PiezoDrive

PX200 – Power Amplifier

Version 2.0

Manual and Specifications

Contents

1 Introduction

The PX200 is a low-noise voltage amplifier designed to drive capacitive and other loads from DC to hundreds of kHz. The output voltage range can be unipolar, bipolar, or asymmetric with a peak-to-peak value of between 50V and 200V. Two amplifiers can be connected in bridge-mode to provide ±200V or +400V. The amplifier will deliver up to 4 Amps peak with a sinusoidal output, or up to 8 Amps peak for pulse applications.

The PX200 is compact, lightweight, and can be powered from any mains supply. The output connectors include LEMO 00, LEMO 0B, BNC (adaptor included), and plug-in screw terminals, so many commercially available piezoelectric actuators can be directly connected. The PX200 is suited to a wide range of applications including: electro-optics, ultrasonics, vibration control, nanopositioning, and piezoelectric motors

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 Specifications

Electrical Specifications			
Output Voltage Range	100 Vp-p	150 Vp-p	200 Vp-p
RMS Current	3.1 A	2.0 A	1.5 A
Pulse Current	8.0 A	8.0 A	8.0 A
Power Bandwidth	110 kHz	93 kHz	55 kHz
Gain	20 V/V		
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 (BNC)		
Current Monitor	1 V/A (BNC)		
Analog Input	Signal input (BNC, Zin = 48.7k)		
Output Connectors	LEMO 0B, LEMO 00, Screw Terminals, BNC		
Power Supply	90 Vac to 250 Vac		

Mechanical Specifications	
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)

4 Output Voltage Range

The desired output voltage range is specified when ordering. The default output range is 0V to +200V (PX200-V0,200). The available voltage ranges and associated current limits are listed below.

Voltage Range	RMS Current	Peak Current	Order Code
0 to +200	1.5 A	2 A	PX200-V0,200
0 to +150	2.0 A	4 A	PX200-V0,150
0 to +100	3.1 A	4 A	PX200-V0,100
0 to +50	3.1 A	8 A	PX200-V0,50
-50 to +50	3.1 A	4 A	PX200-V50,50
-50 to +100	2.0 A	4 A	PX200-V50,100
-50 to +150	1.5 A	2 A	PX200-V50,150
-100 to +50	2.0 A	4 A	PX200-V100,50
-100 to +100	1.5 A	2 A	PX200-V100,100
-100 to 0	3.1 A	4 A	PX200-V100,0
-150 to 0	2.0 A	4 A	PX200-V150,0
-200V to 0	1.5 A	2 A	PX200-V200,0

Table 1. Voltage range configurations

5 Output Current

The PX200 has a peak and average current limits as described in Table 1. The RMS current limit defines the maximum frequency that is achievable with a capacitive load. This topic is discussed in “Power Bandwidth”.

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 “Overload and Shutdown”

6 Pulse Current Option

For applications that require a high peak current, the peak current limit can be increased to 8 Amps by appending the order code with “-PULSE”, e.g. “PX200-V0,200-PULSE”. In this configuration, the average current limit remains the same; however, the peak current limit is increased to 8 Amps and the maximum pulse duration is reduced to the time listed in Table 2. The voltage span is the peak-to-peak output voltage range, e.g. the voltage span for the -50V to +150V range is 200V .

Voltage Span	Pulse Current	Pulse Time
200 V	8 A	150 us
150 V	8 A	200 us
100 V	8 A	300 us
50 V	8 A	300 us

Table 2. Maximum peak current duration in the pulse configuration

For a current pulse that is less than the peak current limit, the maximum pulse duration is described in Figure 1.

