

# Instruction Manual SPI Controller Box

Please read carefully before switching on the power! Please see safety instructions for using piezoelectric actuators and power supplies!



**CE**

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## Table of contents

1	Introduction.....	3
2	Certification of piezosystem jena.....	3
3	Declaration of conformity .....	3
4	Purchased part package .....	4
5	Instructions for using piezo electrical elements and power supplies.....	4
6	Safety instructions.....	5
6.1	Icons.....	5
6.2	Installation & power supply .....	6
6.3	Operation.....	6
6.4	Maintenance and inspection .....	7
6.5	Environmental conditions .....	7
7	General Information .....	8
7.1	Introduction.....	8
7.2	Hardware Structure.....	8
7.3	System Setup .....	8
7.4	Technical Data List .....	9
8	Working Principle of SPI Controller Box.....	9
8.1	Data Processing .....	9
8.2	Mode of Operations .....	10
9	Connectors and Pin Assignment.....	11
9.1	3D Drawing.....	11
9.2	Power Supply Connector .....	11
9.3	SPI Connector .....	12
9.4	Ethernet Connector.....	12
9.5	USB Connector.....	12
9.6	RS232 Connector .....	12
10	Communication with the SPI Controller Box .....	13
10.1	SPI Communication.....	13
10.2	USB, RS232 & Ethernet Communication.....	13
11	PiSoWorks Integration.....	16
11.1	NV200 Configuration .....	16
11.2	Single Position Data .....	17
11.3	Waveform Generation .....	18

## 1 Introduction

This manual provides information about the SPI Controller Box manufactured by piezosystem jena GmbH. You will also find additional information regarding piezoelectric products.

Definition: All systems from piezosystem jena such as electronics, actuators, and optical systems are called “units”.

If you have any problems, please contact the manufacturer of the system: piezosystem jena, Stockholmer Str. 12, 07747 Jena. Phone: +49 36 41 66 88-0

## 2 Certification of piezosystem jena

The company piezosystem jena GmbH has worked according to a DIN EN ISO 9001 certified quality management system since 1999. Its effectiveness is verified and proven by periodic audits by the TÜV.



This instruction manual includes important information for using piezo actuators and electronics. Please take the time to read this information. Piezo positioning systems are mechanical systems that offer the highest precision. Correct handling guarantees that this precision will be maintained over a long period of time.

## 3 Declaration of conformity

The CE Declaration of Conformity is available on our website [www.piezosystem.com](http://www.piezosystem.com).

#### 4 Purchased part package

Please check the completeness of the delivery after receiving the shipment:

- SPI Controller Box
- wide range power supply 24 VDC

For optional needed drivers or available software see our homepage.

#### 5 Instructions for using piezo electrical elements and power supplies


- Piezoelectric actuators from piezosystem jena are controlled by voltages up to 180 V. These values can be quite hazardous. Therefore, read the installation instructions carefully and ensure that only authorized personnel handle the power supply.
- After transportation, piezoelectric actuators should be allowed to adapt to room temperature for approximately 2 hours before being switched on.
- Piezoelectric actuators are made from ceramic materials with and without metallic casings. The piezo-ceramic is a relatively brittle material. This should be noted when handling piezoelectric actuators. All piezo elements are sensitive to bending or shock forces.
- Due to the piezoelectric effect, piezo actuators can generate electrical charges by changing the mechanical load or the temperature, or by actions such as the ones described above.
- Piezoelectric actuators are able to work under high compressive forces. Only actuators with a pre-load can be used under tensile loads (these tensile forces must be less than the pre-load given in the data sheet). Please note that acceleration of the ceramic material (e.g., caused by fall down, discharging, or high dynamic application) will occur.
- After excitation of the actuators by a voltage in the upper control range, the ceramic will move and generate an opposite high voltage after disconnection.
- Heating of the ceramic material will occur during dynamic operation and is caused by structure conditional loss processes. This may cause failure if the temperature exceeds specified values cited below. With increasing temperature up to the Curie temperature  $T_C$ , (usual values approx.  $140\text{ °C} - 250\text{ °C}$ ) the piezoelectric effect disappears. We recommend working in temperatures up to  $T_C/2$  (normally up to  $80\text{ °C}$ ).
- Piezoelectric actuators, such as stacks or other devices, work electrically as a capacitor. These elements are able to store electrical energy over a long period of time (up to some days) and the stored energy may be dangerous.
- If the actuator remains connected to the drive electronics, it will be unloaded within a second after shutdown and quickly reaches harmless voltage values.
- Piezo actuators can only generate voltages by warming or cooling (caused by the longitudinal change). The discharge potential should not be ignored due to the inner capacitance. This effect is insignificant at usual room temperature.
- Piezo actuators from piezosystem jena are adjusted and glued. Any opening of the unit will cause misalignment or possible malfunction and will result in the loss of the guarantee.
- Please only use original parts from piezosystem jena.


Please contact piezosystem jena or your local representative if there are any problems with your actuator or power supply.

