Piezo · Nano · Positioning

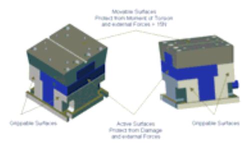
PZ 99E User Manual

E-664 LVPZT Position Servo Controller

Release: 1.0.4 Date: 2003-10-15

This document describes the following product(s):

- **E-664.S3**
  LVPZT Servo Controller



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Release: 1.0.4
File:E-664_User_PZ99E104.doc, 260608 Bytes

0. Manufacturer Declarations

0.1. Declaration of Conformity

The manufacturer,

Physik Instrumente (PI) GmbH & Co. KG
Auf der Roemerstrase 1
D-76228 Karlsruhe, Germany

declares, that the product E-664 LVPZT Servo Controller complies with these specifications:

EMC: EN55022 (1991), Group1, Class B

EN50082-1 (1992) / IEC 801-2:1991 (4 kV Contact Discharge)
(8 kV Air Discharge)

EN50082-1 (1992) / IEC 801-3: 1984 (3V/m)

EN50082-1 (1992) / IEC 801-4: 1988 (1 kV power lines, 0.5 kV Signal lines)

Safety: IEC 1010-1:1990+A1 / EN61010-1:1993 (Low voltage Directive)

The product complies with the requirements of the EMC Directive 89/336/EEC and CE markings have been affixed on the devices.

0.2. Quality and Warranty Clauses

Certification
Physik Instrumente (**PI**) certifies that this product met its published specifications at the time of shipment. The device was calibrated and tested with the PZT actuators specified in the product identification table (see below).

Warranty
This Physik Instrumente product is warranted against defects in materials and workmanship for a period of one year from date of shipment. Duration and conditions of warranty for this product may be superseded when the product is integrated into (becomes a part of) other Physik Instrumente products. During the warranty period, Physik Instrumente will, at its option, either repair **or** replace products which prove to be defective.

Limitation of Warranty
The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Buyer, Buyer supplied products or interfacing, unauthorised modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

The design and implementation of any circuit on this product is the sole responsibility of the Buyer. **PI** does not warrant the Buyer's circuitry or malfunctions of **PI** products that result from the Buyer's circuitry. In addition, **PI** does not warrant any damage that occurs as a result of the Buyer's circuit or any defects that result from Buyer-supplied products.

No other warranty is expressed or implied. Physik Instrumente specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

0.3. Warnings and Safety Instructions

***Warning:* High Voltage**

Read This Before Operation:

E-664s are amplifiers generating **voltages up to 120 V** for driving LVPZTs. The output power may cause serious injury.

When working with these devices or using PZT products from other manufacturers we strongly advise you to follow general accident prevention regulations.

All work done with and on the devices described here requires adequate knowledge and training in handling High Voltages. Any cabling or connectors used with the system must meet the local safety requirements for the voltages and currents carried.

***CAUTION:* Calibration Information**

If you inform PI about your application, your E-664 will be fully calibrated before being shipped. It is usually not necessary for you to do anything more than adjust the zero point before operating the system.

Calibration should only be done after consultation with PI, otherwise internal configuration settings may be destroyed.

Procedures which involve opening the case are to be carried out by qualified authorized personnel only.

1. Introduction

This manual describes the functionality and the use of

E-664 LVPZT Amplifier / Position Servo Controller

The *E-664* is a bench-top device to operate up to three low-voltage piezoelectric translators (LVPZTs) in open-loop and closed-loop (position controlled) mode. The E-664 can be used with LVPZTs equipped with strain gauge displacement sensors. The integrated amplifier can output and sink a peak current of 120 mA and an average current of 40 mA for each channel.

The E-664 can be operated manually by front panel potentiometers or by external analog signals.

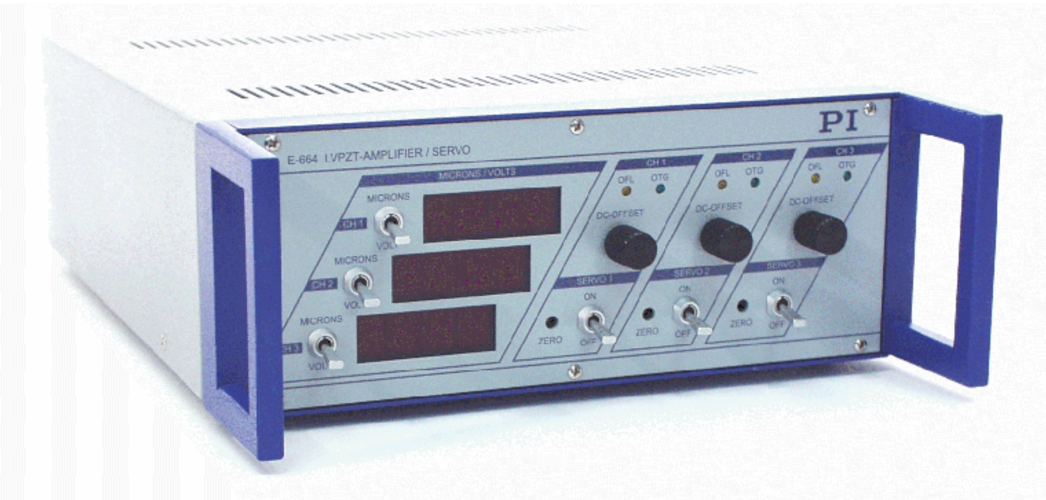


Fig. 1 E-664 LVPZT Servo Controller

2. Quick Start

The E-664 PZT Controller was calibrated with the PZT translators before shipment. During the calibration process, the expansion of the PZT is compared with an external standard scale. Individual characteristics of the amplifier and servo-controller are compensated.

