events
- Network LabVIEW Real-Time targets and OPC devices
- Add security to LabVIEW user interfaces

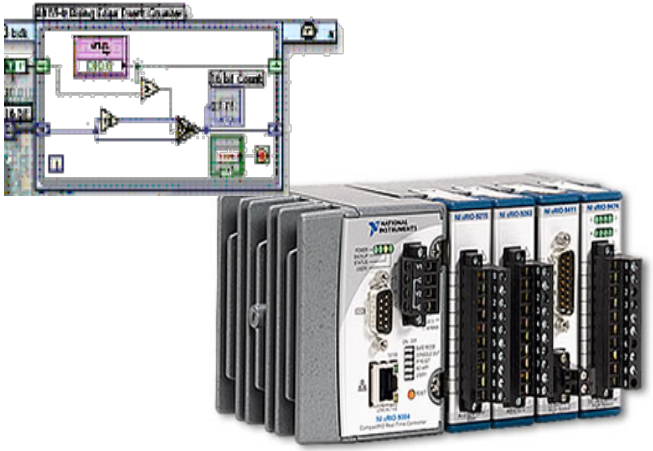


LabVIEW FPGA Module

- Define custom FPGA I/O without VHDL programming
- Achieve hardware deterministic response within 25ns
- Execute tasks with true parallelism

