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MDT693A / MDT694A Piezo Controllers

Operating Manual

Related Products

Model	Description
MDT630A	3-Axis Flexure System with Stage and Controller
MAX302	NanoMax Stage with Piezoelectric Actuators
KC1PZ	Piezo-Electric Kinematic Mount
PE4	Piezo Electric Actuator
APB302	100µm X-Y-Z Piezo Block Translator
ASM00x	Piezo Electric Controlled Optics Mount
AE Series	OEM Piezo Electric Actuators

Table of Contents

WEEE

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out “wheelie bin” logo (see fig. 1)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated

As the WEEE directive applies to self contained operational electrical and electronic products, this “end of life” take back service does not refer to other Thorlabs products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB’s, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste treatment on your own responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of live products will thereby avoid negative impacts on the environment.

Crossed out “wheelie bin” symbol

Section 1: Safety Warnings

WARNING: HIGH VOLTAGE OUTPUTS

The MDT693A can produce hazardous voltages and currents. Use **CAUTION** when operating the MDT693A or MDT694A 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 MDT693A or MDT694A, 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 MDT693A or MDT694A and set the output voltage to 0 volts.

WARNING: HIGH VOLTAGE INSIDE. TO AVOID ELECTRICAL SHOCK THE POWER CORD PROTECTIVE GROUNDING CONDUCTOR MUST BE CONNECTED TO GROUND. DO NOT REMOVE COVER. REFER SERVICING TO QUALIFIED PERSONEL.

Thorlabs provides the proper power input cable with each MDT693A and MDT694A. If something should go wrong with the unit, do not attempt to fix. Call a Thorlabs representative and arrange for repair. The unit should never be opened unless changing the fuse or line voltage as described in Section 5.

WARNING: THE UNIT MUST BE POWERED OFF, UNPLUGGED FROM THE AC INPUT POWER SOURCE, AND DISCONNECTED FROM ALL EXTERNAL DEVICES BEFORE REPLACING THE FUSE. FAILURE TO DO SO MAY CAUSE SERIOUS INJURY TO THE USER SINCE HIGH VOLTAGES EXIST WITHIN THE UNIT.

WARNING: WHEN TURNING OFF THE UNIT, THE OUTPUT MAY EXPERIENCE A VOLTAGE FLUCTUATION ON THE OUTPUT TO THE PIEZO STACK. WHILE THIS DOES NOT DAMAGE THE PIEZO ACTUATOR, IT WILL CHANGE THE POSITION OF THE OPTO-MECHANICAL DEVICE.

Section 2: Specifications

2.1 Physical Features:

	MDT693A	MDT694A
Dimensions (W x H x D):	12.25” x 3.25” x 8” (311.2mm x 82.5 x 203.2mm)	5.8” x 2.8” x 12.5” (147mm x 71mm x 317.5mm)
Input and Output Connectors:	BNC[1]	-----
Manual Controls (DC Offset) [2]:	10-Turn Potentiometer	-----
Scan Trim Controls (Scaling):	12-Turn Potentiometer	N/A
Number of Channels:	3	1
Number of Displays:	3	1
Display Type:	LCD	-----
Display Color:	Green	-----
No of Digits:	3 ½ (000.0 to 150.0)	-----
Display Resolution:	±0.1	-----
Weight:	tbd	tbd
Operating Temperature:	10 - 40°C	-----

2.2 Power Supply:

Input Power Connection[3]:	IEC Connector	-----
Supply Type:	Linear	-----
Voltage Selection:	Switch Selectable (115 / 230)	-----
Input Voltage:	100/115VAC ±10%†	
	230VAC ± 10%	-----
Line Frequency:	50 – 60Hz	-----
Input Power:	85VA max	30VA max
Fuse Ratings:	630mA @ 115VAC†	500mA @ 115VAC†
	400mA @ 230VAC	250mA @ 230VAC
Fuse Type:	IEC60127-2/III (250V, Slow Blow Type ‘T’)	-----
Fuse Size:	5 x 20mm	-----

2.3 Input / Output Specifications:

Ext. Input Voltage Range[4]:	0 – 10V	-----
Ext. Input Impedance[4]:	10KΩ	-----
Output Voltage Range[5]		
Volt Limit Pos 1 (75V)†:	0 - 75V	-----
Volt Limit Pos 2 (100V):	0 - 100V	-----
Volt Limit Pos 3 (150V):	0 – 150V	-----
Max Output Current[5]:	60mA (current limited)	-----
Output Impedance[5]:	150Ω, 0.047µF	-----
Min Load Impedance[7]:	2.5kΩ	-----
EXT Input Gain[4]		
Volt Limit Pos 1 (75V)†:	7.5 V/V ±5%	-----
Volt Limit Pos 2 (100V):	10 V/V ±5%	-----
Volt Limit Pos 3 (150V):	15 V/V ±5%	-----
Output Noise[6]:	1.5mV$_{RMS}$ (~9.9V$_{pp}$)	-----
-3dB Bandwidth[8]		
No Load, Small Signal:	10 kHz	-----
No Load, 150V$_{pp}$:	8.5 kHz	-----
1.6µF Piezo (AE0505D16), 150V:	250 Hz	-----
Stability:	< 0.01% over 5hrs	-----

2.4 A/D and D/A Performance

D/A Resolution:	16-bit	-----
Output Voltage Range:	0 to 150V	-----
Voltage Resolution:	2.75mV	-----
A/D Resolution:	16-bit	-----
Voltage Resolution:	3mV	-----

2.5 Communications:

Communications Port:	RS232	-----
Com Connection:	DB9 Female (Rear Panel)	-----
Required Cable[9]:	DB9 Male to Female (Provided)	-----
Protocol:		
Baud Rate:	9600, 14400, 19200, 28800, 34800 57600, 76800, 115200† bps	-----
Data Bits:	8	
Stop Bits:	1	
Parity:	None	
Handshaking:	None	
Baud Rate Set:	4-Pos Dip Switch (Internal)	----

Notes:

† Factory Default Setting.

1. To operate the MDT693A or MDT694A with Thorlabs Nanomax stages BNC to SMC cables must be used.
2. Includes X AXIS INT, Y AXIS INT, Z AXIS INT and MASTER SCAN INT for the MDT693A and INT for the MDT694A.
3. The MDT693A and MDT694A are supplied with a US style power cord. Units purchased in other countries must supply their own certified rated power cord.
4. Includes X AXIS EXT, Y AXIS EXT, Z AXIS EXT and MASTER SCAN EXT for the MDT693A and EXT for the MDT694A.
5. Includes X AXIS, Y AXIS, and Z AXIS OUTPUTS located on the rear panel of the MDT693A and OUTPUT on the front panel of the MDT694A.
6. The MDT693A and MDT694A were tested without an external load connected (0.047µF output impedance only). Adding a capacitive load, such as a piezo will decrease the noise spec since the capacitance will create a low pass filter with the output resistance.
7. The Min Load Impedance represents the smallest allowable terminating resistance. Applying lower impedances will cause the short circuit protection to limit the output voltage. Continued use in this mode will cause circuit degradation and eventual circuit failure.
8. Assume a ramp function is used. The bandwidth is load dependent and requires calculation for a more representative number. See the Bandwidth section for details.
9. Do not use a null modem cable.