2.1. Starting Operation

1. Being sure not to exceed allowable force limits (see p. 19 for details), mount the NanoCube mechanics carefully.
2. With the controller powered down, connect the NanoCube to the STAGE socket.
3. Set the servo switch to OFF and the DC-OFFSET potentiometer counter-clockwise (CCW) to the hard stop. Switch the display to VOLT.
4. Make sure the power supply is set to allow operation at the proper voltage range. Two ranges are available: from 100 to120 V and from 220 to240 VAC. The line fuses need to be replaced when the supply voltage range setting is changed (see p. 17 for details).
5. Connect the line cord and switch the power on.
6. First watch the VOLT display while turning the potentiometers clockwise. It should be possible to reach 100 V. Turn the pots back full CCW.
7. Switch display to MICRONS (µm). The values should be close to zero (±20 µm).
8. Switch SERVO to ON. Every channel should now have 0.0, the OTG (on target) LED should be on, the OFL (overflow) LED off.
9. Turn potentiometers again to maximum. It should be possible to reach 100.0 µm on every channel.
10. If any channel does not operate correctly, switch it to VOLT and see how much piezo voltage is needed. Typically for 0 to 100 µm, the piezo voltage should be -5 V to +90 V. If this is not the case, bring the voltage into this range with the associated ZERO-potentiometer (see Adjustment and Calibration, p. 10 for more details). For large temperature or load changes it is possible that ZERO needs to be corrected.

The above procedure assures that the system is working correctly in manual mode.

2.2. Troubleshooting

No Operation—Display is dark after switching on

Check supply voltage and fuse.

Display in MICRON mode shows no change

Make sure NanoCube is connected and cable is not defective.

Controller runs into overflow when SERVO ON

Bring operation voltage into -5 V to+90 V range with ZERO potentiometer.

NanoCube oscillates after switching SERVO ON

Switch immediately to SERVO OFF and check mechanical mounting and servo parameters. If load conditions have been changed, the mechanical resonant frequency may also have changed. See the E-802 User Manual for details on resetting the dynamic characteristics (P- and I-term and notch frequency) It will be necessary to open the controller case to make these adjustments.

Warning:* *High Voltage

Read This Before Operation:

E-664s are amplifiers generating **voltages up to 120 V** for driving LVPZTs. The output power may cause serious injury. Only qualified, authorized personnel should work on or with these devices.

3. Operating Modes

The operating mode is settable independently for each channel and is determined by the position of the corresponding SERVO toggle switch and the use of the DC offset potentiometer and CONTROL INPUT terminals.

3.1. Open-Loop (Servo OFF) Mode

3.1.1. Manual Operation

The output voltage can be set by a 10-turn DC Offset potentiometer in the range of approximately 0 to 100 V. For manual operation CONTROL IN should clamped at 0 V.

3.1.2. External Operation

The output voltage is controlled by an analog signal applied to the CONTROL IN BNC input ranging from -2 to +12 V. Multiplying by the gain factor of 10, an analog output voltage range of approximately -20 to +120 V results. The DC-offset potentiometer can be used to add an offset voltage of 0 to 10 V to the signal input, effectively shifting its range between -2 to +12 V and -12 V to +2 V.

3.2. Closed-Loop (Servo ON) Mode

3.2.1. Manual Operation

Displacement of the PZTs can be set by a 10-turn DC-Offset potentiometer in the range of zero to nominal displacement. For manual operation CONTROL IN should clamped at 0 V.

3.2.2. External Operation

Displacement of the PZT is controlled by an analog signal in the range of 0 to +10 V, applied to the CONTROL IN BNC input. The controller is calibrated so that 10 V corresponds to the maximum nominal displacement and 0 V corresponds to zero displacement. The DC-offset potentiometer can be used to add an offset voltage of 0 to 10 V to the signal input, effectively shifting its range between -2 to +12 V and -12 V to +2 V.

4. Block Diagram

Servo-control functions are implemented on an E-802 submodule. The respective User Manual provides detailed information.

