

NIDays

THE LabVIEW CONFERENCE

Under the Hood

LabVIEW Real-Time Module for Linux RT

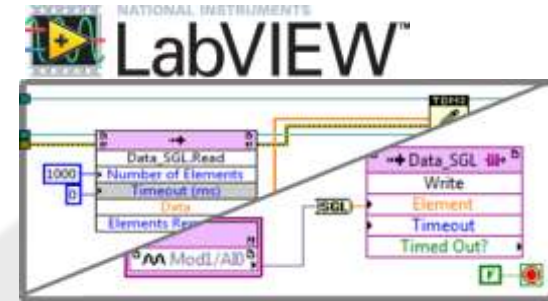
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Northern Region | Certified LabVIEW Developer

Agenda

- Hardware Overview
- Introduction to NI Linux Real-Time
- Filesystem
- Connectivity and Security
- Configuration and Deployment
- Other Key Features
 - New VIs, C/C++ Support, OPKG, etc.

The Redesigned CompactRIO System



NI LabVIEW System Design

- Program with LabVIEW Real-Time and LabVIEW FPGA modules
- Quickly port existing LabVIEW applications

Ultra Rugged

- 40 to 70° C operating temperature range
- 50 g shock and 5 g vibration tolerance

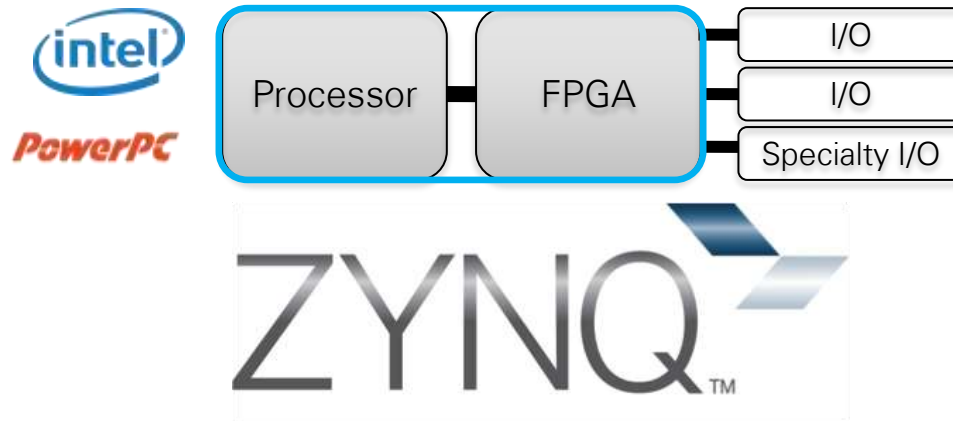
High Performance and Throughput

- Dual-Core ARM 667 MHz processor
- Xilinx 7 Series FPGA fabric with 85k logic cells
- 16 DMA FIFO channels for data streaming

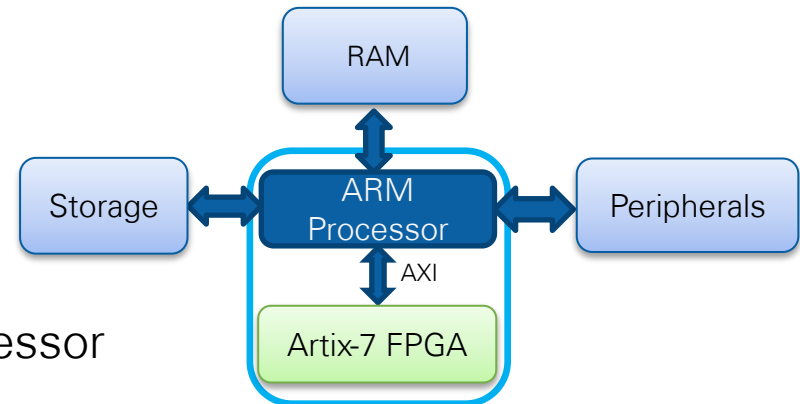
Community and Code Reuse

- NI Linux Real-Time Operating System
- Integrate existing applications and libraries
- Develop, debug, and deploy C/C++ code

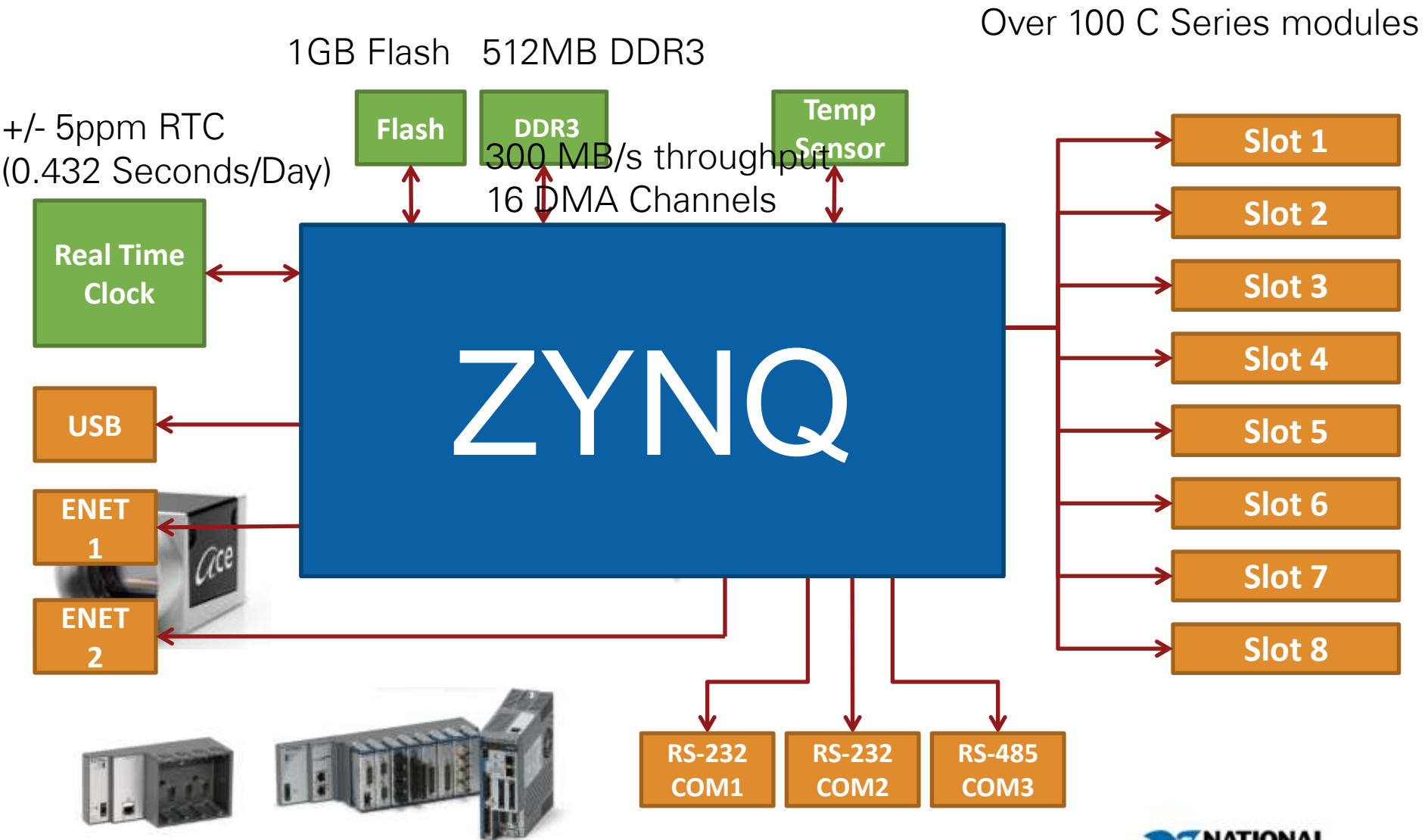
New Value CompactRIO Hardware Architecture