Section 3: Description

The MDT693A and MDT694A are precision, low-noise, low-drift, high voltage controllers for piezo actuators. The MDT693A provides three channels while the MDT694A is a single channel unit. The controllers provide both manual and external control of the piezo drive voltages. The MDT694A is ideal for single piezo control such as the Thorlabs PE4 or AE-series piezos, while the MDT693A can control multiple axis piezo stages such as Thorlabs KC1PZ or MAX312. Typical applications include remote alignment of single-mode fiber couplers, high-resolution translation, microscopy, remote positioning, etc.

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 MDT693A provides independent controls for each channel.

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 the selected gain setting and summed with the manual control voltage.

I.e. $VOUT = V_{MANUAL} + (GAIN * v_{EXT}) + V_{RS232}$

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.

Both the MDT693A and the MDT694A include a voltage limit switch on the rear panels to select the operating voltage ranges and gains for the units. Each unit is shipped set for 0 – 75V (Gain = 7.5 V/V) operation and may be adjusted by the user to provide 0 – 100V (Gain = 10 V/V) and 0 – 150V (Gain = 15 V/V) ranges.

The MDT693A 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 MDT693A and MDT694A include 3 ½ digit LED readouts for displaying the instantaneous output voltages of all three channels. The input power is switch selectable for 115VAC or 230VAC operation.

Section 4: Parts List

Below is a list of all components shipped with the MDT693A/MDT694A Piezo Controller.

- MDT693A or MDT694A Control Box
- Operating Manual
- Fuse Replacement Datasheet
- Software CD
- Power Supply Line Cord
- DB9 Serial Port Cable
- Replacement Fuse for 230VAC operation (400mA fuse for MDT693A's; 250mA fuse for MDT694A's)

The following items are sold separately:

- 2249-C-xx Series: BNC Coaxial Cables
- CA26xx Series: BNC male to SMC male Coaxial Cables
- AE Series: Standalone Piezo Stacks
- PE4: Piezo/Screw Actuator
- MAX300 Series: 3-Axis NanoMax Flexure stages

Section 5: Fuse Replacement / Line Voltage Selection

Thorlabs ships it MDT693A and MDT694A units configure to operate at 115VAC. The line voltage and installed fuse must be changed to operate this unit at 230VAC. To operate at 100VAC, use the 115VAC setting. Follow the instructions below to change the line voltage if necessary.

WARNING: THE UNIT MUST BE POWERED OFF, UNPLUGGED FROM THE AC INPUT POWER SOURCE, AND DISCONNECTED FROM ALL EXTERNAL DEVICES BEFORE REPLACING THE FUSE. FAILURE TO DO SO MAY CAUSE SERIOUS INJURY TO THE USER SINCE HIGH VOLTAGES EXIST WITHIN THE UNIT.

5.1 Materials Needed

- **MDT693A/MDT694A Operating Manual** – The most recent version of this operating manual will be available on Thorlabs web site.
- **400mA Type IEC60127-2/III** – (5x20mm, 250V, Slow Blow Type 'T') The 400mA fuse is required for 230V operation of the MDT693A. Thorlabs supplies a 400mA fuse with all of its MDT693A units and must be installed when operating at 230VAC.
- **630mA Type IEC60127-2/III** – (5x20mm, 250V, Slow Blow Type 'T') The 630mA fuse is installed in MDT693A's from the factory. This must be installed when operating the unit at 100 / 115VAC.
- **250mA Type IEC60127-2/III** – (5x20mm, 250V, Slow Blow Type 'T') The 250mA fuse is required for 230V operation of the MDT694A. Thorlabs supplies a 250mA fuse with all of its MDT694A units and must be installed when operating at 230VAC.
- **500mA Type IEC60127-2/III** – (5x20mm, 250V, Slow Blow Type 'T') The 500mA fuse is installed in MDT694A's from the factory. This must be installed when operating the unit at 100 / 115VAC.
- **Flat Head Screwdriver** – This is required to open the fuse holder.

5.2 Fuse Replacement and Line Voltage Selection

1. **Important** – Disconnect all piezos from outputs and disconnect any input signals present.
2. **Important** – Disconnect the power cord. **Do not open the unit if the power cord is connected**. **See warning above.**
3. Locate the fuse holder below the power input connector. Slide the fuse tray out using a flat head screwdriver. Remove the fuse and replace with the appropriate value as described below:

   MDT693A
   - 400mA Type IEC60127-2/III (5x20mm, 250V, Slow Blow Type 'T') for 230VAC operation
   - 630mA Type IEC60127-2/III (5x20mm, 250V, Slow Blow Type 'T')for 100/115VAC operation

   MDT694A
   - 250mA Type IEC60127-2/III (5x20mm, 250V, Slow Blow Type 'T')for 230VAC operation
   - 500mA Type IEC60127-2/III (5x20mm, 250V, Slow Blow Type 'T')for 100/115VAC operation
4. To change the line voltage, locate the line select on the rear panel. Select the appropriate line voltage by adjusting the switch to either 110 or 220. Select 110 if operating at 100VAC to 120VAC. Select 220 for operation from 220VAC to 240VAC.

Section 6: Getting Started Quickly

This section is provided for those interested in getting the MDT693A or MDT694A up and running quickly as a basic piezo controller. The more advanced features are described in detail in the following sections.

6.1 Setup

1. Carefully unpack the controller and accessories. See section 4 for a complete list of parts. If any of the items appear damaged or missing, do not use the controller. Call Thorlabs, or email RMA@thorlabs.com and arrange for a replacement.
2. If necessary change the input line voltage and replace the fuse. The MDT693A/MDT694A can be operated from 100/115VAC or 230VAC. A voltage selector switch is located on the rear panel of the controller. If you are not sure what operating voltage your unit is set to, proceed immediately to Section 5.0 for instructions on setting the operating voltage.
3. Attach the AC line cord to the MDT693A/MDT694A power input connector located on the back of the unit. Plug the unit into an AC outlet.
4. Verify that the unit is turned off.
5. Select the appropriate output voltage limit on the rear panel. The user can chose between a 75V (7.5V/V), a 100V (10 V/V), or 150V (15 V/V) limits. This switch should only be adjusted while the unit is off. **The internal microprocessor will only check the status of this switch on startup and will set offsets and voltage scaling accordingly. Changing this setting while the unit is on will cause voltage-scaling problems when using the serial communication and may damage any piezo connected to the outputs.**
6. Connect the piezo device to the controller output(s). Do not connect piezo devices to the unit while the unit is on. This can cause damage to the piezo device.
7. Turn the controller on.
8. Use the 'INT' control knobs to adjust the piezo output voltage. For more advanced controls such as the external input, master scan controls, or serial operation see the operating instructions.

