PiezoDrive

PX200 Power Amplifier

Manual and Specifications

Hardware Version 5

Revision History

Date	Revision	By	Changes
15/05/22	1	KB	Document published

Contents

1 Introduction

The PX200 is a low-noise high-current linear amplifier for driving piezoelectric actuators and other loads. The output voltage range can be unipolar, bipolar, or asymmetric from 50V to 200V. Refer to the specifications table for the available output voltage ranges. Two amplifiers can be connected in bridge-mode to provide up to +/-200V or +400V. The PX200 has a high output current up to 13 Amps peak and is well suited to precision applications that require high power and frequency.

The PX200 can drive any load impedance including unlimited capacitive loads such as stack actuators; standard piezoelectric actuators; two wire benders; and three-wire piezoelectric benders requiring a bias voltage. Bias voltages can be generated using two auxiliary outputs linked to the power supply voltages.

A range of front panel controls provide maximum application flexibility, these include input signal inversion, variable gain, DC offset, and variable voltage limits. A 9-pin DSUB connector on the front panel includes signals for the input, voltage monitor, current monitor, shutdown monitor, and shutdown command. A four-digit LCD screen also displays the DC voltage.

The output connectors include BNC, LEMO 00, LEMO 0B.302, and plug-in screw terminals. The PX200 is suited to a wide range of applications including electro-optics, ultrasonics, vibration control, nanopositioning systems, and piezoelectric motors.

Compatible Actuators	
Stack Actuators	Up to +200V
Plates and Tubes	+/-100V or +200V
Two Wire Benders	+/-100V or +200V
Three Wire Benders	Up to +200V with +200V bias, or +/-100V with +/-100V bias

2 Warnings / Notes

This device produces hazardous potentials and requires suitably qualified personnel with an observer trained in first-aid training. Do not operate the device when there are exposed conductors.

3 Output Voltage Ranges

The output voltage range is specified when ordering. The standard voltage ranges and associated current limits are listed below. Since the PX200 has front panel controls for reducing the positive and negative output voltage range, choose a range equal to or slightly greater than required.

Negative Voltage (Volts)	Positive Voltage (Volts)	RMS Current (Amps)	Peak Current (Amps)	Pulse Current [1]	Gain [2]	Var [3]	Order Code
0	200	1.6	3	9	20	A	PX200-P200
0	150	2.1	4	10	15	A	PX200-P150
-50	150	1.6	3	9	15	A	PX200-N50-P150
-50	100	2.1	4	10	10	A	PX200-N50-P100
-100	100	1.6	3	9	10	A	PX200-N100-P100
-100	50	2.1	4	10	10	A	PX200-N100-P50
-100	0	3.1	6	13	10	A	PX200-N100
-150	0	2.1	4	10	15	A	PX200-N150
-200	0	1.6	3	9	20	A	PX200-N200
0	175	1.8	3	10	20	B	PX200-P175
-25	150	1.8	3	10	15	B	PX200-N25-P150
-25	100	2.7	4	10	10	B	PX200-N25-P100
-75	100	1.8	3	10	10	B	PX200-N75-P100
-75	50	2.7	4	10	10	B	PX200-N75-P50
0	125	2.7	4	10	15	D	PX200-P125
-25	125	2.1	4	10	15	D	PX200-N25-P125
-75	75	2.1	4	10	10	D	PX200-N75-P75
0	100	3.1	6	13	10	E	PX200-P100
0	75	4.1	6	13	10	E	PX200-P75
0	50	5.3	9	13	10	E	PX200-P50
0	50	5.3	9	13	10	E	PX200-P25
-25	75	3.1	6	13	10	E	PX200-N25-P75
-25	50	4.1	6	13	10	E	PX200-N25-P50
-25	25	5.3	9	13	10	E	PX200-N25-P25
-50	50	3.1	6	13	10	E	PX200-N50-P50
-50	25	4.1	6	13	10	E	PX200-N50-P25
-50	0	5.3	9	13	10	E	PX200-N50
-75	0	4.1	6	13	10	E	PX200-N75
-100	0	3.1	6	13	10	E	PX200-N100

Table 1. Preferred voltage range configurations.

Notes:

[1] – Refer to Section 6 for details on the pulse current limit

[2] – The gain can be increased by up to another factor of 10 using the front panel control

[3] – The variant is the hardware version required for the chosen configuration

4 Output Current

The peak and RMS output current is listed in Table 1. The RMS current limit determines the maximum frequency that is achievable with a capacitive load. A calculator for the maximum operating frequency is provided in Section 5.

During short-circuit the output current is limited to the rated maximum. The peak current can be drawn for up to five milliseconds before the output is disabled for three seconds. The average current limit has a time-constant of ten milliseconds and is reset 50 milliseconds after a previous current pulse. This behaviour is described in Section 13.

Higher peak currents are achievable with the PULSE option, which is described in Section 6.