**Caution!** Shock forces may damage the built-in ceramic elements. Please avoid such forces, and handle the units with care, otherwise the guarantee will be lost.

## 6 Safety instructions

### 6.1 Icons

 **RISK OF ELECTRIC SHOCK!** Indicates that a risk of electric shock is present and the associated warning should be observed.

 **CAUTION! REFER TO OPERATOR'S MANUAL** – Refer to your operator's manual for additional information, such as important operating and maintenance instructions.

**RISK OF ELECTRIC SHOCK!** 

- Do not open the units! There are no user serviceable parts inside and opening or removing covers may expose you to dangerous shock hazards or other risks. Refer all servicing to qualified service personnel.
- Do not spill any liquids into the cabinet or use the units near water.

**CAUTION!** 

- Allow adequate ventilation around the units so that heat can properly dissipate. Do not block ventilated openings or place the units near a radiator, oven, or other heat sources. Do not put anything on top of the units except those that are designed for that purpose (e.g. actuators).
- Only work with the units in a clean and dry environment! Only specially prepared units (e.g. actuators) can work under other conditions!
- Please only use original parts from piezosystem jena. piezosystem jena does not give any warranty for damages or malfunction caused by additional parts not supplied by piezosystem jena. Additional cables or connectors will change the calibration and other specified data. This can change the specified properties of the units and cause them to malfunction.
- Piezo elements are sensitive systems capable of the highest positioning accuracy. They will demonstrate their excellent properties only if they are handled correctly! Please mount them properly at the special mounting points.

Immediately unplug your unit from the wall outlet and refer servicing to qualified service personnel under the following conditions:

- when the cords or plugs are damaged
- if liquid has been spilled or objects have fallen into the unit
- if the unit has been exposed to rain or water
- if the unit has been dropped or the housing is damaged

## 6.2 Installation & power supply

RISK OF ELECTRIC SHOCK! 

- Do not insert or unplug the power plug with wet hands, as this may result in electrical shock.
- Do not install in rooms where inflammable substances are stored. If flammable substances come into contact with electrical parts inside, it could result in fire or electrical shock.
- Do not damage or modify the power cord. Also, do not place heavy objects on the power cord, or pull on or excessively bend it, as this could cause electrical damage and result in a fire or electrical shock.
- Always grasp the plug portion when unplugging the power cord. Pulling on the power cord may expose or snap the core wire, or otherwise damage the power cord. If the cord is damaged, this could cause an electricity leak and result in a fire or electrical shock.

CAUTION! 

- Do not use accessories other than the ones provided (e.g. power cord). Only plug the power cord into grounded power equipment and sockets.
- Do not place heavy objects on any cables (e.g. power cords, sensor cables, actuator cables, optical cables).
- Do not block ventilated openings or place the units near a radiator, oven, or other heat sources.
- Plug in the power cord completely so that it cannot loosen inadvertently.
- Leave sufficient space around the power plug so that it can be unplugged easily. If objects are placed around the power plug, you will be unable to unplug it in an emergency.
- Install the system so that the on/off-switch is easily accessible at all times.
- The power plug is the cut-off point to the main power supply.

## 6.3 Operation

RISK OF ELECTRIC SHOCK! 

- Do not open the units! There are no user serviceable parts inside and opening or removing covers may expose you to dangerous shock hazards or other risks. Refer all servicing to qualified service personnel.
- Do not spill inflammable substances inside the device. If these items come into contact with an electrical component inside the device, this may result in a fire or electrical shock.

CAUTION! 

- If the device emits smoke, high heat, or unusual smells, immediately turn off the power switch and unplug the power plug from the outlet. Then contact our technical service.

## 6.4 Maintenance and inspection

CAUTION! 

- Before cleaning the exterior box of the SPI Controller Box, turn off the power switch and unplug the power plug. Failure to do so may result in a fire or electrical shock.
- Clean the exterior box using a damp cloth that has been firmly wrung-out. Do not use alcohols, benzene, paint thinner or other inflammable substances. If flammable substances come into contact with an electrical component inside the device, this may result in a fire or electrical shock.

## 6.5 Environmental conditions

The device can be used:

- indoors only
- at an altitude of up to 2000 m
- at a temperature between: 5 ... 35 °C
- at a relative humidity between: 5 ... 95 % (non-condensing)

The recommended environmental conditions:

- indoors only
- at an altitude of up to 2000 m
- at a temperature between: 20 ... 22 °C
- at a relative humidity between: 5 ... 80 % (non-condensing)

## 7 General Information

### 7.1 Introduction

The SPI Controller Box is designed to enhance the capability of using multiple amplifiers to control various axes of actuators provided by piezosystem jena GmbH. It enables the synchronous control of multiple actuator axes or multiple actuators simultaneously, depending on the number of axes involved. The device supports transmitting position data via SPI to connected NV200 units and receiving their responses. Received data can be accessed using the available commands. When operated as an SPI slave, the device also enables real-time control.

