PiezoDrive

TD250 – 6 Channel 250V Amplifier

Manual and Specifications

PiezoDrive Pty. Ltd.
www.piezodrive.com

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1   Introduction

The TD250 is an ultra-low noise, six-channel voltage amplifier with a bipolar 250V output range. The six channels can be driven independently, or configured as three channels with non-inverting and inverting outputs, which are ideal for driving piezoelectric tube scanners. The three-channel configuration can also be used to obtain +/-500V with a bridged load.

The TD250 can drive unlimited capacitive loads such as piezoelectric tubes, stack actuators, standard piezoelectric actuators, and bender actuators. Applications include, nanopositioning, microscopy, electro-optics, vibration control, and piezoelectric motors.

The output connector is an industry standard 9-Pin D-Sub connector. A breakout board is also available which provides BNC connectors for each output and a plug-in screw-terminal connector. OEM and customized versions are also available.

2   Warnings / Notes

This device produces hazardous potentials and should be used by suitably qualified personnel under the supervision of an observer with appropriate first-aid training. Do not operate the device when there are exposed conductors.
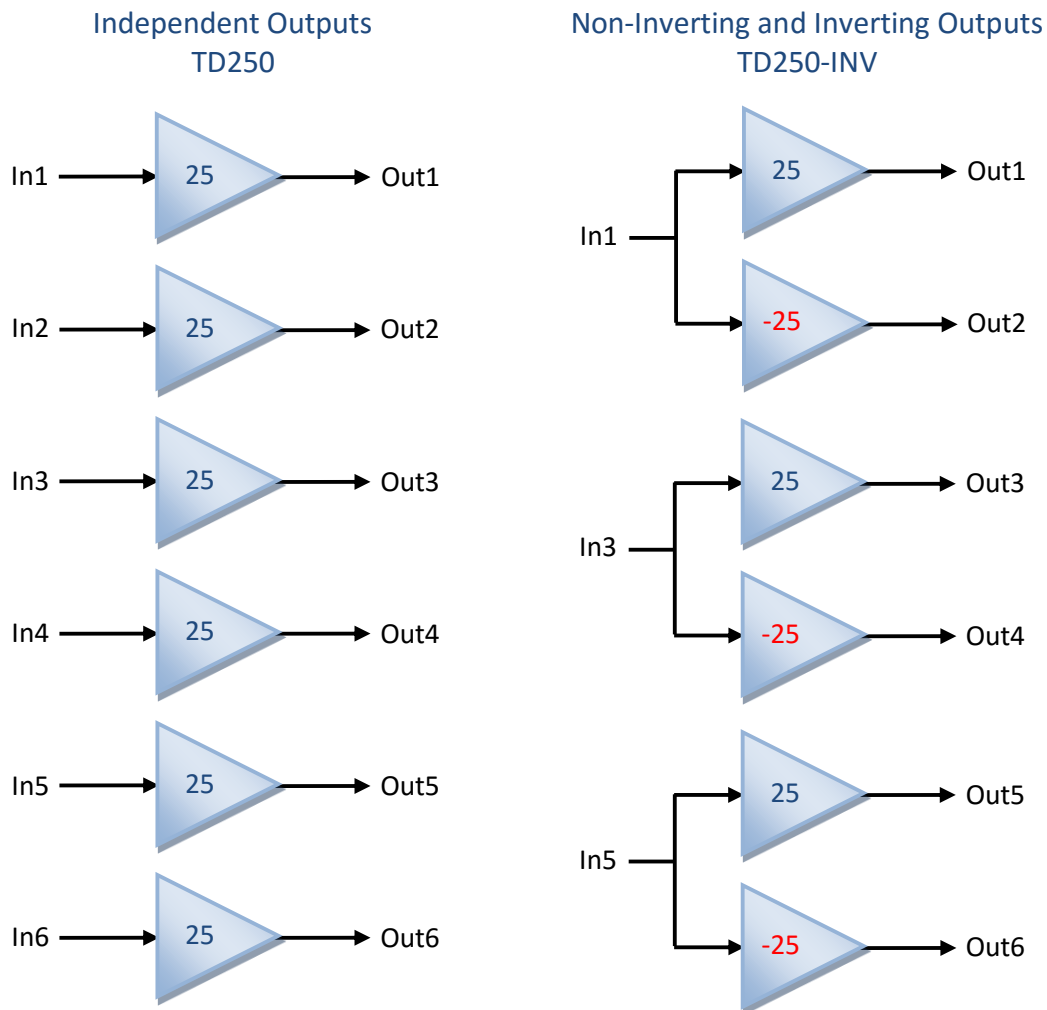