- AXI Bus between FPGA and processor
 - 300 MB/s throughput
- 667 MHz Dual-Core ARM Cortex-A9 Processor
 - Some peripherals routed through FPGA
- Artix-7 FPGA with 85K Logic Cells
 - 220 DSP Slices

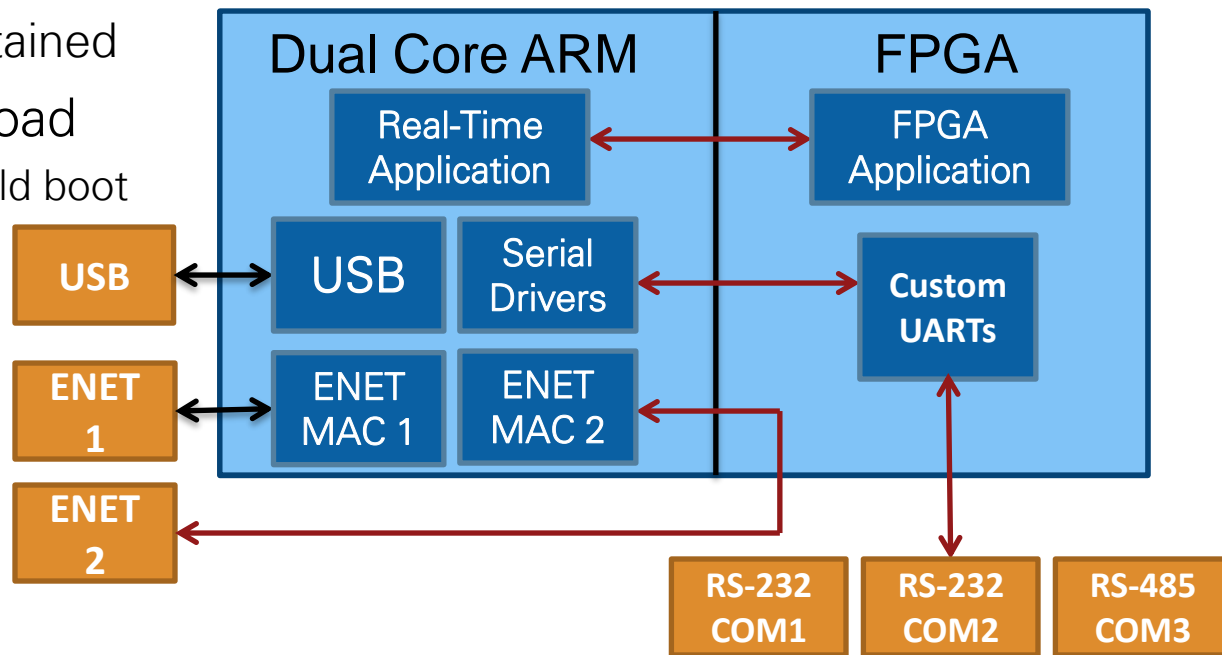


cRIO-9068 Under the Hood



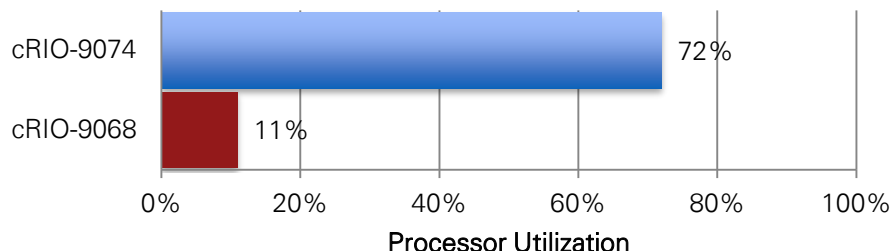
FPGA Inconsistencies on Xilinx Zynq

- FPGA loses configuration when system reboots
 - Arises from combination of processor and FPGA into a single chip
- Ethernet packets on secondary NIC and Serial data lost when FPGA is configured or reset
 - Due to routing of secondary Ethernet and all serial peripherals through FPGA fabric
 - Connection is maintained
- FPGA takes ~1.8s to load
 - 1.8 s is time from a cold boot
 - Faster load time if already running