5 Power Bandwidth

Launch Online Power Bandwidth Calculator

The online power bandwidth calculator estimates the highest achievable frequency with a capacitive load impedance. The calculator considers the current limit, slew-rate, output impedance, and small-signal bandwidth.

With a capacitive load, the maximum operating frequency due to the RMS current limit is

$$f_{max} = \frac{I_{rms}\sqrt{2}}{V_{pp}C\pi} \ ,$$

where I_{rms} is the current limit, V_{pp} is the peak-to-peak output voltage, C is the load capacitance. The above equation is also true for any periodic waveform, including triangle waves and square waves.

The 'power bandwidth' is the maximum frequency at full output voltage. When the amplifier output is open-circuit, the power bandwidth is limited by the slew-rate; however, with a capacitive load, the maximum frequency is limited by the RMS current and load capacitance. The power bandwidth for a range of capacitive loads is listed below.

Load	**50 Vp-p**	**75 Vp-p**	**100 Vp-p**	**125 Vp-p**	**150 Vp-p**	**175 Vp-p**	**200 Vp-p**
10 nF	222930*	148620*	111465*	89172*	74310*	63694*	55732*
30 nF	222930*	148620*	111465*	89172*	74310*	63694*	55732*
100 nF	222930*	148620*	111465*	89172*	62000	45714	35000
300 nF	160000	82667	46667	32000	20667	15238	11667
1 uF	48000	24800	14000	9600	6200	4571	3500
3 uF	16000	8267	4667	3200	2067	1524	1167
10 uF	4800	2480	1400	960	620	457	350
30 uF	1600	827	467	320	207	152	117

Table 2. Maximum frequency (Hz) versus load capacitance and output voltage span

In the above table, the frequencies limited by slew-rate are marked with an asterisk. The slew-rate is approximately 35 V/uS which implies a maximum frequency of

$$f^{max} = \frac{35 \times 10^6}{\pi V_{pp}}$$

6 Pulse Current Option

The PULSE current option provides a higher peak current for approximately 150 us instead of the standard 5 ms. This option is useful in specialty applications that require fast, small changes in the output voltage with large capacitive loads. This option is not recommended for general purpose applications as the shorter overload time is detrimental to frequencies below 1 kHz. The pulse current limits for each configuration are listed in Table 1 and summarized in Table 3. The output voltage span is the peak-to-peak output voltage range, e.g. the voltage span for the -50V to +150V range is 200V.

Output Voltage Span	Pulse Current	Pulse Time
200 Vp-p	9 A	150 us
175 Vp-p	10 A	155 us
150 Vp-p	10 A	180 us
125 Vp-p	10 A	236 us
100 Vp-p	13 A	211 us
75 Vp-p	13 A	286 us
50 Vp-p	13 A	378 us
25 Vp-p	13 A	378 us

Table 3. Maximum peak current duration in the pulse configuration.

The maximum pulse duration versus peak current is described in Figure 1. The pulse current option can be ordered by appending the order code with “-PULSE”, e.g. “PX200-P200-PULSE”.