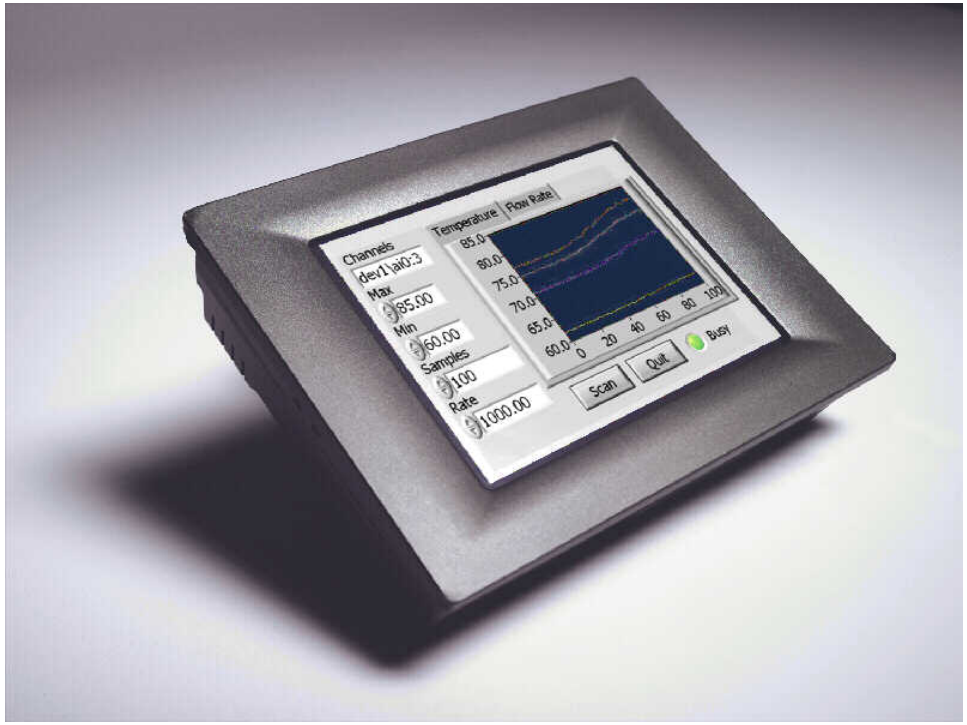


R Series Intelligent DAQ



NI CompactRIO

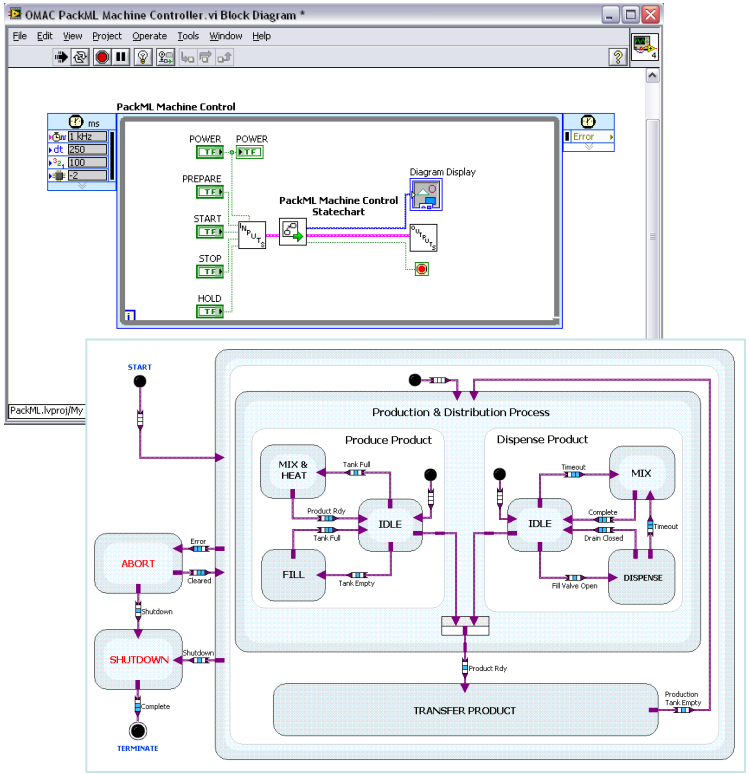
LabVIEW Touch Panel Module



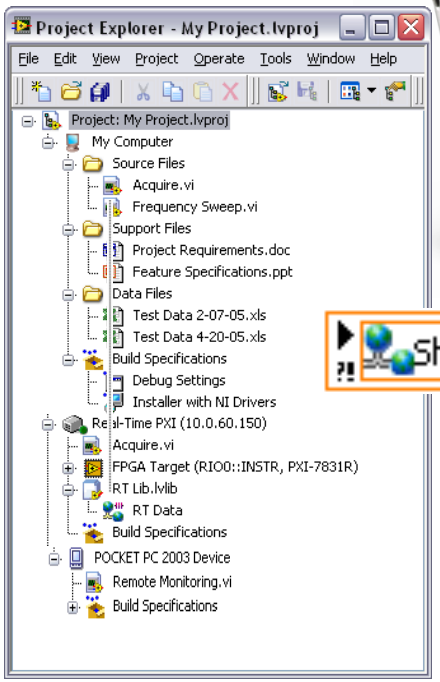
Create custom human-machine interface (HMI) applications for the NI TPC-2006 and other Windows CE devices

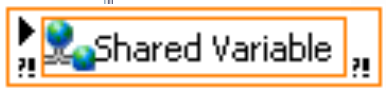
LabVIEW Statechart Module

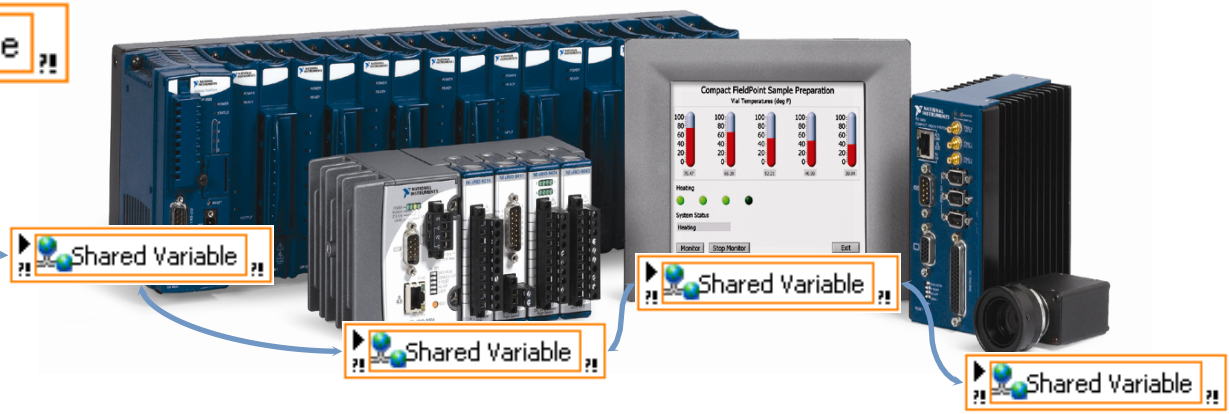
- Statecharts provide high-level abstraction for state based applications
  - Simple semantics represent complex systems
  - Self-documenting design
- Integrate statecharts into existing LabVIEW applications
- Generate code for desktop, Real-time, FPGA, and embedded targets



