PiezoDrive

PDu150
Three Channel, Ultra-low Noise Miniature 150V Piezo Driver

The PDu150 is a complete miniaturized power supply and ultra-low noise driver for up to three 100V, 120V or 150V piezoelectric stack actuators. Output currents up to 100mA per channel are developed at frequencies up to 80 kHz with exceptionally low noise. The three channels can be connected in parallel to produce an output current of 300mA.

The PDu150 is protected against short-circuit, average current overload, and excessive temperature. Passive cooling is available for low power applications or the integrated fan can be used for power dissipations above 5W. The PDu150 can be mounted with four M2.5 screws. The PCB mounting version (PDu150-PCB) is supplied with headers for direct mounting onto a host motherboard.

| Specifications	
Power Supply	+24V, Ground
Output Voltage	-30V to +150V
Peak Current	100 mA per channel 300 mA single channel
RMS Current	78 mA per channel 235 mA single channel
Power Bandwidth	80 kHz (150 Vp-p)
Signal Bandwidth	180 kHz
Slew Rate	38 V/us
Gain	20 V/V
Input Impedance	$9.16\ k\Omega$ (Input), $3.3\ k\Omega$ (Offset)
Input Offset	± 5 mV
Load	Unlimited
Output Noise	26 uV RMS, 1uF Load, 10Hz to 1MHz
Protection	Short-circuit, average current, and under-voltage protection
Quiescent Current	100 mA (10 mA in Shutdown)
Dimensions	76 x 40 x 37 mm (L x W x H)
Environment	-40 to 60°C (-40 to 140°F) Non-condensing humidity
Weight	80 g
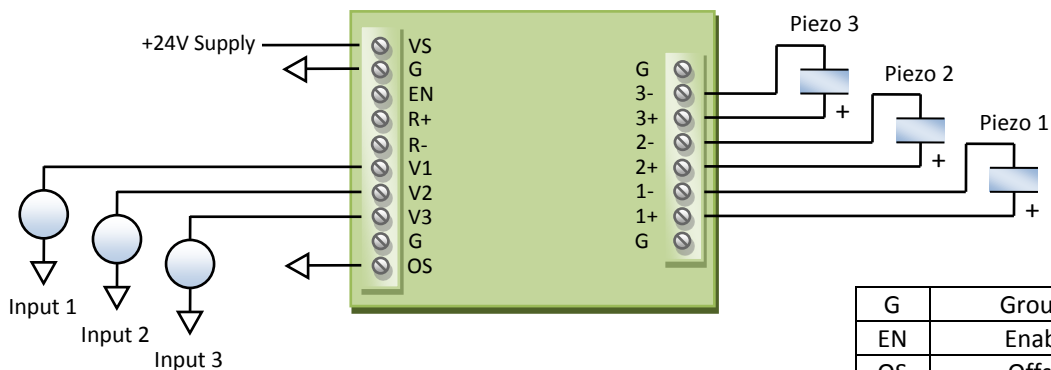
Figure 1. Basic Connection diagram

G	Ground
EN	Enable
OS	Offset
R-	-2V Reference
R+	+10V Reference

Operation

As shown in Figure 2, the amplifiers have differential inputs where the negative input can be connected to an external reference or the internal offset generator. A precision +10V and -2V reference voltage (R+ and R-) are provided to allow external potentiometers to generate the amplifier inputs.

The amplifier outputs use a novel low-noise differential architecture and cannot be connected to ground.
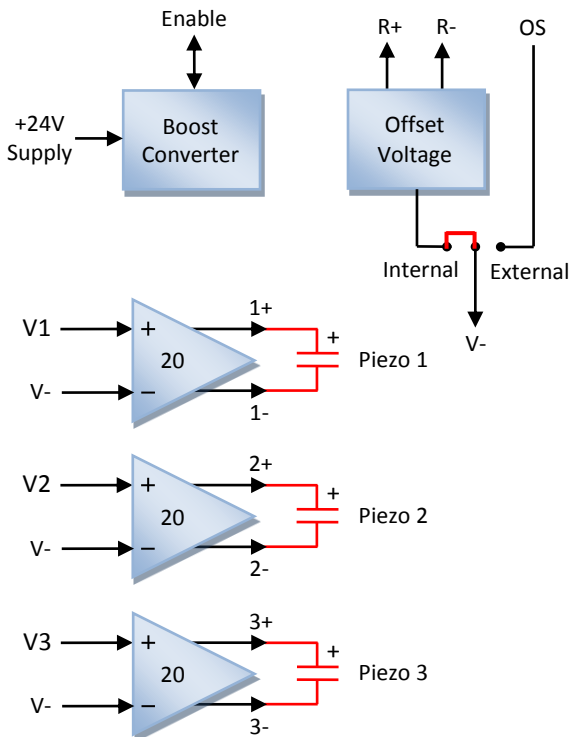