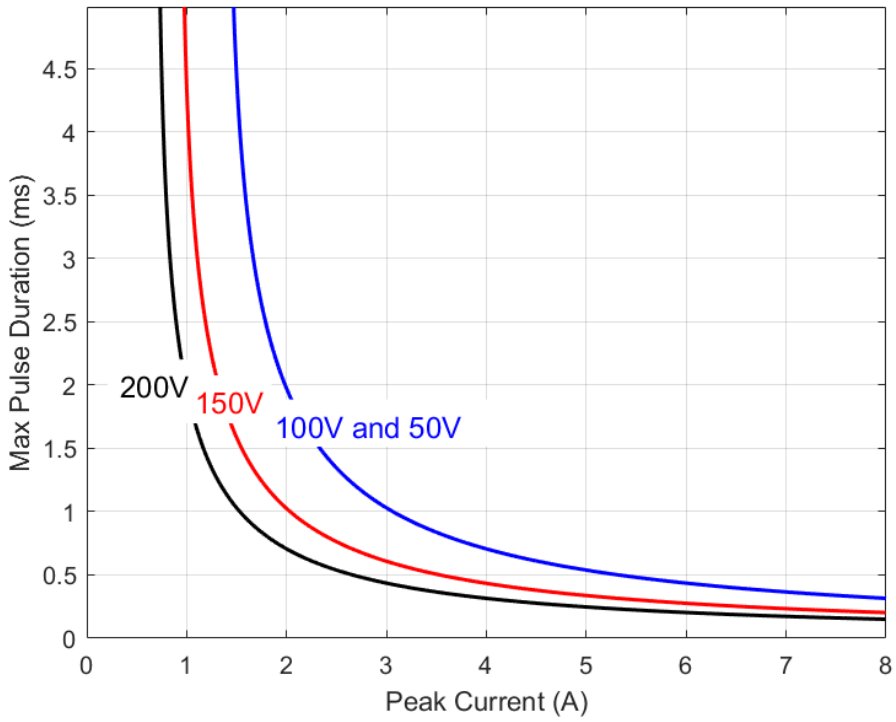


Figure 1. Maximum pulse duration versus peak current and voltage span

7 Power Bandwidth

[Launch Online Power Bandwidth Calculator]

The online power bandwidth calculator takes into account the current limit, slew-rate, output impedance, and small-signal bandwidth.

With a capacitive load, the RMS current for a sine-wave is

$$I_{rms} = \frac{V_{pp} C \pi f}{\sqrt{2}}$$

where V_{pp} is the peak-to-peak output voltage, C is the load capacitance and f is the frequency. Therefore, the maximum frequency for a given RMS current limit (I_{rms}), capacitance, and voltage is

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

The above equation is also true for any periodic waveform, including triangle waves and square waves. This property arises since the amplifier detects average current, which not affected by the waveform shape.

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 Capacitance	50V Range	100V Range	150V Range	200V Range
10 nF	222 kHz	111 kHz	74 kHz	55 kHz
30 nF	222 kHz	111 kHz	74 kHz	55 kHz
100 nF	222 kHz	111 kHz	62 kHz	35 kHz
300 nF	93 kHz	46 kHz	20 kHz	11 kHz
1 uF	28 kHz	14 kHz	6.2 kHz	3.5 kHz
3 uF	9.3 kHz	4.6 kHz	2.0 kHz	1.1 kHz
10 uF	2.8 kHz	1.4 kHz	60 Hz	350 Hz
30 uF	930 Hz	460 Hz	200 Hz	117 Hz

Table 3. Power bandwidth versus load capacitance and output voltage span

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

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

In the following figures, the maximum peak-to-peak voltage is plotted against frequency and capacitance.