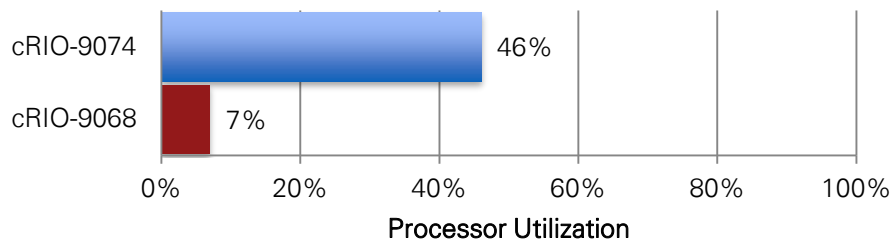


Performance Benchmarks

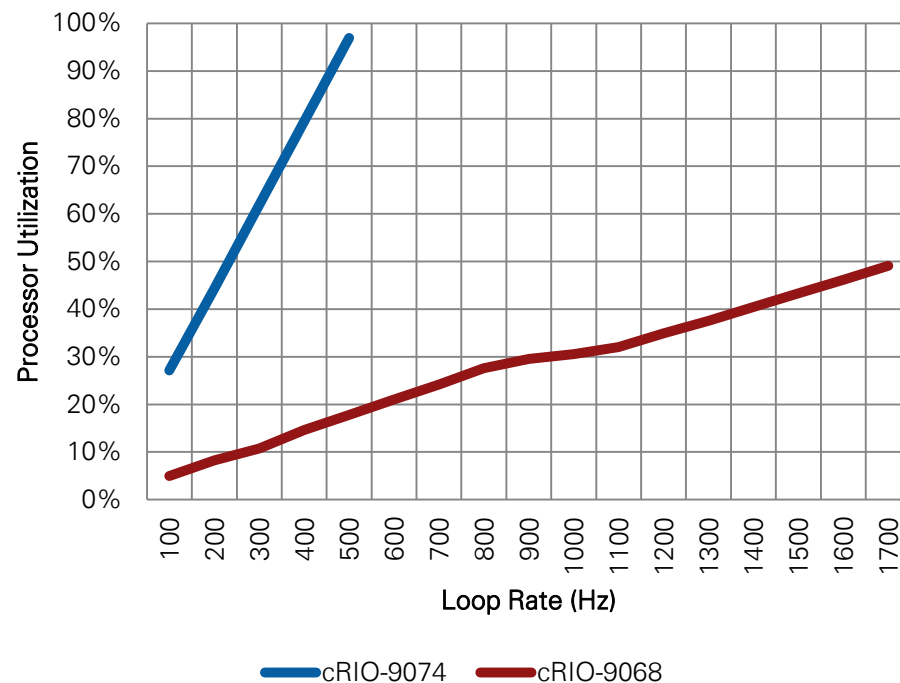
Control Application Benchmark



Streaming Task Benchmark



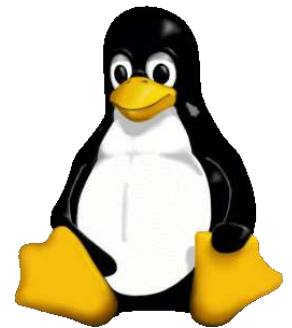
Complex Application Benchmark



The cRIO-9068 has 4 times the performance of a similar 8 slot value CompactRIO system.

NI Linux Real-Time Operating System

- Why Linux?
 - Support across CPU architectures (ARM, x86, etc)
 - Offers better security
 - Not vendor tied, not proprietary
 - Large ecosystem
- NI investment
 - Reliable, real-time performance
 - Future NI maintenance and management



Real-time reliability WITH usability/ecosystem of a general-purpose OS

NI Linux Real-Time Operating System

- PREEMPT_RT
 - Enables pre-emption and priority inheritance
 - Improvements commonly applied to Linux mainline kernel
 - Standard approach to real-time on Linux over last few years
- Dual Mode
 - Increased system resilience and robustness
 - Improved system security
- Scheduler
 - Two schedulers: one for real-time tasks, one for all other tasks
 - Improved system throughput with more efficient scheduling

Boot Modes and Partitions

- Run Mode (read and write)
 - Has access to the root filesystem
 - This is the mode in which LabVIEW runs
- Configuration Partition
 - Holds networking configuration
 - Houses Firewall and VPN settings if set
 - Can be used to communicate between modes
- Safe Mode (read only)
 - Securable with NI-Auth
 - System Web Server is available
- Mode to restore to factory default without RMA

Bootloader

Safe mode & run
mode kernels

Configuration
Partition

Run-mode root
file system

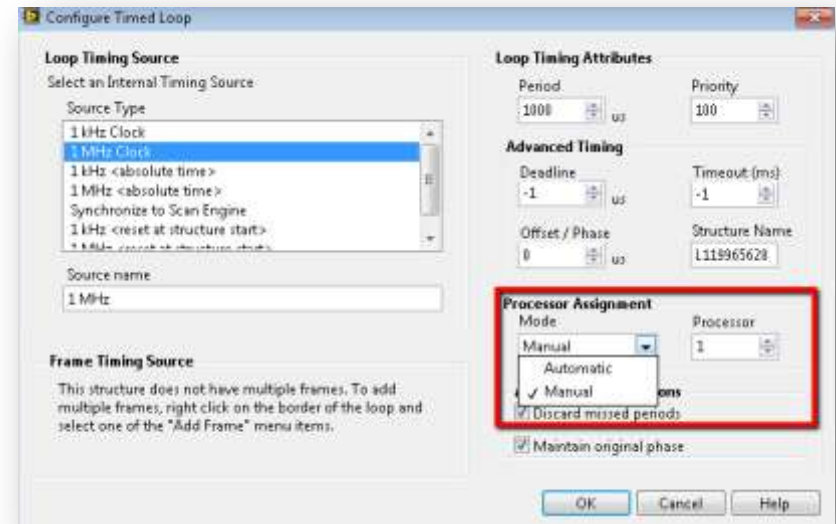
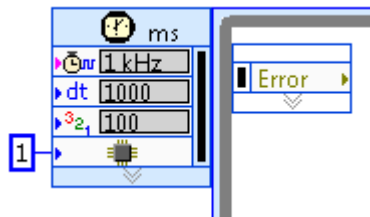
Multicore Performance with the cRIO-9068

- Control Applications
 - One core for critical code, rest on other core
 - [Introduction to LabVIEW Real-Time Symmetric Multiprocessing \(SMP\)](#)
- High-end processing
 - Load balancing across cores
 - [Specifying the Set of CPUs Available for Automatic Load Balancing in LabVIEW Real-Time](#)
- Streaming applications
 - Producer/Consumer architectures
- Take advantage of LabVIEW to more intuitively approach multicore programming



Optimizations for Multicore Programming

- Set Processor Affinity
 - Time critical code on one core
 - Normal priority on another core

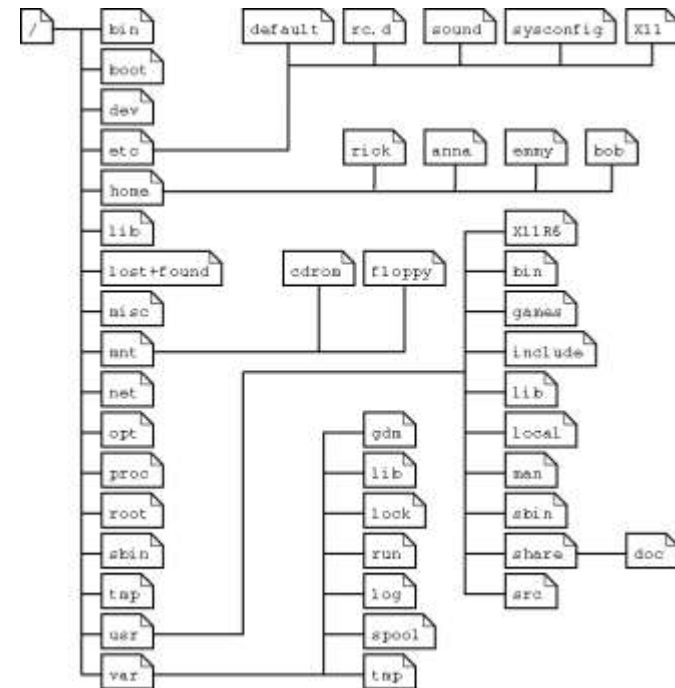


- Best Practices reminder: Avoid 100% CPU use with real-time priority for extended periods of time
 - Lower priority OS threads need access every so often for housekeeping
 - Can affect system performance if housekeeping is starved

I. Filesystem

Filesystem on NI Linux Real-Time

- Compressed Filesystem (UBIFS)
 - Can store more data locally on device
- /tmp clears on reboot
 - RAMDisk, 64MB max size
- Filepath changes
 - Unix style
 - Locations of system files have changed