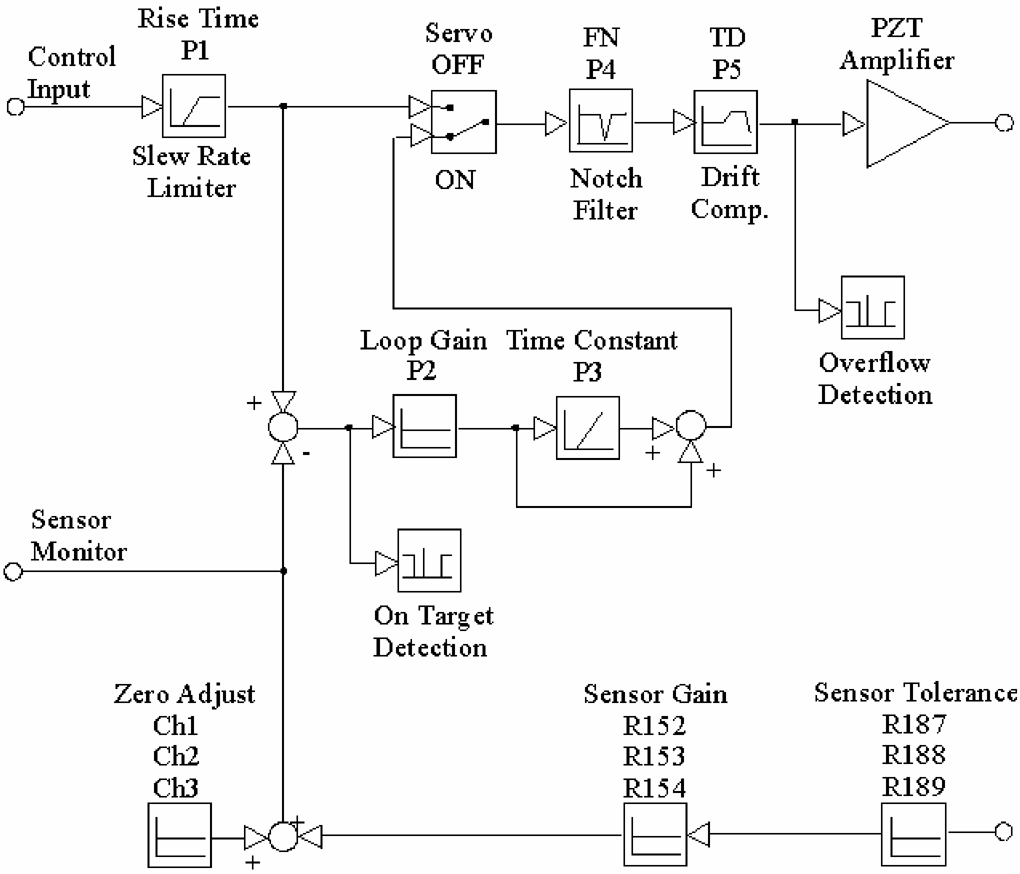


Fig. 2 E-664 block diagram

Note: The potentiometer labelling P1-P5 shown above is that used on the E-802.55-type plug-in submodules, on which these functions are implemented. Some earlier E-802 versions, while pin-compatible, use different component designations (see the E-802 User Manual for details).

Zero adjust is front-panel accessible. See the following pages for details.

5. Adjustment and Calibration Procedures

CAUTION: If you inform PI about your application, your E-664 will be fully calibrated before being shipped. It is usually not necessary for you to do anything more than adjust the zero point before operating the system.

Calibration should only be done after consultation with PI, otherwise internal configuration settings may be destroyed.

Procedures which involve opening the case are to be carried out by qualified authorized personnel only.

For most applications, only the zero point has to be realigned from time to time to compensate for temperature changes. Further adjustments are not required and not recommended as long as system components are not exchanged or modified.

Therefore calibration should only be done if the controller/actuator configuration is changed or elements are replaced.

The full calibration and adjustment procedure includes static calibration (zero point and sensor gain adjustment) and dynamic calibration (servo-loop, slew rate and step response).

5.1. Static Calibration

Proper static calibration makes it possible to accurately drive the PZT system to absolute positions with an external analog control signal running over a 10 V range and without reaching the output voltage limits of the amplifier and causing overflow conditions.

Static calibration consists of zero-point adjustment and static gain adjustment The adjustments are to some degree interdependent and should be repeated until stable settings are obtained.

Note: Zero-point adjustment is the only calibration operation regularly required in most application environments.

The following subsections describe the static calibration procedure for one channel. Note that calibration must be performed separately on each channel.

5.1.1. Zero-Point Adjustment

Proper zero-point adjustment ensures that the full output voltage swing of the amplifier can be used without reaching the output voltage limits of the amplifier and causing overflow conditions, both in open-loop and closed-loop operation.

The zero-point is adjusted with the ZERO potentiometer accessible on the front panel. This potentiometer shifts the output of the sensor processing circuitry and hence the values on the "Sensor Monitor" and servo-loop sensor-input lines

1 Before powering up the system, make sure the PZT actuator is mounted in the same way and with the same load as during normal operations in the

application. In multi-axis systems, make sure the same PZTs are always connected to the same controller channels.

2 Make sure the control input is 0 V and the DC offset potentiometer full CCW.

3 Set the switch on the front panel to Servo OFF.

4 Power up the system.

5 Turn the DC-OFFSET potentiometer full clockwise and than back full counterclockwise (0 V) to exercise the PZT.

6 Adjust the ZERO potentiometer so that the sensor-monitor signal is 0 V. The zero adjustment is now close enough to allow switching on servo-control.

