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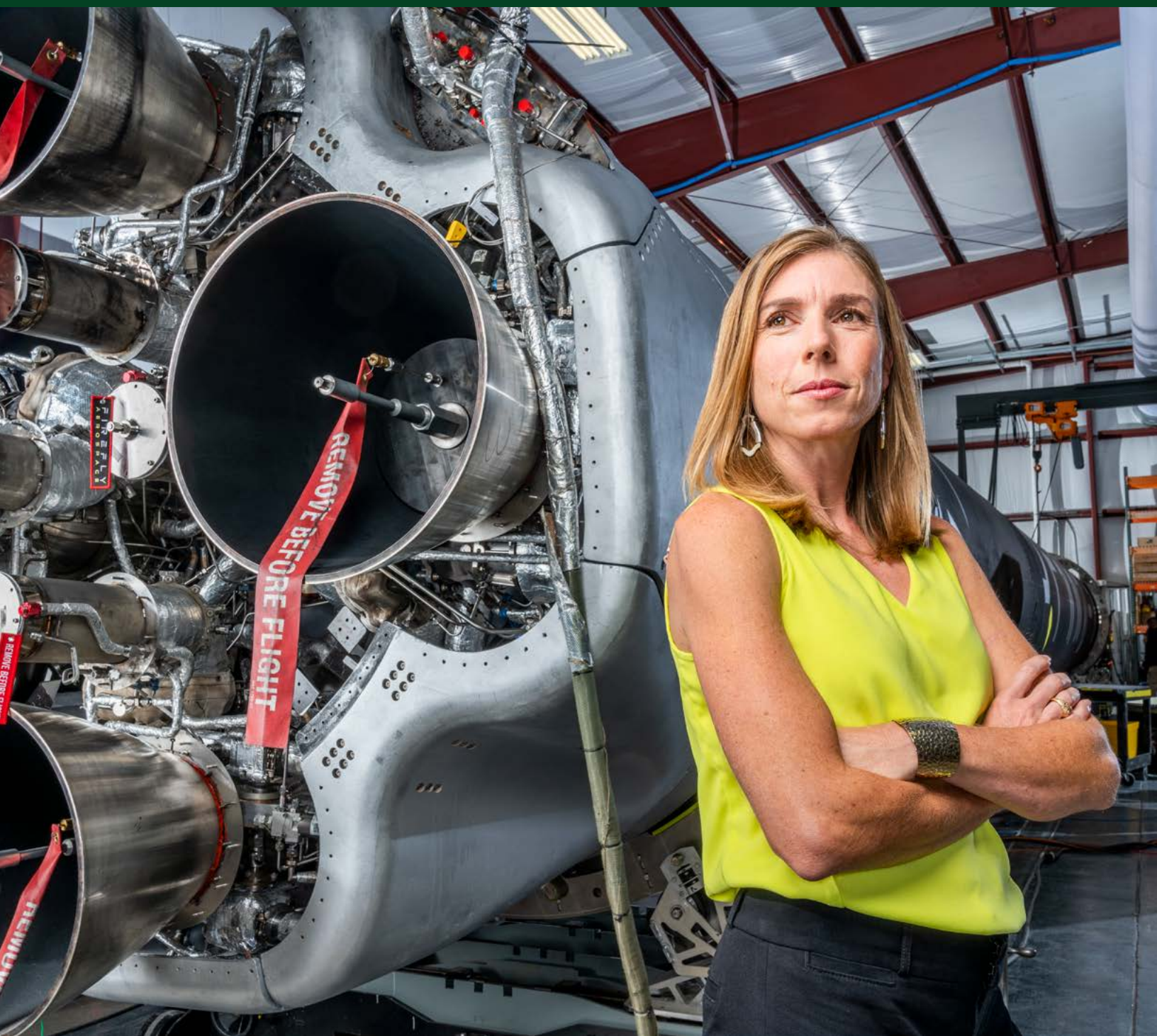
Launch Operations Control and Monitoring



LAUNCH OPERATIONS CONTROL AND MONITORING

Explore NI's Solutions

As space launch engineers work to make space access more reliable, less expensive, and less resource-intensive, they need distributed systems that can reliably control and monitor the processes that lead to the safe launch of a space vehicle. The information they collect is critical for evaluating launch conditions. The processes must be controlled reliably and safely. To meet the demands of a launch operations systems, requirements include: high reliability to ensure system availability; rugged form factor to survive difficult launch site environments; timing synchronization across distributed systems.

