PiezoDrive

PDu150 V6

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 very low noise.

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 (Max 28V)
Output Voltage	-30V to +150V
Peak Current	100 mA per channel
RMS Current	78 mA per 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 44 mm (L x W x H)
Environment	0 to 60°C (-32 to 140°F) Non-condensing humidity
Weight	80 g

G	Ground
EN	Enable
OS	Offset
R-	-2V Reference
R+	+10V Reference
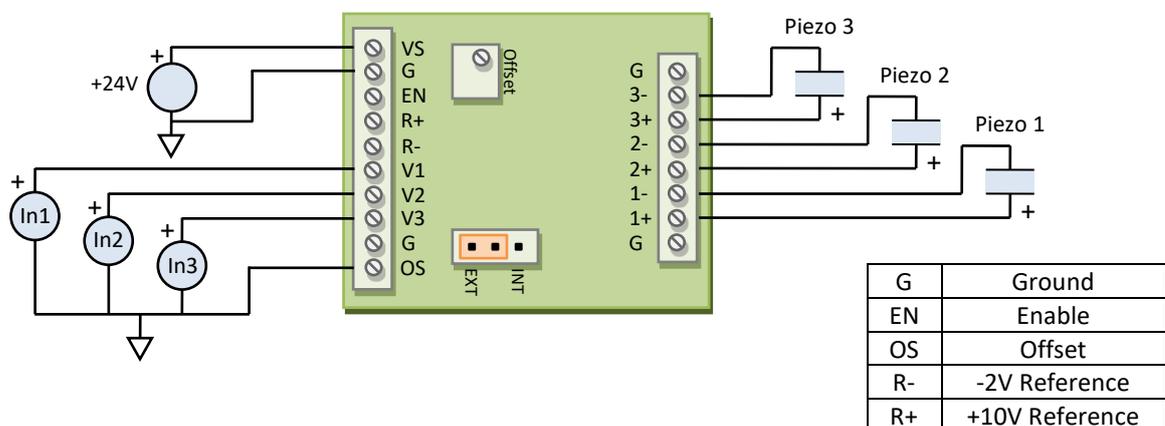
Figure 1. Basic Connection diagram. Offset jumper in EXT position.

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.
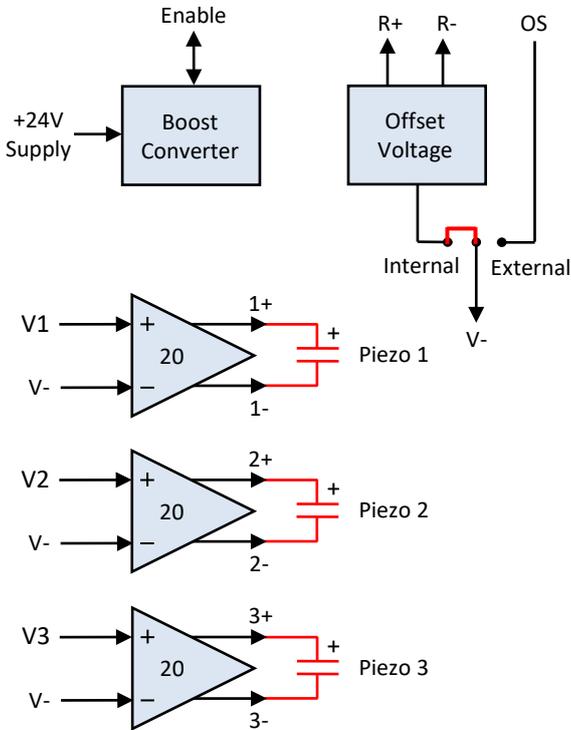
Figure 2. PDu150 Block Diagram

Offset Voltage Configuration

The offset voltage can be set from either the internal potentiometer or by an external source by configuring the jumper 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.
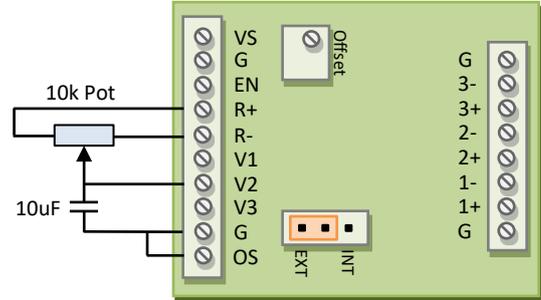
Figure 3. Circuit to create a variable DC input to channel 2

Output Current

The peak output current is 100mA. 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 below 1V with an open collector circuit (requires a pull-down resistance less than 10k). While the module is enabled, the resistance on the Enable pin must be greater than 1 MOhm.