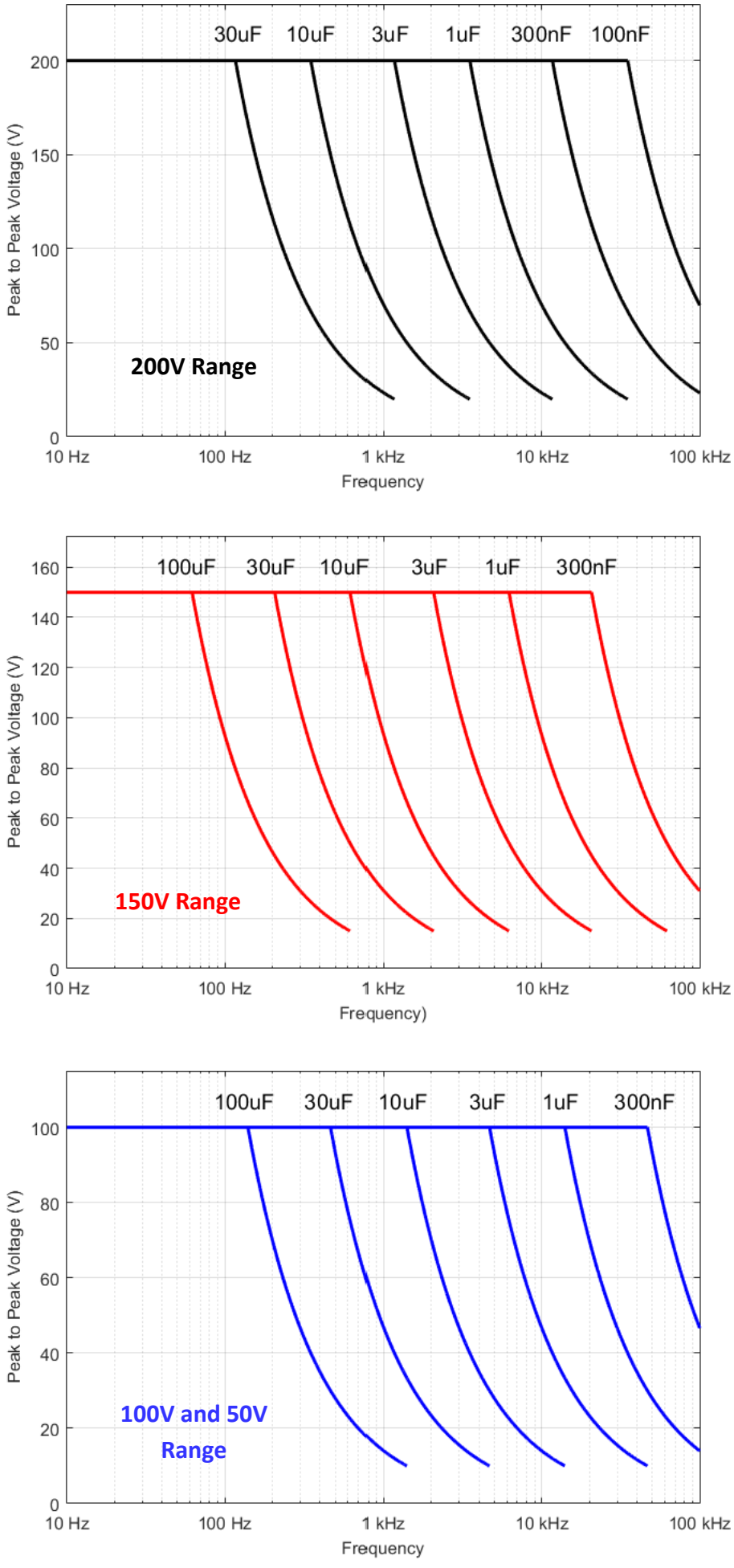


Figure 2. Maximum peak-to-peak voltage versus frequency and load capacitance

8 Small Signal Bandwidth

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