7 Switch the channel to closed-loop (SERVO ON).

8 Set the display to VOLT.

9 Again using the ZERO potentiometer, adjust the PZT output voltage to approx -5 V
The zero-point setting is now close enough to allow checking of the PZT output range

10 Check the PZT output range by applying a voltage which goes from 0 V to +10 V to the CONTROL INPUT and watching the voltage at the PZT.

a) If the output voltage ranges from -10 V to +100V, then zero-point adjustment is finished.

b) If the output voltage exceeds the range from -10 V to +100 V, the zero point should be shifted so that the PZT-output voltage range is in the center of the amplifier output range. For this purpose, return the control input to 0 V and repeat step 9 using a slightly different value, e.g. -10 V for an LVPZT.

Example: Assume the LVPZT used requires 90 V to achieve the nominal displacement of 100 µm. Furthermore take into account that the maximum voltage at the LVPZT should not exceed +100 V in order to maintain a long lifetime. The E-664 amplifiers have an output range from -20 V to +120 V. In this case, the *zero position* PZT voltage can be set within the range from -10 V to +10 V. Then, the nominal displacement of 100 µm will be reached with PZT-out in the +80 V to 100 V range., i.e. there is a cushion of ±10 V available to keep the amplifier from clipping the output when the controller is within the nominal servo-control range.

5.1.2. Static Gain Adjustment

It should only be necessary to readjust the static gain if system components have been exchanged or altered.

The objective of static gain adjustment is to ensure that the PZT actuator expands to its nominal expansion when a control signal input of 10 V is applied (DC-offset set to 0).

The zero-point must be appropriately set before the static gain adjustment can be done. This is an iterative process.

The static gain adjustment procedure is as follows:

1 Before powering up the system, make sure the PZT actuator is mounted in the same way and with the same load as during normal operations in the application. In multi-axis systems, make sure the PZTs are always connected to the same controller channels.

2 Mount an external gauge to measure the PZT displacement. (with PZT power amplifier powered down, the external gauge should read 0; if it does not, note the offset and subtract it from subsequent readings)

3 Set the switch on the front panel to Servo OFF.

4 Make sure the DC-Offset potentiometer is set to zero (full counterclockwise).

5 Power up the system.

6 Adjust the zero potentiometer on the front panel until approx. 0 V is measured at the sensor monitor connector (rear panel).

7 Scan the voltage at CONTROL INPUT from 0 V to +10 V and read the PZT displacement using the external gauge. With +10 V the external gauge should show the PZT at about nominal expansion. Adjust with the sensor gain trim potentiometer (see Fig. 3).

8 Repeat the previous two steps several times until stable results are obtained. Sensor gain is now close enough to allow switching servo ON.

9 Switch servo ON.

10 Apply 10.000 V control voltage to the control input.

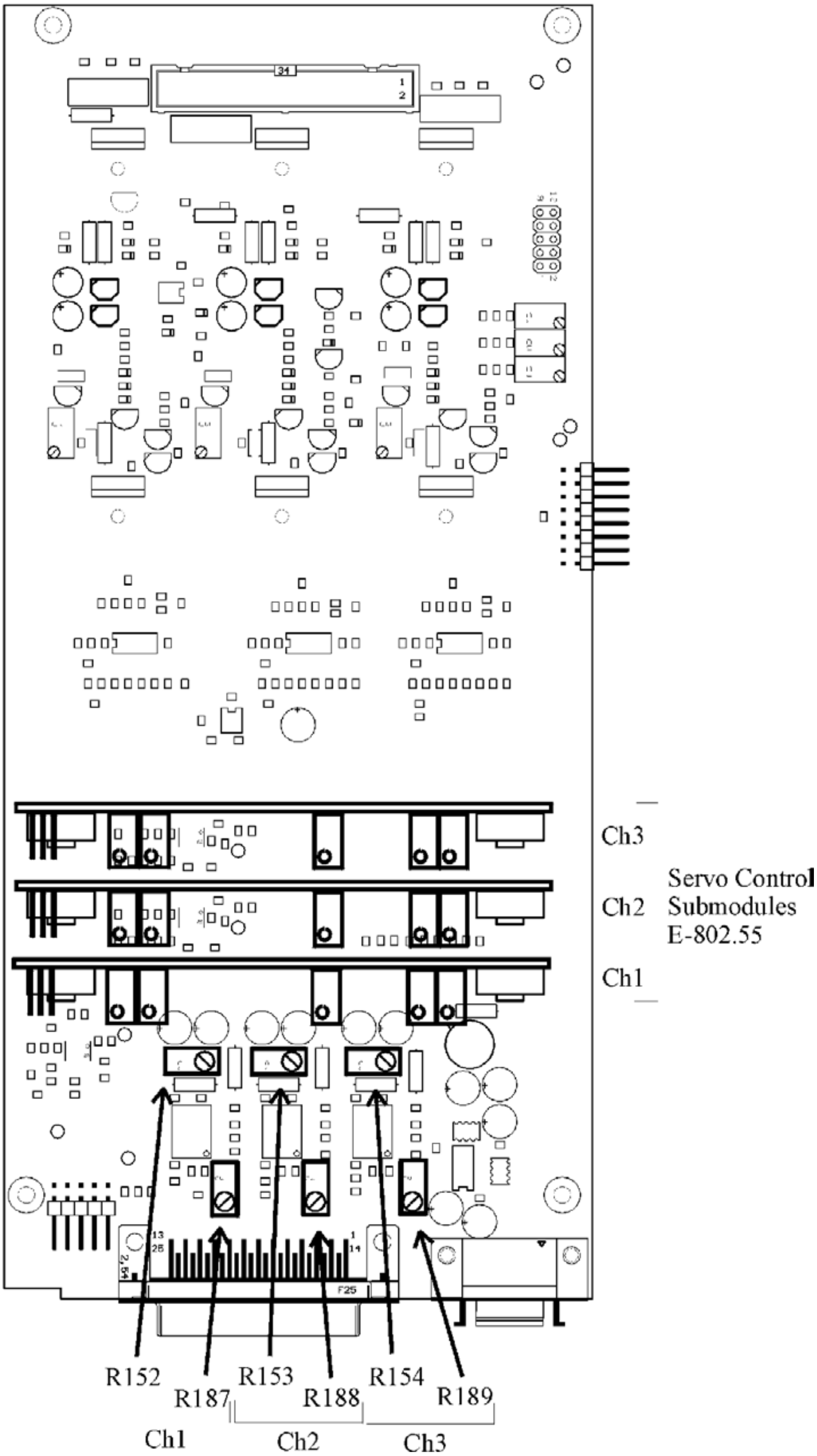
11 Adjust the sensor monitor signal to exactly 10.000 V using the gain adjustment potentiometer on the E-802 servo submodule (different versions of this submodule exist, see the E-802 User Manual for gain adjustment on your unit)