Section 7: Description

7.1 MDT693A Front Panel Features

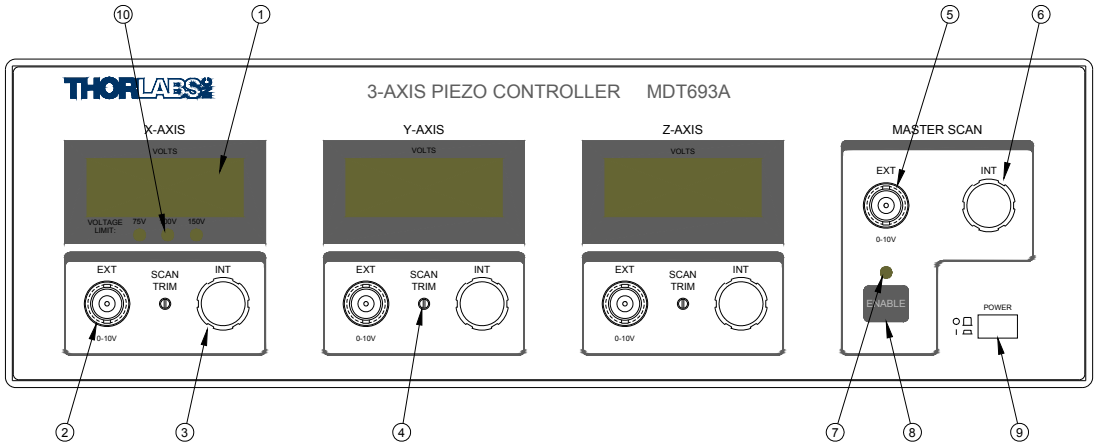

Figure 1 – MDT693A Front Panel

Feature:	Description
1	**3 ½ Digit LED Display** – A 3 ½ 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 7.5, 10, or 15 V/V depending on the 'Output Voltage Limit' setting. There is one input for each channel.
3	**INT Knob** – This knob will adjust the output voltage from 0 to 75, 100, or 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	**EXT 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 MDT693A 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 MDT693A on.
10	**Voltage Limit Indicator** – These LED will indicate voltage limit setting. The Limit setting can be adjusted through the rear panel switch marked "OUTPUT LIMIT".

7.2 MDT693A Rear Panel Features

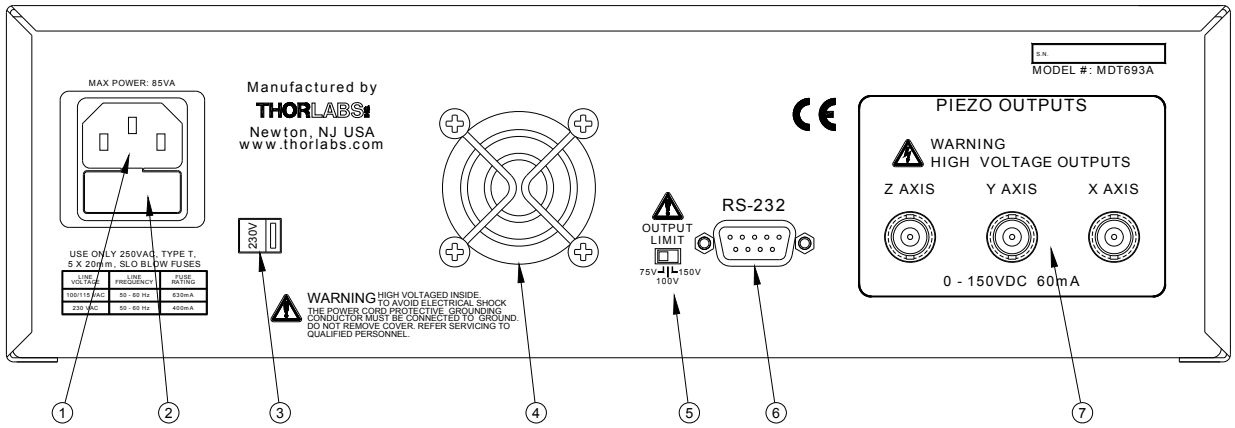

Figure 2 – MDT693A Rear Panel

Feature: **Description**:

1 **AC input receptacle** – This input requires an IEC compatible plug with a properly connected ground terminal. Thorlabs supplied a cord for operation in the United States.

2 **Fuse Holder** – The system fuse is installed here. See section 5 for more details.

3 **Line Voltage Selector Switch** – This switch adjusts the line voltage operation. The factory default is 115 and must be adjusted to operate where the line voltage is 220 – 240VAC.

4 **Cooling fan** – Do not block when the unit is operating.

5 **Output Limit Switch** – Use this to select the output voltage limit and adjust the EXT input gain value. The output voltage limit can be set to 75, 100, or 150V (7.5, 10, 15 V/V gain). **Do not adjust when the unit is powered on**.

6 **RS232 Connector** – Use this to communicate to a PC through serial control. Use a standard DB9 male to DB9 female (Included) cable for connection.

7 **High Voltage Outputs** – These BNC's are used for the piezo connections. Caution: These are high voltage outputs which could cause a shock if accessing without a piezo installed. The outputs on these connectors are the sum of the adjustment knob, the external voltage control and the serial control.

7.3 MDT694A Front Panel Features

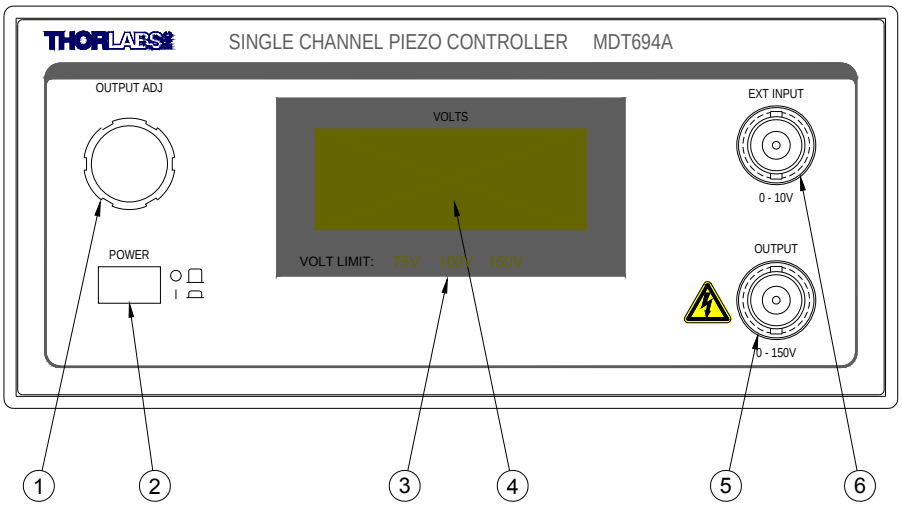

Figure 3 – MDT694A Front Panel

Feature:Description:

1 **INT Knob** – This knob will adjust the output voltage from 0 to 75, 100, or 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.