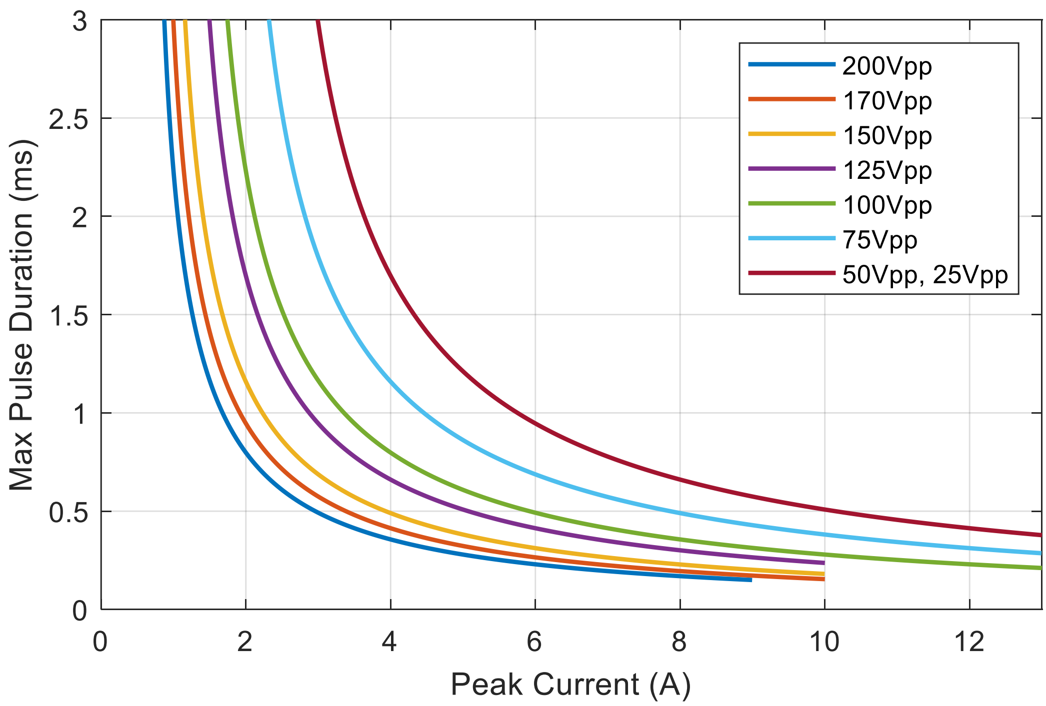


Figure 1. Maximum pulse duration versus peak current for each voltage span

7 Specifications

The voltage, current, and gain specifications are listed in Table 1. Other specifications that are common to all configurations are listed below.

Specification	**Value**
Slew Rate	35 V/us
Signal Bandwidth	390 kHz
Max Power	140 W Dissipation
Load	Any
Noise	150 uV RMS (10uF Load, 0.03 Hz to 1 MHz)
Protection	Continuous short-circuit, thermal
Voltage Monitor	1/20 V/V
Current Monitor	1.5 V/A if peak current is 6 Amps or less 0.5 V/A if peak current is greater than 6 Amps
Input Impedance	48.7 kOhms
Output Impedance	1.5 Ohms
Output Connectors	LEMO 0B, LEMO 00, Screw Terminals, BNC
Power Supply	90 Vac to 250 Vac
Environment	0-40 C (32-104 F) Non-condensing humidity
Dimensions	212 x 304.8 x 88 mm (8.35 x 12 x 3.46 in)
Weight	2 kg (4.4 lb)

8 Small Signal Bandwidth

The small-signal frequency response and -3 dB bandwidth is described in Figure 2 and Table 4.

