
NI-9470

Getting Started

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Connecting the NI-9470

You can connect a variety of industrial devices, such as solenoids, valves, motors, actuators, relays, and lamps to the NI-9470.

Connect the device between the DO+ and DO- pins, and connect the external power supply. Use cables 20 m or shorter for connections from DO- and DO+ to the load.

NI-9470 Pinout

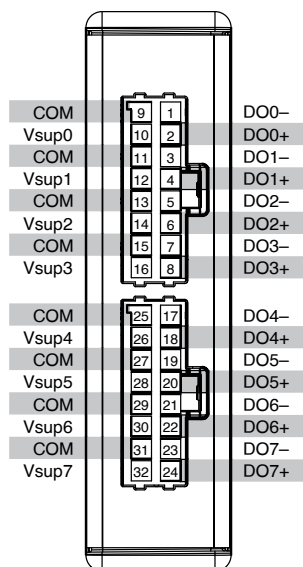


Table 1. Signal Descriptions

| Signal | Description |
|------------------|--|
| COM | Common reference connection for the power supply |
| DO- | Digital output return (negative) connection |
| DO+ | Digital output source (positive) connection |
| V _{sup} | DC voltage power supply connection |

Connecting an External Power Supply to the NI-9470

You must connect an external power supply to each active channel of the NI-9470. The power supplies provide the current for the output channels. Each channel has its own V_{sup} and COM pin, and all COM pins are connected internally in the NI-9470.



Caution Do not install or remove C Series modules from your system if any external power supplies connected to the V_{sup} and COM pins are powered on.



Attention Ne pas installer ou retirer les modules de la Série C de votre système si une alimentation externe connectée aux broches V_{sup} et COM est sous tension.

Complete the following steps to connect an external power supply to the NI-9470. Use cables 10 m or shorter for connections from V_{sup} to COM to the supply to reduce voltage noise and ripple. For lengths longer than 10 m, NI recommends placing more than 2,200 μF of bulk capacitance close to the NI-9470 module.

1. Connect the positive lead of the power supply to V_{sup} .
2. Connect the negative lead of the power supply to COM.

I/O Protection

Each DO+ channel of the NI-9470 has short-circuit protection. Each V sup terminal has reverse polarity protection.



Notice Voltages greater than the supply voltage and negative voltage conditions on DO+ can damage the NI-9470.

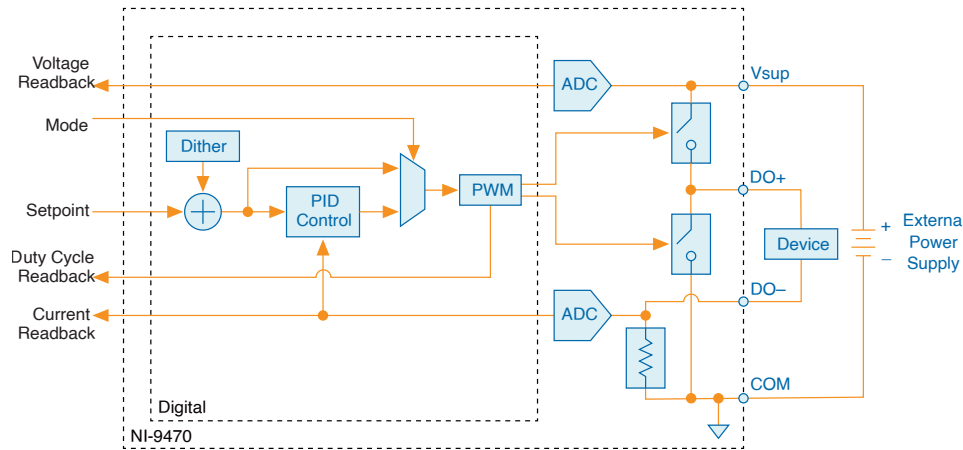


Notice The DO- terminal is not protected against overvoltage conditions.



Note Refer to the **NI-9470 Specifications** for maximum continuous output current, short-circuit behavior, and short-circuit trip time specifications.

NI-9470 Block Diagram



- 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](#) 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 the Output Characteristics section of the **NI-9470 Specifications** 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

$$\text{PercentUsage} = 4.3 \% * (I.ch0^2 + I.ch1^2 + \dots + I.ch7^2)$$

$$\text{PercentUsage} = 4.3 \% * (I.ch0^2 + I.ch1^2 + \dots + I.ch7^2)$$

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

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

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 the Output Characteristics section of the **NI-9470 Specifications** for more information on maximum cable lengths.