2 **POWER Button** – Press in to turn the MDT694A on.

3 **Voltage Limit Indicator** – These LED's will indicate the voltage limit setting. The Limit setting can be adjusted through the rear panel switch marked "OUTPUT LIMIT".

4 **3 ½ Digit LED Display** – A 3 ½ digit display is used to view the output voltage.

5 **High Voltage Output** – This BNC is used for the piezo connection. Caution: This is a high voltage output which could cause a shock if accessing without a piezo installed. The output on this connector is the sum of the adjustment knob, the external voltage control and the serial control.

6 **EXT INPUT BNC** - This input is used to externally control the output. The input voltage range is 0 to 10V with a gain of 7.5, 10, or 15 V/V depending on the 'Output Voltage Limit' setting.

7.4 MDT694A Rear Panel Features

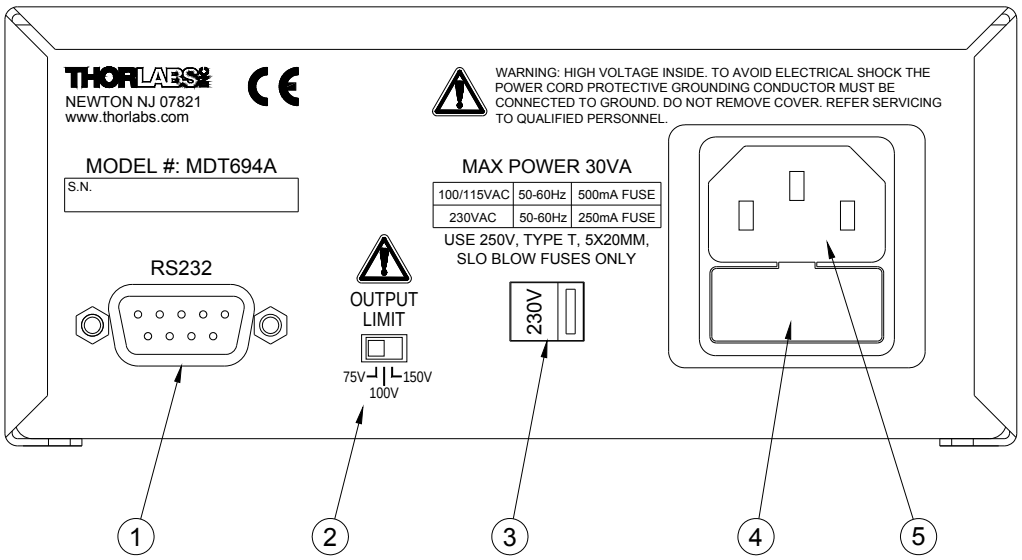

Figure 4 – MDT694A Rear Panel

Feature: **Description:**

1 **RS232 Connector** – Use this to communicate to a PC through serial control. Use a standard DB9 male to DB9 female (Included) cable for connection.

2 **Output Limit Switch** – Use this to select the output voltage limit and adjust the EXT input gain value. The output voltage limit can be set to 75, 100, or 150V (7.5, 10, 15 V/V gain). Do not adjust when the unit is powered on.

3 **Line Voltage Selector Switch** – This switch adjusts the line voltage operation. The factory default is 115 and must be adjusted to operate where the line voltage is 220 – 240VAC.

4 **Fuse Holder** – The system fuse is installed here. See section 5 for more details.

5 **AC input receptacle** – This input requires an IEC compatible plug with a properly connected ground terminal. Thorlabs supplied a cord for operation in the United States.

Section 8: Operating Instructions

WARNING: THE MDT693A AND MDT694A CAN PRODUCE HAZARDOUS VOLTAGES AND CURRENT. USE CAUTION WHEN OPERATING THIS UNIT.

8.1 Setting the Output Voltage Limit

Both the MDT693A and the MDT694A include a voltage-limiting switch on the rear panel that can be used to limit the output voltage range for lower drive voltage piezos. Thorlabs ships the controllers to operate with the 75V limit as a default. The user can easily adjust this value as described below:

1. Determine the maximum allowable voltage for your piezo element. We recommend the following settings:
   - Use the 150V Limit Setting when $V_{PIEZO} \geq 150V$.
   - Use the 100V Limit Setting when $150V \geq V_{PIEZO} \geq 100V$.
   - Use the 75V Limit Setting when $100V \geq V_{PIEZO} \geq 75V$.

   Where V_{PIEZO} is the piezo element maximum voltage
2. Power off the MDT693A, or MDT694A. **Do not adjust the voltage limit switch when the unit is powered on.**
3. Locate the Voltage Limit switch on the rear panel of the MDT693A/MDT694A.
4. Adjust the switch to the desired limit setting as determined above.
5. Turn the Controller On. The onboard micro controller will automatically configure the controller to the appropriate settings. The gain of the EXT input BNC's will vary depending on the gain setting. For the 150V setting the gain is 15V/V, for the 100V setting the gain is 10V/V, and for the 75V setting the gain will be 7.5V/V.

8.2 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 MDT693A rear panel or to the front panel output connector of the MDT694A.

   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.

8.3 Using the EXT INPUT BNC

The EXT inputs on both the MDT693A and MDT694A are designed to allow the user to modulate the channel output or to be used as a feedback for positioning systems. Examples of connections for this input include D/A systems, strain gages with support electronics, and function generators. This control is summed with the INT control knob and the serial port control. To use this feature, follow the steps below.

1. Attach a piezo to each of the high voltage output BNC connectors, located on the rear panel of the MDT693A or to the front panel output connector of the MDT694A.

   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 the EXT INPUT BNC's. The output for each channel will follow the EXT Input voltage with a gain of 7.5, 10, or 15V/V.

   Note: do not place a negative voltage on the EXT input BNC. The MDT693A/MDT694A includes reverse protection diodes on the EXT inputs. These are designed to prevent the piezo output from going negative. Inputting negative voltages for long periods of time will damage these diodes and effect the operation of the unit.

5. For sinusoidal and ramp 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 Appendix A for details). The MDT693A and MDT694A have an output current limiting circuit to prevent damage to the unit, however the output sinusoid will be distorted.

8.4 Using the MASTER SCAN controls (MDT693A Only)

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 MAX312 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.

8.4.1 Enable Button

The ENABLE button located on the front panel (see Section 7.1 – MDT693A Front Panel Features) is used to enable and disable the master scan mode.

8.4.2 Enable LED

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

8.4.3 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 75, 100 or 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).

