

## PZ166E User Manual

### E-625.CR LVPZT Controller/Amplifier

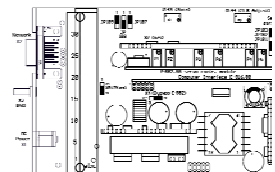
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This document describes the following product(s)\*:

- E-625.CR  
LVPZT Controller/Amplifier, Single Channel, for Capacitive Sensors

\*Strain gauge and LVDT sensor E-625 versions are described in a separate manual, PZ 167E. The E-625.C0 is described in PZ187.



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# Declaration of Conformity

according to ISO / IEC Guide 22 and EN 45014

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**Manufacturer:** Physik Instrumente (PI)  
**GmbH & Co. KG**  
**Manufacturer's Address:** Auf der Römerstrasse 1  
D-76228 Karlsruhe, Germany



The manufacturer hereby declares that the product

Product Name: **LVPZT Controller/Amplifier**  
Model Numbers: **E-625**  
Product Options: **all**

complies with the following European directives:  
73/23/EEC, Low-voltage Directive  
89/336/EEC, EMC Directive

The applied standards certifying the conformity are  
listed below:

**Electromagnetic Emission:** EN 61000-6-3, EN 55011

**Electromagnetic Immunity:** EN 61000-6-1

**Safety (Low Voltage Directive) :** EN 61010-1

December 23 2005  
Karlsruhe, Germany

A handwritten signature in black ink, appearing to read 'K. Spanner', written over a horizontal line.

Dr. Karl Spanner  
President

# About This Document

## Users of This Manual

This manual is designed to help the reader to install and operate the E-625.CR LVPZT Controller/Amplifier. It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.

The manual describes the physical specifications and dimensions of the E-625.CR LVPZT Controller/Amplifier as well as the hardware installation procedures which are required to put the associated motion system into operation.

This document is available as PDF file on the product CD. Updated releases are available for download from [www.pi.ws](http://www.pi.ws) or via email: contact your Physik Instrumente Sales Engineer or write [info@pi.ws](mailto:info@pi.ws).

## Conventions

The notes and symbols used in this manual have the following meanings:

### WARNING

Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.



### DANGER

Indicates the presence of high voltage (> 50 V). Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.



### CAUTION

Calls attention to a procedure, practice, or condition which, if not correctly performed or adhered to, could result in damage to equipment.



### NOTE

Provides additional information or application hints.

## Related Documents

The hardware components and the software tools which might be delivered with E-625.CR LVPZT Controller/Amplifiers are described in their own manuals. All documents are available as PDF files on the product CD. Updated releases are available for download from [www.pi.ws](http://www.pi.ws) or via email: contact your Physik Instrumente Sales Engineer or write [info@pi.ws](mailto:info@pi.ws).

E-802 User Manual, PZ150E

E-816 User Manual, PZ116E

E-816 DLL Software Manual, PZ120E

E-816 LabVIEW Software Manual, PZ121E

Analog Controller LabView Driver Library Software Manual, PZ181E

PZTControl Software Manual, PZ146E

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# 1 Introduction

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## 1.1 Prescribed Use

Based on their design and realization, the E-625.CR LVPZT Controller/Amplifier is intended to drive capacitive loads, in the present case, piezoceramic actuators. The E-625.CR must not be used for applications other than stated in this manual, especially not for driving ohmic (resistive) or inductive loads. E-625.CRs can be operated in closed-loop mode using capacitive position sensors. Appropriate sensors are provided by PI and integrated in the mechanics according to the mechanics product specifications. Other sensors may be used as position sensors only with permission of PI.

Observe the safety precautions given in this User Manual.

E-625.CRs conform to Measurement Category I (CAT I) and may not be used for Measurement Categories II, III or IV. Other use of the device (i.e. operation other than instructed in this Manual) may affect the safeguards provided.

E-625.CRs meet the following minimum specifications for operation\*:

- Indoor use only
- Altitude up to 2000 m
- Ambient temperature from 5°C to 40°C
- Relative humidity up to 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C
- Line voltage fluctuations of up to  $\pm 10\%$  of the line voltage
- Transient overvoltages as typical for public power supply  
Note: The nominal level of the transient overvoltage is the standing surge voltage according to the overvoltage category II (IEC 60364-4-443).
- Degree of pollution: 2

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\* Any more stringent specifications in the Technical Data table are, of course, also met.

## 1.2 Safety Precautions

### DANGER

High Voltage: Read This Before Operation:

E-625 LVPZT Controller/Amplifiers generate 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 equipment 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.

Be sure to connect the grounding stud on the rear panel to a protective ground!

Procedures which require opening the case should be carried out by authorized, qualified personnel only.

Disconnect unit from power when opening the case, and when resetting internal switches or jumpers.

When the unit must be operated with the case open, voltages of up to 120 V can be exposed. Do not touch internal conductors.



### WARNING

Connect the AC power cord of the external power supply to the wall socket (100 to 240 VAC).

To disconnect the system from the supply voltage completely, remove the power plug from the wall socket.

Install the system near the AC outlet and such that the AC power plug can be reached easily.







## CAUTION

Place the system in a location with adequate ventilation to prevent internal heat build-up. Allow at least 10 cm (4 inches) clearance from the top and the rear of the unit and 5 cm (2 inches) from each side.