### 7.2 Hardware Structure

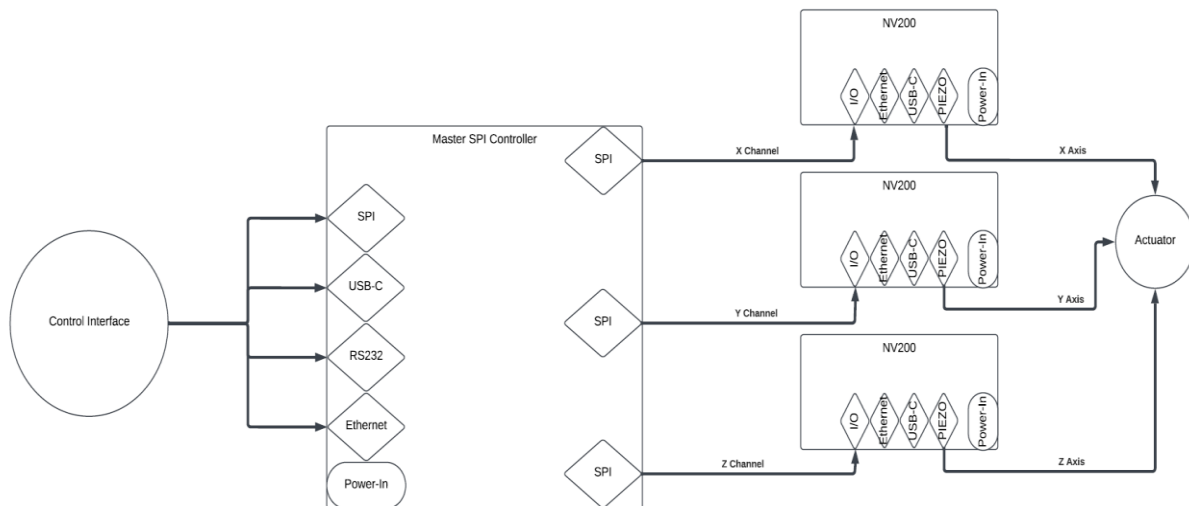
The device's hardware comprises peripheral connections, power, and control circuits. The peripheral connections are listed below:

**Input Ports:** SPI (Internal Slave), Ethernet, USB-C, RS232

**Output Ports:** 3 x SPI (Internal Master)

### 7.3 System Setup

To set up the system, connect the input ports to their corresponding interfaces. The output ports should be directly connected to the amplifiers to enable communication over the SPI channels. Since each amplifier has a single SPI channel, each SPI port on the SPI Controller Box must be connected to a respective amplifier. The complete connection diagram can be seen in the figure below.



## 7.4 Technical Data List

Input voltage (Vdc)	24
Power supply connector	low voltage socket with 2.1 mm pin
Input current (A)	0.15
Power consumption (W)	3.6
Display (LED)	3x SPI outputs: green / orange 3x Interface input: green 1x Power input: blue
Interfaces	SPI, Ethernet, USB, RS232
Interface Connections	15 Pin D-Sub (SPI), Lantronix XPORT (Ethernet), USB-C, 9 Pin D-Sub (RS232)
Resolution (bits)	16
SPI speed (MHz)	Output to NV200: 1.5625 Input: max 6
SPI I/O delay (µs)	max. 30 (last bit clocked to all channels output)
Synchronization delay (µs)	max. 2 (when 3 channels active)
Baud rate	115200
Dimensions (L * W * H) (mm <sup>3</sup> )	120 * 165 * 38
Weight(kg)	0.490

## 8 Working Principle of SPI Controller Box

### 8.1 Data Processing

The SPI Controller Box receives ASCII strings terminated with a carriage return and line feed (CR + LF) through its three serial input interfaces. For SPI input, the device expects four 16-bit data fragments. For detailed information on SPI communication with the SPI Controller Box, refer to chapter 10.1.

The device processes digital signals with a 16-bit resolution. The minimum and maximum setpoints sent to the amplifiers for actuator positioning are adjusted according to 16-bit scale, where 0x0000 represents the minimum setpoint and 0xFFFE represents the maximum setpoint.

Due to the behavior of SPI and the NV200, the response data received from the NV200 is always delayed by 2 cycles. This means that whenever you send request **n** to get the current position of the Piezo Element, the response is from request **n - 2**. Please note that for SPI input there is another added delay cycle.

The SPI output interfaces are used to transmit setpoints to each NV200. Configuration parameters cannot be transferred to the NV200 units via the SPI interface. Therefore, all amplifiers must be preconfigured through the USB or Ethernet interface before operation with the SPI Controller Box. In particular, the **modsrc** and **spisrc** parameters must be set for the NV200 to accept setpoints over SPI and return the correct positional data back to the SPI Controller Box (refer to the NV200 manual for more details). If you are using the SPI Controller Box with the PiSoWorks Software, please refer to section 11 for configuration details.