8.4.4 MASTER SCAN EXT

The MASTER SCAN INT knob will allow the user to adjust all three channels over the full operating range of 0 to 75, 100, or 150V. The MASTER SCAN INT knob will only be active in the MASTER SCAN mode (i.e. the enable LED must be lit).

8.4.5 MASTER SCAN EXT

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 four turns CCW (zero the pot). Adjust the pot CW two 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 4 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 (assuming the voltage limit is 150V).

Section 9: Serial Port

9.1 Overview

The MDT693A and MDT694A serial control is designed specifically to interface the controller directly to computer terminals. The user can operate the piezo driver remotely, or easily incorporate Thorlabs drivers into automated control systems. The output voltage of the piezo driver is directly controlled through software, eliminating the need for external control voltages such as lab power supplies, frequency generators, or analog output cards. Simple functions such as sine waves, voltage ramps, and pulses are possible through PC control.

The MDT693A/MDT694A communicates via a standard RS-232 serial port using most of the common baud rate settings up to 115200Kbs. The baud rate is selectable using an accessible dipswitch, with a factory default baud rate setting of 115200Kbs. The user may communicate directly with the controller using the provided commands and a serial emulator program such as HyperTerminal, through National Instruments LabView, or using the self-executable program provided.

Each piezo output channel is controlled through a 16-bit D/A converter, while an onboard microprocessor interfaces to a 16-bit A/D converter to monitor the output voltage. Each unit is factory calibrated to eliminate all system offsets and provide a linear voltage range of 0 to 75, 100, or 150V.

All user functions for the MDT693A and MDT694A are available within the provided software. The PC software is directly compatible to the National Instruments LabView environment, as well as standard RS-232 port emulation programs. All software upgrades can be downloaded from the Thorlabs website or requested through the Thorlabs technical support department.

9.1.1 Self Executable Software Overview

The self-executable software is a standalone program designed to provide access to all piezo driver hardware controls. In addition, a software signal generator is included to provide basic modulation control. Simple functions such as sine waves, ramps and pulses can be configured to control the piezo output.

9.1.2 Software Manual

The software manual is available in a *.pdf format. Also see section 10.

9.3 Baud Rate and Device Settings

9.3.1 COM Port Protocol

- Baud Rate: Table 1 (115200 default)
- Data Bits: 8
- Parity: none
- Stop Bits: 1
- Flow Control: none

9.3.2 Setting the Baud Rate

The MDT693A and MDT694A allow the user to choose a baud rate to better accommodate their system. The default baud rate is set to 115200Kbs and can be adjusted using the 4-position dipswitch, located inside the controller. Positions 1 to 3 are dedicated to setting the baud rate. Position 4 is no longer used for the MDT693A or MDT694A and may be ignored. See the figure and table below to adjust the proper settings. Follow the directions below for accessing the dip switch.

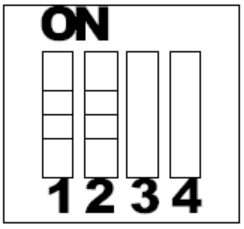

Figure 5 – Dip switch

Baud Rate Setting	D1	D2	D3	D4
9600Kbs	OFF	OFF	OFF	na
14400Kbs	OFF	OFF	ON	na
19200Kbs	OFF	ON	OFF	na
28800Kbs	OFF	ON	ON	na
34800Kbs	ON	OFF	OFF	na
57600Kbs	ON	OFF	ON	na
76800Kbs	ON	ON	OFF	na
115200Kbs	**ON**	**ON**	**ON**	na
Device Selection				
MDT693	na	na	na	**ON**
MDT694	na	na	na	OFF

Table 1 – Dip Switch Settings

1. Turn the unit off and unplug. Caution: High voltages are present inside when the unit is plugged in. DO NOT open the cover when the unit is plugged in.
2. Allow the unit to sit for about 5 minutes to ensure all voltage supplies and high voltage circuitry has a chance to discharge.
3. Remove the two screws holding the cover on. They can be found in the bottom rear of the unit. Slide the cover off.
4. Locate the dipswitch on the main board.
    - MDT693A – Located at the front center of the unit below the two 2x5 headers.
    - MDT694A – Located at the front center between the power switch and the display connection.
5. Set the appropriate settings using Table 1 for reference.
6. Replace the cover and reinstall the two screws.
7. Turn the unit on.

9.4 Serial Command Summary

Command:	AV
Input Parameters:	<voltage>
Description:	Sets all outputs to the set voltage. This command can be compared to the Master Scan function on the front panel.
Command:	XV
Input Parameters:	<voltage>
Description:	Sets the output voltage for the x axis of the MDT693A or to set the single output of the MDT694A to the desired voltage.
Command:	YV
Input Parameters:	<voltage>
Description:	Sets the output voltage for the y axis of the MDT693A to the desired voltage. This function has no affect when using with the MDT694A.
Command:	ZV
Input Parameters:	<voltage>
Description:	Sets the output voltage for the z axis of the MDT693A to the desired voltage. This function has no affect when using with the MDT694A.
Command:	XR?
Input Parameters:	?
Description:	Reads and returns the x axis output voltage for the MDT693A or the single output of the MDT694A.
Command:	YR?
Input Parameters:	?
Description:	Reads and returns the y axis output voltage for the MDT693A. This function has no affect when using with the MDT694A.
Command:	ZR?
Input Parameters:	?
Description:	Reads and returns the z axis output voltage for the MDT693A. This function has no affect when using with the MDT694A.
Command:	XL
Input Parameters:	<voltage> or ?
Description:	This function sets the minimum output voltage limit for the x axis of the MDT693A or the single output of the MDT694A. Sending the '?' parameter will return the current setting.
Command:	YL
Input Parameters:	<voltage> or ?
Description:	This function sets the minimum output voltage limit for the y axis of the MDT693A. Sending the '?' parameter will return the current setting. This function has no affect when using with the MDT694A.
Command:	ZL
Input Parameters:	<voltage> or ?
Description:	This function sets the minimum output voltage limit for the z axis of the MDT693A. Sending the '?' parameter will return the current setting. This function has no affect when using with the MDT694A.
Command:	XH
Input Parameters:	<voltage> or ?
Description:	This function sets the maximum output voltage limit for the x axis of the MDT693A or the single output of the MDT694A. Sending the '?' parameter will return the current setting.

Command: YH

Input Parameters: <voltage> or ?

Description: This function sets the maximum output voltage limit for the y axis of the MDT693A. Sending the '?' parameter will return the current setting. This function has no affect when using with the MDT694A.

Command: ZH

Input Parameters: <voltage> or ?

Description: This function sets the maximum output voltage limit for the z axis of the MDT693A. Sending the '?' parameter will return the current setting. This function has no affect when using with the MDT694A.

Command: I

Input Parameters: none

Description: This command will return the product header, firmware version, etc.