Figure 2. PDu150 Block Diagram

Single Channel Mode

The power bandwidth and output current can be tripled by connecting three amplifiers in parallel as shown below. A third configuration with two parallel channels and one single channel is also possible.


Offset Voltage Configuration

The offset voltage can be set from either the internal potentiometer or by an external source by configuring the jumper LK1 to either "Internal" or "External".

When using the internal offset source, the offset voltage is set by connecting a multimeter across the output and varying the potentiometer until the desired offset is obtained.

In the external offset mode, the offset voltage is determined by the voltage applied to the OS pin. The offset voltage can be set to zero by grounding the OS pin.

Using the Reference Voltages

A precision +10V and -2V reference voltage (R+ and R-) is provided to allow an external potentiometer to generate the amplifier input, as shown below. Multiple potentiometers can be used for multiple channels. The 10uF capacitor reduces the noise bandwidth but is not strictly necessary. The capacitor should preferably be a film type but ceramic is acceptable in most applications.
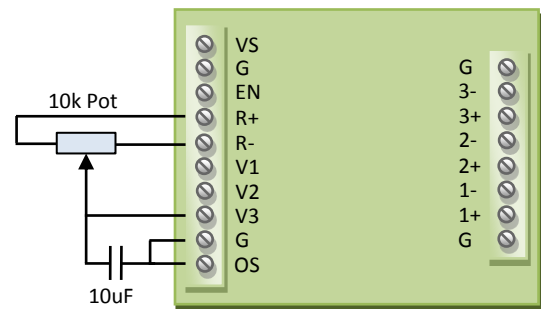
Output Current

The peak output current is 100mA per channel or 300mA for three channels in parallel. In addition, the maximum average current is 35mA per amplifier. The average current is useful for calculating the power dissipation and average supply current. For a sine wave, the average positive output current is equal to

$$I_{av} = \frac{\sqrt{2}}{\pi}\, I_{rms} \ = \frac{1}{\pi} I_{pk}.$$

Supply Current

The quiescent power for the amplifier is approximately 2 W or 85 mA. This can be reduced to <10 mA by pulling the Enable pin low with an open collector circuit. If the fan is used, the quiescent power is increased by 0.5W,

The supply current is related to the total average output current by

$$I_s = \frac{200 \times (I_{av} + 0.010)}{24}.$$

where I_{av} is the total average output current. The maximum supply current is 0.9 A at full power.

Power Bandwidth

The nominal slew-rate of the PDu150 is 38 V/us. Therefore, the maximum frequency sine-wave is

$$f_{max} = \frac{38 \times 10^6}{\pi V_{L(p-p)}}$$

The power bandwidth for a 150 Vp-p sine-wave is 80 kHz.

With a capacitive load, the power bandwidth is limited by the output current. The maximum frequency sine wave is

$$f_{pwr} = \frac{I_{pk}}{\pi V_{L(p-p)} C_L}$$

where I_{pk} is the peak current limit, $V_{L(p-p)}$ is the peak-to-peak output voltage, and C_L is the effective load capacitance. The power bandwidth for a range of load capacitance values is listed in Table 1.