12 Adjust the PZT position to the nominal expansion value using the sensor gain adjustment (Fig. 3) from step 7. Now, because servo ON, the sensor monitor value will not change!

13 Repeat the previous two steps until you get stable readings

If the Gain settings have been changed, the zero-point adjustment should be repeated, and then the static gain rechecked.

5.2. Main Board Calibration Elements



R152- R154 Sensor Gain R187-R189 Sensor Tolerance

Fig. 3 Adjustment element and submodule locations

5.3. Dynamic Calibration

Dynamic performance of the PZT system is determined by the maximum output current of the amplifier and by the mechanical properties of the PZT mechanics, like moving mass, damping and resonant frequencies. Dynamic calibration optimizes step response and suppresses resonance, overshoot, and oscillation. These servo-loop, notch filter and slew-rate limitation setting procedures are all described in detail in the E-802 Servo-Control Submodule User Manual.

6. E-664.S3 Technical Data

Function:	Power amplifier and Servo Position controller for LVPZTs; Functionality and Parameters optimized for NanoCube Nano Positioning System.
Channels:	3
Amplifier:	
Voltage output range:	-20 to +120 V (local mode) 0 to +100 V (remote mode)
Max. output power:	12 W / channel
Average output power:	4 W / channel
Peak output current:	120 mA (for 5 ms)
Current limitation:	short circuit proof
Voltage Gain:	10.66 ± 0.1 (open-loop)
Polarity:	positive
Control Input Voltage:	-2 to +12 V (open-loop)
Input Impedance:	100 kOhm
Position offset setting:	0 to 100V with 10-turn potentiometer
Overflow Detection:	Piezo Voltage outside -20..+120V
Display:	3 x 3½ digits, LED, switchable for voltage or position
Control input socket:	BNC and Mini Delta Ribbon
PZT voltage output socket:	DSub 25 pin female
Dimensions:	235 x 103 x 288 mm
Weight:	3 kg
Operating Voltage:	90-120/220-240 VAC, 50-60 Hz
Fuse:	0.8 / 1.6A slow
Power:	max. 50VA
Power Supply:	Linear Regulated for lowest noise
Operating Temperature:	5..40°C
Storage Temperature:	-20..+80°C
Humidity:	< 75% noncondensing
Position Servo-Control	
Sensor Type:	Strain Gage Full Bridge
Control Input Voltage:	0 to +10 V (closed-loop for nominal expansion)
Position offset setting:	0 to nominal expansion with 10-turn potentiometer
Servo Characteristics:	P-I-Filter with Notch Filter and Drift Compensation
Notch Filter Characteristics:	2nd order, damping 25 dB, Frequency 50..500Hz
On-Target Detection:	Real Position within ± 0.2 µm of Target Position
Sensor Socket:	combined with PZT (DSub)
Sensor monitor output socket:	BNC and Mini Delta Ribbon
Overflow and On Target Signals:	Mini Delta Ribbon, TTL-level

6.1. Frequency Response

E-664 open-loop frequency response with various PZT loads. Capacitance values are in µF.