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### 1.3 Unpacking

Unpack the E-625.CR LVPZT Controller/Amplifier with care. Compare the contents against the items ordered and against the packing slip. The following items should be included:

- Controller unit (E-625.CR)
- Separate power supply (E-661.PS, 15 V)
- Line-power cable
- RS-232 null-modem cable for PC connection (C-815.34)
- SMB/BNC adapter cables (E-692.SMB) 1.5m, two units
- User Manual for E-625.CR (PZ166E), this document
- User Manual for E-816 Computer Interface and Command Interpreter Submodule (PZ 116E)
- User Manual for E-802 Servo-Control Submodule (PZ 150E)
- CD for E-816-interface devices with software and documentation (E-621.CD)

Inspect the contents for signs of damage. If parts are missing or you notice signs of damage contact PI immediately.

Save all packing materials in the event the product needs to be shipped elsewhere.

## 2 Description

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### 2.1 Hardware

The E-625.CR amplifier/controller is a stand-alone desktop device designed to drive and control the displacement of a low-voltage piezoelectric stage or actuator (LVPZT) in a system with capacitive sensor position feedback.

Networking of E-625.CR's with each other or with other devices equipped with the E-816 submodule allows controlling up to 12 devices over a single RS-232 computer interface. Networking requires additional wiring and setup.

The E-625.CR comes with an E-802 Servo-Controller and an E-816 Computer Interface and Command Interpreter installed as standard.

E-625s for use with SGS or LVDT sensors are described in detail in their own manual, PZ167.

The E-625.C0 is the same as the E-625.CR, except that it has the analog control interface only. As a result, some settings are not applicable and/or are disabled. Its basic operation is described in User Manual PZ187; technical details can be found here, albeit by inference.

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### 2.2 Functionality

The E-625.CR features a single-channel power amplifier with an average output power of 6 watts. The design is based on a power amplifier (voltage source), optimized for driving capacitive loads. The unit also includes position sensor excitation and readout, servo-control logic, and computer control with multi-axis networking. These last two functions are implemented on small PCB submodules. The submodules are included with the system and come already installed, though they can be replaced by the user. The block diagram on p. 29 answers most questions about how the various elements interact with each other.

Basic operation involves the user commanding a motion and the E-625 supplying the required voltage on the PZT output line for the PZT to execute the commanded motion. The motion command can be either a string of ASCII characters delivered

over the computer-control interface (computer-controlled operation) or a voltage, perhaps computer generated, on the analog input line (referred to as analog operation in this manual). Furthermore, the motion command can specify either a target position (i.e. closed-loop = servo ON = position-controlled mode), or a target voltage for the PZT (i.e. open-loop = servo OFF = voltage-controlled mode). The various combinations of operating mode are shown in the table below:

Type of Operation Servo Mode	Computer-Controlled <sup>1</sup> Operation Commanded values are specified by commands from host PC	Analog Operation Commanded values are specified by putting a voltage on the Analog Input terminal
Servo OFF (open-loop or voltage-controlled mode) Position sensor output is available but not used internally	Only voltage-setting motion commands are executed	Input voltage is translated directly into a voltage to be applied to the PZT output. The E-625 acts like a linear amplifier
Servo ON (closed-loop or position-controlled mode) <sup>2</sup> Position sensor output is used by the servo-control loop to assure that target position is reached	Only position-setting motion commands are executed; the servo-control loop <sup>2</sup> is used to effectuate the moves	Input voltage is interpreted as a target position for the PZT. The servo-control loop <sup>2</sup> is used to effectuate the move.

*Table 1: E-625 Operating Modes. See below for details.*

The voltage required for analog operation can be generated by a data acquisition card (DAQ) in a PC. PI now offers a LabVIEW driver set that supports this operating mode. Note

<sup>1</sup> Computer control and networking functions are implemented on the factory-installed E-816 plug-in submodule, described in detail in a separate manual. Operating the unit with a computer-generated analog signal is considered under Analog Operation.

<sup>2</sup> Servo-control logic, a notch filter and slew rate limitation are all implemented on an included plug-in submodule (E-802), which is described in detail in a separate manual. Note that with the E-802.55 version, the notch filter and slew rate limiter are active even when the submodule sees the servo-off signal. This can cause PZT voltage changes in open-loop when the notch filter frequency is changed.

that the servo must be on when working with this driver set. With it, you can use the familiar commands of the PI General Command Set in your LabVIEW environment to command the device via the analog input. Documentation on the PI LabVIEW driver set supporting that operating mode, including the Hyperbit™ drivers which make possible position resolution higher than that of the DAQ board used, is on the included E-816 CD. Installation of the LabVIEW Analog Driver set is a Setup option. New releases are available from the download area at [www.pi.ws](http://www.pi.ws). See the included E500T0011 Technical Note for instructions. For the Hyperbit™ extension contact your PI Sales Engineer.

Most users will be using the computer-controlled operating modes. It is possible to command up to twelve E-625s over a single RS-232 interface from a single host PC. The E-625 connected to the RS-232 link (the master) relays commands to the other units (slaves) on the network. Responses from the slaves are then relayed by the master back to the PC. Networking E-625s requires proper setup of each unit and busing of Network connector lines 7, 8 and a GND, with multiple E-625.CRs also requiring busing of lines 3 and 4 among them. PI also supplies software to run on the host PC controlling the E-625(s). Included are LabView drivers, a COM Server, a DLL Library and the *PZTControl* graphic user interface software.