High-Voltage

3   Specifications

Electrical	
Output Voltage Range	$\pm$250V
RMS Current	22 mA per channel
Peak Current	50 mA per channel
Gain	25 V/V
Slew Rate	30 V/us
Signal Bandwidth	50 kHz
Power Bandwidth	20 kHz (400 Vp-p)
Max Power	25 W
Noise	50uV RMS (100nF Load)
Protection	Over-current protection
Input Impedance	100 kΩ
Input Connectors	BNC
Output Connectors	9 Pin D-Sub
Power Supply	90 Vac to 250 Vac

Mechanical	
Environment	0 to 40°C (32 to 104°F) Non-condensing humidity
Dimensions	275 x 141 x 64 mm (10.8 x 5.5 x 2.5 in)
Weight	1 kg (2.2 lb)

4 Channel Configuration

The standard configuration of the TD250 is six independent non-inverting channels, as shown below. However, the outputs can also be configured as non-inverting and inverting pairs for driving piezoelectric tubes and bridged loads, the order code for this configuration is TD250-INV.

Independent Outputs
TD250

In1 → 25 → Out1
In2 → 25 → Out2
In3 → 25 → Out3
In4 → 25 → Out4
In5 → 25 → Out5
In6 → 25 → Out6

Non-Inverting and Inverting Outputs
TD250-INV

In1 → 25 → Out1
In1 → -25 → Out2
In3 → 25 → Out3
In3 → -25 → Out4
In5 → 25 → Out5
In5 → -25 → Out6

The front panel output connector is an industry standard 9-Pin Female D-Sub Connector (TE 3-1634584-2). Any Male 9-Pin D-Sub connector is compatible. The connector pinout is shown below.

5 o o o o o 1
9   o o o o   6

Signal	Connector Pin
Output 1	5
Output 2	9
Output 3	4
Output 4	8
Output 5	3
Output 6	7
Ground	1, 2, 6

5   Driving Piezoelectric Tube Scanners

The voltage range, noise, and bandwidth of the TD250 have been optimized for driving piezoelectric tube scanners, for example the TB6009. Although many configurations are possible, the *driven internal electrode* configuration shown below is simple and provides the maximum X, Y and Z travel range. This configuration requires a tube with a continuous internal electrode and four external electrodes.