LabVIEW Mobile Module



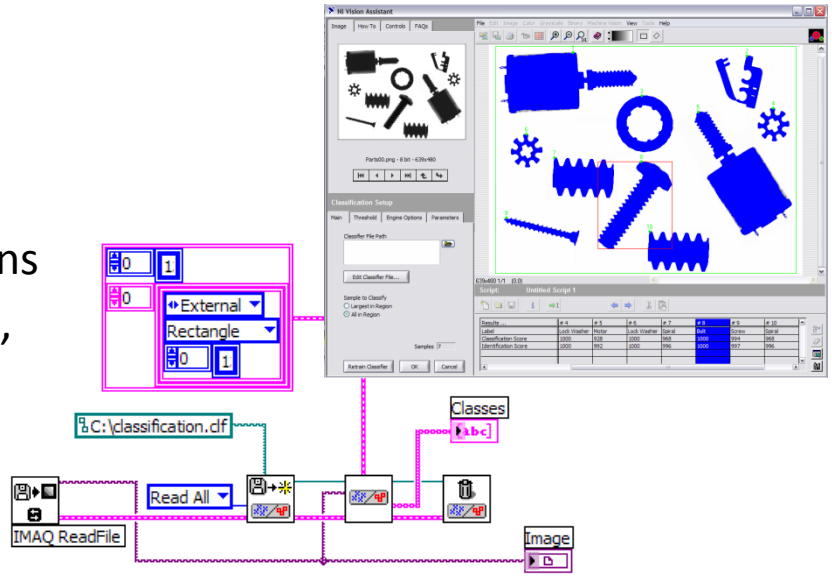


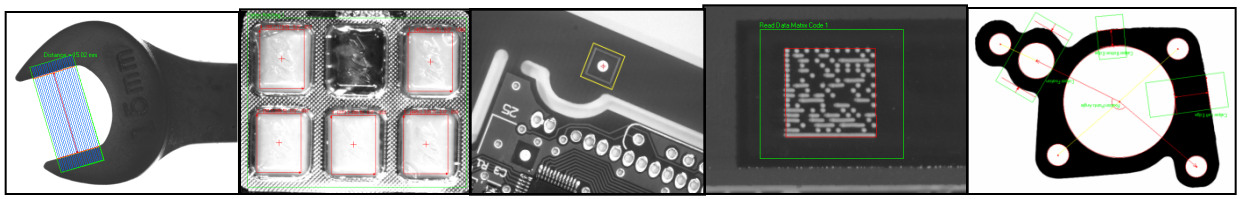


- Wireless communication with shared variable
- Portable low-cost USB DAQ

NI Vision Development Module

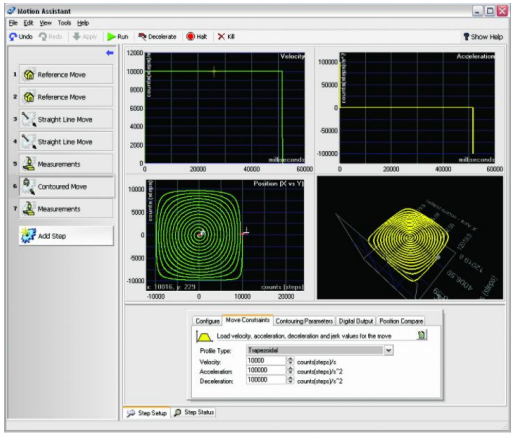
- LabVIEW programming libraries for machine vision and image processing
- Includes Vision Assistant
  - Prototypes and benchmarks applications
  - Generates complete code for LabVIEW, Visual Basic, and C
- Hundreds of tools to:
  - Enhance images
  - Check for presence
  - Locate features
  - Identify parts
  - Measure objects