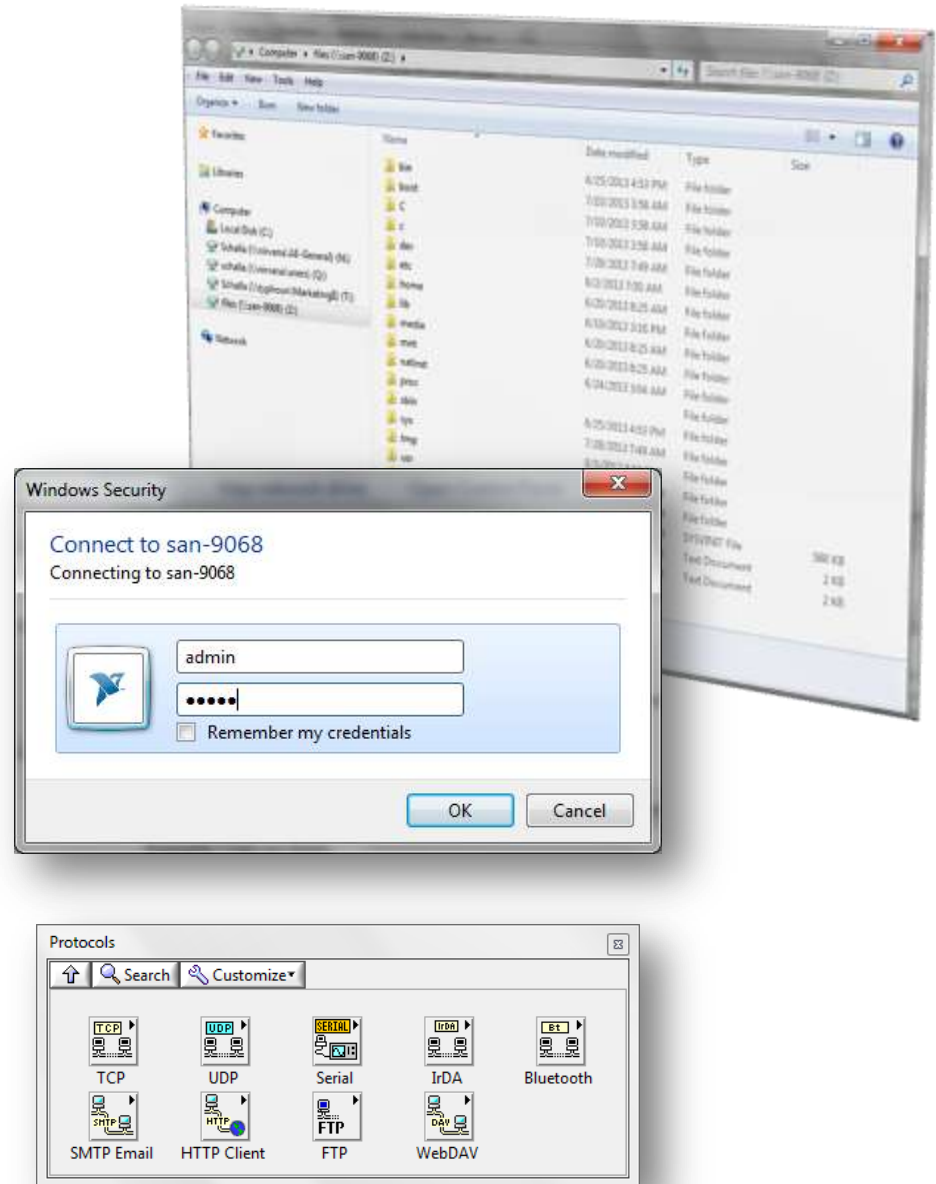
Filepaths on NI Linux Real-Time

- Applications should use Unix-style paths
 - Example: **/c/log.tdms**
- LabVIEW will coerce “wrong” paths to Unix-style
 - **C:\log.tdms** → **/c/log.tdms**
 - **\C\log.tdms** → **/c/log.tdms**
- NI Linux Real-Time is case sensitive
 - **/c/log.tdms** ≠ **/C/Log.tdms**
- Symbolic links (shortcuts) for some backwards compatibility
 - **/c/ni-rt/startup** is changed and renamed to **/home/lvuser/natinst/bin**
 - **/u/** is usb

II. Connectivity and Security

File Transfer: WebDAV

- Industry Standard Protocol
- Manage files on targets remotely over HTTP
- Secure File Access
 - Authentication
 - Encryption
- Supported by all OSes and Web Browsers
- New LabVIEW API for programmatic access

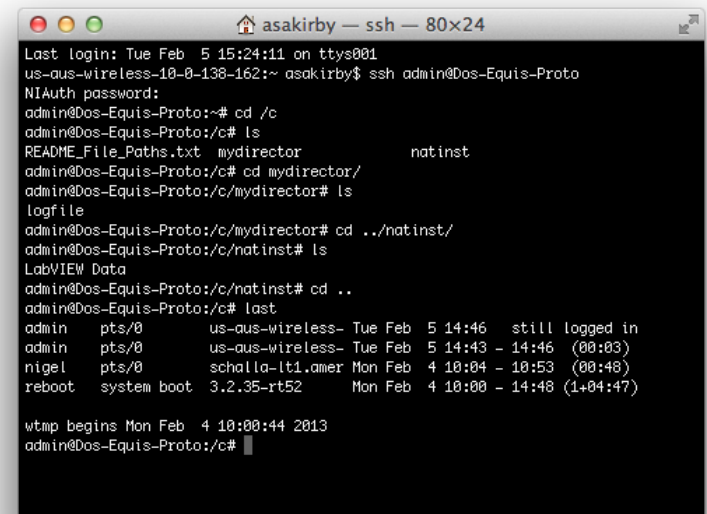


Secure Shell (SSH)

- Enable through MAX and/or Web Interface
- Can be used as a console
- Can be used to transfer files
 - Permissions based on login
 - SFTP
- Credentials synchronized with NI-Auth (Web Interface)