Launch Operations Architecture

As a broad term, launch operations covers many different systems and technologies. NI customers use NI's flexible CompactDAQ chassis and CompactRIO controllers to meet the wide mix of needs of a launch operations platform. With these NI tools at the core, launch operations teams create solutions that meet the challenges of a launch facility.

NI has worked with leaders in the space industry to identify the best practices in designing a launch operations solution. The recommended architecture has the elements listed in Figure 1.

This architecture provides a flexible platform with these benefits:

01
Network redundancy with dual network interface cards arranged in ring topology

02
Signal I/O redundancy with dual or triple data input lines

03
Control redundancy with multiple controllers and fast switch-over techniques

04
Real-time performance to deliver control determinism demanded for launch operations

05
High reliability with available MTBF data on all NI components

06
Network topology flexibility to meet various facility needs

07
Modular instrumentation to design the system to meet varying signal needs

08
Environmental ruggedness to operate in extreme temperature, shock, and vibration settings

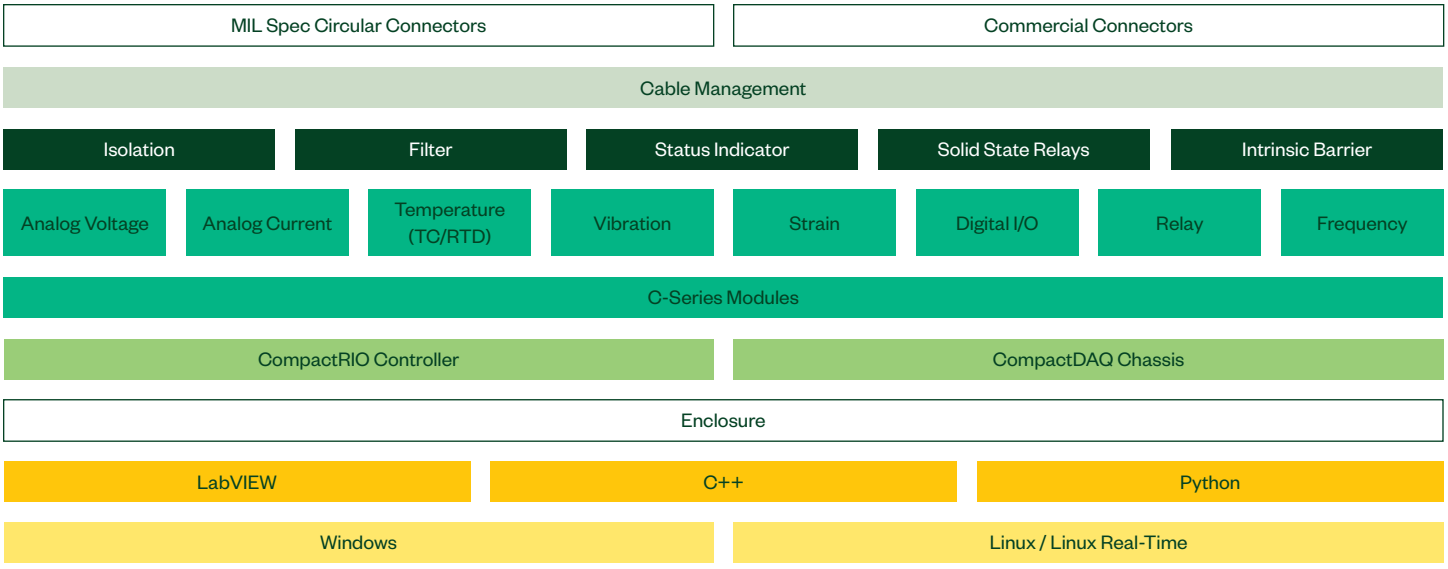


FIGURE 01
Launch Operations Platform Components

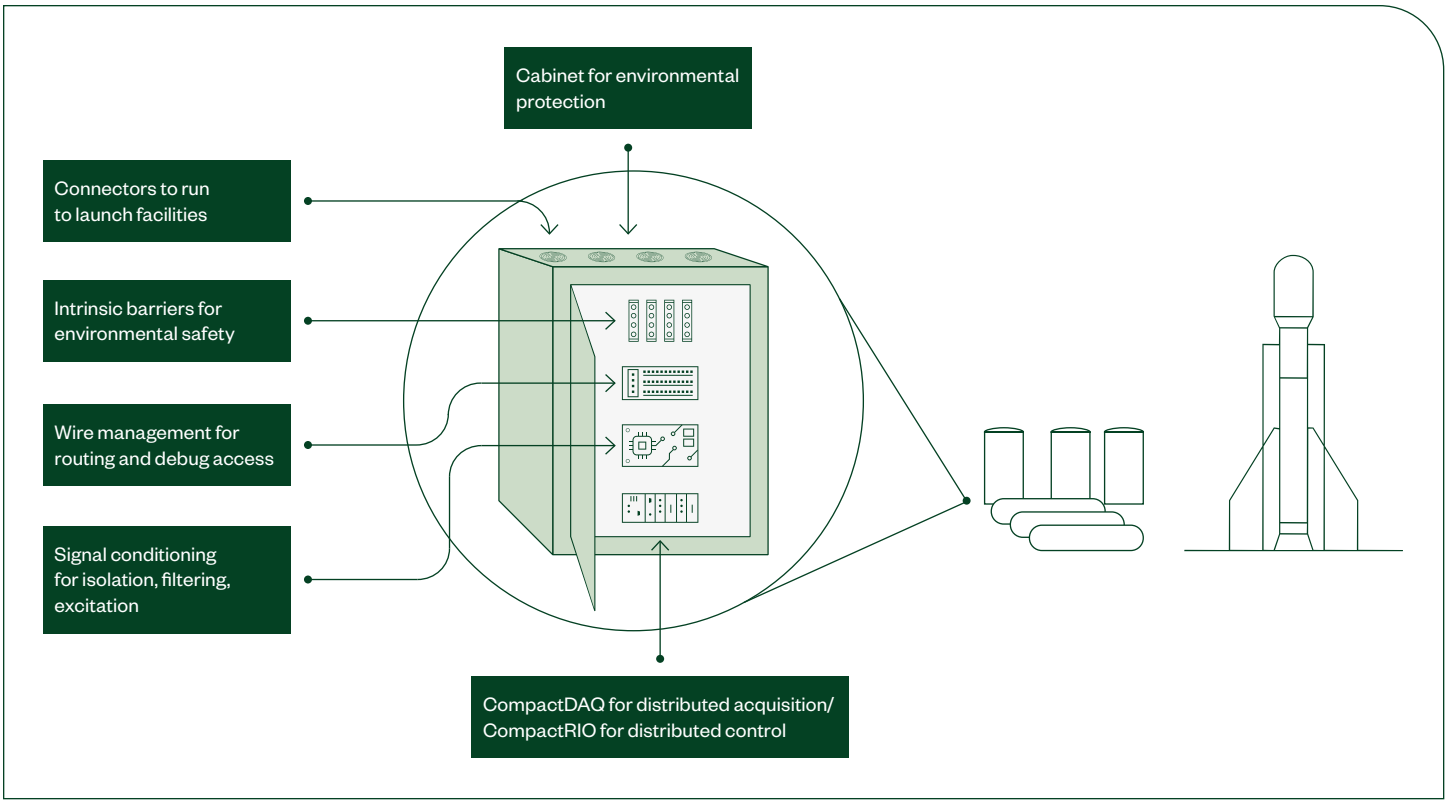


FIGURE 02

Launch Operations Cabinet at Launch Facility

Redundancy is an important part of improving reliability and availability of a system. NI hardware and software technologies enable a variety of redundancy schemes, including sensor, network, and controller redundancy. For more information on implementing redundancy, refer to Redundant System Basic Concepts.

Hardware Architecture

CompactDAQ chassis are deployed to monitoring applications to provide distributed, time-synchronized systems for use around the launch facility. These systems monitor safety systems, environmental conditions, and fluid levels. CompactRIO controllers are also distributed around the facility, and connect to many of the same signals. But CompactRIO controllers provide local closed-loop control with real-time performance for use in control applications.

NI's C-Series modules provide input cards for a variety of signals including analog voltage and current, temperature, strain, vibration, and frequency. C-Series relay modules and discrete I/O modules provide control signals to valves, pumps, and other facility equipment.

