CompactRIO

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Overview
National Instruments CompactRIO is an advanced reconfigurable embedded control and acquisition system powered by NI RIO technology for ultrahigh performance, user customization, and reconfigurability. It is designed to perform in the harshest industrial environments.

Features
- Small, rugged, industrial control and acquisition system
- Powered by reconfigurable I/O (RIO) FPGA technology for ultrahigh performance and customization
- Low-cost architecture with open access to low-level hardware resources
- High-productivity LabVIEW graphical programming tools for rapid development
- Real-time processor and reconfigurable FPGA for reliable stand-alone embedded or distributed applications
- Hot-swappable industrial I/O modules with built-in signal conditioning for direct connection to sensors and actuators
- Design your own custom control or acquisition circuitry in silicon with 25 ns timing/triggering resolution
- NI CompactRIO Extreme Industrial Certifications and Ratings
  - -40 to 70 °C (-40 to 158 °F) operating temperature
  - Up to 2,300 Vrms isolation (withstand)
  - 50 g shock rating
  - International safety, EMC, and environmental certifications
  - Class I, Division 2 rating for hazardous locations
  - Dual 11-30 VDC supply inputs, low power

For ordering information, see page 381.
With NI CompactRIO, you can rapidly build embedded control or acquisition systems that rival the performance and optimization of custom-designed hardware circuitry. Now LabVIEW programmers can take advantage of reconfigurable FPGA technology to automatically synthesize a highly optimized electrical circuit implementation of their input/output, communication, or control applications. Field-programmable gate array (FPGA) devices are widely used by control and acquisition system vendors for their performance, reconfigurability, small size, and low engineering development costs. FPGA-based devices were traditionally vendor defined rather than user defined because of the complexity of the electronic design tools. Now you can take advantage of user-programmable FPGAs to create highly optimized reconfigurable control and acquisition systems with no knowledge of specialized hardware design languages such as VHDL.

Low-Cost Open Architecture

CompactRIO combines a low power consumption real-time embedded processor with a high-performance RIO FPGA chipset. The RIO core has built-in data transfer mechanisms to pass data to the embedded processor for real-time analysis, postprocessing, data logging, or communication to a networked host computer. CompactRIO provides direct hardware access to the input/output circuitry of each I/O module using LabVIEW FPGA elemental I/O functions. Each I/O module includes built-in connectivity, signal conditioning, conversion circuitry (ADC or DAC), and an optional isolation barrier. This represents a low-cost architecture with open access to low-level hardware resources.

I/O Modules

Each CompactRIO I/O module contains built-in signal conditioning and screw terminal, BNC, or D-Sub connectors. By integrating the connector junction box into the modules, the CompactRIO system significantly reduces the space requirements and cost of field wiring. A variety of I/O types are available including ±80 mV thermocouple inputs, ±10 V simultaneous sampling analog inputs/outputs, 24 V industrial digital I/O with up to 1 A of current drive, differential/TTL digital inputs with 5 V regulated supply output for encoders, and 250 V rms universal digital inputs. Because the modules contain built-in signal conditioning for extended voltage ranges or industrial signal types, you can usually make your wiring connections directly from the CompactRIO module to your sensors/actuators. Visit ni.com/compactrio for the latest information on module availability.

Real-Time Processor

The CompactRIO embedded system features an industrial 200 MHz Pentium class processor that reliably and deterministically executes your LabVIEW Real-Time applications. Choose from thousands of built-in LabVIEW functions to build your multithreaded embedded system for real-time control, analysis, data logging, and communication. The controller also features a 10/100 Mb/s Ethernet port for programmatic communication over the network (including email) and built in Web (HTTP) and file (FTP) servers. Using the remote panel Web server, you can automatically publish the front-panel graphical user interface of your embedded application for multiclent remote monitoring or control. The real-time processor also features dual 11 to 30 VDC supply inputs, a user DIP switch, LED status indicators, a real-time clock, watchdog timers, and other high-reliability features.