Computer control and networking are implemented with the E-816 plug-in submodule, which is included in the standard configuration. See the *E-816 User Manual* for details.

The information in this manual, while primarily for those using computer-controlled operation, is also valid for analog operation. Keep in mind that for analog operation, “commanded” or “target” position or voltage refers to the position or voltage associated with the *voltage* put on the analog input terminal. If the unit is in servo-control mode, the voltage on the analog input terminal will be interpreted as a position. In analog operation the servo-control loop can be activated by DIP switch. In computer-controlled operation the servo-control loop can be activated by command. See Operating Modes, p. 11 or refer to the block diagram on p. 29 for details.

Using servo-control mode with a position sensor is the most efficient way to suppress errors due to hysteresis, creep and load variation; the piezo translator can then be controlled with an accuracy that is determined by the accuracy of the sensor used. The capacitive sensors supported by the E-625.CR are the highest accuracy sensor type available.

The maximum output voltage range of the power amplifier is from -20 to +120 V, so as to support the full extension capability of PI low-voltage PZT translators. For maximum PZT lifetime, excursions above 100 V and below -10 V should be kept as short and as infrequent as possible.

E-625s can be used for both static and dynamic applications. High output stability and low noise assures stable micropositioning. Because LVPZT translators have high capacitances, the amplifier is designed to supply appropriately high peak currents for dynamic applications. Excellent linearity and stability allows the use of E-625s in precision measurement and control systems.

### 3 Quick Start

- 1 Connect the E-625 to its external power supply (order# E-661.PS, included), and connect the power supply to the line voltage.
- 2 Make the hardware settings required for the operating mode you wish to use. See "Operating Modes", p. 11 for details.  
Note: The servo must be on for analog operation, when you want to work with a computer-generated signal (e.g. from a DAQ board) and the analog LabVIEW driver set from PI (see step 6 below).
- 3 Connect the piezo stages/actuators to the proper E-625.CR units. If your system was calibrated by PI, the controllers and stages are not interchangeable. The serial numbers of the corresponding stages should be marked on calibration labels on the controller.
- 4 Switch on the power supply.
- 5 If you will be using computer-controlled operation, continue now with the instructions in "Starting Operation" in the E-816 Computer Interface Submodule User Manual. It will lead you through installation of the host software and, if necessary, configuring unique axis identifiers in a multi-axis system. That manual also contains an overview of the included software.
- 6 If you will be using analog operation and generating the analog signal with a DAQ board in a PC running LabVIEW and using PI's LabVIEW Analog Driver Set, install that driver set. It can be installed by running Setup on the included E-816 CD or downloaded from [www.pi.ws](http://www.pi.ws). See the included E500T0011 Technical Note for detailed download instructions, and the driver documentation for operation.

## 4 Operating Modes

As already mentioned, the E-625 supports analog and computer-controlled operation. In analog operation, the PZT is controlled by the voltage of an analog signal on the analog input line. In computer-controlled operation, the PZT is controlled by ASCII commands originating in a host PC.

### NOTE

Controlling the E-625.CR with a computer-generated analog signal (e.g. DAQ board) is treated in this manual as “Analog Control,” not “Computer Control.”

Only the DIP switch block S1 and the Zero potentiometer are accessible without opening the case. To access other adjustment elements (e.g. jumpers), it is necessary to remove the top cover. See Section 7 on p. 18 for more information.

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### 4.1 Computer-Controlled Operation

Select computer-controlled operation by setting DIP switch 2 (on block S1) to ON (down) and switch 1 to OFF. Make sure jumper X4 is in position 2-3 if you wish to use servo-control, the notch filter or slew rate limitation. In computer-controlled operation, many settings (such as servo mode) can be configured to be controllable by command. See the *E-816 Computer Interface and Command Interpreter User Manual* for details.

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### 4.2 Analog Operation

In analog operation, the voltage output to the PZT is controlled by the analog input. The analog input is accepted on the corresponding front-panel connector if DIP switches 2 and 4 are OFF and sw. 1 is ON (see block diagram, p. 29) The nominal input voltage range is 0 to +10 V for a 0 to 100 V output voltage swing. For some applications, where the full expansion capability of the piezo translators is needed, the full output voltage range of -20 to +120 V can be used. The equivalent input voltage range is then -2 to +12 V.

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### 4.3 Open-Loop Operation (Voltage-Controlled, Servo Off)

In open-loop mode (voltage-controlled operation), the position servo-control portion of the E-802.5x submodule circuitry (E-802.5X) is deactivated. With E-802.55 version submodules, the slew rate limitation and notch filter remain active (unless, of course, jumper X4 is in position 1-2). In computer-controlled operation, when servo-mode is OFF, only voltage-setting commands are accepted. In analog operation the system works like a linear amplifier with the PZT operating voltage proportional to the control signal input. (The sensor electronics works independently, and outputs the current piezo position even in open-loop mode, provided a sensor is properly connected. Since there is some variation among different PZTs of the same model, the voltage required to bring the PZT to its nominal expansion will differ.