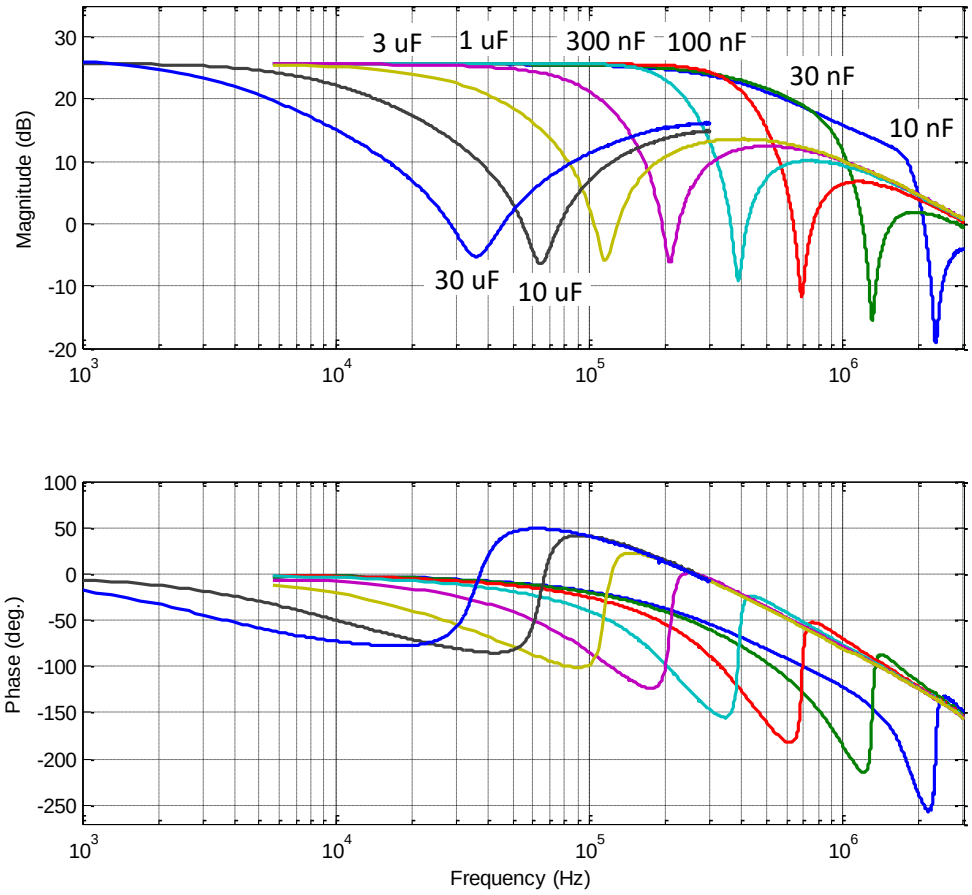


Figure 3. Small signal frequency response for a range of load capacitances.

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 4. The RMS value is 120 uV with a peak-to-peak voltage of 600 uV.