Performance

Using the LabVIEW FPGA Module and reconfigurable hardware technology, you can create ultrahigh performance control and acquisition systems with CompactRIO. The FPGA circuitry is a parallel processing reconfigurable computing engine that executes your LabVIEW application in silicon circuitry on a chip. The LabVIEW FPGA Module features built-in functions for analog closed-loop PID control, fifth-order FIR filters, 1D look-up tables, linear interpolation, zero crossing detection, and direct digital synthesis of sine waves. Using the embedded RIO FPGA hardware, you can implement multiloop analog PID control systems at loop rates exceeding 100 kS/s. Digital control systems can be implemented at loop rates up to 1 MS/s. Multiple rungs of Boolean logic can be evaluated using single-cycle while loops at 40 MHz (25 ns). Because of the parallel nature of the RIO core, adding additional computation does not necessarily reduce the speed of the FPGA application. CompactRIO offers 4 and 8-slot chassis with options for FPGA chips with either 1 million or 3 million gates.
CompactRIO Overview

Size and Weight
CompactRIO is designed for applications in harsh environments and small places. Size, weight, and I/O channel density are critical design requirements in many such embedded applications. By taking advantage of the extreme performance, small size, and lower power consumption of FPGA devices, CompactRIO is able to deliver unprecedented control and acquisition capabilities in a compact, rugged package.

A 4-slot embedded system measures 179.6 by 88.1 by 88.1 mm (7.07 by 3.47 by 3.47 in.) and weighs just 1.58 kg (3.47 lb). An 8-slot system filled with 32-channel I/O modules delivers a mass channel density of 9.7 g/ch (0.34 oz/ch), and a volumetric channel density of 8.2 cm³/ch (0.50 in.³/ch).

NI CompactRIO Extreme Industrial Certifications and Ratings
CompactRIO is a reconfigurable embedded system that combines reliable stand-alone embedded capability with extreme industrial certifications and ratings for operation in harsh industrial environments. CompactRIO is rated for a -40 to 70 °C (-40 to 158 °F) temperature range, 50 g shock, and hazardous locations or potentially explosive environments (Class I, Div 2). Most I/O modules feature up to 2,300 Vrms isolation (withstand), and 250 Vrms isolation (continuous). Each component comes with a variety of international safety, electromagnetic compatibility (EMC), and environmental certifications and ratings.

Key Developer Tools
The LabVIEW development environment, including the LabVIEW FPGA Module and LabVIEW Real-Time Module, provides an array of tools and technologies to accelerate the development of reliable reconfigurable embedded systems.

 Embedded Project Manager
• FPGA hardware target configuration and automatic module discovery
• CompactRIO module and I/O channel alias name management
• FPGA application flash memory download and autoload configuration

LabVIEW FPGA Development Environment
• FPGA device I/O for analog input/output, digital input/output, and I/O property nodes/methods
• Interrupt request (IRQ) generation and synchronization functions
• 40 MHz single-cycle timed loop for LabVIEW code execution in 25 ns timing interval
• Parallel processing with while loop, sequence, case, for loop, and other execution control structures
• FPGA FIFO data buffering and memory read/write
• Boolean logic, comparison, numeric math, saturation arithmetic functions, and bitwise data manipulation functions

Typical Certifications – Actual specifications vary from product to product. Visit ni.com/certification for details.
CompactRIO Overview

LabVIEW Real-Time Development Environment
- Target configuration options including start-up application execution settings and development, Web, remote panel, and file server access
- Open FPGA VI Reference function for programmatic bit-stream download, communication interface reference, and application start
- Deterministic real-time while loop thread synchronization with FPGA-generated IRQ
- FPGA front panel control/indicator read/write for data transfer
- Data scaling/mapping functions for integer to floating-point engineering units conversion
- Real-Time FIFO data buffering for multithread communication
- Timed-loop structure for multirate deterministic control
- Floating-point PID, set-point profiling, gain scheduling, and rate limiter functions
- Point-by-point signal generation, time-domain analysis, frequency-domain transforms and spectrum analysis, filters, statistics, curve fitting/interpolation, linear algebra, array/vector operations
- SMTP E-mail, TCP/IP, UDP, IrDA, DataSocket, and VISA RS232 serial programmatic server/client communication (including 802.11 wireless Ethernet)
- Binary and text file I/O for embedded data logging and retrieval

LabVIEW Networked Host Application Development
- Web browser remote panel graphical user interface plug-in for remote control/monitoring (Windows, Linux, Mac OS X, Solaris)
- Express spectral signal analysis, distortion/tone, amplitude/level, timing/transition, convolution/correlation, mask/limit, histogram functions
- Local or remote database connectivity, text/HTML/DIAdem report generation
- Handheld mobile/portable PDA user interface/remote control (LabVIEW PDA Module)

The CompactRIO Platform is available in two configurations:

CompactRIO Embedded System
In this configuration, CompactRIO is a complete reconfigurable embedded system for rugged stand-alone or networked control and acquisition applications. The reconfigurable embedded system consists of a real-time controller, a reconfigurable chassis containing the user-programmable RIO FPGA, and a variety of hot-swappable industrial I/O modules.