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### 4.4 Closed-Loop Operation (Position-Controlled, Servo ON)

Position-controlled (Servo ON) operation offers both drift-free and hysteresis-free positioning as well as immunity to load variations. To enable the position-controlled mode:

- In computer-controlled operation, use the SVO command; note that jumper X4 must be in position 2-3.
- In analog mode, set sw 3 of DIP block S1 to ON; note that jumper X4 must be in position 2-3.

In position-controlled mode, the servo-control electronics decide what voltage should be output to the PZT based on the commanded position. The operating voltage for the PZT will remain in the range from -20 to +120 V. If the actual expansion of the PZT cannot match that defined by the control signal, an active-low TTL signal on internal connector pin 26a causes the yellow Overflow LED to light.

PI's standard calibration procedure assures that that the PZT reaches its nominal expansion when that position is commanded (in analog mode, when the input control signal is +10 V). Note that due the variation in PZTs, the voltage output to the PZT will not be exactly 100 V.

In position-controlled mode, it is the output of the proportional-integral (P-I) servo-controller that is used as input to the amplifier. The piezo voltage is adjusted until the final target position is reached. In this mode, the relationship between target position and PZT supply voltage may not be linear.



## 5 Installation



### DANGER

Read This Before Operation:

E-625 controller/amplifiers generate 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 equipment 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.

Be sure to connect the GND stud on the rear panel to a protective ground!

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### 5.1 Preparing for Operation

If PI had sufficient knowledge of your application and you ordered your system components together, they will be preinstalled and preconfigured. In that case you only need to perform the steps shown in bold below. All operations on the E-625 board and or the submodules—i.e. setting jumpers, potentiometers or switches—require opening the case and are to be carried out by qualified authorized personnel only.



### DANGER

Disconnect the E-625 from its power supply before opening the case.

1. Set the switches and jumpers on the submodules in the E-625 as required for your application; (for the servo-control and computer interface submodules see the respective user manuals).<sup>3</sup>

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<sup>3</sup> This requires opening the case.

2. Set the switches on the E-625.CR front panel and jumpers on the E-625 main board as required for your application (see p. 19)<sup>4</sup>.
3. Connect the positioner(s) and sensors to the E-625. In precalibrated multi-axis systems, the serial numbers of the corresponding controller/positioner pairs are marked and must be respected.
4. Connect the grounding stud on the rear panel to a protective ground.
5. Power up the E-625 (see p. 35 for power supply specifications) and the host computer.
6. Connect host computer to the E-625 using the RS-232 cable.
7. Start the interface software (e.g. PZTControl; for RS-232 interface settings see the E-816 User Manual). Send a command that gives a response (e.g. \*IDN?). If no response arrives, check that the host software baud rate setting agrees with that of the hardware.
8. Optionally: If the system has more than one E-625, interconnect the E-625s using their Network connectors and an appropriate cable (see Section 5.2 and Section 8.6 on p. 35 for details). Then connect the RS-232 cable from the host computer to each E-625 in turn and configure it. Do not forget to save the configuration with the WPA 100 command. When all E-625s are configured, connect the host computer to the E-625 that is to serve as master. See the E-816 User Manual for details.
9. Check the analog-side, open-loop, zero-point offset of each axis. If it is incorrect, adjust

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<sup>4</sup> This requires opening the case.

the ZERO potentiometer as described on p. 21. It assures that the sensor reports 0 when the position is 0. This value is load-dependent and can drift even on a precalibrated system.

10. Check the analog-side, open-loop sensor range calibration. If it is off, adjust it as described on p. 22. It assures that the sensor section output is 10 V when the PZT is physically at nominal expansion<sup>5</sup>.
11. Check the servo-control (closed-loop) range adjustment. If it is off, adjust it<sup>5</sup>. It assures that when the nominal-range position is commanded (in analog mode, +10 V with servo ON), the PZT is given the output voltage it requires to bring the sensor output to 10 V.
12. Check and adjust the servo-control dynamic behavior<sup>5</sup>. See the E-802 servo-control submodule user manual for details. The settings explained there include the P and I values for the servo-control loop and the notch filter setting to eliminate mechanical resonance.
13. If hardware adjustments have been made, check and adjust the digital sensor offset and gain parameters (Osen and Ksen) accordingly (see the E-816 Computer Interface and Command Interpreter User Manual for details).

---

## 5.2 Networking

For a networked installation, the following conditions must be met:

- Networked units must have the I<sup>2</sup>C networking lines connected in parallel (Network connector pins 3 & 4 and at least one of the ground lines). The network bus lines are limited to a maximum length of 1 m and a maximum capacitance of 300 pF. These lines carry commands and responses.
- If the network includes more than one capacitive sensor unit, one must be set to “sensor master” and the rest to “sensor slave” and they must have their capacitive

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<sup>5</sup> This requires opening the case.

sensor synchronization lines (E-625.CR Network connector pins 7 and 8) bused together (pins 7 and 8 of LVDT and SGS E-625s may be included or not).

A cable with convenient piggy-back D9 connectors is available as E-625.CN for networking up to four E-625s (see p. 35).