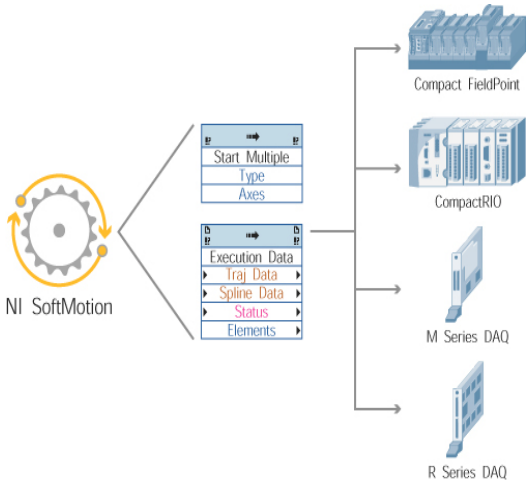
Motion Control with LabVIEW

- **NI Motion Assistant**
  - Interactive environment with 3D visualization
  - Ready-to-run LabVIEW or C code creation
  - Easy trapezoidal or S-curve velocity profile implementation
  - Teach pendant for easy prototyping



- **NI SoftMotion Controller for CANopen and IEEE 1394**
  - Use LabVIEW and NI Motion Assistant to program distributed motion control applications
  - Compatible with intelligent CANopen drives from Copley and IEEE 1394 drives from ORMEC

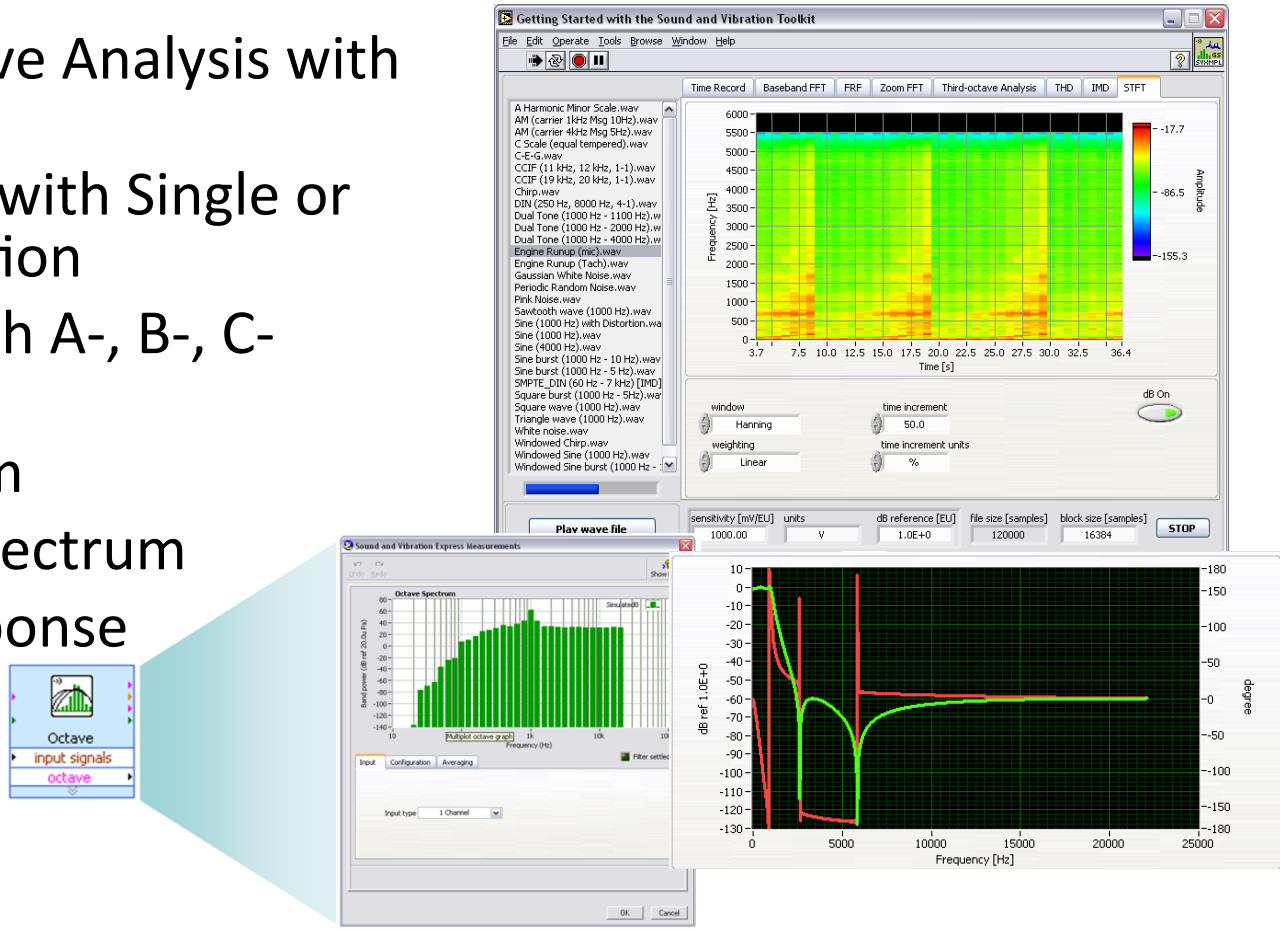
- **NI SoftMotion Development Module**
  - Develop custom motion controllers in LabVIEW Real-Time or LabVIEW FPGA
  - Use trajectory generation, spline interpolation, position, velocity control, and encoder implementation VIs