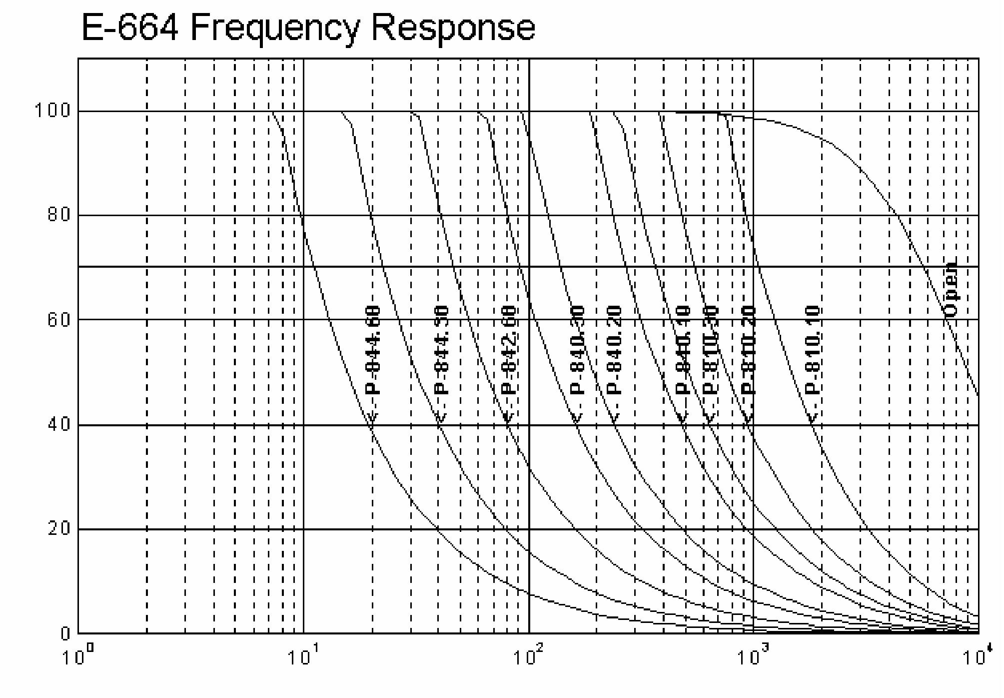


Fig. 4. Frequency response with a selection of PI PZTs

6.2. Electrical Capacitance of Different PI PZTs

P-810.10	0.5 µF
P-810.20	0.9 µF
P-810.30	1.4 µF
P-840.10	1.8 µF (equal to NanoCube P-611)
P-840.20	3.6 µF
P-840.30	5.4 µF
P-842.60	10 µF
P-844.30	22 µF
P-844.60	45 µF

7. Front Panel Elements

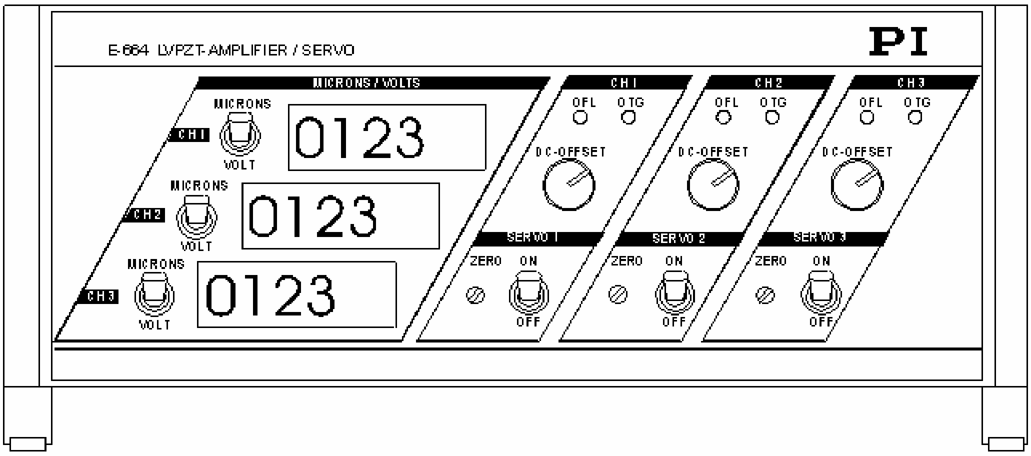
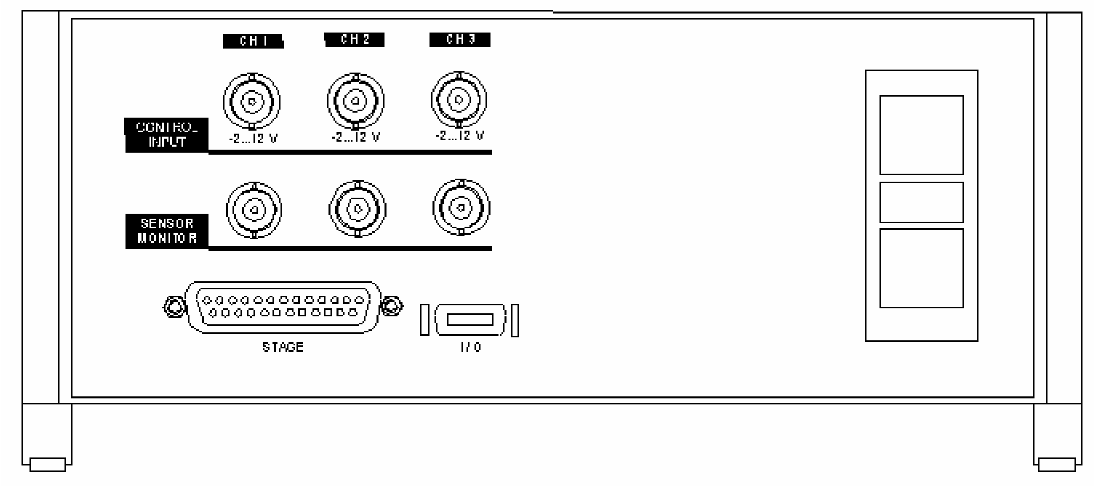