## 6 Operation

### 6.1 Setting Operating Mode

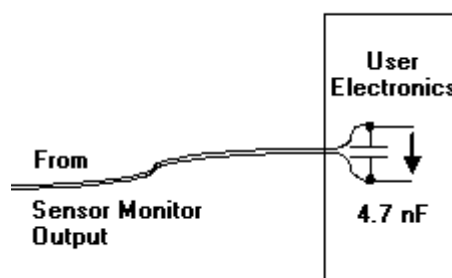
Make sure all switches (on front panel) and jumpers (on the main board in the case) are properly set for the operating mode you require (see "Operating Modes", p. 11). The command set for computer-controlled operation is explained in the User Manual for the E-816 computer interface and command interpreter submodule.

Over the system lifetime you should occasionally check the calibration values. The zero-point should be checked most often. Less frequently, you should check the other calibration adjustments. Recalibration will be required if system components are replaced or changes in loading are made.

### 6.2 User Electronics and Sensor Monitor Signal

If you are connecting your own electronics to the sensor monitor signal, make sure it has sufficient input capacitance to eliminate high-frequency interference.

It may be necessary to add a 4.7 nF (ceramic NP0 or COC type) to the input connector. Use shielded cable if possible, otherwise make sure the lead pair is tightly twisted.



*Fig. 1: Electronics on Sensor Monitor line with required input capacitance*

## 7 Settings, Adjustment and Calibration

The procedures mentioned in the Installation Section above are described here in detail. Do not adjust potentiometers unnecessarily, and be aware that many adjustment points are interdependent and effect both computer-controlled and analog operating modes. Reference to the block diagram (p. 29) can aid in understanding the scope of the various control elements.

### 7.1 Opening the Case

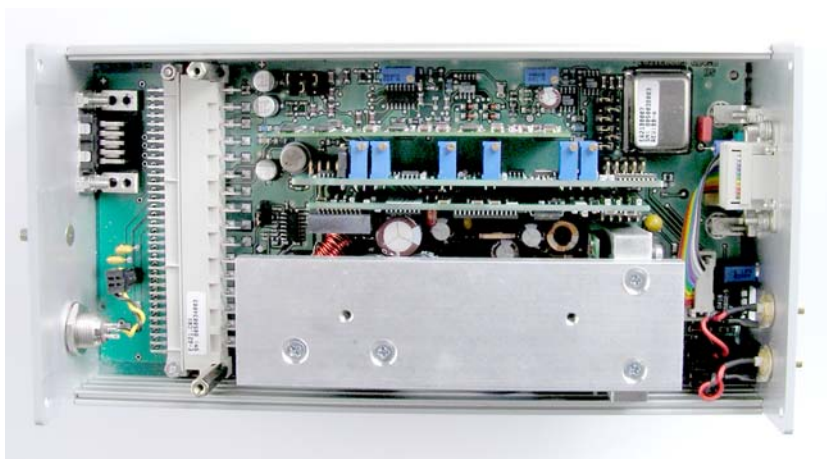
#### DANGER

Procedures which require opening the case should be carried out by authorized, qualified personnel only.

Disconnect unit from power when opening the case, and when resetting internal switches or jumpers.

When the unit must be operated with the case open, voltages of up to 120 V can be exposed. Do not touch internal conductors.

Only the DIP switch block S1 and the Zero potentiometer are accessible without opening the case. To access other adjustment elements, it is necessary to remove the top cover.



*Fig. 2: E-625.CR with cover off*

## 7.2 E-625.CR Switch and Jumper Settings

Check the switch and jumper settings carefully: the resulting improper operation may not be immediately evident.

### 7.2.1 Computer-Controlled vs. Analog Operation

Choose between computer control and analog operation. Analog operation is called for by some calibration procedures, otherwise most users will always be using computer-controlled operation.

	Computer Control	Analog Operation
DIP block S1, switch sw1* (Use Analog In line as target)	OFF	ON
DIP block S1, switch sw2* (computer control target)	ON	OFF
DIP block S1, switch sw3* (servo-control signal)**	OFF	see Sect. 7.2.2 & 8.1
DIP block S1, switch sw4* (Use Analog In line as wave trigger)	ON	OFF
Jumper X4 (servo bypass off)	2-3**	2-3**

\*S1 is accessible through the front panel under "settings"; sw 1 is at the left, and the ON position is down

\*\*X4 in 2-3 is the default position, and there is almost never any reason to change it. If X4 is in position 1-2, then servo-control, notch filter and slew-rate limiting will all be off, no matter how anything else is set or commanded. See the block diagram on p. 29.

For details of computer-controlled operation, follow the instructions in the *E-816 Computer Interface and Command Interpreter User Manual*.

### 7.2.2 Servo Mode Selection

The servo-control loop, notch filter and slew-rate limitation is all implemented on the E-802 submodule. If jumper X4 is in position 1-2 the E-802 is completely bypassed no matter what the other settings.

With X4 in position 2-3 the E-802 is connected. Servo mode can then be controlled in a number of different ways.

Servo mode can be switched ON in *either* of two ways:

- By computer command (only if computer-controlled operation is enabled, sw2 ON).
- By setting DIP switch 3 (on block S1, accessible on the front panel under “settings”, 3rd from the left) to ON (down)

Servo mode is OFF if *none* of the above items have it switched ON. With the E-802.55 version of the servo-controller, slew-rate limitation and notch filtering remain on even when servo mode is switched off at the card, but not if the card is bypassed by having jumper X4 in position 1-2).

---

## 7.3 Sensor Connection and Adjustment

### NOTE

If you inform PI about your application, your E-625s 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.