LabVIEW Sound and Vibration Toolkit

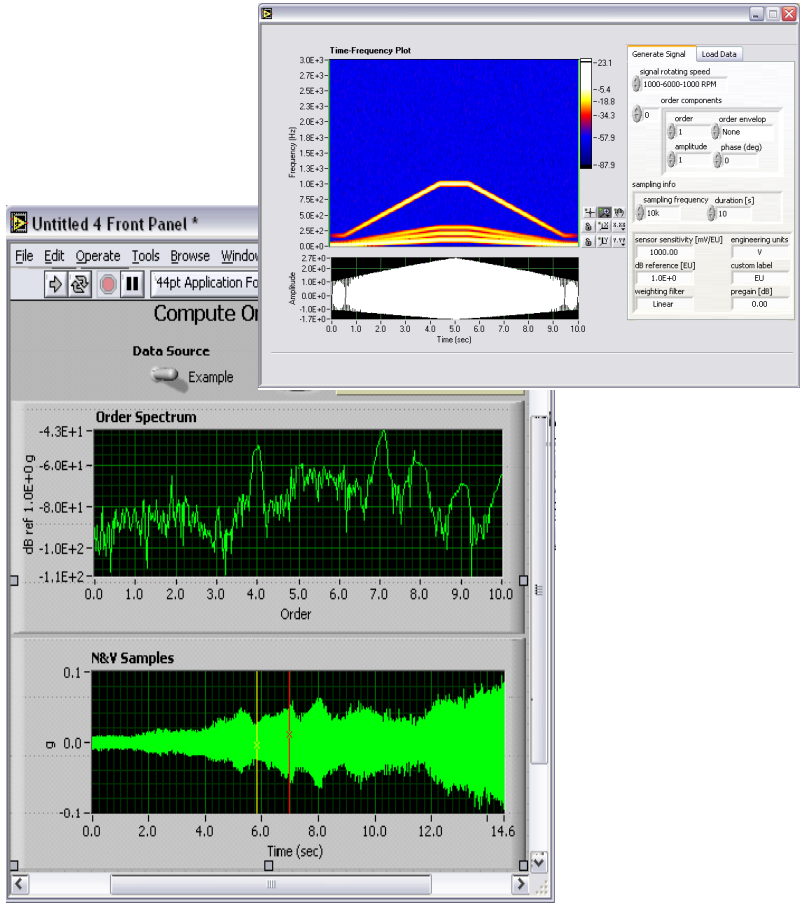
10 Express VIs

- Fractional Octave Analysis with Weighting
- Vibration Level with Single or Double Integration
- Sound Level with A-, B-, C-Weighting
- Power Spectrum
- Zoom Power Spectrum
- Frequency Response
- Peak Search
- Power in Band
- Limit Testing



