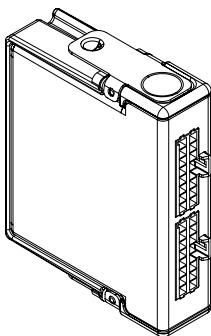


DATASHEET

NI 9470

5 V DC to 30 V DC, 8-Channel (Sourcing Output), 2 kHz C Series Digital Module



- Crimp terminal connectivity
- 60 V DC, Measurement Category I channel-to-earth ground isolation
- Independent output mode configuration for each channel
- Overcurrent detection, field-side power supply fault detection, overtemperature detection, and field-side power supply voltage readback
- Each channel has its own SAR ADC, PWM engine, and PID controller

NI C Series Overview



NI provides more than 100 C Series modules for measurement, control, and communication applications. C Series modules can connect to any sensor or bus and allow for high-accuracy measurements that meet the demands of advanced data acquisition and control applications.

- Measurement-specific signal conditioning that connects to an array of sensors and signals
- Isolation options such as bank-to-bank, channel-to-channel, and channel-to-earth ground
- -40 °C to 70 °C temperature range to meet a variety of application and environmental needs
- Hot-swappable

The majority of C Series modules are supported in both CompactRIO and CompactDAQ platforms and you can move modules from one platform to the other with no modification.

CompactRIO



CompactRIO combines an open-embedded architecture with small size, extreme ruggedness, and C Series modules in a platform powered by the NI LabVIEW reconfigurable I/O (RIO) architecture. Each system contains an FPGA for custom timing, triggering, and processing with a wide array of available modular I/O to meet any embedded application requirement.

CompactDAQ

CompactDAQ is a portable, rugged data acquisition platform that integrates connectivity, data acquisition, and signal conditioning into modular I/O for directly interfacing to any sensor or signal. Using CompactDAQ with LabVIEW, you can easily customize how you acquire, analyze, visualize, and manage your measurement data.



Software

LabVIEW Professional Development System for Windows



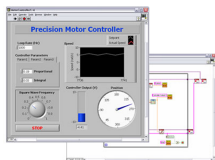
- Use advanced software tools for large project development
- Generate code automatically using DAQ Assistant and Instrument I/O Assistant
- Use advanced measurement analysis and digital signal processing
- Take advantage of open connectivity with DLLs, ActiveX, and .NET objects
- Build DLLs, executables, and MSI installers

NI LabVIEW FPGA Module



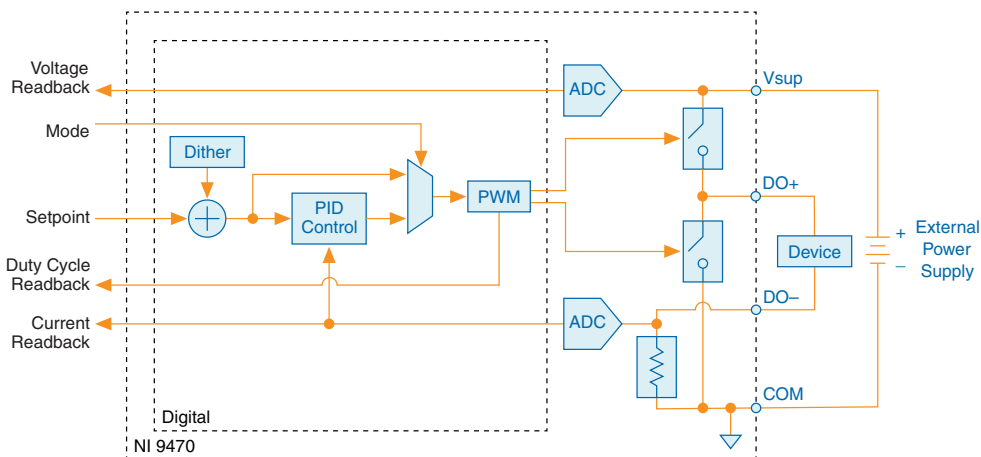
- Design FPGA applications for NI RIO hardware
- Program with the same graphical environment used for desktop and real-time applications
- Execute control algorithms with loop rates up to 300 MHz
- Implement custom timing and triggering logic, digital protocols, and DSP algorithms
- Incorporate existing HDL code and third-party IP including Xilinx IP generator functions
- Purchase as part of the LabVIEW Embedded Control and Monitoring Suite