### CAUTION

Calibration should only be done after consultation with PI, otherwise the internal configuration data may be destroyed by erroneous operation.



Capacitive position sensors are connected to the front panel connector. If you wire your own connector and interchange Target and Probe lines, the system will still operate but may not attain the specified accuracy.

The output from the sensor-processing circuitry is an analog signal that is directly proportional to the piezo's expansion and is available at Sensor Monitor on the front panel. See the “Sensor Synchronization” section, starting on p. 34 and the Capacitive Sensor User Manual for more details.

As seen in the block diagram (p, 29), the sensor signal goes through the sensor range settings (JP101-JP106), ILS linearization (R144), gain (R143) and zero-adjust (R13), and then branches to the Sensor Monitor output, the computer-interface submodule and the servo-control submodule. The voltage range setting (JP108, JP109) must remain as set at the factory. In addition to the adjustments on the analog side, there are digital offset and range corrections on the computer



interface submodule. See the E-816 User Manual for details.

Since the servo-control and computer interface submodules see “copies” of the sensor signal, it is important that the zero point and gain in the sensor circuitry be properly adjusted. The zero point is especially likely to need correction.

The A/D converter on the computer interface submodule is always precalibrated and its offset and gain values stored in EPROM: they are not customer modifiable.

If the hardware adjustments are exact, then the Osen (sensor offset) digital correction factor should be set to 0 and Ksen, the sensor coefficient, should be set to a value equal to the travel range (in  $\mu\text{m}$ ) divided by 10 volts (the nominal sensor readout electronics output range).

### **7.3.1 Analog-Side Open-Loop Zero-Point Adjustment**

Analog, zero-point calibration has the goal of making the point of zero sensor readout coincide with the point of zero commanded voltage or position. If the electrical zero point is adjusted properly, the full output voltage range of the amplifier can be used and only a small offset is required to get a zero reading. This prevents overflow conditions from occurring.

There might be some small deviation of the electrical zero-point caused by thermal drift or changes in mechanical loading. Let the system warm up for several minutes before setting the zero point.

This procedure can be carried out either in computer-controlled or in analog mode. If you use analog mode, you will need a voltmeter. In computer-controlled mode the voltmeter is helpful but not required. Before starting, install the positioner(s) with the same loads and in the same positions as they will have in your application.

OPEN-LOOP SENSOR ZERO POINT	Computer-Controlled Mode	Analog Mode
1. Set switches on the front panel for operating mode	sw1 OFF, sw2 ON, sw4 ON; connect RS-232 cable to this unit	sw1 ON, sw2 OFF, sw4 OFF
2. Set up for servo-off operation	sw3 OFF	sw3 OFF
3. Connect	Connect directly to host PC with RS-232 cable and power up	Power up
4. Exercise the PZT over the nominal expansion range	Command voltages from 0 to 100 V	Apply analog signals 0-10 V to the analog input. Then set the PZT to 0 by applying 0 V to the analog input.
5. Command 0 V	Note the setting of the Osen (sensor offset) parameter (SPA A8 n) and set it to 0 (SPA A8 n)  Command a voltage of 0 volts (SVA A0)	Put 0 V (= analog ground) on analog input
6. Read sensor	POS?, or read the value at the sensor monitor line with a voltmeter (SMB output on front panel)	Read the value at the sensor monitor line with a voltmeter (SMB output on front panel)
7. Correct zero	Correct the zero setting with the ZERO potentiometer on the front panel.	
8. Save Osen	When the zero setting has been corrected, the Osen value of 0 must be saved to EEPROM (SPA A8 n, WPA 100) to assure proper digital operation after the next power up.	

### 7.3.2 Analog-Side, Open-Loop Sensor Range Adjustment

The object of analog-side, open-loop sensor range calibration is to assure that when the PZT is at nominal expansion the sensor will report the nominal-expansion position. (Note that the voltage required to cause the PZT to expand to its nominal value will not be exactly 100 V, but somewhere in the 85-105 V range.)

All piezo positioning systems ordered together with a PZT translator are delivered with performance test documents to verify the system performance.

The system ordered is calibrated in our labs prior to shipment. Normally there is no need for the customer to perform a full

calibration. Only if the PZT, the sensor, extension cable or the mechanical setup is changed, may new calibration be necessary.

Open-loop sensor range adjustment requires an external measuring device with 0.1  $\mu\text{m}$  resolution

## DANGER

Procedures which require opening the case should be carried out by authorized, qualified personnel only.

Disconnect unit from power when opening the case, and when resetting internal switches or jumpers.

When the unit must be operated with the case open, voltages of up to 120 V can be exposed. Do not touch internal conductors.