The modularity of the C-Series platform means that customers can get the exact sensor mix at each station that they need for their facility.

Some facility equipment may require additional isolation, filtering, or other conditioning. Valves, pumps, and other equipment may require higher power relays. The openness of NI's platform makes it easy to integrate third-party or custom equipment into the solution.

Additional equipment may be required for explosive environments. NI customers add intrinsic barriers in these environments to limit the electrical power that can be transmitted out of the system. NI customers may also add status indicators or test access points to facilitate debugging.

Sensor wires from these measurement and conditioning modules are routed through a marshalling system to group I/O channels. These wire connections provide an access point between the instrumentation and the field systems to simplify sensor changes and provide test access points.

All of these components are contained in an environmental cabinet. Launch facility certifications may demand that the cabinet meet environmental requirements, including Class 1 / Div 1. In these cases, the cabinet must be designed for the environment, which may include sealed cabinets or applying positive air pressure to prevent gas saturation within the cabinet. Connectors on the cabinet provide access to connect field wiring to the launch operations system.

The CompactDAQ chassis or CompactRIO controller is networked to other systems around the launch facility and back to the launch control system. The system is programmed using a variety of software tools including LabVIEW, C++, and Python. Most facilities run the software on Windows, Linux OS, or a Linux Real-Time Operating System.

Altogether, these system components provide a flexible platform suited to meet the demanding needs of a launch facility. NI's professional engineering teams can help you identify the requirements of your facility and design a system to meet those needs.

Software Architecture

Launch operations systems are most often controlled as part of the mission control software. This is especially true when the system is used as part of an actual launch, but is often true when the system is used to conduct rocket or component tests.

In all cases, system reliability is crucial. The software stack depicted in Figure 3 provides multiple points for the distribution of control and monitoring functions, which is ideal for programming multiple redundancy points.

CompactRIO controllers include a user-programmable FPGA and a real-time processor. These can be programmed using NI's LabVIEW FPGA and LabVIEW Real-Time tools to keep everything in a single tool chain, or they can be programmed using other FPGA and Linux tools.

CompactRIO and CompactDAQ systems send data over the network to a host PC, running user code written in a variety of standard languages. This code either communicates to, or is integrated directly into, the mission control software. This allows the system to be controlled as part of the overall launch process.

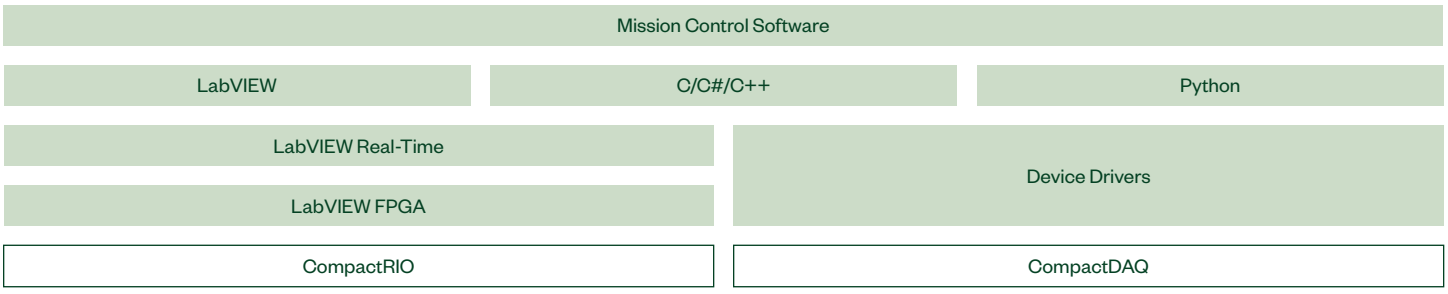


FIGURE 03
Launch Operations Software Stack

Hardware Components

CompactDAQ

CompactDAQ systems collect and deliver the data validation you need to meet test requirements at any distance and in any environment, including launch facilities and other harsh environments. These portable, customizable solutions—made of data acquisition modules that can synchronize measurements across a network—help you get exactly the measurement capability you need while digitizing data closer to sensors, minimizing noise, and simplifying cabling in the field.

CompactDAQ chassis and modules are designed to meet the rigorous requirements of launch facilities and withstand operating temperatures from -40 °C to 70 °C and up to 50 g of shock. CompactDAQ chassis and modules operate in environments of up to 90% humidity, and up to 5,000 meters of altitude.

