MDT693

Three Channel Piezo Driver

Operating Manual

MDT693 Accessories

- MDT631
- PIEZO ELECTRIC MULTI-LAYER ACTUATOR
- PE4
- KC1-PZ & KC1-T-PZ

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Section 1.0 Specifications

Physical Features:
- Dimensions: 12 1/4" x 3 3/4" x 8"
- External Input Connectors: BNC’s
- Output Connectors: BNC’s
- Manual Controls: 10-Turn Potentiometers
- Scan Trim Controls: 12-Turn Potentiometers
- RS-232 Interface: Female DB9
- Number of Channels: 3
- Number of Displays: 3
- Display Type: 3 1/2 Digit LED
- Display Color: Red
- Power Supply: Switch Selectable between 115 / 230 VAC
- Input Power: 100 / 115 / 230 VAC, 50-60 Hz
- Computer Interface: RS-232 Interface (Optional)

Max Ratings:
- Max Output Current: 60mA per channel
- Max Ext. Input Voltage: 10V
- Fuse Rating: 500mA @115VAC
  250mA @ 230VAC

Electrical Characteristics:
- Ext. Input Voltage Range: 0 to 10V
- Ext. Input Resistance: 10KΩ
- Output Impedance: 50Ω
- Output Voltage Range: 0 to 150V
- External Input Gain: 15 V/V +/- 5%
- Noise: 1.5 mVRMS
- -3dB Bandwidth: 40kHz
- Stability: <0.01% over 5 hours
- Operating Temp: 0 to 40 °C
- Storage Temp: 0 to 40 °C

Notes:
3. The noise was measured with the output set to 150V and an output capacitance of 0.09μF (Thorlabs AE0203D04). The noise will decrease with higher output capacitance and increase with no output capacitance.
4. The Bandwidth was measured at 150V output with no load. Piezo’s connected to the output will produce an RC filter with the 50Ω output impedance. This will limit the bandwidth. (See Section 6: Application Notes)
IMPORTANT SAFETY NOTES

The MDT693 can produce hazardous voltages and currents. Use CAUTION when operating the MDT693 and handling the piezo actuators!

The piezo elements are electrical capacitors capable of storing electrical energy over long periods of time. Besides storing charge from the MDT693, the piezo can accumulate static charge over time due to varying storage temperature and/or mechanical loads.

To safely discharge a piezo, connect it to the MDT693 and set the output voltage to 0 volts.

The MDT693 has no user serviceable parts. Service should be performed by trained service personnel only!

Section 2.0 Overview

The MDT693 is a precision, low-noise, low-drift, high voltage 3-channel controller for piezo actuators. The MDT693 provides both manual and external control of the piezo drive voltages. The MDT693 is an ideal driver for use with Thorlabs Piezo Actuators including the PE4, KC1PZ, MDT631 and the AE-series piezo elements. Typical applications include remote alignment of single-mode fiber couplers, high-resolution translation, microscopy, remote positioning, etc.

Each of the three piezo drive voltages can be controlled independently. Precision 10-turn potentiometers on the front panel allow for precise manual setting of the outputs over the full operating range. This allows hands-off control of the piezo translators to take full advantage of the inherently high resolution of the piezo element.

The drive voltage can also be controlled externally by applying an analog voltage (from 0 to 10V) to the front panel BNC inputs or remotely controlled by a computer terminal through an RS-232 interface. This voltage is multiplied by a gain of 15 V/V and summed with the manual control voltage.

I.e. \[ V_{OUT} = V_{MANUAL} + (15 \times V_{EXT}) + (15 \times V_{RS232}) \]

The external control voltage can be supplied by any stable voltage source including function generators, DAC outputs, or DC supplies. Also, the external voltage can be used as part of a feedback loop for automated alignment systems. Since both the manual control and the external input voltage are summed, the manual control can be used for offset adjustments without having to readjust the external voltage source.

The Master Scan feature allows all three channels to be controlled by one manual adjustment or by one external control signal. In this mode, each channel can be precisely adjusted by an offset voltage (i.e. the INT control knob for each axis) and by a gain adjustment (i.e. SCAN TRIM adjustment pot for each channel). The gain adjustment allows the output for each channel to be amplified from 80 to 120 % of the master control signal.