NI LabVIEW Real-Time Module



- Design deterministic real-time applications with LabVIEW graphical programming
- Download to dedicated NI or third-party hardware for reliable execution and a wide selection of I/O
- Take advantage of built-in PID control, signal processing, and analysis functions
- Automatically take advantage of multicore CPUs or set processor affinity manually
- Take advantage of real-time OS, development and debugging support, and board support
- Purchase individually or as part of a LabVIEW suite

NI 9470 Circuitry



- Each channel of the NI 9470 has an independent SAR ADC that measures voltage across a shunt resistor between DO- and COM for load current readback. The ADC samples at a constant rate at least 32 times the module data rate. All samples captured during each channel pulse width modulation (PWM) cycle are averaged before readback.
- Each channel of the NI 9470 has a PWM engine that drives a field-effect transistor (FET) half-bridge that drives out to the load with a PWM frequency.
- Each channel on the NI 9470 has an independent PID controller and dither that you can configure to any load. Refer to *PID Control* on page 7 for more information.

- Each channel has an external power supply connected to V_{sup} , and the voltage is sampled by a delta-sigma ADC that runs at a constant rate independent of channel PWM frequencies.
- Software input and output to the NI 9470 are in engineering units because the module hardware performs calibration and scaling. Therefore, you do not need to convert raw binary to engineering units.

Maximum Output Current

The maximum output current rating of the NI 9470 is limited by the total module dissipation rating. No single channel's peak current can exceed 3.5 A. Refer to the Maximum Current Per Channel table in [Output Characteristics](#) on page 9 for more information on several permissible load current cases.

For applications not covered in the table mentioned above, use the following formula to determine whether the total module current of your loads for active channels is within the specification. The total percentage must remain under 100%.

Figure 1. Total Module Current Equation

$$\text{Percent Usage} = 4.3\% * (I_{ch0}^2 + I_{ch1}^2 + \dots + I_{ch7}^2)$$

For example, an NI 9470 with two channels at 500 mA, two channels at 1 A, and four channels at 2 A is within the maximum current rating. See the following calculation.

Figure 2. Example Calculation

$$4.3\% * (2 * 0.5^2 + 2 * 1^2 + 4 * 2^2) = 79.6\%$$

PWM Output Alignment

The NI 9470 PWM waveforms are rising edge-aligned. Configuring multiple channels to use the same external power supply can lead to higher transient currents drawn from the supply, thus increasing supply ripple and noise. You can reduce voltage ripple and noise by keeping V_{sup} cabling short and by providing bulk capacitance on the supply near the module. The supply must be capable of sourcing the peak current required. Refer to [Output Characteristics](#) on page 9 for more information on maximum cable lengths, and refer to the [NI 9470 Getting Started Guide](#) on ni.com/manuals for more guidance on connecting cables to the module.

Output Modes

The NI 9470 has two output modes: Duty Cycle mode and Average Current mode. You can configure the output mode of each channel individually.

Duty Cycle mode sets the channel to an open-loop mode without an internal control mechanism. The duty cycle output setpoint controls the PWM engine output regardless of the

load. Use Duty Cycle mode if you need to characterize and test the current response of a load or to implement a custom current control in LabVIEW FPGA.

Average Current mode sets the channel to a closed-loop mode using an internal PID control loop. A PID controller controls the PWM engine duty cycle output and regulates the average current readback of a load based on the average current output setpoint. Use Average Current mode if you need to directly set the average current of a load in software without implementing any custom current control in LabVIEW FPGA.

Output State

When the NI 9470 powers on out of sleep, all DO+ channel outputs will be in the tristate condition with both high and low-side FET switches turned off. If you enable a channel before or after starting the software task, the DO+ output will drive low to COM. PWM output on DO+ channels will start after the software task has started.

Overcurrent fault, power supply fault, and overtemperature fault conditions will result in shutting down the channel, and the DO+ channel output will drive low to COM.



Note The NI 9470 will disable and tristate all DO+ channel outputs if the module goes to sleep or an imported external timebase is lost due to a master module being removed from the system.

Data Rates

The frequency of the master timebase (f_M) controls the module data rate (f_S), PWM, and dither frequencies of the NI 9470. The NI 9470 includes an internal master timebase with a frequency of 12.8 MHz, but the module can also accept an external master timebase or export its own master timebase. To synchronize the data rate of a NI 9470 module with other modules that use master timebases to control sampling, you must configure all the modules to share a single master timebase source.

The following table lists the available data rates of the NI 9470.