OPEN-LOOP SENSOR RANGE	Computer-Controlled Mode	Analog Mode
1. Make adjustment elements accessible	Open the case (qualified, authorized personal only)	Open the case (qualified, authorized personal only)
2. Set switches on the front panel for operating mode	sw1 OFF, sw2 ON, sw4 ON, connect RS-232 cable to this unit	sw1 ON, sw2 OFF, sw 4 OFF
3. Set up for servo-off operation	sw3 OFF	sw3 OFF.
4. Exercise the PZT over the nominal expansion range	Command voltages from 0 to 100 V	Apply analog signals 0-10 V to the analog input <sup>6</sup> . Then set the PZT to 0 by applying 0 V to the analog input <sup>6</sup> .
5. Command 0 V	Note the setting of the Osen (sensor offset) parameter (SPA? A8 n) and set it to 0 (SPA A8 n)  Command a voltage of 0 volts (SVA A0)	Put 0 V (= analog ground) on analog input <sup>6</sup>
6. Check/adjust zero-point	POS?, or read the value at the sensor monitor line with a voltmeter (SMB output on front panel)	Read the value at the sensor monitor line with a voltmeter (SMB output on front panel)
7. Expand the PZT to its nominal expansion as indicated by external gauge	Use a series of commands like SVA A90 followed by repeated SVR A1	Increase analog input voltage slowly
8. Adjust sensor gain	Adjust the sensor gain potentiometer on the main board (see Section 8.2 p. 30 for component location)	
9. Recheck	It may be necessary to repeat the last steps until stable readings are obtained.	
10. Save Osen and Ksen	When the zero setting has been corrected, an Osen value of 0 and a Ksen value of (nominal range)/(10 V) must be saved to EEPROM (SPA A8 n, SPA A7 n, WPA 100) to assure proper digital operation after the next power up.	

### 7.3.3 Servo-Control Static Gain Calibration

The object of servo-control static gain adjustment is to assure that the PZT moves to the nominal travel range end position

<sup>6</sup> Analog input is on the SMB socket on the front panel.

when that position is commanded in servo-on mode (in analog operation, 10 V control input).

You will need an external measuring device.

Since the servo-controller uses the sensor signal as a basis, the analog sensor zero point and open-loop range should be adjusted before the static servo-gain is set.

This procedure can be carried out with the unit in either digital or analog mode. If done in analog mode, you will also need a highly accurate voltage source and meter.

## DANGER

Procedures which require opening the case should be carried out by authorized, qualified personnel only.

Disconnect unit from power when opening the case, and when resetting internal switches or jumpers.

When the unit must be operated with the case open, voltages of up to 120 V can be exposed. Do not touch internal conductors.

CLOSED- LOOP SERVO STATIC GAIN	Computer-Controlled Mode	Analog Mode
1. Make adjustment elements accessible	Open the case (qualified, authorized personal only)	Open the case (qualified, authorized personal only)
2. Set switches on the front panel for operating mode	sw1 OFF, sw2 ON, sw 4 ON, connect RS-232 cable to this unit	sw1 ON, sw2 OFF , sw4 OFF
3. Set servo ON	Jumper X4 must be in position 2-3  Send SVO A1 command	Set sw3 to ON, X4 must be in position 2-3.
4. Check for oscillation	If the PZT goes into oscillation, you will have to perform the dynamic adjustments (especially notch filter) first.	
5. Set external gauge to 0	MOV A0 and set external gauge to 0	Ground analog input and set external gauge to 0.
6. Command a position equal to the end of the nominal travel range	e.g. MOV A100  The PZT should expand to the nominal expansion, and the sensor monitor output* should be exactly 10 V. Verify this with the external gauge and meter	Using an appropriately accurate source apply +10.0000 V to the analog input. The PZT should expand to the nominal expansion, and the sensor monitor output <sup>7</sup> should be exactly 10 V. Verify this with the external gauge and meter
7. Adjust sensor monitor output	To adjust the sensor monitor output <sup>7</sup> to exactly 10.000 V use the GAIN Fine Adjust potentiometer on the servo submodule, E-802.5x	
8. Adjust PZT expansion	To adjust the expansion without changing the sensor monitor output (servo-control is on!) use the gain adjustment potentiometer R143 on the main board (see Section 8.2 p. 30 for component location)	
9. Repeat the last steps several times until stable results are obtained		

This adjustment can only be done accurately for one type of input (analog input or digital interface input). If you use the unadjusted input, 1% error in the sensor monitor output voltage can be expected.

### 7.3.4 Second Order Polynomial Linearization (ILS)

#### DANGER

Procedures which require opening the case should be carried out by authorized, qualified personnel only.

<sup>7</sup> Sensor monitor output, SMB connector on front panel

Disconnect unit from power when opening the case, and when resetting internal switches or jumpers.

When the unit must be operated with the case open, voltages of up to 120 V can be exposed. Do not touch internal conductors.

The capacitive sensor electronics on the main board includes a trim pot (ILS) for minimizing second-order polynomial non-linearity. To adjust the ILS proceed 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 units.
- 2 Mount an external gauge to measure the PZT displacement. Only if the external measurement system offers higher precision than the capacitive sensor can the maximum performance be achieved. 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 Scan the voltage at ANALOG IN from 0 V to +10 V and read the PZT displacement using an external gauge.
- 4 Adjust the Integrated Linearization System (ILS) by turning the ILS potentiometer (see p. 30) and maximize the linearity of the PZT displacement.

### 7.3.5 Servo-Control Dynamic Characteristics

The object of servo-control dynamic calibration is to regulate behavior such as overshoot, ringing and settling time. The servo-control submodule also has a notch filter which makes it possible to eliminate vibration at the mechanical resonant frequency of the system.

Dynamic calibration procedures require an oscilloscope (a digital storage oscilloscope is recommended), frequency generator to output square and sine functions from 1 Hz to 1 kHz, an ohmmeter with a range from 0.1 to 100 k-ohm and, depending on the installation.