In the driven internal electrode configuration, the X and Y electrodes are driven in the standard way with equal and opposite voltages. By applying the full-scale negative voltage to the internal electrode, a contraction equal to half the vertical scan range is obtained. This method exploits the higher positive electric field strength of the piezoelectric material, which is usually five times the negative electric field strength. Care must be taken not to apply positive voltages to the internal electrode, since this can risk depolarization if the tube voltage limit is less than ±500V, which is commonly true for tubes less than 1.2mm thick.
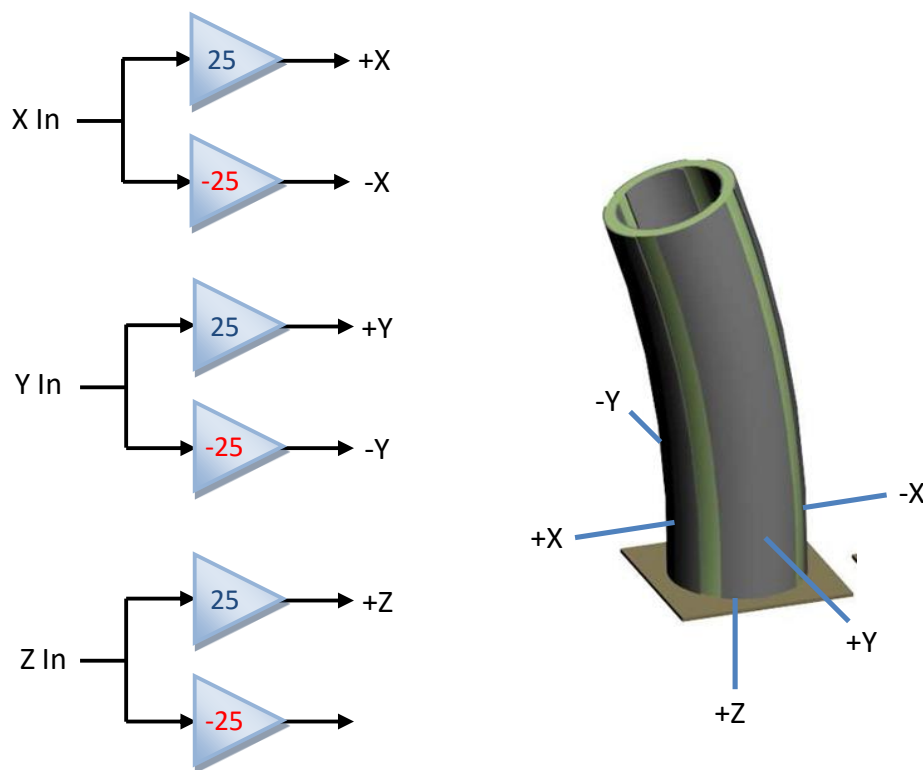

Figure 1. Driving piezoelectric tubes

Another common electrode configuration uses a separate circumferential electrode for the Z axis. This electrode is driven by a single channel with the full bipolar range.

In larger piezoelectric tubes, it is possible to quarter the external and internal electrodes. The internal electrodes can be either grounded or driven in the bridged configuration. Since the bridged configuration doubles the voltage difference across the piezo material, the thickness can also be doubled which significantly improves the resonance frequency. The disadvantages of this method include increased wiring and fabrication difficulty.

6   Bridged Load Configuration

To obtain an output voltage range of +/-500V, the TD250-INV can used with a bridged load, as illustrated below.
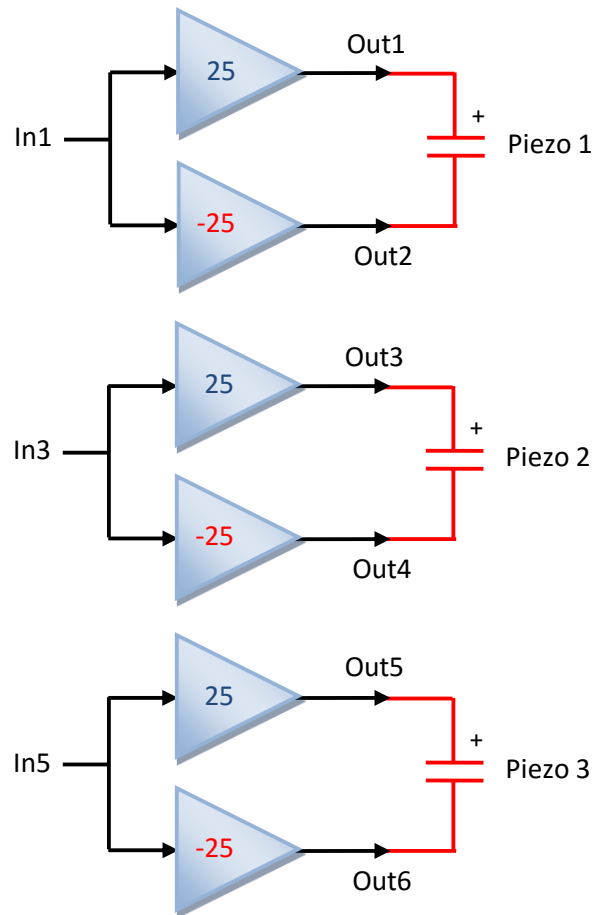
In the bridged configuration, the power bandwidth can be assessed by using the full peak-to-peak load voltage in the calculator, or by doubling the effective capacitance.