With the modularity of CompactDAQ, you can create monitoring systems with a variety of sensor channels to match the needs of your launch facility.

The cDAQ-9189 chassis complies with IEEE 802.1 Time Sensitive Networking (TSN) synchronization standards that enable the tight alignment of measurements taken from distributed instruments from distributed measurements using existing ethernet cabling.

CompactDAQ offers best-in-class measurement performance at the best price point with accurate voltage, thermocouple, RTD, vibration, frequency, and other measurements, resulting in a highly reliable and repeatable measurement system.

CompactRIO

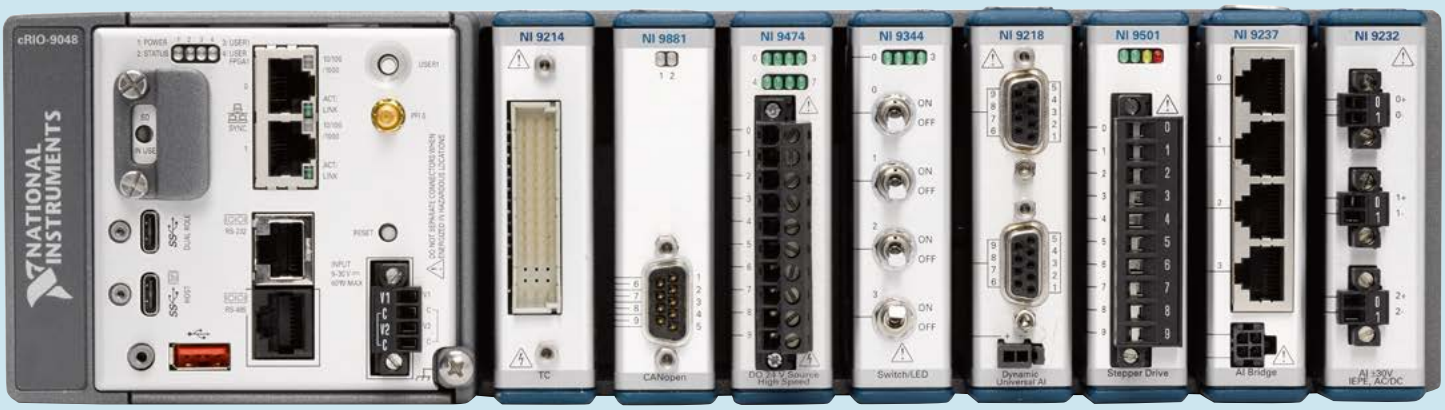
CompactRIO systems provide high-performance processing capabilities, sensor-specific conditioned I/O, and a closely integrated software toolchain that make them ideal for Industrial Internet of Things, monitoring, and control applications. The real-time processor offers reliable, predictable behavior, while the FPGA excels at smaller tasks that require high-speed logic and precise timing.

CompactRIO Controllers and modules are designed to meet the rigorous requirements of launch facilities and withstand operating temperatures from -40 °C to 70 °C and up to 50 g of shock. CompactRIO chassis and modules operate in environments of up to 90% humidity, and up to 5,000 meters of altitude.

Harness the openness of the NI Linux Real-Time OS through thousands of open-source applications, IP, and examples, while collaborating with an active community of users and developers.

Because each module is connected directly to an FPGA in the CompactRIO chassis, you experience almost no control latency for system response compared to other controller architectures.

Abstract low-level code and use a single toolchain to build and deploy time-critical applications on your CompactRIO system using LabVIEW and the real-time and FPGA modules.



C Series Voltage Input Module

The NI-9215 performs differential analog input. The module contains NIST-traceable calibration, a channel-to-earth ground double isolation barrier for safety and noise immunity, and high-common-mode voltage range. It is also offered in two connectivity variants: 10-position screw terminal or BNC.

NI-9215

±10 V, 100 kS/s/ch, 16-Bit, Simultaneous Input, 4-Channel C Series Voltage Input Module

KEY SPECIFICATIONS	
Input range	±10 V
Resolution	16-bit
Accuracy	Input noise: 1.2 LSBrms or 7 LSB (peak-to-peak)
Sample rate	100 kS/s/channel
Channels	4 simultaneously sampled
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	1,167,174 hours at 25 °C; Bellcore Issue 6, Method 1, Case 3, Limited Part Stress Method

C Series Current Input Module

The NI-9208 measures analog current input. The module contains NIST-traceable calibration, a channel-to-earth ground double isolation barrier for safety and noise immunity, and high-common-mode voltage range. It is also offered in two connectivity variants: 37-pin DSUB or spring terminal.