Startup Settings

Safe Mode	<input type="checkbox"/>
Console Out	<input checked="" type="checkbox"/>
IP Reset	<input type="checkbox"/>
Disable RT Startup App	<input type="checkbox"/>
Disable FPGA Startup App	<input type="checkbox"/>
Enable Secure Shell Server (sshd)	<input checked="" type="checkbox"/>



```
asakirby - ssh - 80x24
Last login: Tue Feb 5 15:24:11 on ttys001
us-aus-wireless-10-0-138-162:~ asakirby$ ssh admin@Dos-Equis-Proto
NIAuth password:
admin@Dos-Equis-Proto:~# cd /c
admin@Dos-Equis-Proto:/c# ls
README_File_Paths.txt  mydirector          natinst
admin@Dos-Equis-Proto:/c# cd mydirector/
admin@Dos-Equis-Proto:/c/mydirector# ls
logfile
admin@Dos-Equis-Proto:/c/mydirector# cd ../natinst/
admin@Dos-Equis-Proto:/c/natinst# ls
LabVIEW Data
admin@Dos-Equis-Proto:/c/natinst# cd ..
admin@Dos-Equis-Proto:/c# last
admin pts/0      us-aus-wireless- Tue Feb 5 14:46 still logged in
admin pts/0      us-aus-wireless- Tue Feb 5 14:43 - 14:46 (00:03)
nigel pts/0      schalla-1t1.amer Mon Feb 4 10:04 - 10:53 (00:48)
reboot system boot 3.2.35-rt52 Mon Feb 4 10:00 - 14:48 (1+04:47)

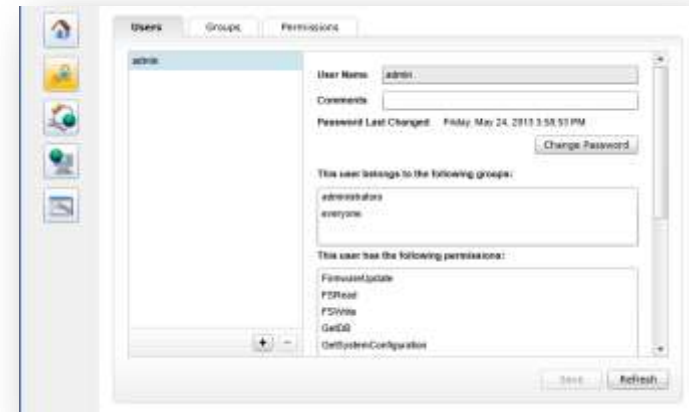
wtmpt begins Mon Feb 4 10:00:44 2013
admin@Dos-Equis-Proto:/c#
```

NI-Auth and NI Linux Real-Time Integration

- All user authentication goes through NI-Auth
- Use the Web Interface to manage users

- PAM Integration

- Users in NI-Auth are users in Linux
 - admin user is superuser



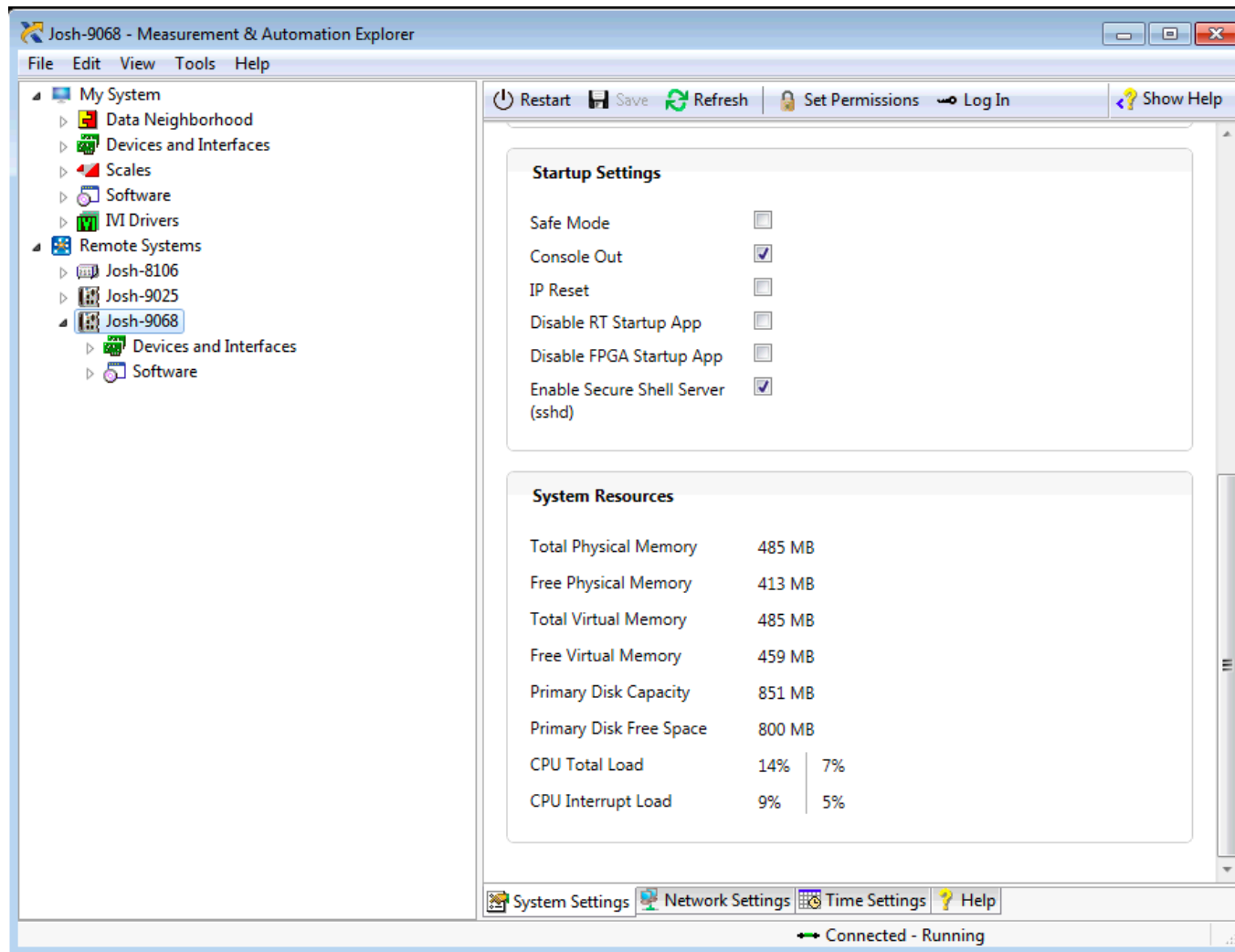
- If admin password is lost, target must be reset to factory default
 - Must contact NI