Fig. 5. Front panel operating and display elements

VOLTS/MICRONS	Toggle switch for LED Display
	VOLTS: Display showing current PZT output
	MICRONS: Display showing current sensor reading
OFL	Overflow LED
OTG	On Target LED
ZERO	Adjustment potentiometer for operating voltage
ON/OFF	Toggle switch for Servo ON / Servo OFF
DC-OFFSET	Potentiometer for manual PZT setting
Channel Description	For the NanoCube actuators
	Ch1 corresponds with mechanical X
	Ch2 corresponds with mechanical Y
	Ch3 corresponds with mechanical Z

8. Rear Panel Elements



Line Switch	Power On/Off (opens completely)
Voltage Selector	Two default ranges (220-240 V or 110-120 V). Selected value is visible in window (see figures). Pry out and re-orient fuse carrier to change range selection. Fuses will also need to be replaced.
Fuses	Fuses are voltage dependent: use 0.8 A for 230 V and 1.6 A for 110 V (slow type)

Fuse carrier

Door with window

Line cord connector

Fuse access

Fig. 6. Fuse access

Stage Connector	Single connector for combined piezo actuator and sensor signals
Control Input	Control voltage for open / closed-loop operation
Sensor Monitor	Current sensor value
I/O Connector	Combines control input, sensor monitor, overflow and on target signals for all three channels for easy access to complete functionality. If this connector is used, do not connect BNC-inputs.

8.1. Connectors

8.1.1. Piezo Stage Connector (Backpanel)

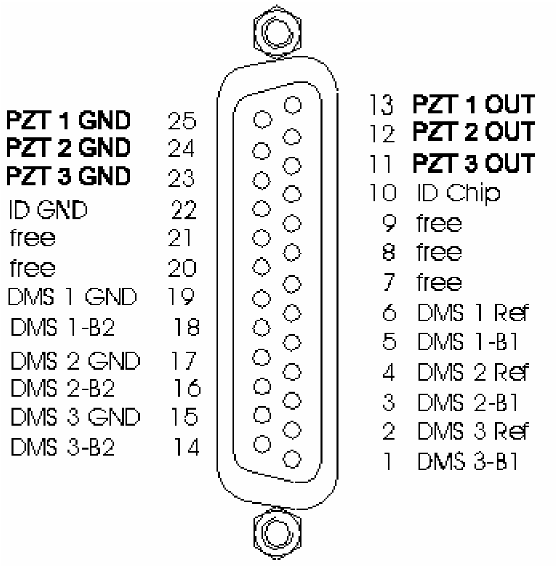


Fig. 7. Type: Sub-D 25 pin female

Caution: Voltage up to 130 V on pins 11, 12 and 13

8.1.2. I/O Connector (back panel)

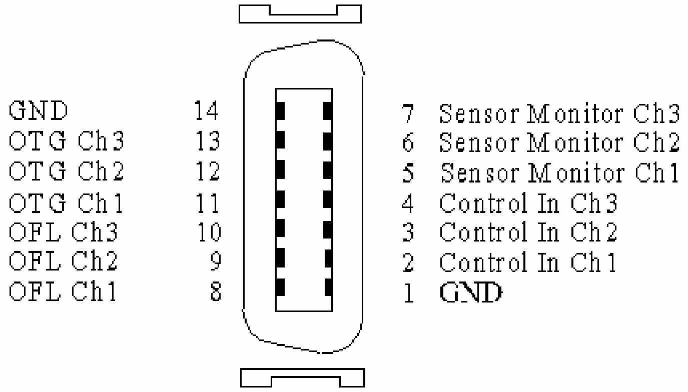


Fig. 8. Mini-D ribbon (MDR) connector

Caution: use either BNC inputs or I / O inputs, not both at the same time

Type: 3M / Mini D Ribbon (MDR) .050" / 14 Positions

Order numbers: 101 14 3000VE (plug) and 103 14 52FO008 (casing)