NI-9208

±20 mA, 500 S/s, 24-Bit, Simultaneous Input, 16-Channel C Series Current Input Module

KEY SPECIFICATIONS	
Input range	±20 mA
Resolution	24-bit
Accuracy	Input noise: 50 nArms
Sample rate	500 S/s/channel
Channels	16
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	2,766,252 hours at 25 °C; Bellcore Issue 6, Method 1, Case 3, Limited Part Stress Method

C Series Temperature Input Model

The NI-9213 is a high-density thermocouple input module that is designed for higher channel-count systems. With this module, you can add thermocouples to mixed-signal test systems without taking up too many slots. The NI-9213 includes anti-aliasing filters, open-thermocouple detection, and cold-junction compensation for high-accuracy thermocouple measurements. It features NIST-traceable calibration and a channel-to-earth ground double isolation barrier for safety, noise immunity, and high-common-mode voltage range.

NI-9213

16-Channel, 75 S/s Aggregate, ±78 mV C Series Temperature Input Module

KEY SPECIFICATIONS	
Thermocouple compatibility	J, K, T, E, N, B, R, S thermocouple types
Resolution	24-bit
Sensitivity	Up to 0.02 °C measurement sensitivity
Sample rate	75 S/s aggregate
Channels	16 multiplexed
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	852,407 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Strain/Bridge Input Model

The NI-9235 and NI-9236 measure dynamic strain on all channels simultaneously, allowing for synchronized, high-speed measurements. This capability is important for applications, such as impact tests, that require comparison across many channels at a particular instant in time.

The NI-9235/36 includes built-in voltage excitation for quarter-bridge sensors. It also has 60 VDC isolation and 1,000 Vrms transient isolation, providing high-common-mode noise rejection and increased safety.

NI-9235/36

10 kS/s/channel, 120 Ω Quarter-Bridge Strain Gage, 8-Channel, C Series Strain/Bridge Input Module

KEY SPECIFICATIONS	
Strain gage compatibility	120 Ω / 350 Ω quarter-bridge
Resolution	24-bit
Accuracy	9235 Input noise: 0.38 µV/V RMS @ 1 kS/s; 0.85 µV/V RMS @ 1 kS/s 9236 Input noise: 0.25 µV/V RMS @ 1 kS/s; 0.5 µV/V RMS @ 1 kS/s
	SFDR (1 kHz, -60 dBFS): 9235: 110 dB 9236: 115 dB
	THD (1 kHz, -20 dBFS): 9235: -90 dB 9236: -95 dB
Sample rate	10 kS/s/channel
Channels	8 simultaneously sampled
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	566,796 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Vibration Model

The NI-9232 is a 3-channel C Series dynamic signal acquisition module for making industrial measurements from integrated electronic piezoelectric (IEPE) and non-IEPE sensors with NI CompactDAQ or NI CompactRIO systems.

NI-9232

3-Channel, 102.4 kS/s, ±30 V IEPE Vibration Input Module

KEY SPECIFICATIONS	
Connectivity	Screw terminal or BNC
Resolution	24-bit
Sample rate	102.4 kS/s simultaneous
Channels	3 simultaneous
Excitation	IEPE, software selectable (0 mA or 4 mA)
Isolation	60 VDC, CAT I, channel-to-earth isolation
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	1,357,958 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Frequency Input Model

The C Series Frequency Input Module is designed to acquire isolated frequency inputs from magnetic pickup sensors, variable reluctance sensors, Hall effect sensors, and other transducers with a frequency output. Additionally, the C Series Frequency Input Module provides isolation, configurable thresholds, selectable filtering, and embedded counter measurement logic.