Demo

CONNECTIVITY AND SECURITY ON NI LINUX REAL-TIME

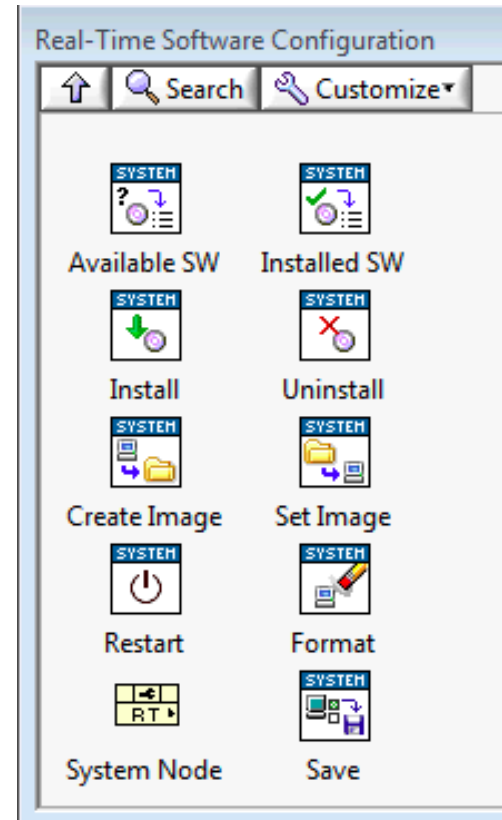
III. Configuration and Deployment

Monitor Critical Controller Attributes

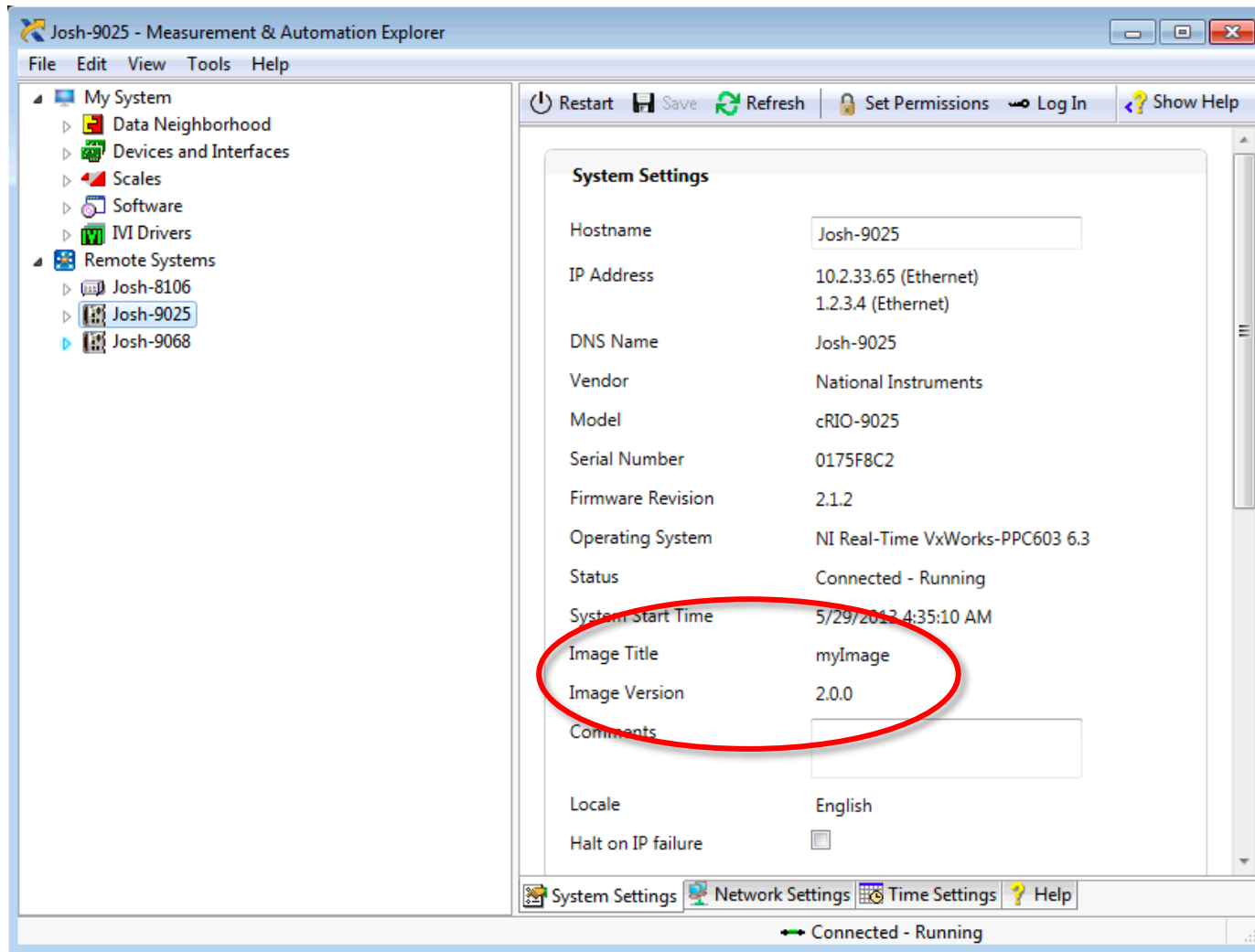


System Updates on NI Linux Real-Time

- NI Linux Real-Time targets can directly call "Set Image"
 - Enables targets to reimage themselves
 - Images can be pulled down from the network or stored on a USB drive
- Specify additional metadata when creating an RT image (title, version, description)
- Blacklist Wildcards with System Imaging*
 - Globbing: "*" and "?"
 - Character set matches: [abc]



View Image Meta-Data from MAX or WIF



Manage FPGA Bit Files

- Update and erase the FPGA bit files on NI Linux Real-Time targets programmatically, from MAX, and the web

The image displays two overlapping software windows from National Instruments. The background window is 'Hardware Configuration' (MAX), showing a tree view of a system named 'My System'. Under 'Remote Systems', 'Josh-9068' is expanded, showing 'Devices and Interfaces' with 'NI cRIO-9068 "RIO0"' selected. The foreground window is 'Josh-9068 : NI Web-based Configuration & Monitoring', showing the 'System Configuration' page. It lists devices: 'cRIO-9068' (Name: Josh-9068), 'NI cRIO-9068' (Name: RIO0), and three 'ASRL' serial ports. The 'Settings' panel on the right shows details for the selected 'RIO0' device, including Name, Vendor, Model, Serial Number, and Status, with buttons for 'Erase Firmware' and 'Update Firmware'.

Hardware Configuration

NI cRIO-9068 "RIO0" - Measurement & Automation Explorer

File Edit View Tools Help

My System

- Data Neighborhood
- Devices and Interfaces
- Scales
- Software
- IVI Drivers
- Remote Systems
 - Josh-8106
 - Josh-9025
 - Josh-9068
 - Devices and Interfaces
 - NI cRIO-9068 "RIO0"
 - ASRL1::INSTR
 - ASRL2::INSTR
 - ASRL3::INSTR
 - Software

Josh-9068 : NI Web-based Configuration & Monitoring

Josh-9068 : #Home

Josh-9068 : System Configuration

Restart Login Help

Search

Save Refresh

Settings

Name	RIO0
Vendor	National Instruments
Model	NI cRIO-9068
Serial Number	01856EAC
Status	Present