CompactRIO R Series Expansion System
In this configuration, a CompactRIO expansion chassis connects to the digital port on a PCI or PXI R Series FPGA device. The R Series device can be installed in any desktop PC, industrial PC (IPC), or ruggedized PXI/CompactPCI computer system running Windows or one of the LabVIEW Real-Time OSs. The RIO FPGA resides on the R Series device while CompactRIO converts a digital port on the R Series device into a high-performance expansion I/O and signal conditioning system.
Application Examples

Due to its low cost, reliability, and suitability for high-volume embedded measurement and control applications, CompactRIO can be adapted to solve the needs of a wide variety of industries and applications. Examples include heavy industrial machine control, in-vehicle data acquisition, machine condition monitoring, and rapid control prototyping (RCP):

• Batch control
• Discrete control
• Motion control
• In-vehicle data acquisition
• Machine condition monitoring
• Rapid control prototyping (RCP)
• Industrial data acquisition
• Distributed data acquisition and control
• Mobile/portable noise, vibration, and harshness (NVH) analysis
Build your CompactRIO reconfigurable control and acquisition system in three easy steps:

**Step 1. Choose your CompactRIO real-time embedded controller, PXI controller, or industrial PC.**

<table>
<thead>
<tr>
<th>Type of Controller</th>
<th>Reconfigurable Embedded System</th>
<th>R Series Expansion System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard real-time</td>
<td>cRIO-9002 embedded controller, 64 MB storage</td>
<td>PXI-8145 RT, PXI-1031 (real-time PXI)</td>
</tr>
<tr>
<td>Premium real-time</td>
<td>cRIO-9004 embedded controller, 512 MB storage</td>
<td>PXI-8186 RT, PXI-1031 (real-time PXI)</td>
</tr>
<tr>
<td>Windows PCI</td>
<td>NI PXI-8186, PXI-1031</td>
<td>Any desktop or industrial PC</td>
</tr>
<tr>
<td>PCI real-time (ETS)</td>
<td>Certified desktop PC (Dell Optiplex, model GX270) or industrial PC</td>
<td></td>
</tr>
</tbody>
</table>

**Step 2. Select a reconfigurable chassis or R Series device and expansion chassis.**

<table>
<thead>
<tr>
<th>Type of Chassis</th>
<th>Reconfigurable Embedded System</th>
<th>R Series Expansion System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard real-time</td>
<td>cRIO-9101 4-slot 1 M gate RIO chassis</td>
<td>PXI-7831R or PXI-7811R, and cRIO-9151 expansion chassis</td>
</tr>
<tr>
<td>Premium real-time</td>
<td>cRIO-9102 8-slot 1 M gate RIO chassis</td>
<td>PXI-7831R or PXI-7811R, and cRIO-9151 expansion chassis</td>
</tr>
<tr>
<td>Windows PXI</td>
<td>cRIO-9103 4-slot 3 M gate RIO chassis</td>
<td>PXI-7831R or PXI-7811R, and cRIO-9151 expansion chassis</td>
</tr>
<tr>
<td>Windows PCI</td>
<td>cRIO-9104 8-slot 3 M gate RIO chassis</td>
<td>PXI-7831R or PXI-7811R, and cRIO-9151 expansion chassis</td>
</tr>
<tr>
<td>PCI real-time (ETS)</td>
<td>PCI-7831R and cRIO-9151 expansion chassis</td>
<td>cRIO-9151 expansion chassis</td>
</tr>
</tbody>
</table>