The MDT693 includes 3 1/2 digit LED readouts for displaying the instantaneous output voltages of all three channels. The MDT693 input power is switch selectable for 115VAC or 230VAC operation.
These Piezo-Electric Actuators transform electrical energy into precisely controlled mechanical displacements. A room temperature epoxy is the recommended method for making connections to these piezo-electric stacks; When mounting, avoid bending forces. Center the mechanical load on the piezo-electric end faces. If the actuator is incorporated into a design which calls for a preload, it is recommended that the preload not exceed 50% of the specified clamp force (45lbs for AE0203 models, and 190lbs for AE0505 models).

The PE4 incorporates one of our piezo-electric stacks (Item #AE0505D16, See page 106) and a manual 3/16"-100 threads per inch lead screw. The manual adjuster has better than 1µm sensitivity, which complements the 15µm range of the piezo stack. When the PE4 is combined with our MDT693 or MDT694 drivers, translation on the order of 10nm is achievable.
## Section 4.0 Description

### Front Panel Features

![Front Panel Features Diagram]

**Feature** | **Description**
---|---
1 | 3 1/2 Digit LED Display – A 3 1/2 digit display is used to view the output voltage for each channel.
2 | EXT INPUT BNC - This input is used to externally control the output. The input voltage range is 0 to 10V with a gain of 15 V/V. There is one input for each channel.
3 | INT Knob – This knob will adjust the output voltage from 0 to 150V DC. It can also be used as an offset for any external input, since it is summed with the EXT INPUT BNC. There is a separate control knob for each channel.
4 | SCAN TRIM – This will adjust the output gain for each channel from 80% to 120% while in the Master Scan mode.
5 | MASTER SCAN EXT – Add a 0 to 10V analog signal to this input to control all three outputs. This input is summed with MASTER SCAN INT, SCAN TRIM and INT. The Master Scan mode must be enabled to use this feature.
6 | MASTER SCAN INT – The Master Scan INT knob will allow the user to adjust the DC offset of all three channels over the full operating range. The Master Scan mode must be enabled to use this feature.
7 | MASTER SCAN Enable LED – will indicate when the MDT693 is operating in the Master Scan mode.
8 | ENABLE Button – This button is used to enable the master scan mode.
9 | POWER Button – Press in to turn the MDT694 on.
Rear Panel Features

![Rear Panel Features Diagram](image)

<table>
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<tr>
<th>Feature</th>
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<td>AC input and fuse receptacle</td>
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<td>2</td>
<td>Line Voltage Selector Switch</td>
</tr>
<tr>
<td>3</td>
<td>Cooling fan</td>
</tr>
<tr>
<td>4</td>
<td>RS-232 Serial Port Connector</td>
</tr>
<tr>
<td>5</td>
<td>Z AXIS output connector</td>
</tr>
<tr>
<td>6</td>
<td>Y AXIS output connector</td>
</tr>
<tr>
<td>7</td>
<td>X AXIS output connector</td>
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Figure 2. Rear Panel

Section 5.0 Operating Instructions

**DANGER**

**High Voltage**

The MDT693 can produce hazardous voltages and current. Use caution when operating this unit.

Using the INT adjustment knob

The INT knobs manually control the output voltages for each channel between 0 and 150 VDC. It can also be described as a DC offset voltage since it will be summed with the external input control and RS-232 control. Follow the procedure described below for operation in this mode.

1. Attach a piezo to each of the high voltage output connectors on the MDT693 rear panel. **Note:** the BNC center conductor is positive and the shield is at ground potential. Be certain to match piezo polarity to the connector since most piezo elements will be permanently damaged if connected backwards.

2. Set all the output voltages to 0V by turning the manual control knobs counter-clockwise until the mechanical stop is reached.

3. Turn the power switch (located on the front panel) to the ON position. The digital displays should begin displaying the output voltages.
4. Adjust the INT knob for each channel until the desired voltages are displayed or until the desired displacements are met.  
**Note:** the maximum output voltage for the MDT693 is 150V per channel. This may be too high for some piezo elements.