7 Power Bandwidth

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

$$I_{pk} = \pm V_{pp} \pi C f$$

where V_{pp} is the peak-to-peak output voltage, C is the load capacitance, and f is the frequency. Given a peak current limit I_{pk}, the maximum frequency is therefore $f = I_{pk}/V_{pp}\pi C$. However, the TD250 is protected by both peak and average current limits. The average current I_{av+} is defined as the average positive or negative current. For example, for a sine-wave

$$I_{av+} = \frac{1}{2\pi} \int_0^\pi I_{pk} \sin(\theta)\, d\theta = \frac{I_{pk}}{2\pi}[-cos]_0^\pi = \frac{I_{pk}}{\pi} \ .$$

Therefore, for a sine-wave $I_{av+} = I_{pk}/\pi$. Since the average current limit of the TD250 is 10 mA, the maximum frequency sine-wave, or power bandwidth of the TD250, is equal to

$$f = \frac{0.01}{V_{pp} C} \ .$$

The above result is true for any periodic waveform such as triangular signals. The RMS current for a sine-wave can also be related to the average current,

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

The power bandwidths for a range of load capacitance values are listed below.

Load	Peak to Peak Voltage			
Cap.	200	300	400	500
No Load	50 kHz	33 kHz	25 kHz	20 kHz
3 nF	12 kHz	8.3 kHz	6.2 kHz	5.0 kHz
10 nF	4.5 kHz	3.0 kHz	2.2 kHz	1.8 kHz
30 nF	1.6 kHz	1.0 kHz	800 Hz	640 Hz
100 nF	490 Hz	330 Hz	240 Hz	190 Hz
300 nF	160 Hz	110 Hz	83 Hz	66 Hz
1 uF	50 Hz	33 Hz	25 Hz	20 Hz

Table 1. Power bandwidth versus load capacitance

In the above table, the frequencies limited by slew-rate are marked in green while the frequencies limited by signal bandwidth are marked in blue. The slew-rate is approximately 30 V/uS which implies a maximum frequency of

$$f^{max} = \frac{30 \times 10^6}{\pi V_{pp}}$$

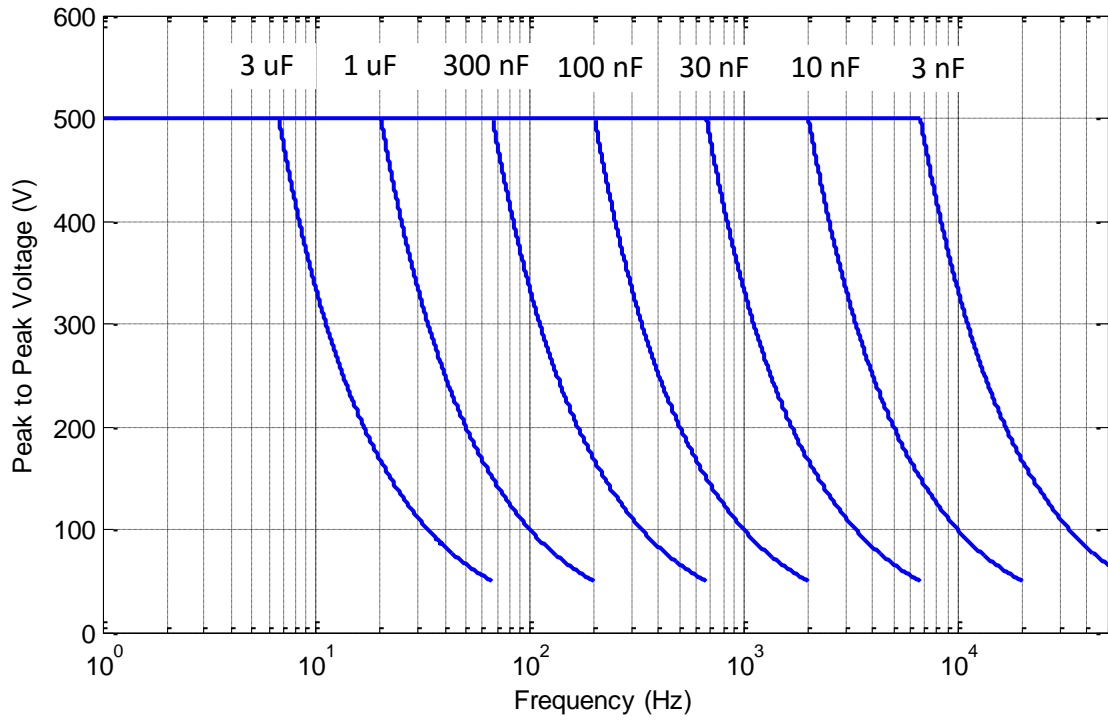In the following figure, the maximum frequency periodic signal is plotted against the peak-to-peak voltage.