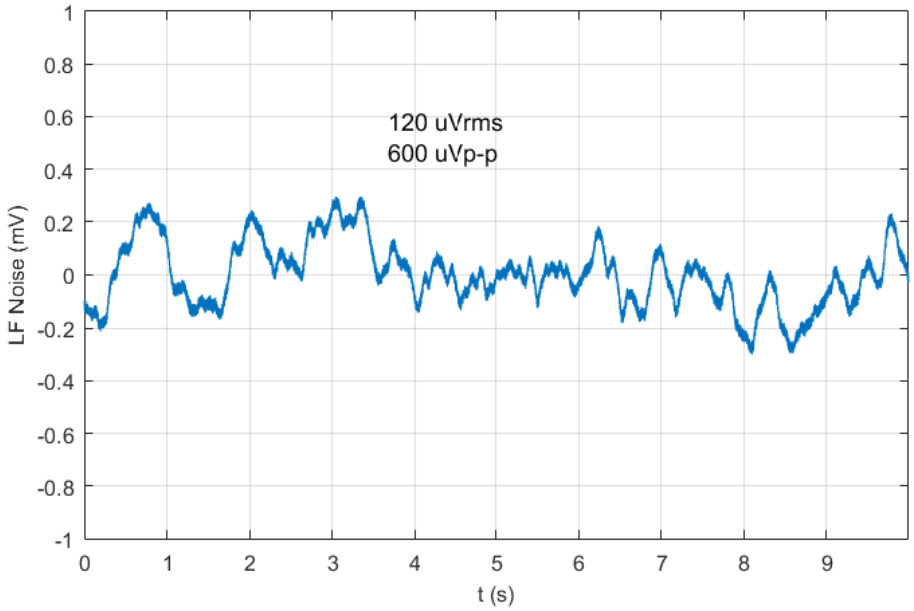


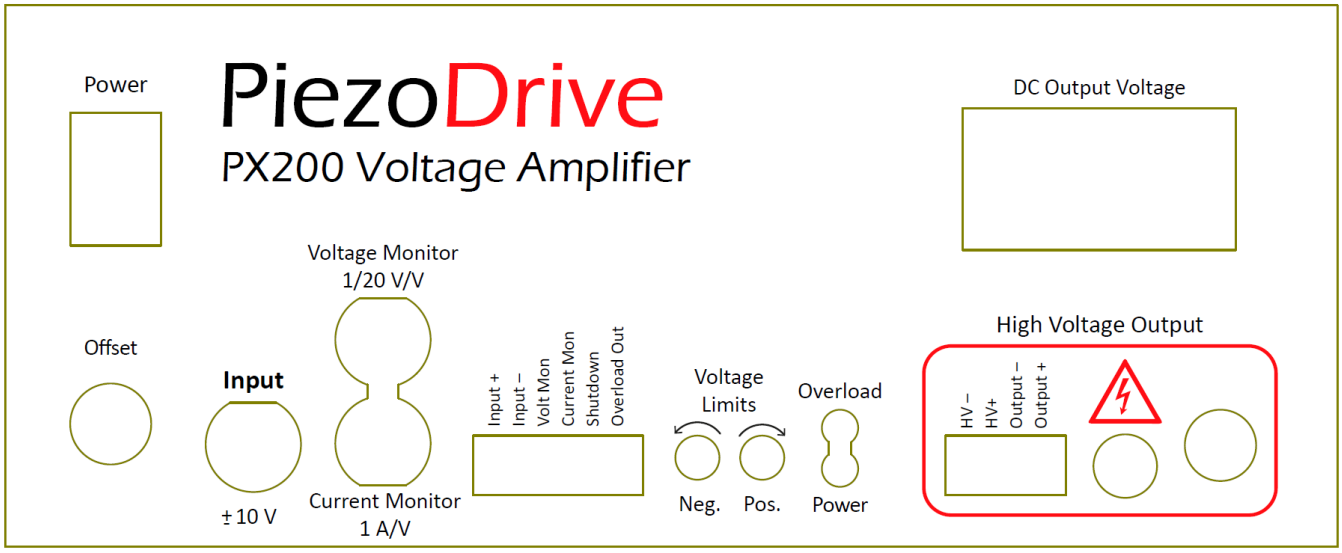
Figure 4. Low frequency noise from 0.03 Hz to 20 Hz

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 Cap.	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
Offset		Adds a DC offset to the input signal
Input	Input	Input signal (±15V max)
Voltage Monitor	Output	The measured output voltage, scaled by 1/20
Current Monitor	Output	The measured output current, 1 A/V
Input+	Input	Internally connected to the centre pin of the Input BNC connector
Input-	Input	Internally connected to the shield of the Input BNC connector
Volt Mon	Output	Internally connected to the Voltage Monitor BNC Output
Current Mon	Output	Internally connected to the Voltage Monitor BNC Output
Shutdown	Input	A voltage from +2V to +24V (relative to Input-) disables the amplifier
Overload Out	Output	+5V output when the amplifier is disabled or in overload state
Voltage Limits		Limits the maximum negative and positive output voltage
Overload		RED when the amplifier is disabled or in an overload state
Power		GREEN when the power is on
HV-	Output	Connected to the negative high-voltage power supply rail
HV+	Output	Connected to the positive high-voltage power supply rail
Output-	Output	High-voltage output signal return (used to measure current)
Output+	Output	High-voltage output signal
LEMO 00 Output	Output	High-voltage output connector, suits LEMO FFA.00.250 cable plug
LEMO 0B Output	Output	High-voltage output connector, suits LEMO FGG.0B.302 cable plug
DC Output Volt.		Display showing average output voltage

11 Amplifier Configuration

The amplifier can be configured with an inverting, or non-inverting input, and a gain of either 20 or 10.

Amplifier Configuration	Order Code	Notes
Non-inverting		(default)
Inverting	-INV	
Gain = 20		(default)
Gain = 10	-Gain10	

Table 6. Amplifier configuration

The DC offset control is configurable with a positive range, or a bipolar range. The front panel potentiometer can be disabled by enabling a PCB mounted trim-pot.

Offset Configuration	Order Code	Notes
0V to +200V Offset Range		(default)
±200V Offset Range	-OR2	
Front panel source		(default)
PCB trim-pot source	-OS2	Disables front panel adjustment

Table 7. Offset configuration

12 Bridged Mode

In bridged mode, two amplifiers are connected in series to double the output voltage range and power.