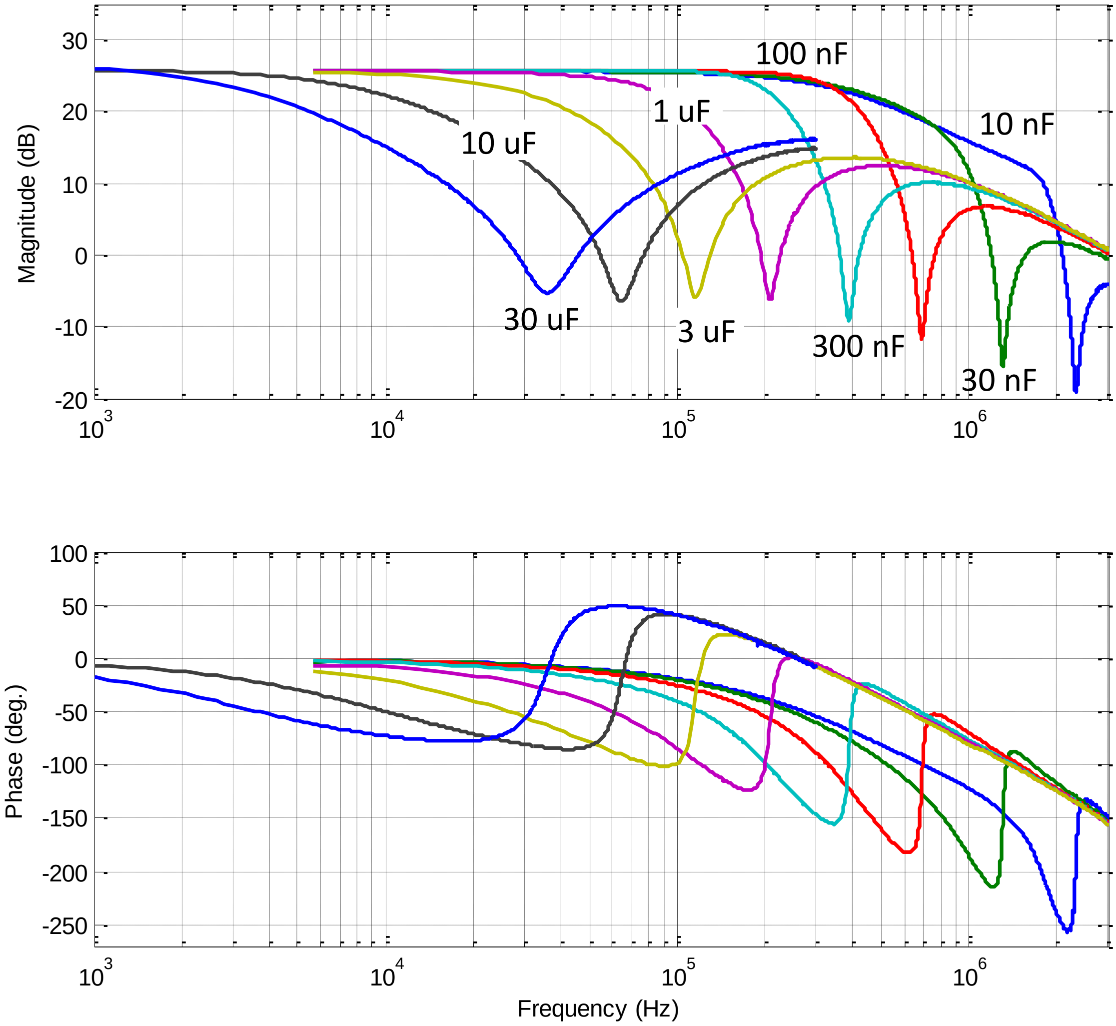


Figure 2. Small signal frequency response for a range of load capacitances.

Load Capacitance	Bandwidth
10 nF	393 kHz
30 nF	431 kHz
100 nF	367 kHz
300 nF	208 kHz
1 uF	88 kHz
3 uF	30 kHz
10 uF	9.3 kHz
30 uF	3.7 kHz
110 uF	1.3 kHz

Table 4. Small signal bandwidth versus load capacitance (-3dB)

9 Noise

The output voltage noise contains a low frequency component (0.03 Hz to 20 Hz) that is independent of the load capacitance; and a high frequency (20 Hz to 1 MHz) component that is approximately inversely proportional to the load capacitance.

The noise is measured with an SR560 low-noise amplifier (Gain = 1000), oscilloscope, and Agilent 34461A Voltmeter. The low-frequency noise is plotted in Figure 3. The RMS value is 120 uV with a peak-to-peak voltage of 600 uV.

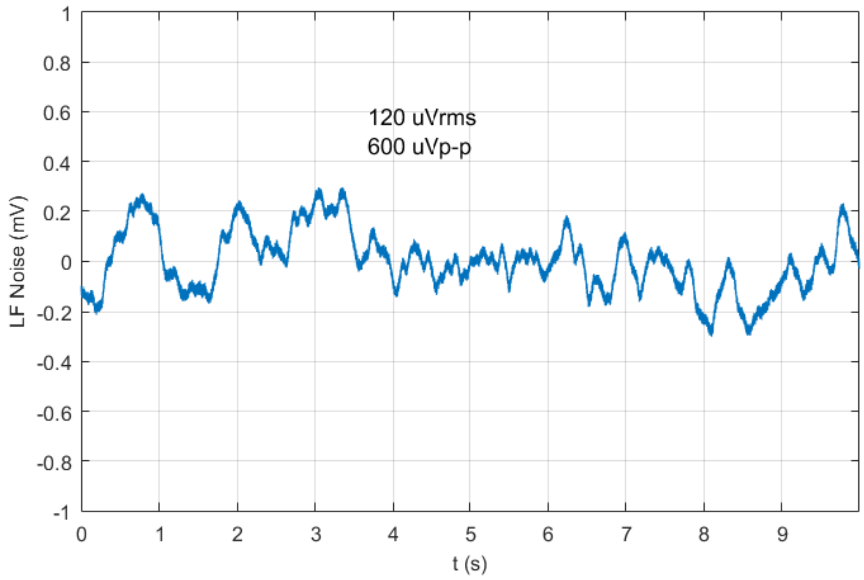


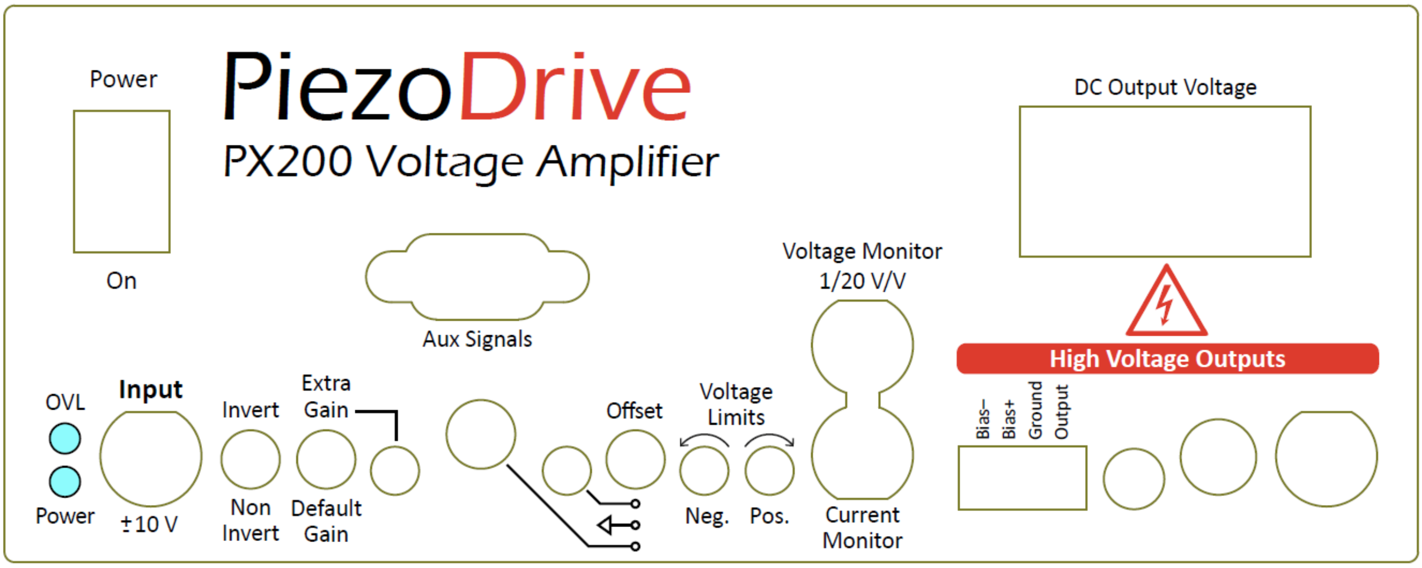
Figure 3. Low frequency noise from 0.03 Hz to 20 Hz