**Step 3. Choose your I/O modules.**

<table>
<thead>
<tr>
<th>Type of Signal</th>
<th>Signal</th>
<th>Module</th>
<th>Channels</th>
<th>Special Features(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input</td>
<td>Thermocouple</td>
<td>cRIO-9211</td>
<td>4</td>
<td>24-bit, 15.5 mV, differential (K, R, S, T, N, E, and B thermocouple types)</td>
</tr>
<tr>
<td></td>
<td>IEPE(^2) (±5 V)</td>
<td>cRIO-9233</td>
<td>4</td>
<td>24-bit, 50 kS/s per ch, simultaneous, antialiasing, nonisolated, TEDS</td>
</tr>
<tr>
<td></td>
<td>Small voltage (±80 mV)</td>
<td>cRIO-9211</td>
<td>4</td>
<td>24-bit, 15.5 mV, differential</td>
</tr>
<tr>
<td></td>
<td>Medium voltage (±10 V)</td>
<td>cRIO-9215</td>
<td>4</td>
<td>16-bit, 100 kS/s per ch, simultaneous, differential</td>
</tr>
<tr>
<td></td>
<td>High voltage (±40 V)</td>
<td>cRIO-9221</td>
<td>8</td>
<td>12-bit, 800 kS/s</td>
</tr>
<tr>
<td></td>
<td>Medium voltage (±10 V)</td>
<td>cRIO-9233</td>
<td>4</td>
<td>16-bit, 100 kS/s per ch, simultaneous</td>
</tr>
<tr>
<td>Digital Input</td>
<td>24 V sinking</td>
<td>cRIO-9421</td>
<td>8</td>
<td>100 µs, 24 V logic, 40 V protection</td>
</tr>
<tr>
<td></td>
<td>250 AC/DC universal</td>
<td>cRIO-9435</td>
<td>4</td>
<td>3 µs, ±5 to 250 VDC, 10 to 250 VAC, universal, sink/source</td>
</tr>
<tr>
<td></td>
<td>Differential or TTL</td>
<td>cRIO-9411</td>
<td>8</td>
<td>1 µs, ±5 to 24 V, single-ended TTL or differential, regulated 5 V supply output</td>
</tr>
<tr>
<td>Digital Output</td>
<td>24 V sourcing</td>
<td>cRIO-9442</td>
<td>8</td>
<td>100 µs, 24 V logic, 750 mA max per ch, 30 V protection, short-circuit-proof</td>
</tr>
<tr>
<td></td>
<td>250 AC/DC universal</td>
<td>cRIO-9474</td>
<td>8</td>
<td>1 µs, high-speed, 24 V logic, 1 A max per ch, 30 V protection, short-circuit-proof</td>
</tr>
<tr>
<td>Relay Output</td>
<td>Form A (SPST)</td>
<td>cRIO-9481</td>
<td>4</td>
<td>1 s, 30 VDC (2 A), 60 VDC (1 A), 250 VAC (2 A) electromechanical form A (SPST)</td>
</tr>
<tr>
<td>Counter/Pulse</td>
<td>Counter/timer (24 V)</td>
<td>cRIO-9423</td>
<td>8</td>
<td>1 µs, high-speed, 24 V logic, 35 V protection</td>
</tr>
<tr>
<td></td>
<td>Counter/timer (LTU)</td>
<td>cRIO-9411</td>
<td>8</td>
<td>1 µs, ±5 to 24 V, single-ended TTL or differential, regulated 5 V supply output</td>
</tr>
<tr>
<td></td>
<td>Quadrature encoder (differential)</td>
<td>cRIO-9411</td>
<td>6</td>
<td>1 µs, ±5 to 24 V, single-ended TTL or differential, regulated 5 V supply output</td>
</tr>
<tr>
<td></td>
<td>PWM</td>
<td>cRIO-9474</td>
<td>8</td>
<td>1 µs, high-speed, 24 V logic, 0 to 30 V, A max per ch, 30 V protection, short-circuit-proof</td>
</tr>
</tbody>
</table>

\(^1\)NI CompactRIO Extreme Industrial Certifications and Ratings: All modules except cRIO-9233 feature 2,300 V\(_{\text{rms}}\) withstand isolation, 250 V\(_{\text{rms}}\) continuous isolation channel-to-earth ground.

\(^2\)Integrated electronic piezoelectric (IEPE) sensors include accelerometers, strain gages, load cells, and microphones.
Overview and Applications
The National Instruments CompactRIO reconfigurable chassis are the heart of the CompactRIO system because they contain the reconfigurable I/O (RIO) core. The RIO FPGA core, which has an individual connection to each I/O module, is programmed with easy-to-use elemental I/O functions to read or write signal information from each module. Because there is no shared communication bus between the RIO FPGA core and the I/O modules, I/O operations on each module can be precisely synchronized with 25 ns resolution. The RIO core can perform local integer-based signal processing and decision-making and directly pass signals from one module to another.

The RIO core is also connected to the CompactRIO real-time controller through a local PCI bus interface. The real-time controller can retrieve data from any control or indicator on the front-panel of the RIO FPGA application through an easy-to-use FPGA Read/Write function. The RIO FPGA can also generate interrupt requests (IRQs) to synchronize the real-time software execution with the RIO FPGA. Typically, the real-time controller is used to convert the integer based I/O data to scaled floating-point numbers. In addition, the real-time controller typically performs single-point control, waveform analysis, data logging, and Ethernet/serial communication.