Erase Firmware Update Firmware

ni.com

IV. Other Key Features

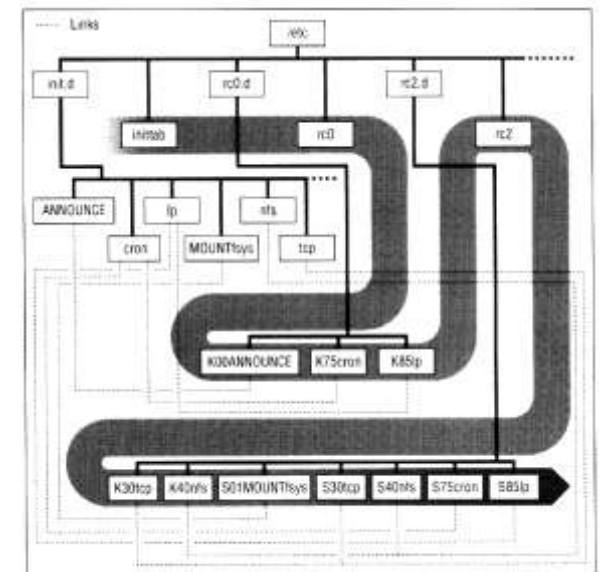
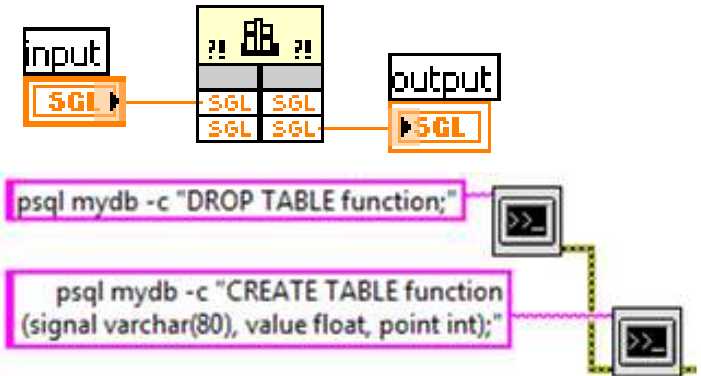
Interacting with Code on NI Linux Real-Time

- To/From LabVIEW

1. Call Library Function Node
2. System Execution calls
3. Localhost communication

- Beyond LabVIEW

1. Init scripts – for initializing at startup
2. Cron – for periodic execution
3. Network enabled SSH programs



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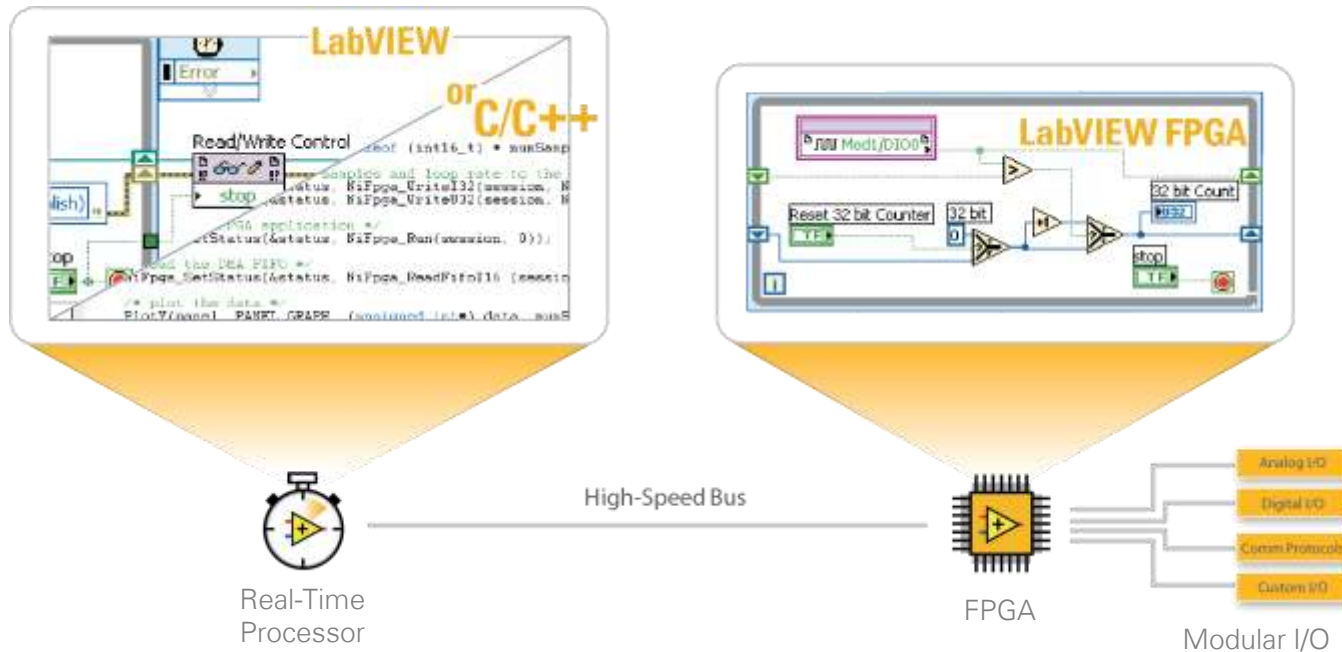
Quality of Life Improvements

- Time Zone changes don't need reboot
- Improved System Logging
 - Increased traceability on Linux – ex: syslog
- Common Linux utilities
 - top, ps, netstat, etc.
- Memory use
 - Don't have to track contiguous memory
 - Virtual (Paged) memory on NI Linux Real-Time

A screenshot of a PuTTY terminal window titled "10.0.60.147 - PuTTY". The terminal displays system statistics at the top: "Mem: 147040K used, 355052K free, 0K shrd, 0K buff, 99884K cached", "CPU: 0% usr 8% sys 0% nic 81% idle 0% io 0% irq 0% airq", and "Load average: 0.00 0.01 0.05 2/113 7147". Below this is a table of running processes with columns: PID, PPID, USER, STAT, VSZ, %VSZ, %CPU, and COMMAND. The table lists various processes including postgres, webserver, lvuser, admin, and system daemons like cron, nrtmdnsResponder, and NI WSD Watchdog.

PID	PPID	USER	STAT	VSZ	%VSZ	%CPU	COMMAND
7147	7134	admin	R	2216	0%	8%	top
3185	1	postgres	S	42000	8%	0%	postgres -D /home/postgres/postgresData/
4941	3185	postgres	S	42000	8%	0%	postgres: writer process
4942	3185	postgres	S	42000	8%	0%	postgres: wal writer process
4943	3185	postgres	S	42000	8%	0%	postgres: autovacuum launcher process
580	579	webserver	S	35340	7%	0%	(SystemWebServer) /usr/local/natinst/share/N
802	735	lvuser	S	20760	4%	0%	(MainAppThread) ./lvrt
701	1	admin	S	13008	3%	0%	(nlsueth daemon) /usr/local/natinst/share/NIA
419	1	admin	S	11264	2%	0%	/usr/sbin/syslog-ng --process-mode-background
4944	3185	postgres	S	10268	2%	0%	postgres: stats collector process
7131	407	admin	S	10256	2%	0%	(sshd) sshd: admin@pts/0
407	1	admin	S	8476	2%	0%	/usr/sbin/sshd
735	1	lvuser	S	8936	2%	0%	/bin/su - -- lvuser -l -c /usr/local/natinst
7134	7131	admin	S	6896	1%	0%	-bash
422	1	admin	S	6512	1%	0%	/usr/sbin/cron -c /etc/cron/crontabs
558	1	nobody	S	6292	1%	0%	/usr/local/natinst/bin/nimdnsResponder
555	1	lvuser	S	4964	1%	0%	/usr/local/natinst/bin/NiRioRpcServer
698	1	admin	S	4720	1%	0%	/usr/local/natinst/bin/nrtmdns
453	1	admin	S	4436	1%	0%	/usr/local/natinst/bin/nisvclac -D
579	1	webserver	S	4288	1%	0%	(NI WSD Watchdog) /usr/local/natinst/share/N
733	1	admin	S	2352	0%	0%	/sbin/getty 38400 tty0
734	1	admin	S	2352	0%	0%	/sbin/getty 38400 tty1
426	1	admin	S	2348	0%	0%	/usr/bin/afplugd -i eth0 -fI -u0 -d0 -a -m e