The high frequency noise (20 Hz to 1 MHz) is listed in the table below versus load capacitance. The total RMS noise from 0.03 Hz to 1 MHz is found by summing the RMS values, that is $\sigma = \sqrt{\sigma_{LF}^2 + \sigma_{HF}^2}$. For a load capacitance of less than 1 uF, the noise is primarily broadband thermal noise; however, for a capacitance of greater than 1 uF, the noise is primarily due to low-frequency noise.

Load	Bandwidth	HF Noise RMS	Total Noise RMS
10 nF	393 kHz	530 uV	543 uV
30 nF	431 kHz	586 uV	598 uV
100 nF	367 kHz	689 uV	699 uV
300 nF	208 kHz	452 uV	468 uV
1 uF	88 kHz	261 uV	287 uV
3 uF	30 kHz	106 uV	160 uV
10 uF	9.3 kHz	56 uV	132 uV
30 uF	3.7 kHz	52 uV	131 uV
100 uF	1.3 kHz	47 uV	129 uV

Table 5. RMS noise versus load capacitance (0.03 Hz to 1 MHz)

10 Front Panel



Control	Type	Function
Power		Power On/Off
Overload LED		RED when the amplifier is disabled or in an overload state
Power LED		GREEN when the power is on
Input	Input	Input signal (±10V max, protected up to +/-20V)
Invert switch		Multiplies the input signal by -1 in the upward position
Gain switch		Adds additional gain to the input signal when in the upward position
Gain pot		Clockwise rotation increases the additional gain (up to a factor of 10)
Offset knob		Single turn potentiometer for DC offset
Offset pot		Multiple turn potentiometer for DC offset
Offset switch		Selects between the offset sources, or zero in the middle position
Voltage Limits		Limits the maximum negative and positive output voltage
Voltage Monitor	Output	The measured output voltage, scaled by 1/20
Current Monitor	Output	The measured output current, 1.5 V/A or 0.5 V/A (See Section 7)
Bias-	Output	DC Bias connected to the negative high-voltage power supply rail
Bias+	Output	DC Bias connected to the positive high-voltage power supply rail
Ground	Output	Ground, connect to the load negative terminal
Output	Output	Amplifier output, connect to the load positive terminal
LEMO 00 Output	Output	EPL.00.250 connector, suits LEMO FFA.00.250 cable plug
LEMO 0B Output	Output	FGG.0B.302 connector, suits LEMO FGG.0B.302 cable plug
BNC Output	Output	Suits male BNC cable plug
DC Output Volt.		Display showing average output voltage

The mating connector for the 4-way screw terminal connector is OQ0432510000G.

The screw terminals or LEMO 0B.302 connector are recommended for applications requiring more than 1 Amp RMS output current. Preassembled LEMO cable assemblies (e.g. PD-0B302-W-120) are available from www.PiezoDrive.com

The auxiliary signals connector is a 9-way DSUB receptacle which suits any 9-way male DSUB plug. The signals and pin layout are shown in Figure 4 and Table 6.