## 8.2 Mode of Operations

The device offers two operational modes:

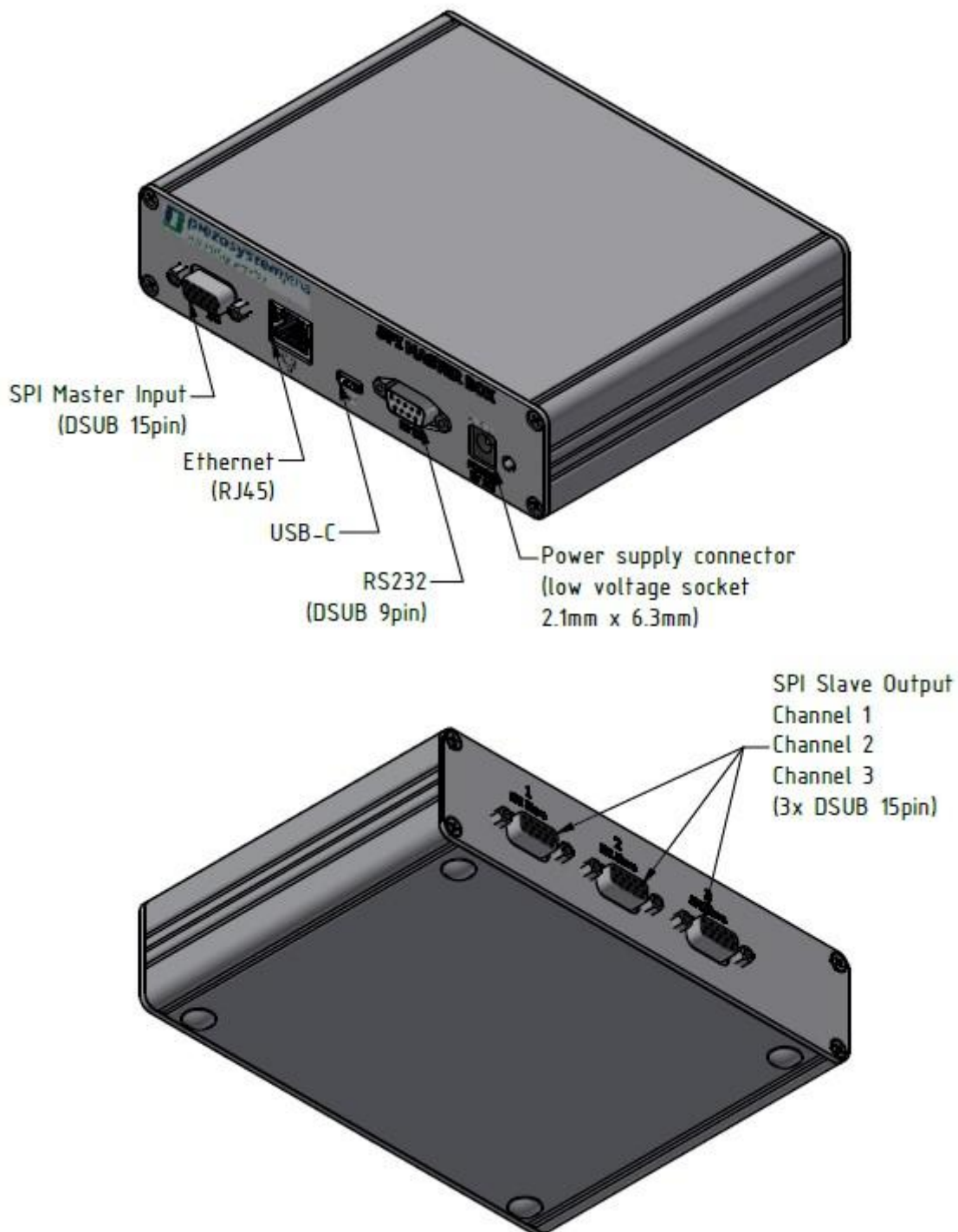
- 1. Single Data Packet Transmission/Reception over Multiple Axes**
- 2. Waveform Data Packet Transmission/Reception over Multiple Axes**

Using the serial interfaces, both modes can be addressed with multiple commands (refer to chapter 0). Using the SPI interface, only the single data packet mode is available, as only positional data is received.

To start an operation, pre-configuration commands must be entered into the respective amplifiers. Failure to complete pre-configuration may result in data flow errors or no output at all. After the configurations are set, data can be transmitted and received through the SPI Controller Box. Note that while all input ports can be connected simultaneously, data must not be sent over different input ports at the same time.

## 9 Connectors and Pin Assignment

### 9.1 3D Drawing



### 9.2 Power Supply Connector

The power supply connector is a low voltage socket with a 2.1mm plug. The supply voltage is 24V.