9. NanoCube Handling

Safe Handling of the XYZ Nano-Positioning Systems
P-611.3SF and P-611.3OF NanoCube

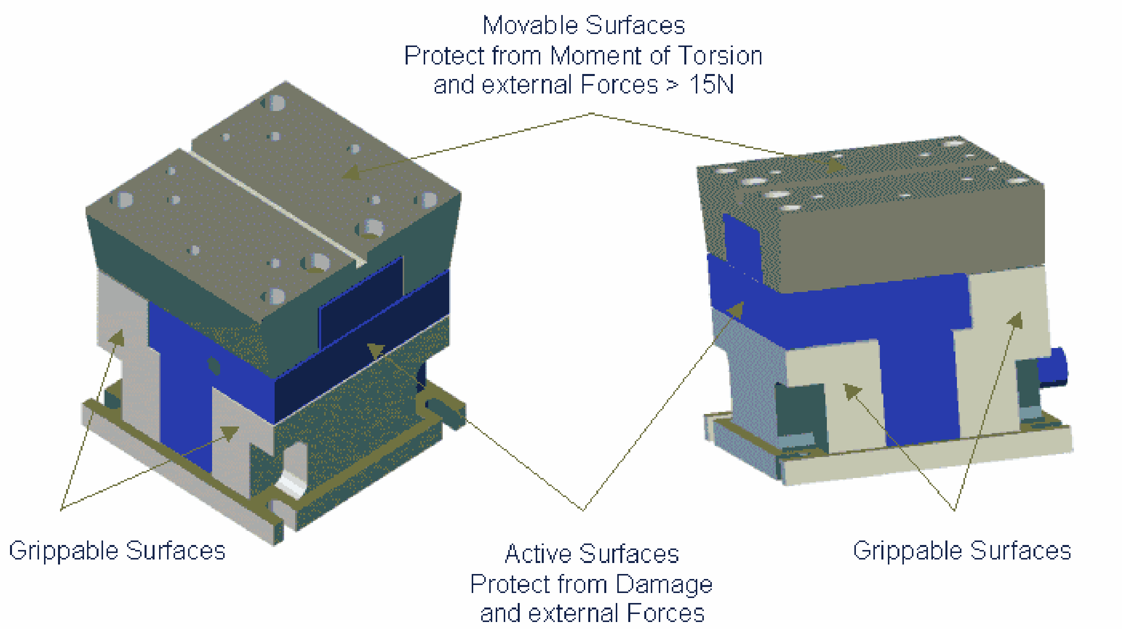


Fig. 9 P-611.3SF and P-611.3OF versions

P-611.3S and P-611.3O NanoCube

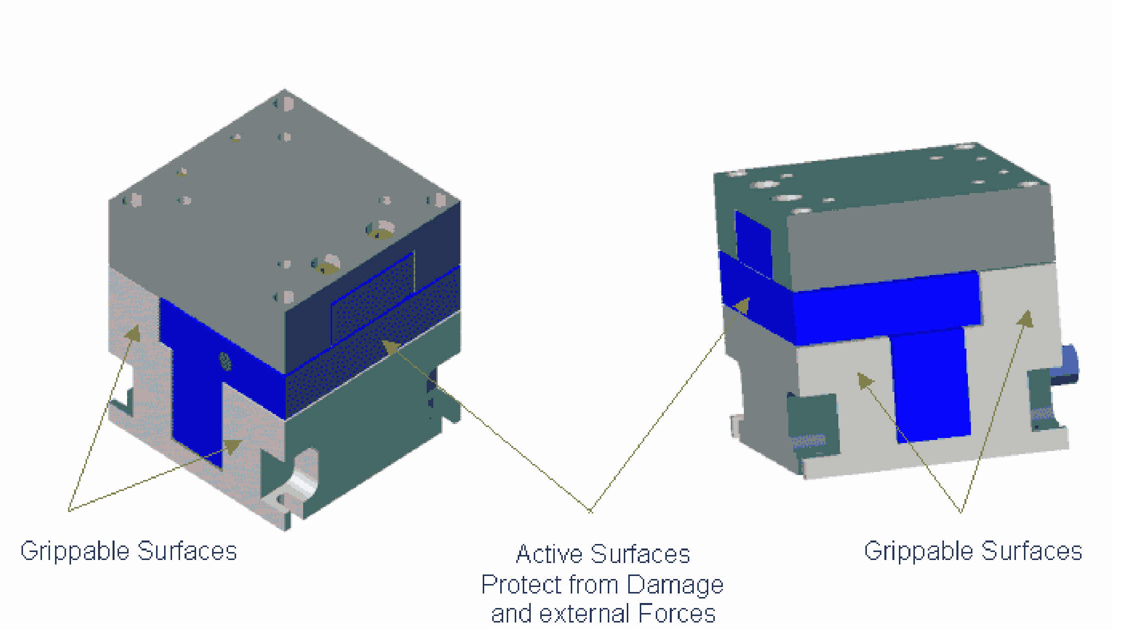


Fig. 10. P-611.3S and P-611.3O versions