Command: E

Input Parameters: none

Description: When the echo mode is on the command parameters will be returned, or echoed back, to the communication program.

Command: %

Input Parameters: none

Description: Returns the output voltage limit setting.
(75V returns 0, 100V returns 1, and 150V returns 2)

Section 10: Software Operation

10.1 Software Installation

All software required to operate the MDT693A and MDT694A can be found on the provided CD-ROM disk. Software updates may be available in the future and may be downloaded from the Thorlabs website at http://www.thorlabs.com. To install the software follow the procedure listed below.

10.1.1 Software Requirements

- Microsoft Windows 95/98/NT/2000/XP (Windows NT and 2000 will need administrator rights to install software)
- PC with a Pentium/AMD class processor (Pentium II recommended)
- 32MB or more RAM recommended
- 6 MB hard disk space
- CD-ROM drive
- Mouse or compatible pointing device
- 800 x 600 minimum display resolutions
- 256-color minimum

10.1.2 Software Installation Instructions

1. Place the provided software disk into the CD-ROM drive. The install program should auto start.
2. Start the Setup.exe file located on the CD-ROM disk if the auto start did not initiate.
3. Follow the on-screen prompts. The default location will be C:\Program Files\Thorlabs\. Note that the software will look for installed files in the directory provided. If any are found the program will uninstall the existing software (see section 10.1.3 for details). Run setup.exe again to reinstall.

   Note: The Software will ask if you want to reboot. Select Yes.
4. Make sure that the MDT693A, or MDT694A, is connected to the correct computer COM port. Turn on the MDT693A or MDT694A.
5. Start the software by pressing **"Start > Program Files > Thorlabs > MDT695".**
6. Refer to Section 10 for software operation.

10.1.3 Software Uninstall Instructions

1. Place the provided software disk into the CD-ROM drive. The install program should auto start.
2. Start the Setup.exe file located on the CD-ROM disk if the auto start did not initiate.
3. The setup program will prompt the user for the install directory. Enter the directory of the existing software if different from the default.
4. The program will automatically uninstall any existing MDT695 software.
5. To reinstall the software see section 10.1.2.

10.2 Running the Software for the First Time

To start the Thorlabs Piezo Controller Software, click on **Start > Program Files > Thorlabs > MDT695**. The software will automatically determine the device type, MDT693A or MDT694A, and will try to connect to the piezo driver. The unit must be turned on prior to starting the program.

During the first time startup, the software will auto-detect the COM port and baud rate, starting with the system default values (i.e. baud = 115200KBs, port = COM1). If the device was not detected a communication error message will appear.

See the troubleshooting section for details on how to correct this problem. The port and baud rate settings will be remembered by the program and will be used during startup.

10.3 Overhead Menu Options

10.3.1 Exiting the Software

To exit the software, click **File > Exit** in the top menu structure.

10.3.2 Closing a Window

To close a window, click **File > Close** in the top menu. This will always display the compact view.

10.3.3 Setting the Default Startup Window

The user can change the default startup window by clicking **View > Start Window > {option}**. The ✓ will indicate the default startup device selected. The next time the user runs the piezo control software the default startup window will open.

10.3.4 Manually Adjusting the Communication Settings

It is possible to manually select the COM port and baud rate settings. To open the communications window click **Tools > COM Setup**. The window, seen below will appear. Select the "Manual Select" button and change the baud rate and COM port to the appropriate settings. Click the "Set Values" Button to remember settings. "OK will close the window. For further details on the communication protocol or hardware setup see "Appendix B – Baud Rate and Device Settings".

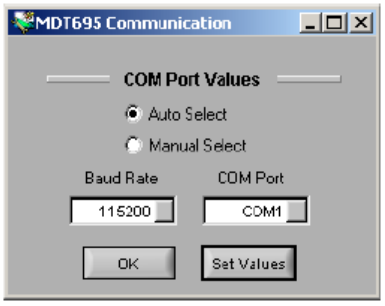

Figure 6 – COM Port Settings

10.3.5 Voltage Limit Settings

Voltage limits may be set to limit the output voltage driving the piezo device. These voltage limits may be used for two purposes. They can provide a voltage limit that will prevent accidentally overdriving lower voltage piezos (Piezos with maximum voltages less than 150V). They may also be used to set the mechanical travel limits.

It should be noted that these limits do not limit the MDT693A/MDT694A directly. The limits prevent devices from being overdriven by the software. They will not limit the adjustment knobs located on the front panel of the MDT693A or MDT694A. The MDT693A and MDT694A will add the manual control knobs, the external input, and the soft ware-generated signals. For example, a 75V limit is set through software. The software and control card will not output a voltage greater than 75V. However, the user may still adjust the manual adjustment knob, or add a signal to the Ext Input BNC that will cause the output voltage to exceed 75V.

To access the voltage limit window click **Tools > System Setup** in the top menu. See Figure 7 for details. Limits for each channel can be changed by clicking on the appropriate box and entering the voltage, or by using the up/down arrows. A global limit box is available to provide one limit for all channels. To use this option, check the enable box and fill in the limit values. Note that the X, Y, and Z limit adjustments will be made unavailable. Press "OK" to accept new values, “Cancel” to close panel, or "Restore Defaults" to reset all values to the max limit settings (min = 0V, max = 150V).

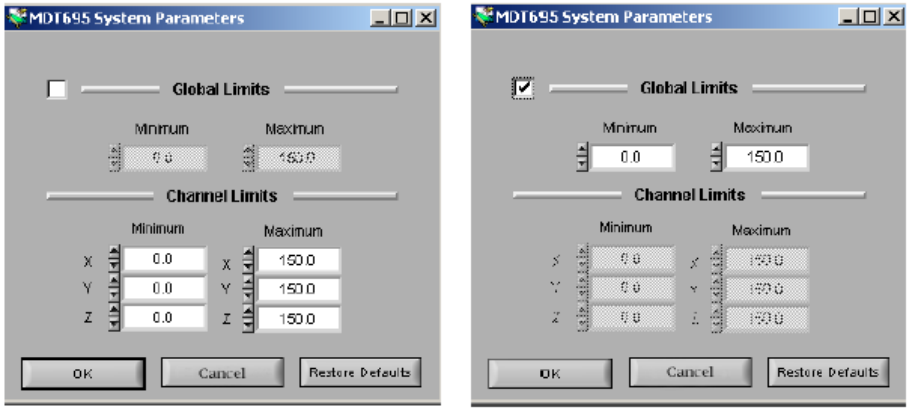

Figure 7 – Voltage Limit Window

10.3.6 Help > About Windows

The **Help > About MDT695** screen will provide the customer with all of the pertinent information about the system such as the controller (MDT693A / MDT694A), software version, and firmware version. The **Help > About Thorlabs** window will provide the customer with all of the pertinent Thorlabs contact information.