### 9.3 SPI Connector

**Type:** 15 pin D-Sub HD jack

Pin	Label	Description
4	SCK	Clock
5,7,8	GND	Ground
9	MOSI	Master-Out-Slave-In
13	CS	Chip Select
14	MISO	Master-In-Slave-Out

### 9.4 Ethernet Connector

The RJ45 Ethernet connector allows the device to be controlled via a Telnet connection.

### 9.5 USB Connector

The USB-C type connector supports USB 2.0 and allows the device to be controlled via a serial COM-Port.

### 9.6 RS232 Connector

**Type:** 9 pin D-Sub HD jack

Pin	Label	Description
2	TX	Transmitted Data
3	RX	Received Data
5	GND	Ground

## 10 Communication with the SPI Controller Box

### 10.1 SPI Communication

The SPI Controller Box uses the SPI protocol for both input and output. Input data is received from the user, while the SPI outputs communicate with up to three amplifiers. Relevant SPI parameters are listed in the table below.

Parameters	Values
Supply voltage (V)	3.3
Word length (bits)	16
Data preference	MSB (Most Significant Bit)
SPI clock speed (MHz)	Max. 6
SPI clock modes	3 (CPOL = 1, CPHA = 1)
Chip Select Level	Active Low

The SPI Controller Box expects a total of four words to be transmitted over the SPI interface before data output to the NV200 units can begin. The first three words contain 16-bit position data for the three channels, and the fourth word serves as an end-of-transmission (EOT) marker, indicating that the transmission is complete. If the SPI Controller Box receives more than four words without an EOT, the SPI interface enters a fault state and waits for the next valid EOT word. Once this is received, normal transmission resumes.

The response is supplied in the same four-word format. The first three bytes correspond to the previous response of each NV200 while the fourth byte is an EOT marker. See the table below for detailed information. Please note that due to both the behavior of SPI and the NV200, the response you receive from the SPI Interface is always delayed by 3 cycles. This means that when sending data packet **n**, you will get the piezo position for packet **n - 3**.

Word	1	2	3	4
<b>Input</b>	Setpoint Ch. 1	Setpoint Ch. 2	Setpoint Ch. 3	EOT (0x0D0A)
<b>Output</b>	Output Ch. 1	Output Ch. 2	Output Ch. 3	EOT (0x0D0A)

### 10.2 USB, RS232 & Ethernet Communication

The USB-C and RS232 ports can be used for serial communication. Ethernet can be used for telnet communication on Port 23. Communication on these interfaces is command based and allows the user to utilize both operating modes.

Parameter	Value
Baud rate	115200
Data (bit)	8
Stop (bit)	1
Parity	-
CTS	-
Send on enter	CR-LF

### 10.2.1 Handling Commands

The general structure of a command is as follows:

**<command>[,<parameters>]\r\n**

The **<parameters>** field is an optional, comma-separated list of arguments for the specified command. If no parameters are provided, the SPI Controller Box returns the current value of the corresponding command. All available commands for the SPI Controller Box are listed in the table below.

Command	Description	Value Range
<b>General Commands</b>		
<b>reset</b>	Hardware-reset of the SPI Controller Box.	-
<b>fwver</b>	Display Firmware Version.	-
<b>s</b>	Display all available commands.	-
<b>&lt;empty&gt;</b>	Returns the name of the device.	-
<b>Single Dataset</b>		
<b>set</b>	Set channels to the specified relative position. The position must be a hex value ranging from 0000 (0%) to FFFE (100%).  <b>set,&lt;channel1&gt;,&lt;channel2&gt;,&lt;channel3&gt;</b>	0 – FFFE (hex)
<b>Waveform Generation</b>		
<b>wfset</b>	Set a position in the sampling buffer for each channel at the specified index. The position must be a hex value ranging from 0000 (0%) to FFFE (100%).  <b>wfset,&lt;index&gt;,&lt;channel1&gt;,&lt;channel2&gt;,&lt;channel3&gt;</b>	<b>&lt;index&gt;:</b> 0 – 20000 (dec)  <b>&lt;channel&gt;:</b> 0 – FFFE (hex)
<b>wfcycle</b>	Set the number of cycles to run the waveform for each channel.  <b>wfcycle,&lt;channel1&gt;,&lt;channel2&gt;,&lt;channel3&gt;</b>	1 – 65535 (dec) 0 = infinitely
<b>wfscout</b>	Set the number of samples of the waveform for each channel.  <b>wfscout,&lt;channel1&gt;,&lt;channel2&gt;,&lt;channel3&gt;</b>	1 – 20000 (dec) 0 = disabled
<b>wfsfactor</b>	Waveform output sampling factor for each channel (<value> * 50µs).  <b>wfsfactor,&lt;channel1&gt;,&lt;channel2&gt;,&lt;channel3&gt;</b>	1 – 65535
<b>wfrun</b>	Start or stop the waveform generator.  <b>wfrun,&lt;value&gt;</b>	0 = Stop 1 = Start
<b>wfrcount</b>	Returns the number of responses in the waveform generator response buffer. The maximum number of samples stored is <b>60000</b> with a sampling period of <b>50µs</b> .	-
<b>wfget</b>	Retrieve a set of waveform response data at the specified index.  <b>wfget,&lt;index&gt;</b>	0 – <b>&lt;wfrcount&gt;</b>