Table 1. NI 9470 Data Rates

12.8 MHz Master Timebase	13.1072 MHz Master Timebase
3.200 KS/s	3.277 KS/s
3.125 KS/s	3.200 KS/s
2.560 KS/s	2.621 KS/s
2.000 KS/s	2.048 KS/s

Because the NI 9470 has a limited set of module data rates available, you must configure other modules to run at the same sample rate as the NI 9470 module data rate to synchronize and phase-align samples. Data rates of 3.125 KS/s or 2.000 KS/s with a 12.8 MHz master timebase or 3.200 KS/s or 2.048 KS/s with a 13.1072 MHz are compatible with other dynamic signal acquisition (DSA) modules for phase-aligned samples. If correlated and non-phase-aligned

samples are acceptable for your application, then you can configure other modules using the same master timebase to a faster sample rate than the NI 9470 module data rate.

You can configure the PWM divisor of each channel of the NI 9470 independently with a range of one to 511 to further divide down the module data rate to a channel PWM frequency. Software will operate the NI 9470 I/O nodes at the per-channel frequency. If I/O nodes from different channels or modules with different data rates are combined in the same loop, then the I/O node that runs the slowest will determine the loop time. The faster node will repeat output setpoints, drop readback samples, and a software warning will appear.

You can configure the dither divisor of each channel independently with a range of four to 4,095 that further divides down the channel PWM rate. Larger dither divisor values will increase the number of data points in the generated dither triangle waveform operating around the output setpoint.

Current Readback

The NI 9470 uses a hardware digital comb filter to average current ADC samples and reject noise at harmonics of the channel PWM frequency. The current readback samples returned in software are an average of all samples captured during each PWM cycle. Slower PWM frequencies will have more ADC samples in the average compared to faster PWM frequencies. The minimum number of samples used in an average is 32 samples when the per-channel divisor is set to one.

Diagnostic Features

The NI 9470 supports the following diagnostics features.

- **Overcurrent detection**—The NI 9470 has built-in circuitry to detect over-current fault on its DO+ outputs. If the fault occurs when the NI 9470 is outputting PWM on a channel, then the PWM engine will disable and drive the DO+ output low to COM.
- **Field-side power supply fault detection**—The NI 9470 has built-in circuitry to detect if voltages on its V_{sup} inputs are connected and operating within specification. If the fault occurs when the NI 9470 is outputting PWM on a channel, then the PWM engine will shut down and drive the DO+ output low to COM.
- **Overtemperature detection**—The NI 9470 has an overtemperature sensor to safeguard against excessive power dissipation within the module. If an overtemperature fault occurs when the NI 9470 is outputting PWM, all PWM engines will disable and drive all DO+ outputs low to COM.
- **Field-side power supply voltage readback**—The NI 9470 uses a delta-sigma ADC to measure the voltage on V_{sup} channels at a constant sample rate independent of the channel PWM frequencies. Refer to [Voltage Readback](#) on page 10 for more information. You should configure voltage readback in its own loop separate from software loops on the per-channel output setpoint, current, and duty cycle readback.

PID Control

Each channel of the NI 9470 has a hardware digital PID controller with its own set of independent coefficients. The PID controller activates when you set the channel output mode to Average Current mode.

You can set the PID controller response to Slow, Medium, or Fast, or you can use a custom response that allows you to choose any PID coefficient value. The following table shows the approximate load characteristics for the preset PID responses.

Table 2. Preset PID Responses Guidelines

PID Response	Load L/R
Slow	0.02 H/Ω to 0.15 H/Ω
Medium	0.005 H/Ω to 0.02 H/Ω
Fast	0.001 H/Ω to 0.005 H/Ω

You can use the Slow PID response option with a lower PWM frequency for high-inductance loads and the Fast response option with a higher PWM frequency for low-inductance loads.