The supply current is related to the sum of the of average output current for all channels

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

where I_{av} is defined in Output Current. The maximum supply current is 0.9 A at full power. If the fan is used, the quiescent power is increased by 0.5W.

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
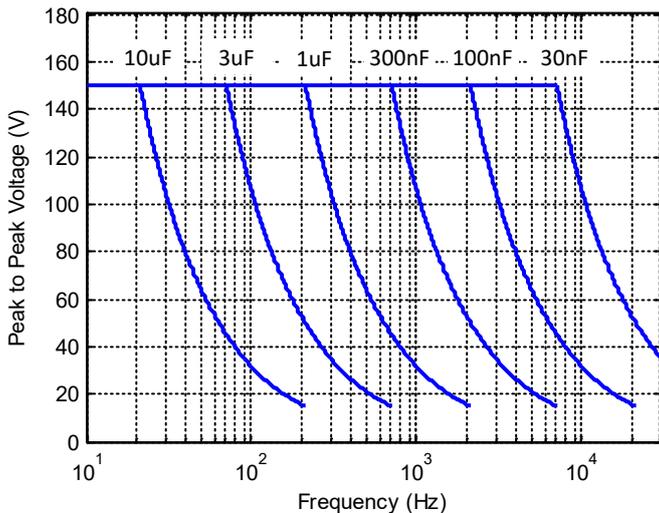
The maximum peak-to-peak voltage is plotted below.

Figure 4. 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 5.

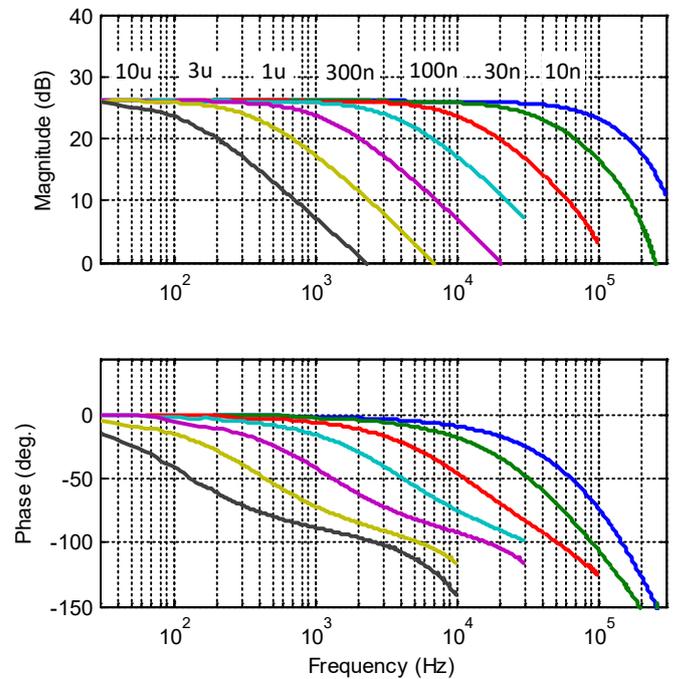| Load Capacitance	Signal Bandwidth
No Load	180 kHz
10 nF	105 kHz
30 nF	40 kHz
100 nF	11 kHz
300 nF	3.8 kHz
1 uF	1.0 kHz
3 uF	320 Hz
10 uF	62 Hz
30 uF	24 Hz

Table 2. Small signal bandwidth (-3 dB)

Figure 5. 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.

Optimal noise performance is achieved with passive cooling as magnetic fields from the fan can induce mV level interference in the outputs. In low noise applications, where the fan is removed, some external air-flow is required if the power dissipation is above 5W, refer to Heat Dissipation for further details.

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 6. The RMS value is 15 uV with a peak-to-peak voltage of 100 uV.
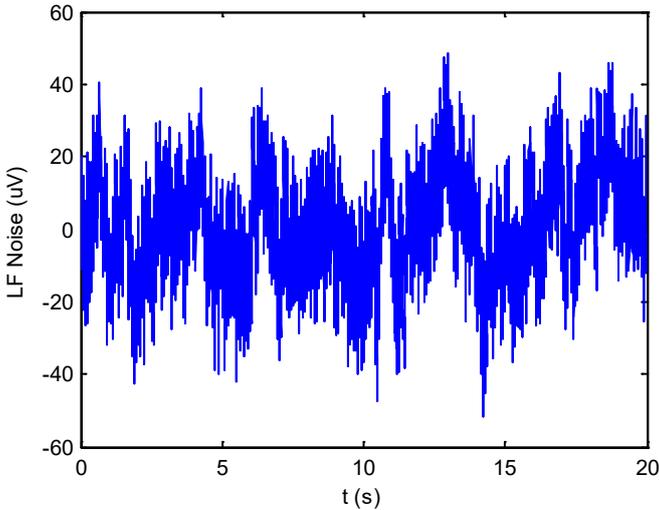