**Using the EXT INPUT BNC**

1. Attach a piezo to each of the high voltage output BNC connectors, located on the rear panel of the MDT693.  
   *Note:* the BNC center conductor is positive and the shield is at ground potential. Be certain to match piezo polarity to the connector since most piezo elements will be permanently damaged if connected backwards.

2. Set the output voltages to 0V by turning the manual control knobs counter-clockwise until the mechanical stop is reached.

3. Turn the power switch on.

4. Connect an analog input signal (AC or DC), with a voltage between 0 and 10V, to each of the EXT INPUT BNC’s. The output for each channel will follow the EXT Input voltage with a gain of 15V/V.  
   *Note:* do not place a negative voltage on the EXT input BNC that will cause the outputs to go below 0V. It is possible for the output voltages to go to a negative 15V. This has the potential of damaging a piezo element. A negative input voltage is possible if an offset voltage (set by the INT knob) is present. In this case the negative voltage must not allow the output to go below 0V.

5. For sinusoidal signals, calculate the output current and verify that it will not exceed the maximum current rating of 60mA. A piezo acts like a capacitor, therefore the output current is a function of the change in voltage divided by the change in time (see Section 5 for details). The MDT693 has an output current limiting circuit to prevent damage to the unit, however the output sinusoid will be distorted.

**Using the MASTER SCAN controls**

The master scan controls are provided so that the user can control all three channels from a single source. This source can be an external voltage or a manual control knob. Each channel also has a gain adjustment, which allows the user to compensate for differences in the piezos. The output of each channel is summed with the INT adjustment knobs to allow for a dc offset.

The Master Scan mode is especially useful for adjusting three axis mounts such as the MDT631 and KC1PZ. The SCAN TRIM gain controls and the INT control knobs allow the user to precisely tune each output separately, while the MASTER SCAN INT and EXT controls allow the user to adjust all three channels in sync.

**ENABLE button**

The ENABLE button located on the front panel (see Section 3 – Front Panel Features) is used to enable and disable the master scan mode.

**Enable LED**

The enable LED, located directly above the ENABLE button, will light when in the master scan mode.

**MASTER SCAN EXT**

An analog voltage between 0 and 10V can be applied to this input to control all three channels over a voltage range of 0 to 150V. This input will be summed with the MASTER SCAN INT and the individual INT knobs for each channel. The MASTER SCAN EXT input will only be active in the MASTER SCAN mode (i.e. the enable LED must be lit).
**MASTER SCAN INT**
The MASTER SCAN INT knob will allow the user to adjust all three channels over the full operating range of 0 to 150V. The MASTER SCAN INT knob will only be active in the MASTER SCAN mode (i.e. the enable LED must be lit).

**SCAN TRIM Adjustments**
The SCAN TRIM adjustments scale each channel separately with a gain of 80% to 120% of the Master Scan INT and EXT signals. This is useful to compensate for differences in reactance from one piezo to another. The SCAN TRIM adjustments are only active in the MASTER SCAN mode (i.e. the enable LED must be lit).

**Note:** the 100% mark is half way through the adjustment range of the SCAN TRIM potentiometer. To approximately set the SCAN TRIM to 100% turn the pot a minimum of 12 turns CCW (zero the pot). Adjust the pot CW six turns. To precisely set the SCAN TRIM to 100% follow the procedure below:
- Adjust all of the INT control knobs CCW as far as they will go.
- Disconnect any EXT input connections.
- Adjust the SCAN TRIM pots a minimum of 12 turns CCW.
- Apply a 5V dc voltage source to the MASTER SCAN EXT BNC.
- Adjust the SCAN TRIM pots CW until their display reads 75 volts.

**Using the RS-232 Control (Optional)**
See the instructions provided with the interface card.

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**Section 6.0 Application Notes**

**Predicting Piezo Performance**
The MDT693 is a precision, low-noise, low-drift voltage amplifier designed specifically to drive piezo actuators. Since piezo crystals can be modeled essentially as capacitors, it is easy to predict their dynamic performance using a basic set of equations:

\[
i(t) = C \frac{dV}{dt} \quad (\text{Eq.1})
\]

For a linear ramp:
\[
I = C \frac{\Delta V}{\Delta t} \quad (\text{Eq.2})
\]