Load	Voltage Range		
(uF)	50 V	100 V	150 V
0.01	64000	32000	21000
0.03	21000	11000	7100
0.1	6400	3200	2100
0.3	2100	1100	710
1	640	320	210
3	210	110	71
10	64	32	21
30	21	11	7

Table 1. Power bandwidth (in Hz) with a capacitive load
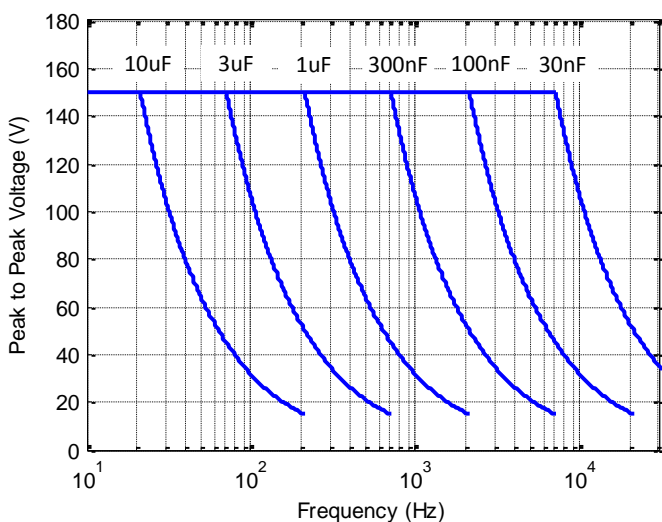
The maximum peak-to-peak voltage is plotted below.

Figure 3. Power Bandwidth (150 Vp-p)

Signal Bandwidth

The small-signal bandwidth for a range of capacitive loads is listed in Table 2. The small-signal frequency responses are plotted in Figure 4.

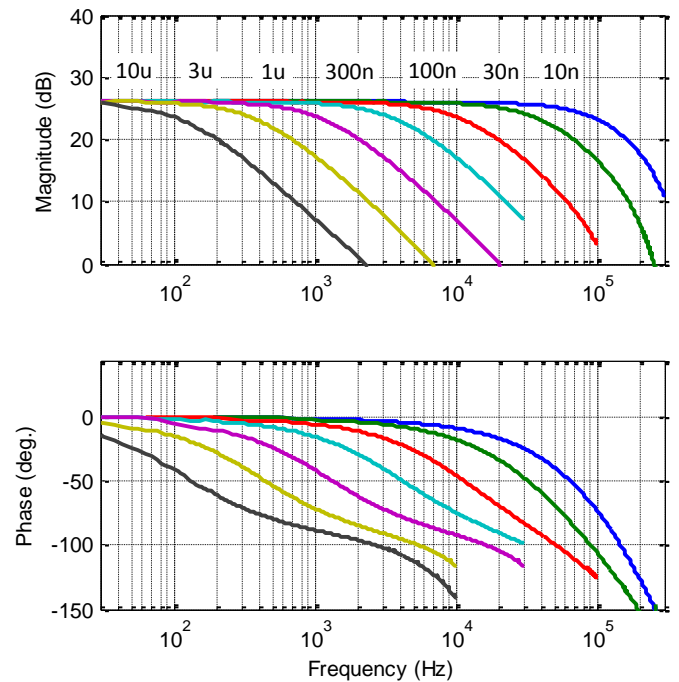| Load Capacitance	Signal Bandwidth
No Load	180 kHz
10 nF	105 kHz
30 nF	40 kHz
100 nF	11 kHz
300 nF	3.8 kHz
1 uF	1.0 kHz
3 uF	320 Hz
10 uF	62 Hz
30 uF	24 Hz

Table 2. Small signal bandwidth (-3 dB)

Figure 4. Small signal frequency response

Noise

The output noise contains a low frequency component (0.03 Hz to 10 Hz) that is independent of the load capacitance; and a high frequency component (10 Hz to 1 MHz) that is inversely related to the load capacitance.

Note that many manufacturers quote only the AC noise measured by a multimeter (20 Hz to 100 kHz) which is usually a gross underestimate.

The noise is measured with an SR560 low-noise amplifier (Gain = 1000), oscilloscope, and an Agilent

34461A Voltmeter. The low-frequency noise is plotted in Figure 5. The RMS value is 15 uV with a peak-to-peak voltage of 100 uV.
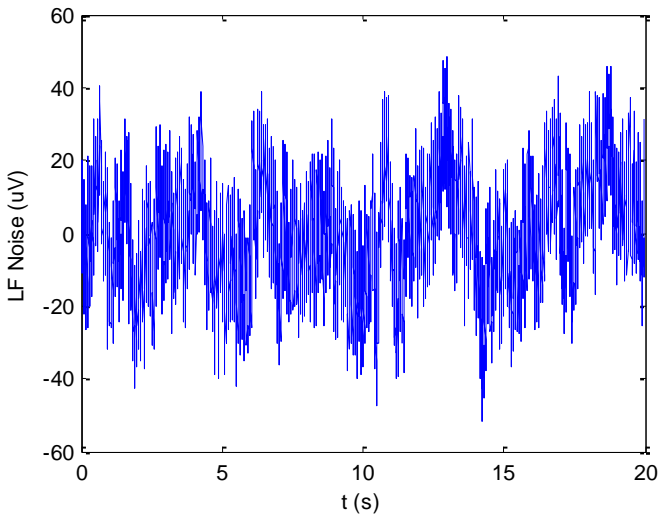