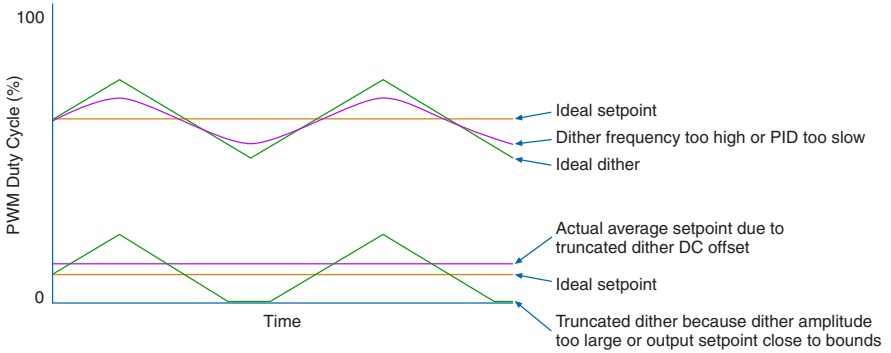
Custom PID coefficients use the unit duty cycle percentage divided by amp. For example, if the integral coefficient $I = 1\%/Amp$ and other coefficients are zero, then an error of 1 A between the current setpoint and the readback will change the PWM duty cycle output by one percent.

Dither

Each channel of the NI 9470 has a dither engine that allows you to configure amplitude and frequency per channel. The dither engine generates a triangle wave with a zero DC average superimposed on the output setpoint depending on the channel output mode.

Because you can configure the NI 9470 features in a wide range of flexibility, you may encounter cases where the actual dither output on PWM and corresponding average current do not align with the configuration you desire. The following diagram illustrates two general non-ideal cases that may occur independently or simultaneously.

Figure 3. Example Scenario



The ideal case for dither is a triangle waveform with the desired peak amplitude matching the configured amplitude and superimposed on the output setpoint value. In both output modes, if the dither amplitude is too large, or the output setpoint value is too close to bounds, then it results in the PWM output railing at 0% or 100% duty cycle. If the overall ideal dither waveform is truncated, then a non-zero DC offset will be present on the output setpoint and corresponding average current measurement.

In Average Current mode, the PID response will impact dither because PID typically acts like a low-pass filter that zeroes the DC error between the average current output setpoint and readback. The superimposed dither waveform may experience reduced amplitude or will be filtered out if the dither frequency is too high, or the PID response is too slow.

In Duty Cycle mode, be aware that implementing an external average current PID control loop in LabVIEW FPGA will generally nullify the NI 9470 dither that is applied on the duty cycle output setpoint because the PID will normally regulate average current to a setpoint and not allow current variations caused by dither on the PWM duty cycle.

NI 9470 Specifications

Definitions

Warranted specifications describe the performance of a model under stated operating conditions and are covered by the model warranty.

Characteristics describe values that are relevant to the use of the model under stated operating conditions but are not covered by the model warranty.

- *Typical* specifications describe the performance met by a majority of models.
- *Nominal* specifications describe an attribute that is based on design, conformance testing, or supplemental testing.

Specifications are *Typical* unless otherwise noted.

Conditions

Specifications are valid for the range -40 °C to 70 °C unless otherwise noted.

Output Characteristics

Number of output channels	8 push-pull
Current-sensing inputs	8 low-side sensing resistors
Data rate	
12.8 MHz timebase	3.2 kHz 3.125 kHz 2.56 kHz 2 kHz
13.1072 MHz timebase	3.277 kHz 3.2 kHz 2.621 kHz 2.048 kHz
PWM frequency configuration	Per channel
PWM frequency	$\frac{Data\ Rate}{1}$ to $\frac{Data\ Rate}{511}$
PWM frequency, maximum	2.048 kHz
PWM frequency accuracy	0.01%
Duty cycle range	0% to 100%
Pulse distortion	430 ns maximum

Table 3. Maximum Current Per Channel

Number of Channels	Maximum Current Per Channel
Two channels	3 A
Four channels	2.3 A
All channels	1.6 A



Note Maximum current is the average output current for inductive loads and is the RMS current for resistive loads. The RMS current for a resistive load is given by the peak current times the square root of the duty cycle.

Maximum peak current per channel	3.5 A
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Maximum cable length

External power supply cable maximum length	10 m
Digital output cable maximum length	20 m

Current Readback

Sample rate	Once every PWM cycle
ADC type	Oversampled SAR
Readback resolution	16 bits
Nominal input range	-0.35 A to 3.5 A

Table 4. Accuracy

Measurement Conditions	Percent of Reading (Gain Error)	Percent of Range ¹ (Offset Error)
Maximum (-40 °C to 70 °C)	1.36%	0.571%
Typical (-40 °C to 70 °C)	0.652%	0.174%

Stability

Gain drift	74 ppm/°C
Offset drift	51 μ C/°C
Integral non-linearity	0.073%
Noise	200 μ A RMS

Voltage Readback

Sample rate	$\frac{\text{Data Rate}}{10}$
ADC type	Sigma-Delta
Readback resolution	11 bits
Nominal input range	0 V to 40 V
Gain accuracy	1.2%
Offset accuracy	200 mV
Noise	10 mV RMS

¹ Range = 3.5 A.