### 10.2.2 Using the Waveform generator

To use the internal waveform generator, several configuration parameters must be specified before the output can start. The general structure is as follows:

1. Select how often each channel should cycle through the sample buffer (wfcycle)
2. Specify the number of samples for each channel (wfscount)
3. Optionally slow down the waveform generator by setting a sample factor (wfsfactor)
4. Fill the sample buffer from index = 0 to index = sample count (wfset)
5. Finally, start the waveform generation (wfrun)

After the waveform is completed, the response buffer can be read:

1. Retrieve the number of samples in the response buffer (wfrcount)
2. Retrieve the response buffer from index = 0 until index = wfrcount

### 10.2.3 Handling Error Messages

When the user sends wrong inputs to the device, the SPI Controller Box responds with an error message in the form **error,x** where **x** is an error number from the table below.

Error Number	Error Prompts
1	Error not specified
2	Unknown Command
3	Parameter missing
4	Admissible parameter range exceeded
5	Command's parameter count exceeded
6	Parameter is locked or read only
7	Underload
8	Overload
9	Parameter too low
10	Parameter too high

## 11 PiSoWorks Integration

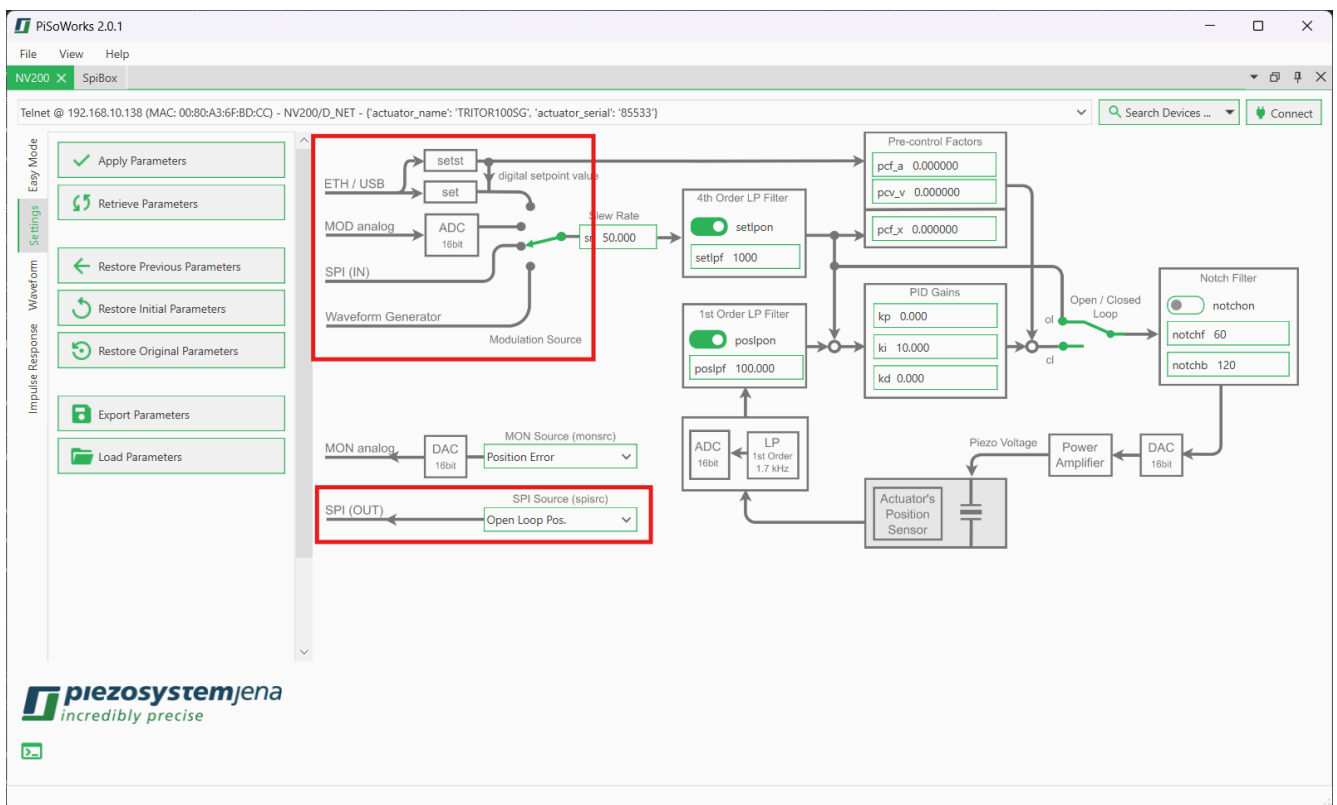
The SPI Controller Box can be fully operated using the PiSoWorks software provided by piezosystem jena GmbH. To begin, connect the SPI Controller Box to a computer via Ethernet or USB and launch the PiSoWorks application. In the PiSoWorks interface, add an **SPI Box View** and establish a connection to the device. From this interface, you can send individual setpoints, start the playback of various waveform types, and retrieve recorded data from waveform playback.