Figure 3. Power bandwidth versus voltage and load capacitance
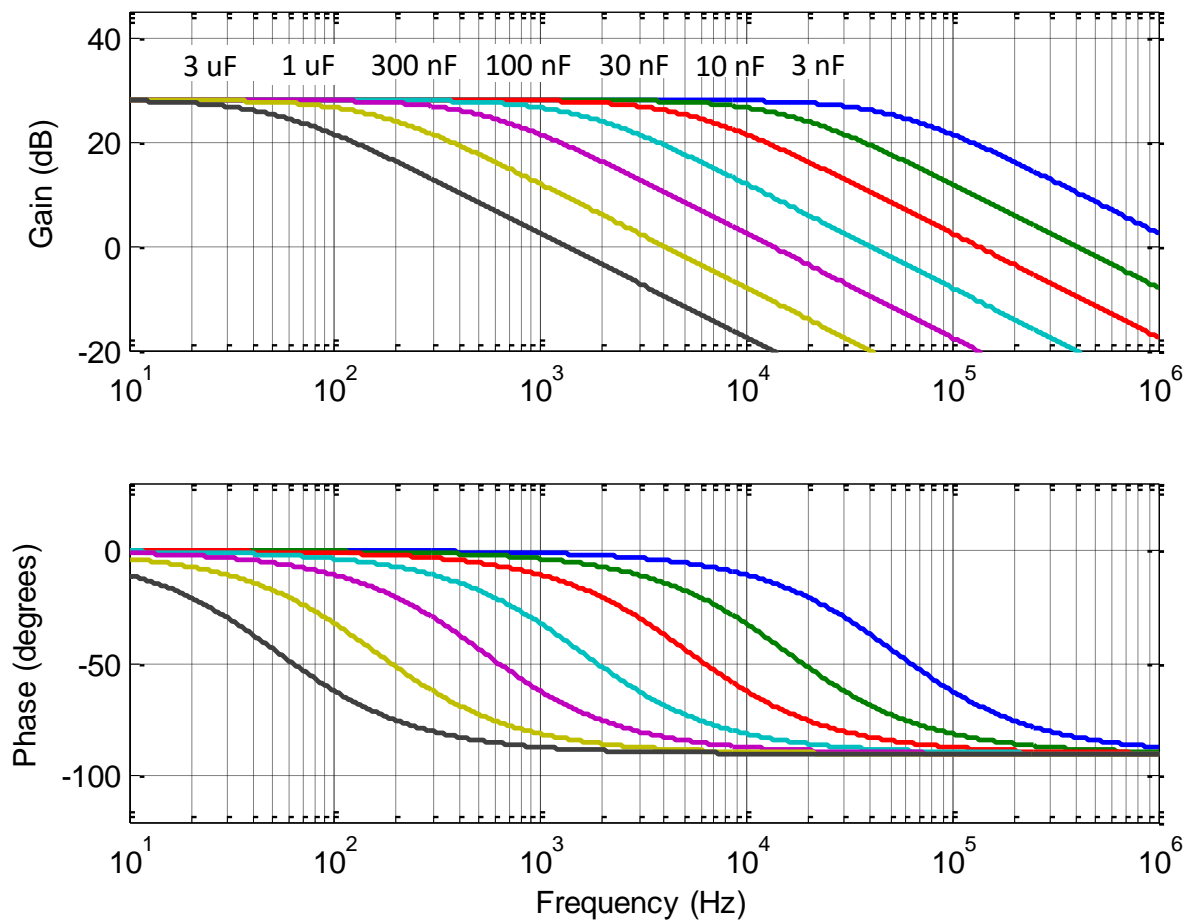
8   Small Signal Frequency Response