Figure 5. Low frequency output noise (0.03 Hz to 10 Hz)

The high frequency noise (10 Hz to 1 MHz) is listed in the table below versus load capacitance. The total noise from 0.03 Hz to 1 MHz is found by summing the RMS values, that is $\sigma = \sqrt{\sigma_{LF}^2 + \sigma_{HF}^2}$.

Load Capacitance	HF Noise	Total Noise
10 nF	450 uV	450 uV
30 nF	170 uV	170 uV
100 nF	60 uV	62 uV
300 nF	34 uV	37 uV
1 uF	21 uV	26 uV
3 uF	16 uV	23 uV
10 uF	16 uV	22 uV
30 uF	18 uV	23 uV

Table 3. HF Noise (10 Hz to 1 MHz) and total noise

Overload Protection / Shutdown

The PDu150 is protected against short-circuit and average current overload.

The amplifier can be shutdown manually by pulling the Enable pin low with an open-collector, or open-drain circuit. The Enable pin normally floats at 5V and should not be driven directly.

Heat Dissipation

The heat dissipation is approximately

$$P_d = 200 \times (I_{av} + 0.010).$$

For example, with a sinusoidal output, the power is

$$P_d = 200 \times \left(V_{L(p-p)} C_L f + 0.010 \right).$$

For low-current applications that dissipate less than 5W, the heatsink fan may be removed. If the power dissipation is above 5W, forced air or the included fan is required.

Safety

This device produces hazardous potentials and should be used by suitably qualified personnel. Do not operate the device when there are exposed conductors.

Parts of the circuit may store charge so precautions must also be taken when the device is not powered.

Dimensions

The mounting posts accept M2.5 screws. For the PCB mounting version (PDu150-PCB), a schematic and footprint library are available for Altium Designer. Contact info@piezodrive.com to receive the file.
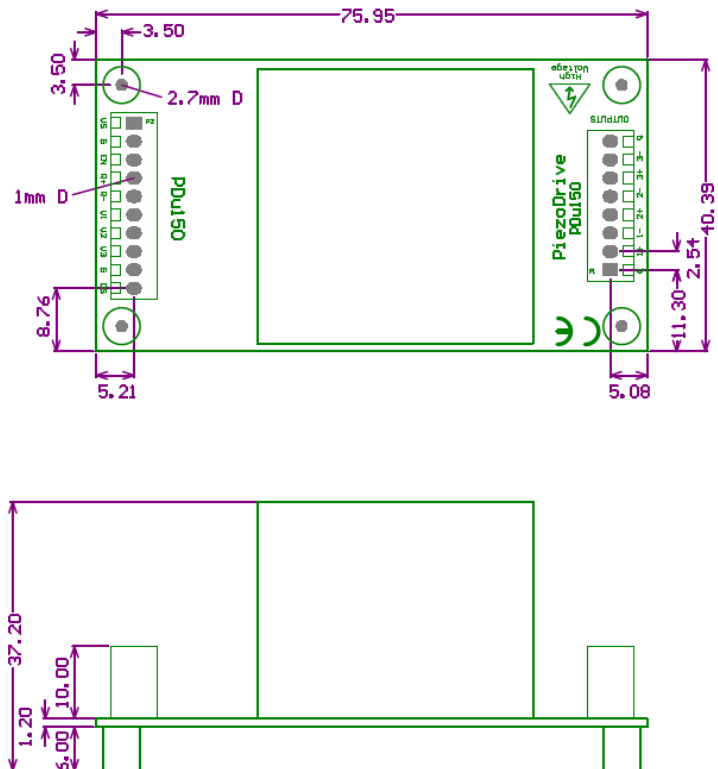

Figure 6. Dimensions (mm)

Contact / Support

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