For example, Figure 5 shows the configuration to obtain ±200V across the load. A ±5V signal applied to both inputs produces ±200V across the load. In bridged mode, only the **Output+** terminal from each amplifier is used, the negative output terminal is not connected. Since there is no current returning through the negative terminal, the current monitor is disabled; however, the overload and protection features are unaffected. Common bridged-mode configurations are listed in Table 7.

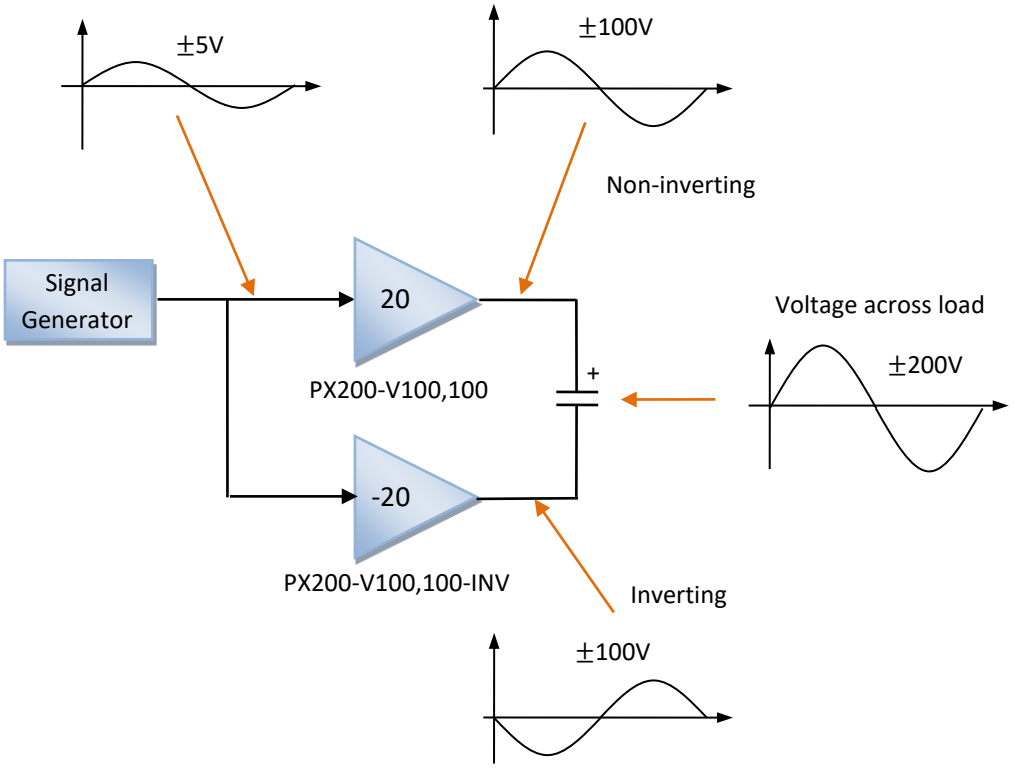


Figure 5. Bridge mode configuration for obtaining ±200V

Load Voltage	RMS Current	Positive Amp	Negative Amp
±200V	1.5 A	PX200-V100,100	PX200-V100,100-INV
±100V	3.1 A	PX200-V50,50	PX200-V50,50-INV
0V to 200V	3.1 A	PX200-V0,100	PX200-V100,0-INV
0V to 300V	2.0A	PX200-V0,150	PX200-V150,0-INV
0V to 400V	1.5A	PX200-V0,200	PX200-V200,0-INV

Table 8. Common bridge-mode configurations

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 **Overload Out** 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 (relative to **Input-**). The impedance of the shutdown input is approximately 5 kΩ.

14 Front Panel Connectors

The front panel connectors and recommended mating plugs are listed below.