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 2. 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 PWM 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 the Voltage Readback section of the **NI-9740 Specifications** 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 3. 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.

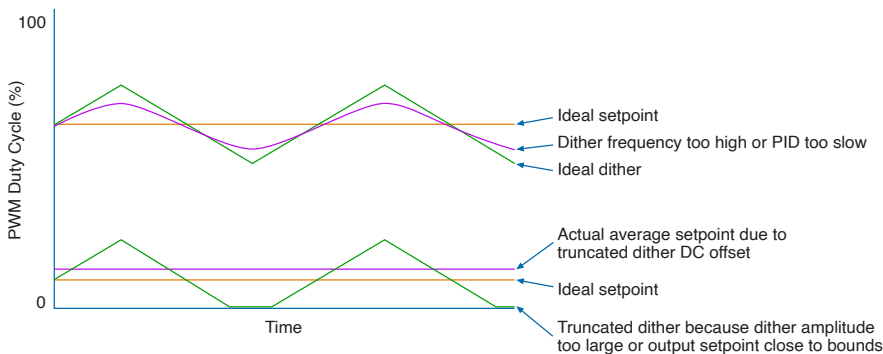
Custom PID coefficients use the unit duty cycle percentage divided by amp. For example, if the integral coefficient $I = 1\%/Amp$ and other coefficients are zero, then an error of 1 A between the current setpoint and the readback will change the PWM duty cycle output by one percent.

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.

Cables and Accessories

The following table lists some cables and accessories that are compatible with the NI-9470. For a complete list of accessories and ordering information, refer to the pricing section of the NI-9470 product page on ni.com.

Table 4. NI-9470 Cables and Accessories

| Cable/Accessory | Part Number |
|-----------------|-------------|
| 1 M Cable | 132410A-01 |
| 2 M Cable | 132410A-02 |
| 5 M Cable | 132410A-05 |

If you would like to build your own cables for the NI-9470, you will need to purchase the following crimp tools or their equivalents. Refer to the manufacturer's documentation on www.molex.com for more information on building your own cables.

Table 5. Crimp Tools for Building Your Own Cables

| Description | Molex Part Number | Supported Wire AWG |
|---|-------------------|--------------------|
| Hand Crimp Tool for Ultra-Fit Tangless Crimp Terminals, 20-22 AWG (UL1061) Wire | 2002184700 | 22 AWG to 20 AWG |
| Hand Crimp Tool for Ultra-Fit Tang-less Crimp Terminals, 16-18 AWG (UL1061) Wires | 2002184600 | 18 AWG to 16 AWG |

In addition to the provided connector housings, you will need the following parts for each cable. The Ultra-Fit housing leaves the crimps exposed at the rear of the housing. NI recommends insulating the back of the connector with 25 mm(1.0 in.) diameter heat shrink.

Table 6. Parts for Building Your Own Cables

| Description | Molex Part Number | Support Wire AWG | Quantity |
|------------------------------------|-------------------|------------------|----------|
| Ultra-Fit Tangless Crimp Terminal, | 1722536112 | 22 AWG to 20 AWG | 16 |

| Description | Molex Part Number | Support Wire AWG | Quantity |
|--|-------------------|------------------|----------|
| Female, 0.76µm Gold (Au) Plating, 20-22 AWG | | | |
| Ultra-Fit Tangless Crimp Terminal, Female, 0.76µm Gold (Au) Plating, 16-18 AWG | 1722536012 | 18 AWG to 16 AWG | 16 |

Conformal Coating

The NI-9470 is available with conformal coating for additional protection in corrosive and condensing environments, including environments with molds and dust.

In addition to the environmental specifications listed in the **NI-9470 Safety, Environmental, and Regulatory Information**, the NI-9470 with conformal coating meets the following specification for the device temperature range. To meet this specification, you must follow the appropriate setup requirements for condensing environments. Refer to **Conformal Coating and NI RIO Products** for more information about conformal coating and the setup requirements for condensing environments.

| | |
|---|---------------------------|
| Operating humidity (IEC 60068-2-30 Test Db) | 80 to 100% RH, condensing |
|---|---------------------------|

Related information:

- [Conformal Coating and NI RIO Products](#)