### 11.1 NV200 Configuration

Before sending data from the SPI Controller Box to the amplifiers, each NV200 must be configured to accept SPI input and provide the desired output. To start, connect the NV200s to your computer and add an **NV200 View** (View → Add NV200 View...). Connect to the selected NV200 and switch to the **Settings** tab. Two parameters must be configured for proper operation with the SPI Controller Box:

- To enable setpoint control via SPI, set the *modulation source* to **SPI (IN)**.
- For SPI output, select the desired data source from the **SPI (OUT)** dropdown menu.

Additional parameters such as slew rate, PID settings, and filters may also be adjusted as needed.



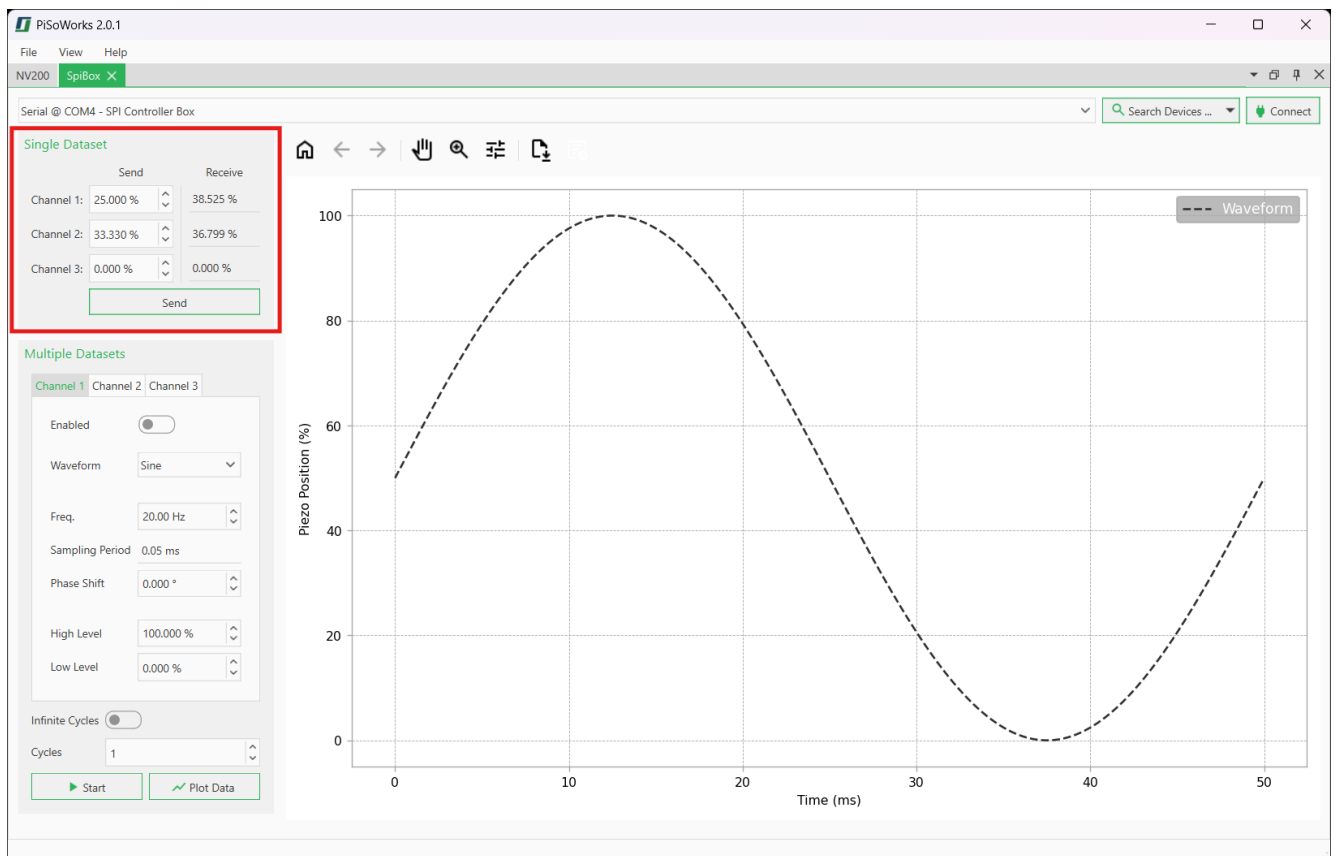
## 11.2 Single Position Data

After configuring the NV200 amplifiers, you can send both single position commands and waveform data to the NV200 units. Use the **Single Dataset** box to send position values simultaneously to each individual channel. Position values are specified as percentages from 0 to 100, where **0%** represents the minimum possible voltage or position (depending on whether the system is in open- or closed-loop mode), and **100%** represents the maximum possible voltage or position for the connected actuator.