Temperature Readback

Sample rate	$\frac{\text{Data Rate}}{10}$
ADC type	Sigma-Delta
Readback resolution	12 bits
Nominal measurement input range	-40 °C to 125 °C

Output Mode Characteristics

Setpoint mode	Per channel
Duty Cycle mode	
Duty cycle setpoint	0% to 100%
Duty cycle setpoint resolution	0.025% maximum
Average Current mode	
Current setpoint	0 A to 3.5 A
Current setpoint resolution	12 bits
PID coefficients	$\frac{0\%}{A}$ to $\frac{16,383.999\%}{A}$
PID coefficient resolution	$\frac{0.001\%}{A}$

Dither

Dither control	Per channel
Waveform	Triangle
Dither frequency	$\frac{PWM\ Frequency}{4}$ to $\frac{PWM\ Frequency}{4,095}$
Maximum dither period error ²	4 PWM cycles
Open-loop mode	
Peak amplitude	0% to 100%
Amplitude resolution	12-bit

² NI recommends selecting a dither divisor that is a multiple of four to generate an optimal dither triangle wave with zero period error. Other values for the dither divisor will be rounded up to the next multiple of four in generating the dither waveform to ensure there is an even number of points in each quarter section of the triangle waveform. The dither triangle wave slope will differ from an ideal triangle wave, especially at small dither divisor values that are not multiples of four.

Closed-loop mode

Peak amplitude	0 A to 3.5 A
Amplitude resolution	12-bit

Diagnostics and Protection

Error flags (per channel)

Voltage out-of-range flag	$V_{\text{sup}} < 4.2 \text{ V}$ or $V_{\text{sup}} > 34 \text{ V}$
Overcurrent flag	$I_{\text{sup}} > 8.5 \text{ A}$ (4.3 A minimum, 14 A maximum)



Note I_{sup} is the current sourced from the supply on V_{sup} to the load on DO+.

PWM shut down conditions

Shut down behavior	Drive output low (DO+ = COM)
Overvoltage	$V_{\text{sup}} > 35 \text{ V}$
Undervoltage	$V_{\text{sup}} < 4 \text{ V}$
Overcurrent	$I_{\text{sup}} > 8.5 \text{ A}$ (4.3 A minimum, 14 A maximum)
Overcurrent response time	2.5 μs
Overtemperature protection	Per module
PWM output tristate conditions	Power up, power down, master timebase loss
Reverse polarity protection (V_{sup} -to-COM)	-30 V

I/O Wiring

I/O plug type Molex Ultra-Fit, part number 1722583116

Crimp terminal

18 AWG to 16 AWG	Molex Ultra-Fit, part number 1722536012
22 AWG to 20 AWG	Molex Ultra-Fit, part number 1722536112
Wire gauge	22 AWG to 16 AWG



Note NI recommends using 2x Molex Ultra-Fit terminal position assurance retainers (Molex part number 1722644008) with each connector to prevent terminal back-out.

Software Support

Application software	LabVIEW 2019 or later
Add-Ons	LabVIEW FPGA Module
Driver support	NI CompactRIO 19.6 or later

Safety Guidelines for Hazardous Locations

Follow these guidelines if you are installing the device in a potentially explosive environment. The device has been evaluated as compliant with the ATEX directive and is IECEx certified. Each device is marked Ⓢ II 3G and is suitable for use in Zone 2 hazardous locations, in ambient temperatures of $-40\text{ °C} \leq T_a \leq 70\text{ °C}$. The device is suitable for use in non-hazardous locations and the following hazardous locations.

U.S. (UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, AEx nA IIC T4 Gc
Canada (C-UL)	Class I, Division 2, Groups A, B, C, D, T4; Ex nA IIC T4 Gc
Europe (ATEX) and International (IECEx)	Ex nA IIC T4 Gc; DEMKO 12 ATEX 1202658X; IECEx UL 14.0089X

Safety Voltages

Connect only voltages that are below these limits.

$V_{\text{sup-to-COM}}$	0 V DC to 30 V DC maximum, Measurement Category I
Isolation	
Channel-to-channel	None
Channel-to-earth ground	
Continuous	60 V DC, Measurement Category I
Withstand	1,000 V RMS, verified by a 5 s dielectric withstand test

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as *MAINS* voltage. *MAINS* is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.