LabVIEW Order Analysis Toolkit

- Gabor order tracking algorithm analyzes signals from rotating machinery
- Resampling order analysis for online condition monitoring
- Flexible order energy selection in the joint time-frequency domain
- Plot order versus time or RPM
- Order extraction tools separate order-specific signal components
- Digital and analog tachometer signal processing



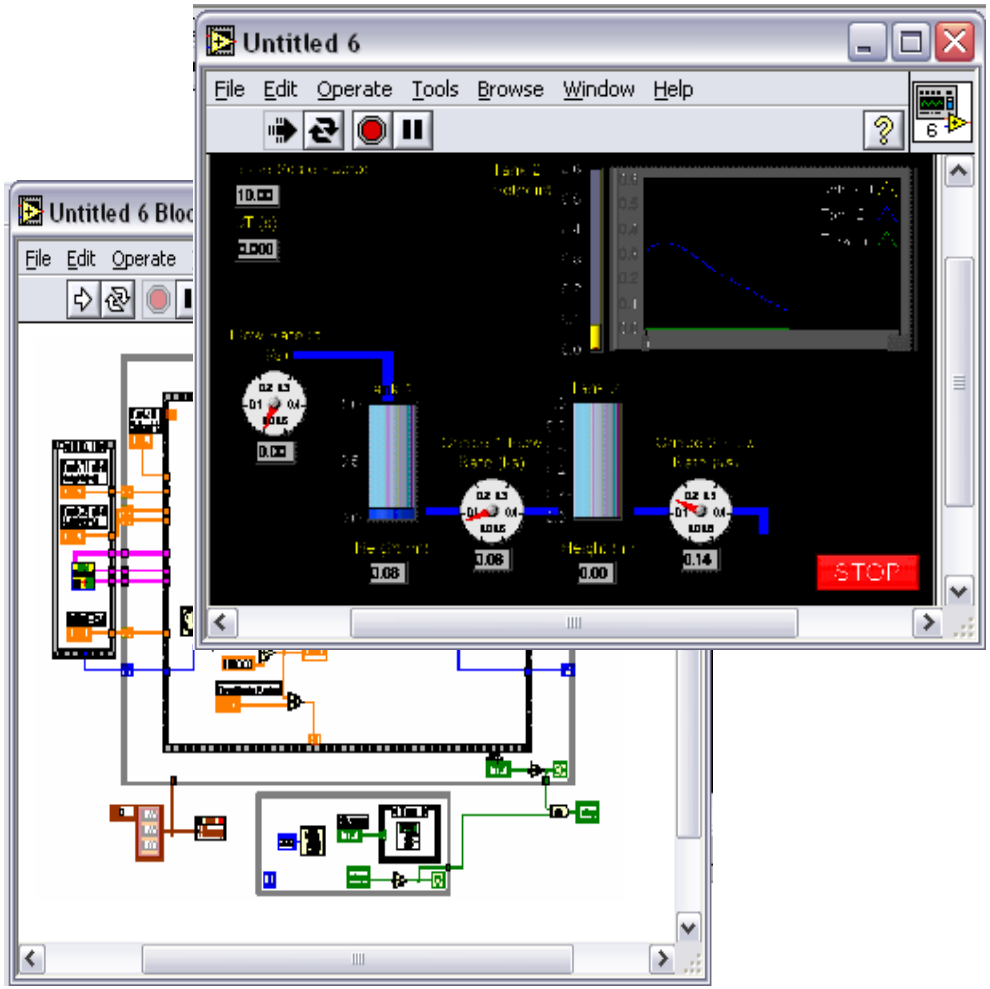
PID Control Toolkit

PID Control

- Autotuning
- Gain scheduling

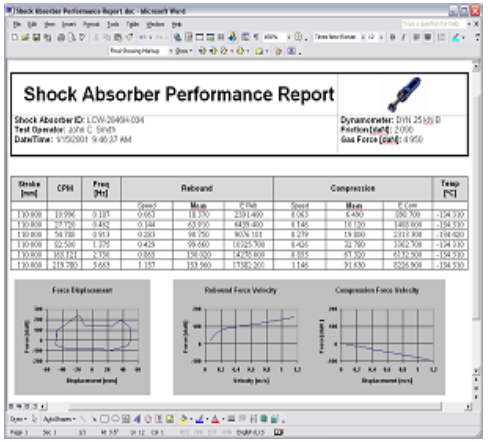
Fuzzy Logic

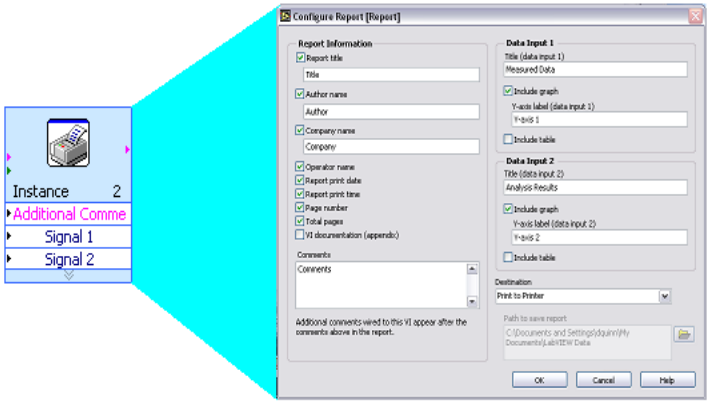
- Control strategies
- Decision making



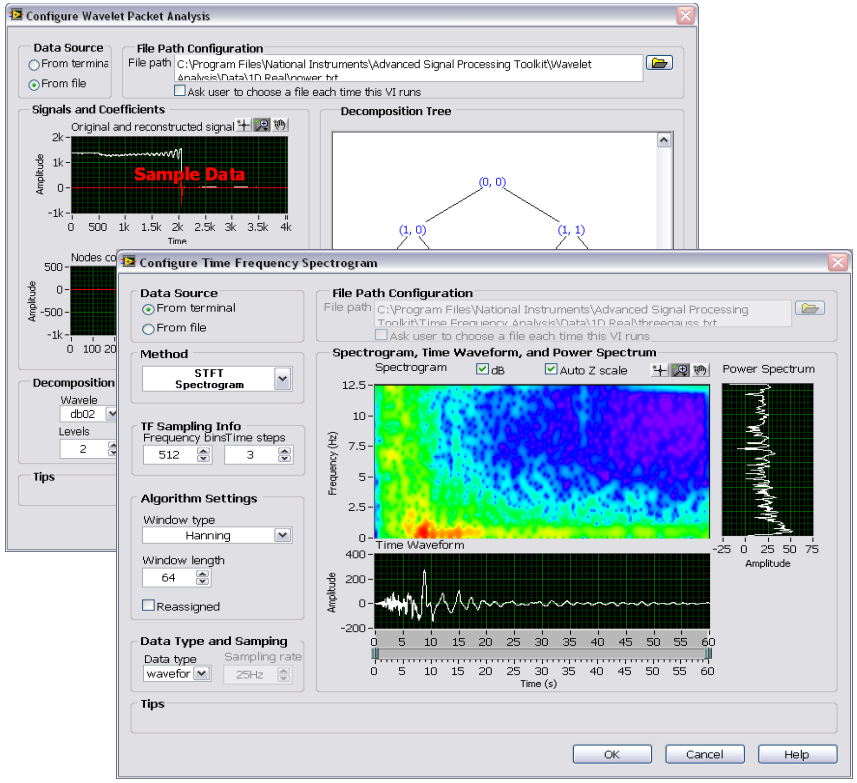
Report Generation Toolkit for Microsoft Office

- Programmatically create and edit reports in Microsoft Word and Excel
- Populate report templates
- Manage report layout, format, and appearance
- E-mail reports and run macros
- Express VI included





LabVIEW Advanced Signal Processing Toolkit



- Time-Frequency Analysis
- Time-Series Analysis
- Wavelet and filter bank design
- Applications
  - Automotive
  - Biomedical
  - Seismology
  - Radar/Sonar

Database Connectivity Toolkit

- Insert, select data from OLE DB, ODBC databases
  - Microsoft Access, SQL Server, Oracle, etc.
- Create, drop tables
- Save records in XML format
- Execute SQL queries
  - Immediate, parameterized
- Execute stored procedures
- Accept, reject multiple operations (transactions)