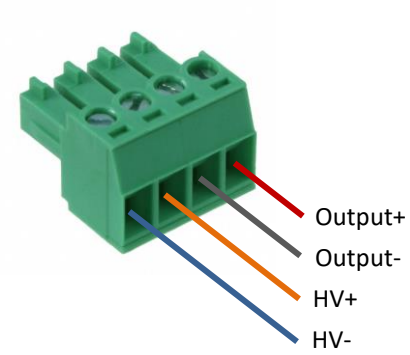
Connector	Mating Connector	Manufacturer	PCB Component
BNC	Any BNC		
6-Way Screw Terminal	TJ0431530000G	Amphenol	OQ0632510000G
4-Way Screw Terminal	TJ0631530000G	Amphenol	OQ0432510000G
LEMO 00	FFA.00.250	LEMO	EPL.00.250
LEMO 0B	FGG.0B.302	LEMO	EPG.0B.302

The LEMO 0B connector is recommended for applications requiring more than 1 Amp RMS output current. Preassembled LEMO cable assemblies are available from www.PiezoDrive.com

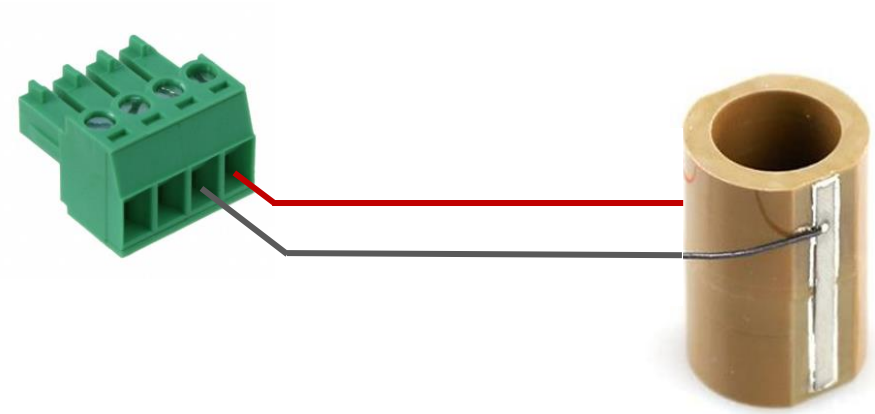
A LEMO 00 to Female BNC adaptor cable (PD-00-FBNC-30) is supplied with the amplifier.

14.1 HV Output Screw Terminals

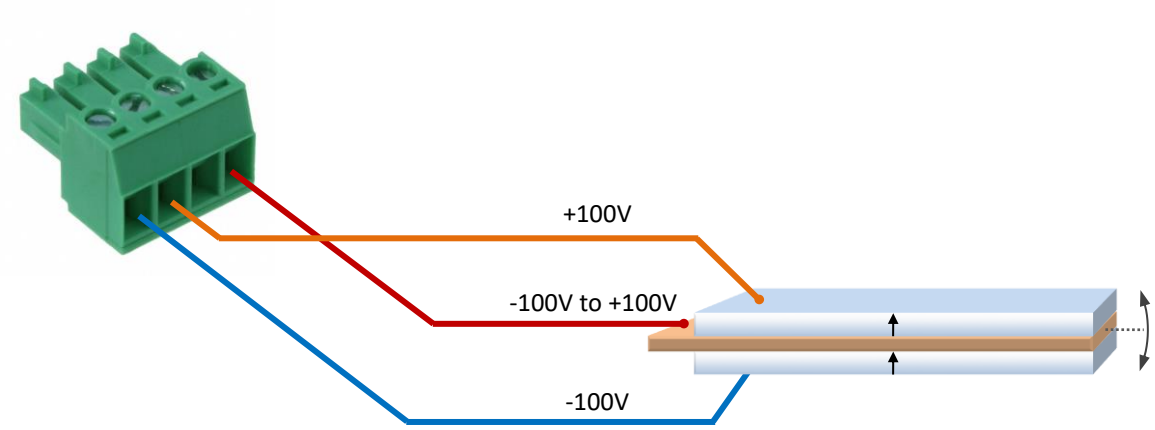
The screw terminal output has contacts for the output voltage, output return, and the internal HV supply rails. The **Output-** signal is connected to ground through a 0.1 Ohm resistor.



Stack actuators are connected as shown below.