10.4 The Compact Window

As soon as the Piezo Controller Software connects to the MDT693A/MDT694A the Compact window will appear (see figure 8). The software will automatically determine the host device, MDT693A or MDT694A, through the serial connection.

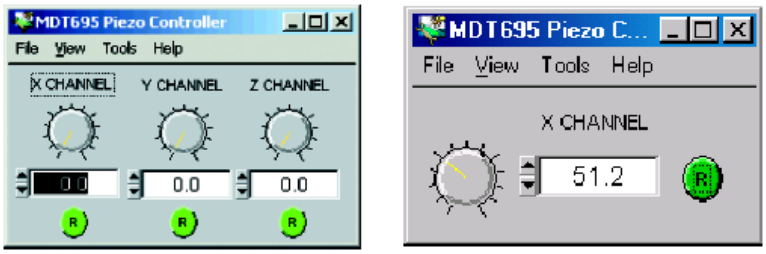

Figure 8 – Compact Window

The compact windows shown provide the simplest operation of the piezo controller. Thorlabs recognizes the need for a small interface window. In most cases the piezo controller software will be used while operating other software. To minimize interference the compact window should be used.

10.4.1 Changing the Voltage

The output voltage for each channel can easily be adjusted in three ways:

1. The mouse cursor may be used to adjust the knob available for each channel.
2. The ▲ and ▼ arrows may be used to increase or decrease the output voltage with a 0.1V resolution.
3. The voltage may be directly changed by clicking on the text box and typing in the desired voltage. The text box will accept values to three decimal places. The output will be set to the nearest 16-bit value.

   Note that the display box will round this number, however this will not affect the voltage setting.

10.4.2 Reset Buttons

The reset buttons, marked "R", allows the user to quickly set the output voltages to the minimum voltage limit, typically 0 volts (see the "Voltage Limit Settings" section for details). This button is available on most panels.

10.5 The Main Panel Window

For more complete control of the piezo driver output the main window should be used. From this window all voltages can be adjusted as described above, however the function generator mode and master scan mode (not available when operating the MDT694A) will now be available. To open the main window click **View > Main Panel** in the top menu. To revert back to the compact view, simply click **View > Compact Panel** in the top menu. The main window can be seen in Figure 9.

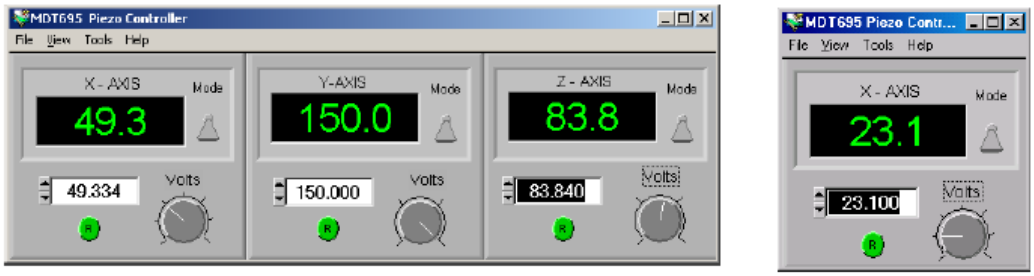

Figure 9 – Main View Window

10.5.1 Display Mode Switch

The displays are capable of operating in two modes while using the full screen window. The default mode (shown in figure 9) will display the DC output voltage. The voltage controls below will change the voltage and maintain the setting until the next adjustment.

Toggling the "Mode" switch, located next to each display, will change the display to the graph mode. The display will change from a numerical to graphical format. In order to adjust the graphical settings, open the "Function Generator" window by clicking **View > Function Generator** located in the top menu.

10.6 The Master Scan Window

The master scan option operates exactly the same as the MDT693A master scan mode. The voltage control adjusts the output voltage of all channels simultaneously with the same voltage. To enable this option click **View > Master Scan** in the top menu. Note that this option is only available with the multi-channel MDT693A. The window shown in Figure 10 will appear. Toggle the "Master Scan" switch to enable this feature.

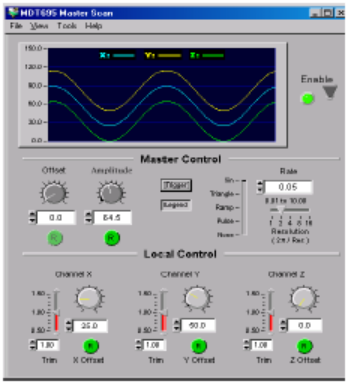

Figure 10 – Master Scan Window

10.6.1 Master Controls

Offset Voltage - An offset voltage can be added to all channels by adjusting this control. Simply adjust the knob, located to the left of the "Master Control" section. The offset voltage range can be adjusted in the system settings window (see Voltage Limit Settings" section for details).

Amplitude Control -The amplitude control adjusts the peak-to-peak voltage level of an input function. Simply adjust the knob to change the amplitude from 0V to the voltage limit. Note that this voltage is added to the offset voltage. If the signal plus the offset exceed the voltage limit (typically 150V) the signal will be clipped at the limit.

Function Bar - This slide bar allows the user to select a function, such as Sine, Triangle, Ramp, or Pulse wave forms, to be output to the piezo device.

Trigger Button - The trigger button clears the graph window and resets all functions to start from their 0 position.

Legend Button - This button will display the graph legend on the graph, providing the user an easy way to distinguish between displayed channels.

Rate Control - The rate control adjusts the speed of the sampling rate. This is based on an internal timer and may vary from computer to computer. These numbers are not based on a fixed sample time, such as ms.

Resolution Control – The resolution adjusts the number of samples per waveform. The max number is 180 samples per waveform (2p). The resolution bar displays the factor that 180 is divided by.

Example Resolution is equal to 4. The number of samples per function period equals 180/4 or 45.

10.6.2 Local Controls

Trim Gain - The Scan Trim Gain allows the user to compensate for differences in displacement (i.e. volt to displacement slope) between piezo elements by scaling the master control signal per channel. To adjust the gain simply adjust the slide bar or enter the correct gain into the box. Any voltage or graph signals will be amplified or scaled by this value.

Offset Control - The offset controls for each channel allow the user to set an offset voltage independent of the other channels. This offset is added to the master offset and the function.

10.7 The Function Generator Window

The function generator window operates with the main panel. It allows the user to apply simple modulation functions to the output. To operate with higher frequency or waveforms it is recommended that the EXT input BNC's are used. To access this window click **View > Function Generator**. The functions will not be applied to the output until the correct display mode is selected in the main window.