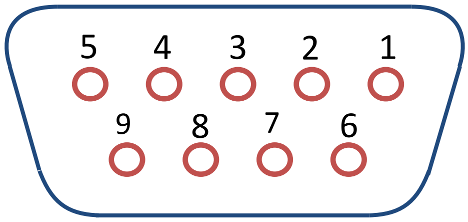


Figure 4. Front view of auxiliary signals connector

Signal	Pin	Function
Input+	1	Input signal
Input-	2	Ground for input signal
Voltage Monitor	3	Voltage monitor
Current Monitor	4	Current monitor
Ground	5	Ground
Shutdown	6	+2V to +20V disables the amplifier
Shutdown Monitor	7	+5V when the amplifier is shutdown
NC	8, 9	Not connected

Table 6. Auxiliary signals pinout

11 Signal Path

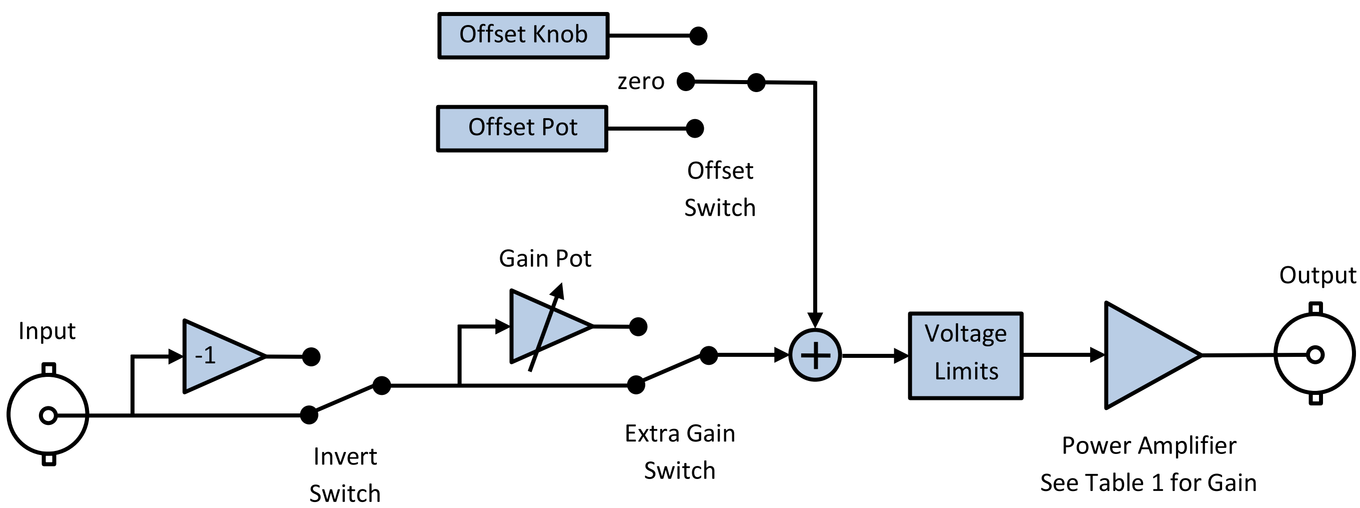


Figure 5. Signal path with switches in default positions.

12 Voltage Limits

The output voltage range can be restricted to an arbitrary positive and negative value using two potentiometers on the front panel. To set the voltage limit:

- Remove loads connected to the outputs
- Apply a 100-Hz sine wave to the input of channel 1 with an amplitude that covers the full range of the amplifier. For example, with a 0V to +200V model, apply a 0V to +10V input.
- Measure the output voltage of channel 1 with an oscilloscope and confirm the full voltage range is achieved. If there is any clipping of the sine wave, the voltage limits may have already been set, and may need resetting by winding the potentiometers in the direction of the arrows.
- To limit either the negative or the positive voltage, turn the potentiometer in the opposite direction to the arrow, until the voltage is limited to the desired level.

13 Overload and Shutdown

The amplifier is protected against short-circuit, over-current, and excessive temperature. During these conditions, the front panel overload indicator will illuminate, and the Shutdown Monitor signal is +5V.

During an overload or shutdown state, the output is partially disabled and may float at approximately 50% of the voltage range.

When the amplifier is switched on, the overload protection circuit is engaged by default and clears after three seconds.

The amplifier can be shut down by an external source by applying a voltage of between +2V and +24V to the Shutdown input. The impedance of the shutdown input is approximately 5 kΩ.

14 Bias Outputs and Piezo Benders

The bias outputs are labelled HV+ and HV- on the front-panel screw terminals. The output voltages are fixed at the maximum output voltages of the amplifier and are not affected by the voltage limit potentiometers. For example, a PX200-N100-P100 (with a +/-100V output range) will output +100V and -100V on HV+ and HV- respectively. For amplifier configurations where the HV- output is zero (e.g. PX200-P200), it is preferable to use ground rather than the HV- output.

The bias outputs provide a small DC output current of approximately 30mA; however, they can source or sink large AC currents, which is ideal for driving piezoelectric actuators. Bender actuators can be driven with a single or dual bias voltage.

The most common bender actuators are parallel-poled and driven using the 'biased unipolar' or 'three-wire' configuration [1], as shown in Figure 6.