Bender actuators can be driven with a single bias voltage, for example 200 V, or a bipolar bias voltage, for example ±100 V. The ±100 V bipolar configuration is shown below.

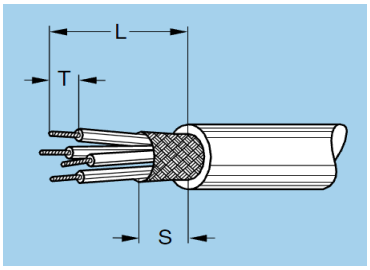


14.2 LEMO OB Cable Assembly

The LEMO 0B socket is the preferred output connector and is rated for 10 Amps RMS. The shield is directly connected to ground, rather than **Output-**.

Preassembled LEMO cable assemblies are available from www.PiezoDrive.com

The recommended cable is Belden 8451. The recommended cable preparation is shown below for solder, and crimp-terminal plugs.



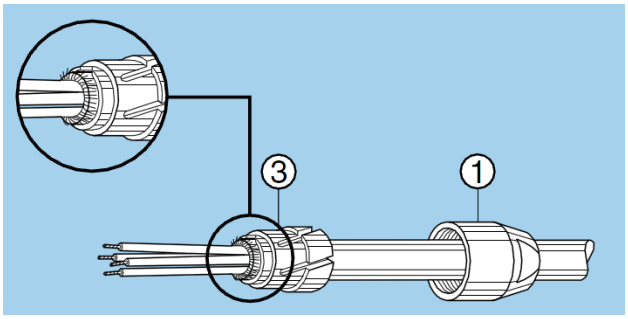
Dimension	Solder Terminals	Crimp Terminals
L (Free Length)	13 mm	17 mm
S (Shield Length)	7 mm	7 mm
T (Strip Length)	3 mm	4 mm

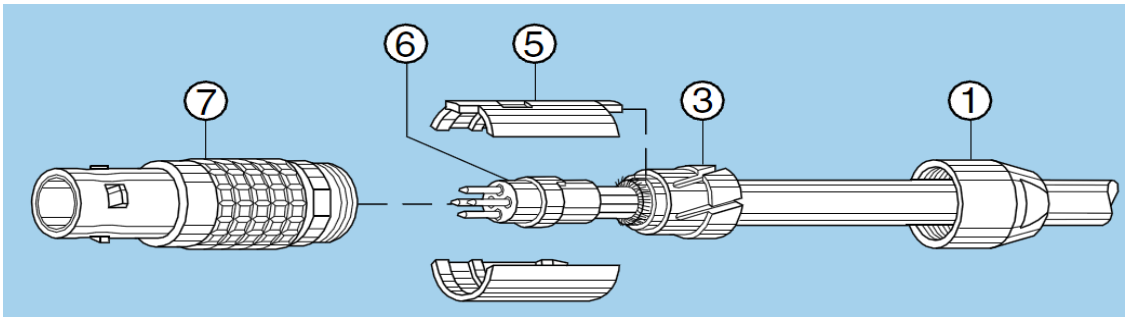
The parts list for the LEMO 0B.302 plug are:

- FGG.0B.302.CLAZ (solder terminals) or FGG.0B.302.CYCZ (crimp terminals)
- FGG.0B.742.DN - collet for 3.1mm to 4mm cable
- GMA.0B.035.DN - strain relief boot for 3.5mm to 3.9mm cable

The plug assembly process is:

1. Strip the cable as above
2. If the cable is shielded, fold the shield back over the cable
3. Slide the strain relief, collet nut (1) and collet (3) onto the cable.
4. Solder or crimp the conductors onto the contacts.
5. Assemble the plug, as shown below.





15 Enclosure

The PX200 has a side air intake and rear exhaust, which can not be obstructed. If sufficient airflow is not available, the amplifier will enter a thermal overload state as discussed in “Overload and Shutdown”.

The PX200 can be installed in a 19-inch x 2U rack space using the **PX200-Rack1** kit. Two amplifiers can also be installed in a side-by-side configuration using the **PX200-Rack2** kit.

16 Warranty

PiezoDrive amplifiers are guaranteed for 3 months. The warranty does not cover damage due to misuse or incorrect user configuration of the amplifier.