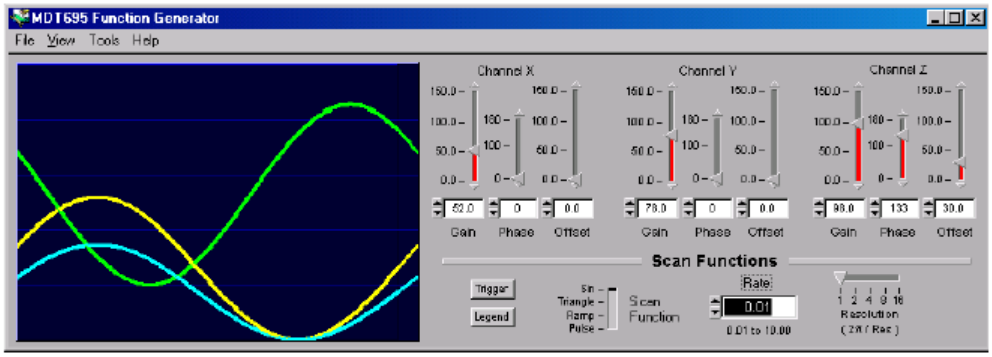

Figure 11 – Function Generator Window

Gain Control - The gain control adjusts the peak-to-peak voltage level of the function. Simply adjust the slide bar or input the voltage in the text box to change the amplitude from 0V to the voltage limit. Note that this voltage is added to the channel offset voltage. If the signal plus the offset exceed the voltage limit (typically 150V) the signal will be clipped at the limit. The voltage limits can be adjusted in the system setup window.

Offset Control - The offset controls for each channel allow the user to set an offset voltage independent of the other channels. This offset is added to function and is limited by the voltage limit settings.

Phase Control - The phase control bars allow the user to change the phase between channels. To adjust simply move the slide bar or add the appropriate phase correction to the text box.

Trigger Button - The trigger button clears the graph window and resets all functions to start from their 0 position.

Legend Button - This button will display the graph legend on the graph, providing the user an easy way to distinguish between displayed channels.

Function Bar - This slide bar allows the user to select a function, such as Sine, Triangle, Ramp, or Pulse waveforms, to be output to the piezo device.

Rate Control - The rate control adjusts the speed of the sampling rate. This is based on an internal timer and may vary from computer to computer. These numbers are not based on a fixed sample time, such as ms.

Resolution Control -The resolution adjusts the number of samples per waveform. The max number is 180 samples per waveform (2π). The resolution bar displays the factor that 180 is divided by. Example: Resolution is equal to 4. The number of samples per function period equals 180/4 or 45.

10.8 Serial Port Error Messages

10.8.1 *"System Setting Error"*

These messages may appear while operating in the System Parameters window (Tools > System Setup). They indicate that an out of range voltage was selected for a limit setting. The full range is 0V to 150V. Any voltages less than 0V, or greater than 150V, will cause these errors to occur. Check the limit values and correct where necessary.

10.8.2 *"MDT695 File Error"*

This error message indicates that one of the system .ini files was not found or that the system could not save settings to an .ini file. An .ini file may not be found if it was deleted, moved or corrupted. The program will create a new file and will use the default settings. Remember that your settings should be updated before using the driver. Example: the default voltage limits may be reset. If the device connected requires voltages to be less than the default, there will be no piezo protection. Note that some operating systems may not allow the user to save or update system settings files without administrator rights (Windows NT/2000). If this message occurs ("MDT695 File Error", "I/O File error, could not save new system settings, using defaults...") contact your system administrator.

10.8.3 *"Communication Error"*

Communication errors occur when the software cannot communicate with the MDT695.To correct this problem verify that the device is host driver (MDT693 or MDT694) is plugged in and the power is on. Verify that the serial cable is securely connected to the computer COM port. The cable provided with the MDT695 must be used. A standard serial cable will not work. If a replacement is required, contact Thorlabs. Also note that this error will also occur if the baud rate and com ports are manually set to the wrong values. Either correct the settings or select auto-detect so that the software detects the correct settings.

10.8.4 *"RS232 Communication"*

This is a Windows generated error, which may occur if the COM ports are being used by another device. To correct this, verify the communication settings and hardware connections. If everything appears OK, reboot the computer.

Section 11: Maintenance and Troubleshooting

11.1 Cleaning

The MDT693A/MDT694A should only be cleaned with a soft cloth and mild soap detergent or isopropyl alcohol. Do not use a solvent-based cleaner. Do not use any cleaners on the LED display windows since the finish may be marred.

11.2 Maintenance and Troubleshooting

The MDT693A and MDT694A have no user serviceable parts. Do not open the unit. High voltages exist inside. If problems occur contact a Thorlabs representative to arrange for a repair, for replacement, or for general operation questions.

Appendix A: Bandwidth Performance

The MDT693A is a precision, low-noise, low-drift voltage amplifier designed specifically to drive piezo actuators. There are two limitations on the system that need to be considered. Since piezo crystals can be modeled essentially as capacitors, it is easy to predict their dynamic performance using a basic set of equations as described below.

A.1 Low Pass Filter

Since the piezo can be modeled most accurately as a capacitor, the piezo will create a low pass filter with the output impedance of the driver. For both the MDT693A and MDT694A, the output impedance is specified as 150Ω, 0.047µF.

$$BW = 1/ (2*\pi*R_{OUT}*C)$$
$$\text{Where: } C = C_{OUT} + C_{PIEZO}$$

For example, we are connecting a piezo with a 1.6µF capacitance to our MDT693A. Using the output impedances given in the spec section:

$$BW = 1 / (2 * \pi * 150\Omega * (0.047\mu F + 1.6\mu F))$$
$$BW = 644Hz$$

A.2 Output Current Limit

The output current limit also needs to be considered when determining system performance. Since the piezo is electrically equivalent to a capacitor (C_{PIEZO}), the charge rate ($\partial V/\partial t$) needs to be considered. The max current for the MDT693A and MDT694A is 60mA (I_{OUT})

$$I_{OUT} = C_{PIEZO} * \partial V/\partial t$$

The output current requirements are a factor of how quickly the piezo needs to be charged, not the voltage applied to it. Below are some common waveforms and their calculations.

A.2.1 Linear Ramp Signal

$$I_{OUT} = C * \Delta V/\Delta t$$
$$\Delta t = (C * \Delta V) / I_{OUT}$$
$$\text{Where } C = C_{OUT} + C_{PIEZO}$$

A.2.2 Triangle Wave

$$I_{OUT} = 2 * C * \Delta V/\Delta t$$
$$f = I_{OUT} / (2 * C * \Delta V)$$
$$\text{Where } C = C_{OUT} + C_{PIEZO}$$

A.2.3 Sinusoid Wave

$$\text{Where } V = V_{AMP} * SIN (\omega t)$$
$$\text{And } C = C_{OUT} + C_{PIEZO}$$
$$\text{And } \omega = 2\pi f$$

$$I_{OUT} = C * \omega * V_{AMP} * COS (\omega t)$$
$$I_{OUT} \text{ (peak)} = 2\pi f * V_{AMP} * C$$
$$f = I_{OUT} / (2 * \pi * V_{AMP} * C)$$

Section 12: Contacts

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