For a sinusoid:
\[
i(t) = CV \cos(\omega t) \frac{d}{dt}
\]
\[
i(t) = -\omega CV \sin(\omega t) \quad (\text{Eq.3})
\]
\[
BW = \frac{1}{t} \quad (\text{Eq.4})
\]
\[
I_{\text{max}} = \omega CV \quad (\text{Eq.5})
\]
Example 1

Q. How much current is needed to drive a Thorlabs piezo (p/n AE0505D16) a distance of 5µm in 10 ms? For this piezo, we know the following:

\[ C = 1.4 \mu F \]
\[ S = 0.116 \mu m / V \] (Displacement factor)

Therefore:

\[ \Delta V = \Delta d / S \quad \text{(Eq. 6)} \]
\[ \Delta V = 5 \mu m / (0.116 \mu m / V) = 43 V \]

\[ I = C \times \Delta V / \Delta T \]
\[ I = 1.4 \mu F \times 43 V / 10 ms = 6 mA \]

The MDT693 has an output current of 60mA, therefore it should have no difficulty driving this application. The output limit of the MDT693 is controlled internally. The current limit will limit the system bandwidth. (See Eq. 1-5)

Bandwidth

The output bandwidth will be affected in three ways. The maximum no load bandwidth is 40kHz at 150V. This is due to the open loop gain of the output amplifier. The maximum bandwidth will increase as the output signal amplitude decreases.

The MDT693 incorporates a 60mA current limiting circuit on the output. This will limit the output bandwidth, or rise time for linear ramps, automatically. For large capacitive loads the bandwidth will decrease as described in the "Predicting Piezo Performance" section of the manual.

Lastly, the output bandwidth will be a function of the output impedance (50Ω) and the capacitance of the piezo as described below:

\[ BW = 1 / (2 \times \pi \times 50 \Omega \times C_{PIEZO}) \quad \text{(Eq. 7)} \]
\[ BW = .0032 / C_{PIEZO} \]

Hysteresis

Due to the inherent properties of the piezo crystal, all piezo actuators exhibit a certain amount of positional hysteresis that can affect repeatability and accuracy. Thorlabs piezo actuators have a typical hysteresis of about 5-10% at room temperature. One way to minimize the error due to hysteresis is to always approach a location from the same direction. A better approach would be to use an external encoder to give direct positional feedback.

Section 7.0 Serial Interface (Optional)

The MDT693 allows for an optional computer interface card to be installed. The rear panel DB9 connector will not be active unless the interface card is installed.
The RS-232 serial interface port will allow the user to remotely control and monitor the output voltage. The serial port can be connected to a PC running an ASCII terminal emulator program to remotely access the MDT693 features. The MDT693 has an interactive menu, which is accessible from the serial port. For experienced programmers, the serial interface may be incorporated into a user program developed on a serial port system.

Section 8.0 Maintenance & Troubleshooting

Setting the Line voltage

The MDT693 is shipped from the factory configured for 100-120VAC operation while the MDT693-EC is shipped from the factory configured for 220-240VAC operation. If the operating voltage needs to be changed, follow the procedure below:

1. Turn the MDT693 power switch OFF and remove the AC line cord.
2. Locate the voltage selector switch on the rear panel of the MDT693.
3. Slide the voltage selector switch, using a flat head screwdriver, to the desired line voltage. (i.e. The Line Voltage Selector Switch will display the set operating voltage as either 115V or 230V)
4. Replace the fuse for the proper line voltage. The fuse rating is located on the rear panel of the MDT693 and in the Specifications section of this manual.
5. Connect the AC Line cord and turn the power on.

Fuse Replacement

The main fuse is located inside the AC receptacle on the back cover. To replace the fuse, remove the AC line cord and pry the fuse holder out of the receptacle. Replace the fuse with the type fuse indicated on the rear panel.

Cleaning

The MDT693 should only be cleaned with a soft cloth and mild soap detergent or isopropyl alcohol. Do not use a solvent-based cleaner.

Technical Support

You may use any of the following methods to contact Thorlabs in case of difficulty or if you have questions regarding your MDT694.

www.thorlabs.com  Thorlabs web site will have up to date application notes and frequently asked questions regarding our products.
Techsupport@thorlabs.com  Send a detailed email message and one of our application engineers will respond promptly (within 1 business day).

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