Note Measurement Categories CAT I and CAT O are equivalent. These test and measurement circuits are for other circuits not intended for direct connection to the

MAINS building installations of Measurement Categories CAT II, CAT III, or CAT IV.



Caution Do not connect the NI 9470 to signals or use for measurements within Measurement Categories II, III, or IV.



Attention Ne connectez pas le NI 9470 à des signaux et ne l'utilisez pas pour effectuer des mesures dans les catégories de mesure II, III ou IV.

Safety Compliance and Hazardous Locations Standards

This product is designed to meet the requirements of the following electrical equipment safety standards for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA C22.2 No. 61010-1
- EN 60079-0, EN 60079-15
- IEC 60079-0: Ed 6, IEC 60079-15; Ed 4
- UL 60079-0; Ed 6, UL 60079-15; Ed 4
- CSA C22.2 No. 60079-0, CSA C22.2 No. 60079-15



Note For UL and other safety certifications, refer to the product label or the *Product Certifications and Declarations* section.

Electromagnetic Compatibility Standards

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326-1): Class A emissions; Industrial immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions



Note Group 1 equipment (per CISPR 11) is any industrial, scientific, or medical equipment that does not intentionally generate radio frequency energy for the treatment of material or inspection/analysis purposes.



Note In the United States (per FCC 47 CFR), Class A equipment is intended for use in commercial, light-industrial, and heavy-industrial locations. In Europe, Canada, Australia and New Zealand (per CISPR 11) Class A equipment is intended for use in non-residential locations.

Environmental Characteristics

Temperature and Humidity

Temperature

Operating	-40 °C to 70 °C
Storage	-40 °C to 85 °C

Humidity

Operating	10% RH to 90% RH, noncondensing
Storage	5% RH to 95% RH, noncondensing

Ingress protection	IP40
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Pollution Degree	2
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Maximum altitude	5,000 m
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Shock and Vibration

Operating vibration

Random	5 g RMS, 10 Hz to 500 Hz
Sinusoidal	5 g, 10 Hz to 500 Hz

Operating shock	30 g, 11 ms half sine; 50 g, 3 ms half sine; 18 shocks at 6 orientations
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Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *Commitment to the Environment* web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)



EU Customers At the end of the product life cycle, all NI products must be disposed of according to local laws and regulations. For more information about how to recycle NI products in your region, visit ni.com/environment/weee.

电子信息产品污染控制管理办法（中国 RoHS）



中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

Environmental Standards

This product meets the requirements of the following environmental standards for electrical equipment.

- IEC 60068-2-1 Cold
- IEC 60068-2-2 Dry heat
- IEC 60068-2-30 Damp heat cyclic (12 + 12h cycle)
- IEC 60068-2-64 Random operating vibration
- IEC 60068-2-6 Sinusoidal operating vibration
- IEC 60068-2-27 Operating shock



Note To verify marine approval certification for a product, refer to the product label or visit ni.com/certification and search for the certificate.

Power Requirements

Power consumption from chassis

Active mode	571 mW
Sleep mode	1 mW

Thermal dissipation (at 70 °C)

Active mode	1.5 W
Sleep mode	200 mW

Current per channel

Two channels active	3 A
Four channels active	2.3 A
Eight channels active	1.6 A
V_{sup}	5 V to 30 V

External power supply	5 V to 30 V
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Physical Characteristics



Tip For two-dimensional drawings and three-dimensional models of the NI 9470 and connectors, visit ni.com/dimensions.

Dimensions

Length	76 mm (3 in.)
Width	23 mm (0.9 in.)
Height	88 mm (3.5 in.)
Weight	140 g (4.9 oz)

CE Compliance

This product meets the essential requirements of applicable European Directives, as follows:

- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)
- 2014/34/EU; Potentially Explosive Atmospheres (ATEX)
- 2011/65/EU; Restriction of Hazardous Substances (RoHS)

Calibration

You can obtain the calibration certificate and information about calibration services for the NI 9470 at ni.com/calibration.

Calibration interval 2 years

Product Certifications and Declarations

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for NI products, visit ni.com/product-certifications, search by model number, and click the appropriate link.

Worldwide Support and Services

The NI website is your complete resource for technical support. At ni.com/support, you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

Visit ni.com/services for information about the services NI offers.

Visit ni.com/register to register your NI product. Product registration facilitates technical support and ensures that you receive important information updates from NI.

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