Flexible Software Integration



Code Reuse

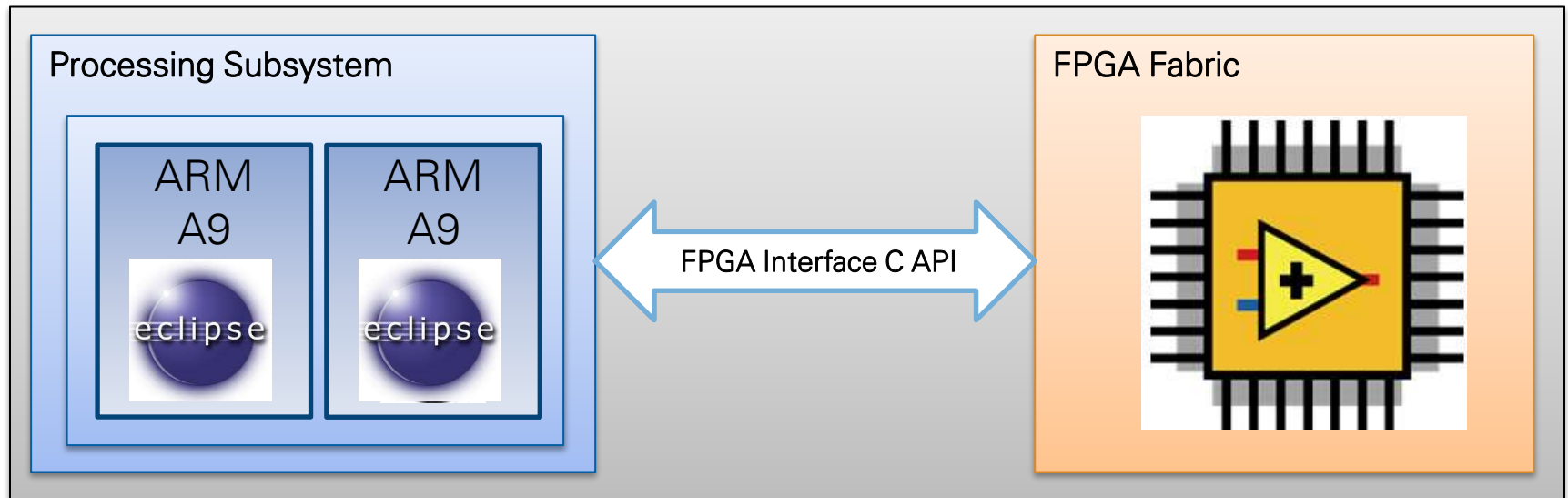
- Integrate existing applications and libraries
- Develop, debug and deploy C/C++ code
- Use Eclipse or IDE of choice
- Leverage the Linux ecosystem
- Interoperate with LabVIEW-programmed FPGA

Programmable Hardware

- Offload critical, decision-making code to the FPGA
- Reliable, precision timing for control or processing
- Achieve high-speed, high-accuracy I/O
- Use graphical programming to leverage FPGA technology without HDL expertise

Eclipse for the CompactRIO-9068

- Choice of C and/or LabVIEW for programming processor
 - LabVIEW FPGA still required
 - [FPGA Interface C API](#) provides access to the FPGA from C
- Installer provided that includes Eclipse and Compiler
 - Available on ni.com/downloads



What is Eclipse?

- Free IDE Framework, originally for Java development
- De facto Standard IDE for Embedded Development
- Updated with tools for C/C++ development and debugging
- Eclipse C/C++ Development Toolkit (CDT)
- Target Management/Remote System Explorer
- Note: NI Provided Installer is for Windows
- **It is not necessary to use Eclipse**



FPGA Interface C API

- Enables C/C++ applications to interact directly with compiled LabVIEW FPGA VIs on RIO devices
- Must be [downloaded](#) in addition to Eclipse installer
- Supports
 - Reading/writing to named controls and indicators
 - DMA data transfers
 - Wait on and acknowledge interrupts
- **Is NOT and interface for RSI or Scan Engine.**
- Note: C API is currently supported on PharLap, Linux and Windows

Demo

ECLIPSE 'LED' DEMO

Accessing the Linux Community: Package Manager



- What is a package manager?
 - Set of software tools for installing, updating, configuring and removing applications
 - Think of the App Store, VIPM, etc.
- CompactRIO-9068 shipping with a package manager pre-installed called “opkg”
 - Does not take the place of MAX
- Access to hundreds of applications in the Linux community

Support Policy

- Limited user mode support
 - Equivalent to 3rd party C code with Call Library Nodes on Desktop
- No support for kernel mode changes
 - You can get the NI Linux Real-Time open source kernel by emailing licensing@ni.com
- Feel free to innovate and explore
 - Can restore to factory default state without having to RMA

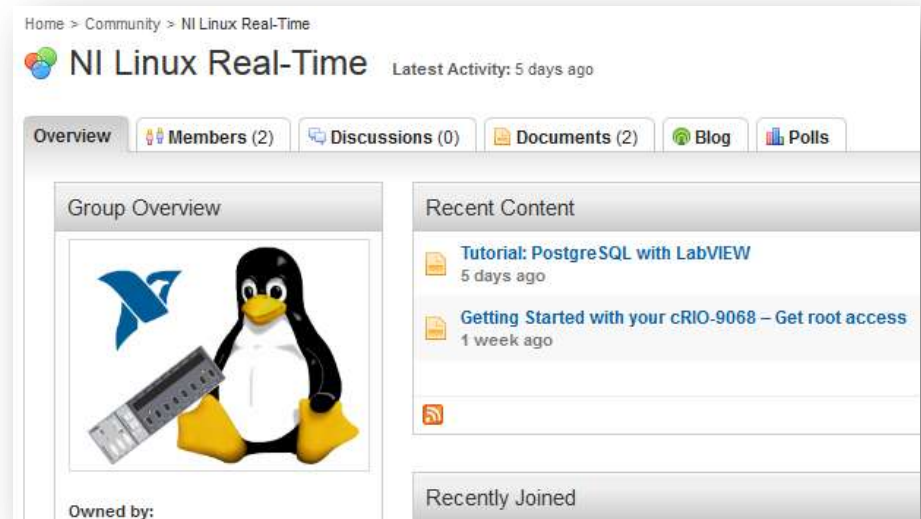
Key Resources

- [Linux Real-Time Community](#)

- Tutorials
- Documentation
- Forum for discussions

- [ni.com/linux](#)

- Links to whitepapers
- Embedded and Desktop uses



Questions?