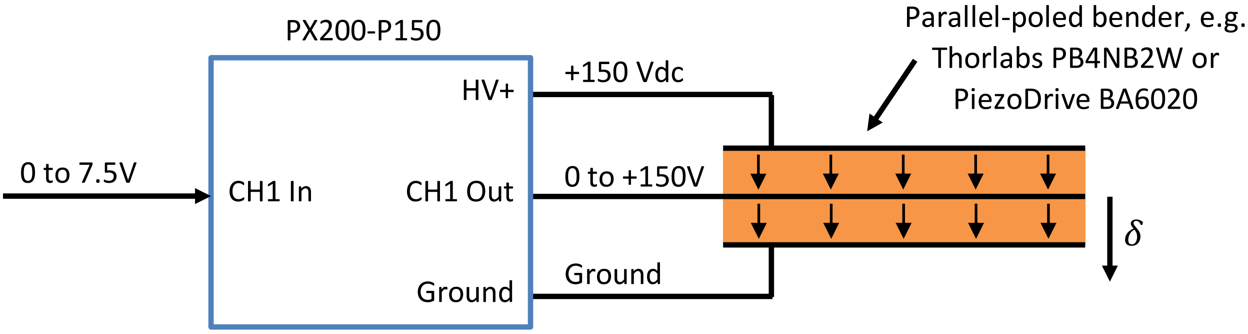


Figure 6. Parallel-poled bender driven in the biased unipolar configuration [1].

A zero volt input results in +150V across the top piezo layer and maximum upward deflection. A 7.5V input results in +150V across the bottom piezo layer and maximum downward deflection. The deflection δ can be represented by

$$\delta = \frac{V_{in} - 7.5/2}{7.5} \delta_{pp}$$

where δ_{pp} is the peak-to-peak displacement of the bender.

To reduce the maximum DC voltage, a negative bias voltage can be used, as shown in Figure 7.

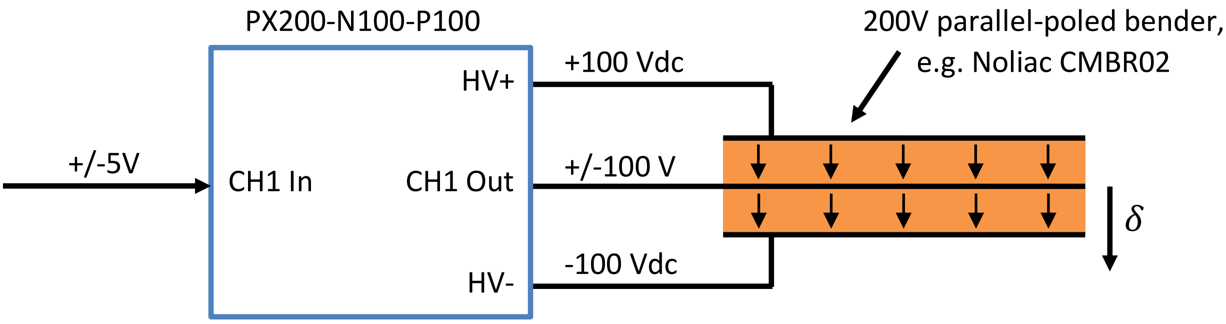


Figure 7. 200V Parallel-poled bender driven with dual bias sources.

In Figure 7, the deflection is

$$\delta = \frac{V_{in}}{10} \delta_{pp}$$

where δ_{pp} is the peak-to-peak displacement of the bender.

References

[1] A New Electrical Configuration for Improving the Range of Piezoelectric Bimorph Benders; S. A. Rios, A. J. Fleming; Sensors and Actuators A: Physical, 2015.

15 Bridged Mode

In bridged mode, the load is connected between the outputs of two amplifiers, which doubles the output voltage span and power. Grounded loads cannot be driven using bridged mode. Care should be taken not to connect the negative side to ground accidentally, for example, by using a grounded oscilloscope probe.

Figure 8 shows how two amplifiers are connected to achieve +/-200V across a load. A +/-10V signal is applied to both amplifiers, and the bottom amplifier is configured in inverting mode. The total voltage across the load is +/-200V and the effective gain is twice the gain of a single amplifier. Common bridged-mode configurations are listed in Table 7.

The current limits in bridge mode are identical to normal operation. The power bandwidth calculator can also be used for predicting bridge-mode performance by entering the total voltage across the load. For the example in Figure 8, the total peak-to-peak output voltage is 400V. When entering this value to the calculator, an error will be shown since 400V is greater than the voltage span of a single amplifier; however, the calculator output is remains valid.