Figure 4. Small signal frequency response.

Load Cap.	Bandwidth
No Load	100 kHz
3 nF	39 kHz
10 nF	14 kHz
30 nF	5.1 kHz
100 nF	1.5 kHz
300 nF	520 Hz
1 uF	150 Hz

Figure 5. Small signal bandwidth versus load capacitance (-3dB)

9   Noise

The output noise contains a low frequency component (0.03 Hz to 20 Hz) that is independent of the load capacitance; and a high frequency component (20 Hz to 1 MHz) that is inversely related to the load capacitance. Many manufacturers quote only the AC noise measured in the 20 Hz to 100 kHz range, which is usually a gross underestimate.

The noise is measured with an SR560 low-noise amplifier (Gain = 1000), oscilloscope, and Agilent 34461A Voltmeter. The low-frequency noise is measured to be 50 uV RMS with a peak-to-peak voltage of 300 uV. This noise level is significantly less than the least significant bit of an 18-bit digital-to-analog converter.

The high frequency noise (20 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 of the low and high frequency components, that is $\sigma = \sqrt{\sigma_{LF}^2 + \sigma_{HF}^2}$.

Load Cap.	Bandwidth	HF Noise RMS	Total Noise RMS
No Load	100 kHz	130 uV	139 uV
3 nF	39 kHz	80 uV	94 uV
10 nF	14 kHz	50 uV	71 uV
30 nF	5.1 Hz	30 uV	58 uV
100 nF	1.5 Hz	40 uV	64 uV
300 nF	520 Hz	50 uV	71 uV
1 uF	150 Hz	70 uV	86 uV

Table 2. RMS noise versus load capacitance (0.03 Hz to 1 MHz)

10   Overload Protection

Each channel is independently protected against average and peak current overload. Exceeding these limits will result in signal distortion.

The front-panel overload indicator will illuminate when the total power supplied to all channels is greater than 25W. This can occur when all channels are simultaneously operated at full power or when there is a failure of one or more channels. During a maximum power overload, the power supply is temporarily disabled and will reset once the power drops below 25W.

When the amplifier is first turned on, the overload protection circuit is engaged by default and will require approximately two seconds to reset.

11 Breakout Box / Cables

The breakout box provides BNC connectors for each output and a plug-in screw-terminal connector (Amphenol 20020004-D081B01LF). The breakout box connects to the amplifier via an included 75cm male-male 9-Pin D-Sub cable.

Order Code: TD250-Breakout

Figure 6. TD250 breakout box

Figure 7. Plug-in screw terminal connector

A number of 300 V D-Sub cables are available for the amplifier. All are supplied with at least one 9-Pin D-Sub connector for connecting to the amplifier. The second connector is either a D-Sub connector for connecting to the breakout box, or free wires.

Connector 2	Length	Order Code
9 Pin Male	75 cm	DSUB9-MM-75cm
9 Pin Male	150 cm	DSUB9-MM-150cm
Free Wires	75 cm	DSUB9-MW-75cm
Free Wires	150 cm	DSUB9-MW-150cm

Table 3. 9-Pin D-Sub cables

12   Enclosure

The TD250 enclosure has a side air intake and rear exhaust. These vents should not be obstructed.

13   Warranty

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