The reconfigurable chassis, real-time controller, and I/O modules combine to create a complete stand-alone embedded system. Application development consists of three steps:
1. Target the reconfigurable chassis to automatically detect the I/O modules and develop the RIO FPGA application,
2. Compile the RIO application to automatically synthesize an optimized high-performance electrical circuit implementation of your application,
3. Develop the real-time controller application to add floating-point control, signal processing, data logging, and communication

Key Features
- Create any local or multichassis timing, triggering, and synchronization scheme with 25 ns resolution
- Use multiple while loops to create a parallel processing application for high-performance signal processing or multirate control systems
- Built-in PID control functions for control system loop rates greater than 100 kHz
- Generate waveforms or implement nonlinear look-up tables (LUTs) using LabVIEW FPGA express VIs
- Integrate widely available third-party HDL cores using the LabVIEW FPGA Module HDL Node
- Enforce critical logic and interlocks in silicon hardware circuitry, or use the parallel RIO architecture to create dual, triple, or quadruple redundant systems

Visit ni.com/compactrio for example programs, application notes, and other developer tools.

For ordering information, see page 381.
## Ordering Information

### Developer Kits
- NI cRIO-9961 Embedded System Developer Hardware Evaluation Kit .......................... 779107-01
- NI Reconfigurable I/O Software Development Kit .................................................. 779149-03

### Reconfigurable Embedded Systems
#### Real-Time Controllers
- NI cRIO-9002 ................................................ 779000-01
- NI cRIO-9004 ................................................ 779055-01

#### Reconfigurable Chassis
- NI cRIO-9101 ................................................ 779052-01
- NI cRIO-9102 ................................................ 779007-01
- NI cRIO-9103 ................................................ 779053-01
- NI cRIO-9104 ................................................ 779054-01

### Power Supplies
- NI PS-1 .......................................................... 777567-01
- NI PS-2 .......................................................... 777584-01
  - Japan 100 VAC/US 120 VAC ........................................ 777584-01
  - North American 240 VAC ......................................... 777584-05
- NI PS-3 .......................................................... 777585-01
  - Japan 100 VAC/US 120 VAC ........................................ 777585-01
  - North American 240 VAC ......................................... 777585-05
- NI PS-4 .......................................................... 778586-90
- NI PS-5 .......................................................... 778805-90

### R Series Expansion Systems
#### Expansion Chassis
- NI cRIO-9151 chassis ........................................ 779008-01
- SH68-C68-S cable, 2 m ........................................ 186381-02

#### R Series Devices
- NI PXI-7811R Digital I/O ................................. 778800-01
- NI PXI-7831R Multifunction I/O ......................... 778668-01
- NI PCI-7831R Multifunction I/O ......................... 778797-01

### Input/Output Modules

#### Analog Input Modules
- NI cRIO-9201 .................................................. 779013-01
- NI cRIO-9211 .................................................. 779001-01
- NI cRIO-9215 .................................................. 779011-01
- NI cRIO-9221 .................................................. 779014-01
- NI cRIO-9233 .................................................. 779015-01

#### Analog Output Module
- NI cRIO-9263 .................................................. 779012-01

#### Digital Input and Counter/Timer Modules
- NI cRIO-9411 .................................................. 779005-01
- NI cRIO-9421 .................................................. 779002-01
- NI cRIO-9423 .................................................. 779009-01
- NI cRIO-9435 .................................................. 779010-01

#### Digital Output and Relay Modules
- NI cRIO-9472 .................................................. 779004-01
- NI cRIO-9474 .................................................. 779003-01
- NI cRIO-9481 .................................................. 779006-01

### Accessories
- NI cRIO-9912 .................................................. 779019-01
- NI cRIO-9915 .................................................. 779018-01
- NI cRIO-9932 .................................................. 779017-01
- NI cRIO-9933 .................................................. 779103-01
- NI cRIO-9934 .................................................. 779104-01
- NI cRIO-9935 .................................................. 779106-01
- NI cRIO-9936 .................................................. 779105-01
- NI cRIO-9937 .................................................. 779106-01

### Ethernet Cables
- CAT5 5 m ...................................................... 182219-05
- CAT5 Crossover 5 m .......................................... 187375-05

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1 Visit [ni.com/compactrio](http://ni.com/compactrio) for up-to-date information on module availability.

**BUY NOW!**

For complete product specifications, pricing, and accessory information, call (866) 265-9891 (U.S. only) or go to [ni.com](http://ni.com) and search on a four-digit model number listed above.