NI-9326

6-Channel frequency input module; up to 128 kHz input, up to 150 Vrms

KEY SPECIFICATIONS	
Frequency input range	0.025 Hz to 128 kHz
Voltage input range	150 Vrms maximum; ±50 mV minimum
Resolution	24-bit
Channels	6
Isolation	150 Vrms, CAT I, ch-to-ch and ch-to-earth
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	1,517,451 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Digital Model

The C Series Digital Modules interact with a range of industrial switches, transducers, and devices. Some modules include an LED per channel that indicates the state of the channel. They support input, output, or a combination of digital lines, and they can interact with a variety of voltages and logic levels, so they are well-suited for a variety of benchtop and industrial environments. Additionally, the C Series Digital Modules also offer isolation options and sinking or sourcing capabilities to add further protection to your digital I/O application.

NI-9375

16-Channel input, 16-Channel output, 0 to 30 VDC digital module

KEY SPECIFICATIONS	
Digital input channels	16 channels
Digital output channels	16 channels
Voltage range	0 VDC to 30 VDC
Update/transfer time	7 µs maximum
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	2,133,561 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Relay Model

The C Series Relay Output Module enables you to switch up to four signals at 60 VDC / 250 AC maximum switching voltage and up to 2.5 A of maximum switching current. For quick reference, every channel features an LED to indicate the state of that channel.

NI-9482

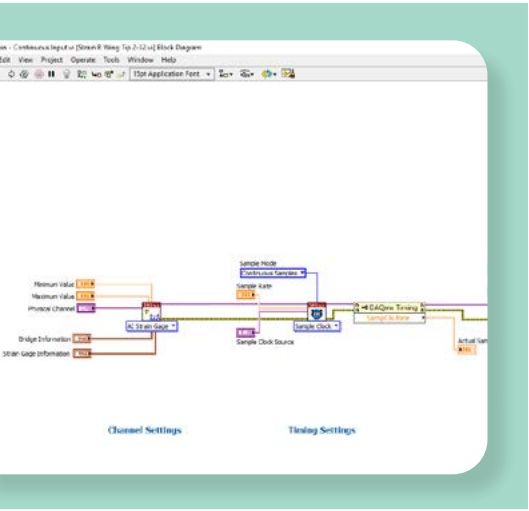
4 channel relay output module, 60 VDC or 250 Vrms switching

KEY SPECIFICATIONS	
Relay Channels	4 electromechanical relay channels
Switching capacity	60 VDC or 250 Vrms
Switching current	1A @ 60 VDC; 2.5 A at 30 VDC or 250 Vrms
Switching rate	1 operation per second
Mechanical Life	20,000,000 operations (no load) 100,000 operations (load)
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	7,077,141 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

Software Components

NI Device Driver Software

All NI hardware is supported by a software device driver. C-Series data acquisition modules are supported by NI-DAQmx. NI-DAQmx provides a programming interface to NI hardware for a variety of programming environments across a variety of operating systems.



SUPPORTED OS:

- Windows 10 (32- and 64-bit)
- Windows 7 (32- and 64-bit)
- Windows XP (32-bit) 3742
- Windows Vista (32- and 64-bit)
- Windows 2000
- Linux (SUSE, Redhat, Mandriva)
- Phar Lap with LabVIEW Real-Time

SUPPORTED DEVELOPMENT ENVIRONMENTS:

- NI LabVIEW
- C / C# / C++
- Visual Basic .NET
- Python

SystemLink Application Software

SystemLink software helps enterprises analyze test and measurement data to remove operational inefficiencies, uncover actionable insights, and improve overall performance across their test workflows. This network-based test system and test data management tool can operate on a dedicated or enterprise network.

LAUNCH OPERATIONS TEAMS USE SYSTEMLINK TO:

- Centrally manage and support launch instrumentation
- Manage calibration and other maintenance actions
- Ensure system configuration compliance
- Efficiently manage, search, share, and analyze measurement data

Ensuring Successful Launch Operations Systems

NI offers a variety of service options including system design support. Work with our teams to properly integrate NI's architecture with third-party components to maximize the performance and reliability of your Launch Operations systems.

Additionally, NI service teams are available to provide hardware services and calibration, on-site system calibration, installation verification to ensure the NI content is properly installed and configured in your system, and in-person or online training for NI software.

Contact your account manager or call or email us to learn more about how NI can help you reduce the design, deployment, and commissioning times in your next Launch Operations system at (888) 280-7645 or info@ni.com.

NI Services and Support

- Repair and Calibration
- Installation Reviews and Verification
- Software Training
- Global Support

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