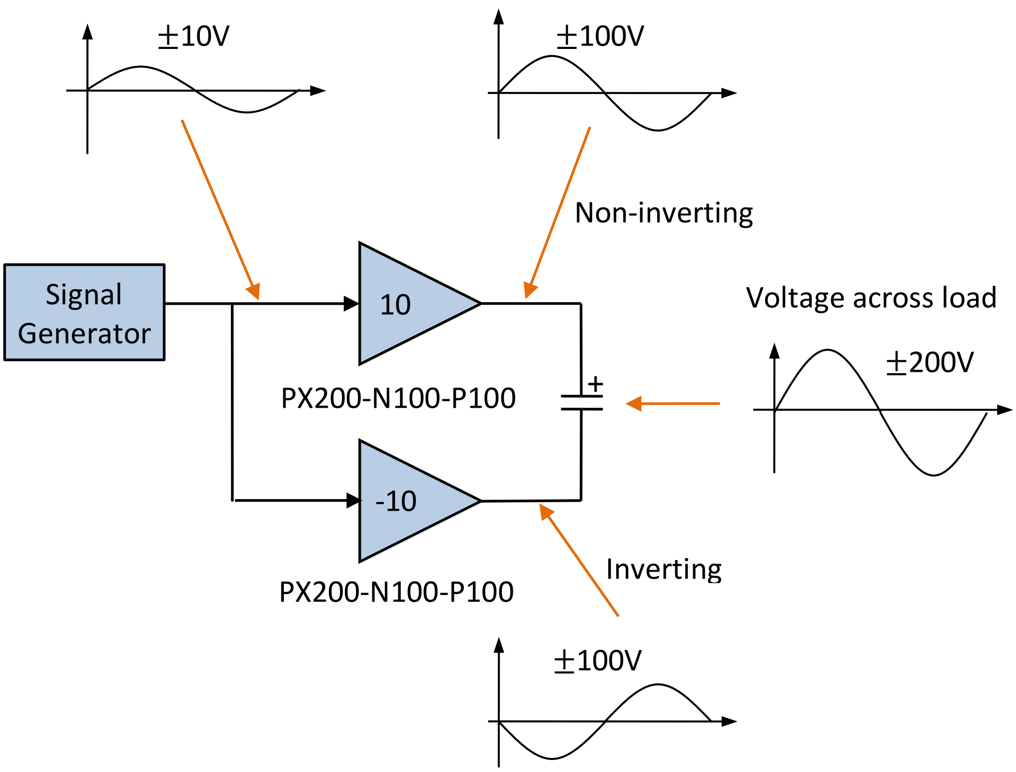


Figure 8. Bridge mode configuration for obtaining ±200V

Load Voltage	RMS Current	Non-Inverting Amp	Inverting Amp
±200V	1.5 A	PX200-N100-P100	PX200-N100-P100
±100V	3.1 A	PX200-N50-P50	PX200-N50-P50
0V to 200V	3.1 A	PX200-P100	PX200-N100
0V to 300V	2.1 A	PX200-P150	PX200-N150
0V to 400V	1.5 A	PX200-P200	PX200-N200

Table 7. Common bridge-mode configurations

16 Rack Mounting

The PX200 can be installed in a 19-inch x 2U rack space using the single unit rack kit
(order code: SingleRackKit-2U).

Two amplifiers can also be installed in a side-by-side configuration using the double unit rack kit (order code: DoubleRackKit-2U). The double rack kit is assembled in the factory and includes coupling screws for the enclosure, the same handles as the single rack kit, and

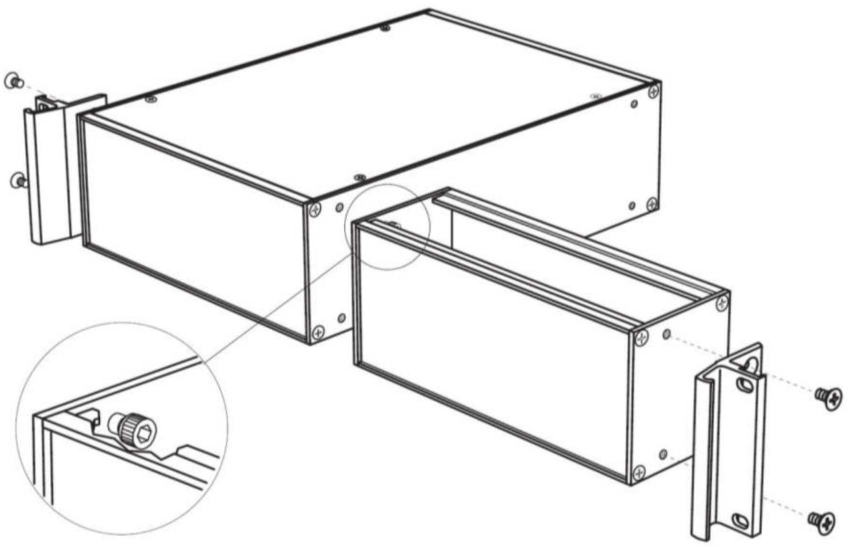


Figure 9. Single rack kit, showing the amplifier on left, and the rack adaptor on right.

17 Delivery Contents

- PX200 amplifier with plug-in screw terminal installed
- IEC C13 power cable, suited to the shipping destination

18 Warranty

PiezoDrive amplifiers are guaranteed for 12 months from the date of delivery. The warranty does not cover damage due to misuse.