For example:

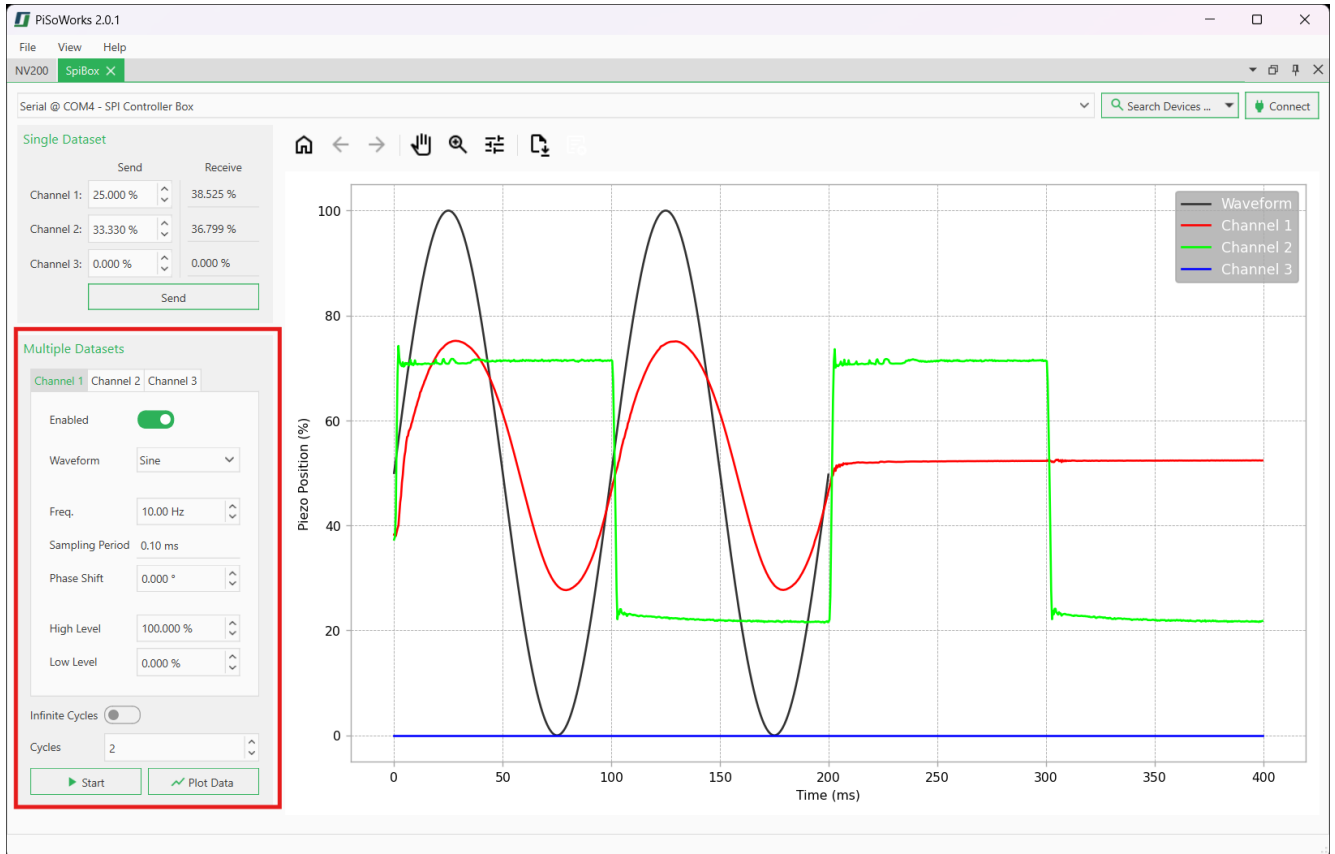
- If an actuator with a travel range of 200  $\mu\text{m}$  is operated in closed loop and you want to move it to 50  $\mu\text{m}$ , you must enter **25 %** as the position value.
- If an actuator is driven in open loop with a voltage range of  $-20\text{ V}$  to  $130\text{ V}$ , and you want to output 30 V, the corresponding position value is **33.33 %**.

To apply the selected position values, click **Send**. The returned SPI data (e.g., actuator position, setpoint values, etc.) is displayed in the **Receive** column.



### 11.3 Waveform Generation

To configure waveform output for each channel, use the **Multiple Datasets** box. Select the waveform parameters for a channel by switching between the corresponding tabs. After configuring the waveform settings, click **Start** to upload and begin playback of the waveform data. To retrieve the stored SPI responses for each waveform data point, click the **Plot Data** button. The recorded response will then be plotted in the embedded graph.



You can also provide a custom waveform in the form of a CSV or Excel file for playback. The file must contain a single column, with each row representing one data point. Each data entry specifies a position value expressed as a percentage from 0 to 100.