Figure 6. Low frequency output noise (0.03 Hz to 10 Hz)

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 at https://www.piezodrive.com/resources/
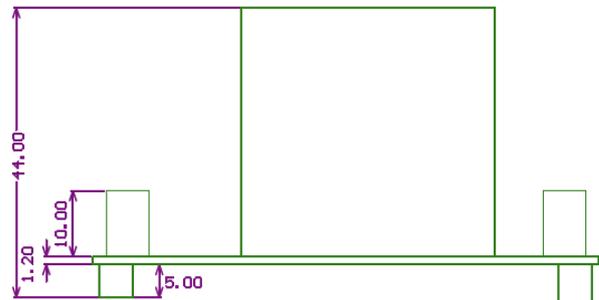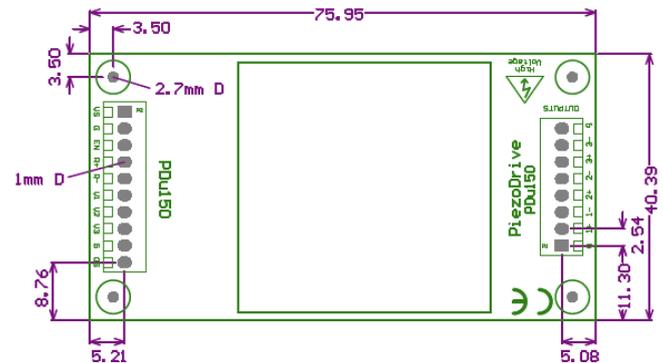

Figure 7. Dimensions (mm)

Test Procedure

To test the PDu150, follow these instructions:

1. Move the OFFSET jumper to EXT
2. Connect a 24V supply between VS and ground.
3. Connect a +1V DC signal to V1, V2, and V3
4. Connect the OS pin to ground
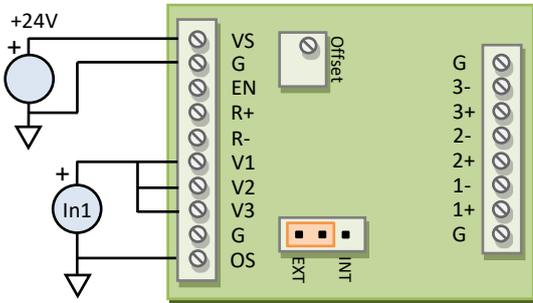5. Check that the circuit connections match the diagram below.

Figure 8. Test Configuration

Turn the power on and use a battery powered multimeter to measure the voltage between the following positive and negative positions. The measured voltages should be within the minimum and maximum values stated below.

Positive	Negative	Min	Max
VS	G	23V	25V
V1	G	0.95V	1.05V
V2	G	0.95V	1.05V
V3	G	0.95V	1.05V
OS	G	-0.01V	+0.01V
1+	1-	+19.5V	+20.5V
2+	2-	+19.5V	+20.5V
3+	3-	+19.5V	+20.5V

Table 4. First test points and expected voltages

After this test is successful, increase the input voltage to 7.5V and repeat the test points. The measured voltages should be within the stated minimum and maximum values stated below.

Positive	Negative	Min	Max
VS	G	23V	25V
V1	G	7.45V	7.55V
V2	G	7.45V	7.55V
V3	G	7.45V	7.55V
OS	G	-0.01V	+0.01V
1+	1-	+148V	+152V
2+	2-	+148V	+152V
3+	3-	+148V	+152V

Table 5. Second test points and expected voltages

Trouble Shooting Notes

The most common perceived issues with the PDu150 are due to incorrect measurement of the output voltages. The PDu150 output is differential, and the negative outputs (1-, 2-, and 3-) cannot be connected to ground. To measure the output voltage use a battery powered multimeter to measure the voltage between 1+ and 1-, for example.

To measure the output voltage with an oscilloscope, connect the oscilloscope ground to the PDu150 ground (any G pin), and connect the probe to either the 1+, 2+, or 3+ output. The actual voltage across the load is double what is being measured, which can be accounted for manually, or by doubling the probe sensitivity in the oscilloscope settings, e.g. change the probe sensitivity from 10x to 20x. Do not connect the oscilloscope ground to the 1-, 2-, or 3- terminals.

Contact / Support

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Revision History

Date	Rev	By	Changes
19/01/06	V6.2	KB	Removed ref to parallel mode
10/08/23	V6.1	KB	Removed single channel mode
27/08/22	R6	KB	Updated limits, Vs and Enable
20/01/21	R5	KB	Updated test procedure
20/01/21	R4	KB	Test procedure added
16/01/21	R3	KB	Temp range updated