## DANGER

Procedures which require opening the case should be carried out by authorized, qualified personnel only.

Disconnect unit from power when opening the case, and when resetting internal switches or jumpers.

When the unit must be operated with the case open, voltages of up to 120 V can be exposed. Do not touch internal conductors.

The dynamic calibration procedures are described for execution in analog operating mode, though using the wave table it should be possible to perform them in computer-controlled mode. They are described in the User Manual for the E-802 servo-control submodule.

Note that with the E-802.55 (current production) version of the servo-control submodule, the notch filter and slew rate limiter are not deactivated by the servo-off line. Resetting the notch filter frequency in this mode (open-loop via servo-off signal) can cause the PZT output voltage to change by as much as 5%. To deactivate the notch filter and slew rate limiter, use jumper X4 in position 1-2 to remove the E-802 from the circuit entirely (see block diagram below).



## 8 Electronics

### 8.1 E-625.CR Block Diagram

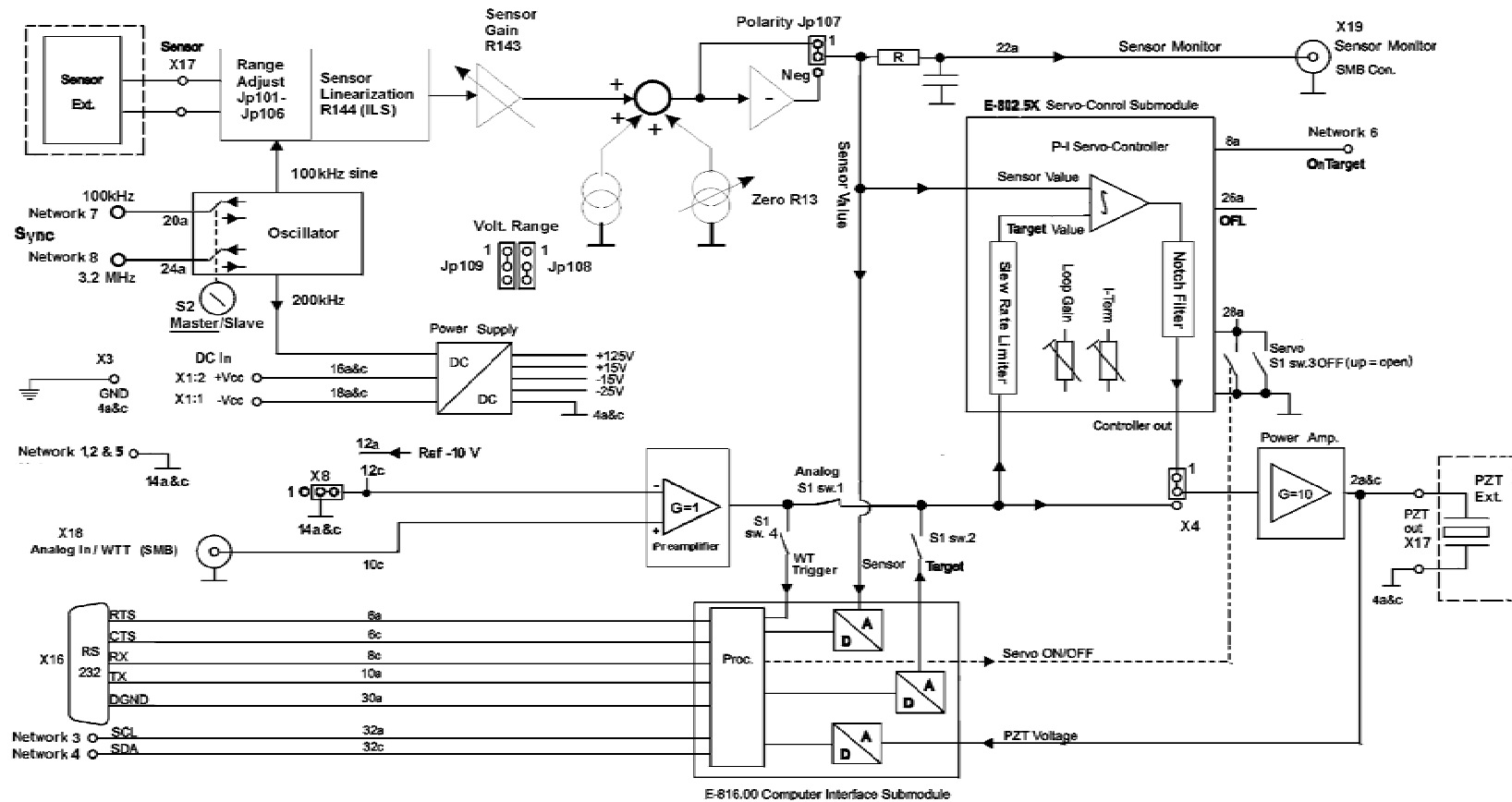


Fig. 3:  
E-625.CR  
Block  
Diagram

NOTE:

Depending on the switch settings, input signals on the analog input line will be used either as target position or voltage, or as digital input for wave table triggering.

IPin numbers 2a through 32c refer to the internal 32-pin connector and are given for informational purposes only.

## 8.2 Components and Adjustment Elements

See also the E-802 User Manual for adjustment elements on that submodule which are not described here.

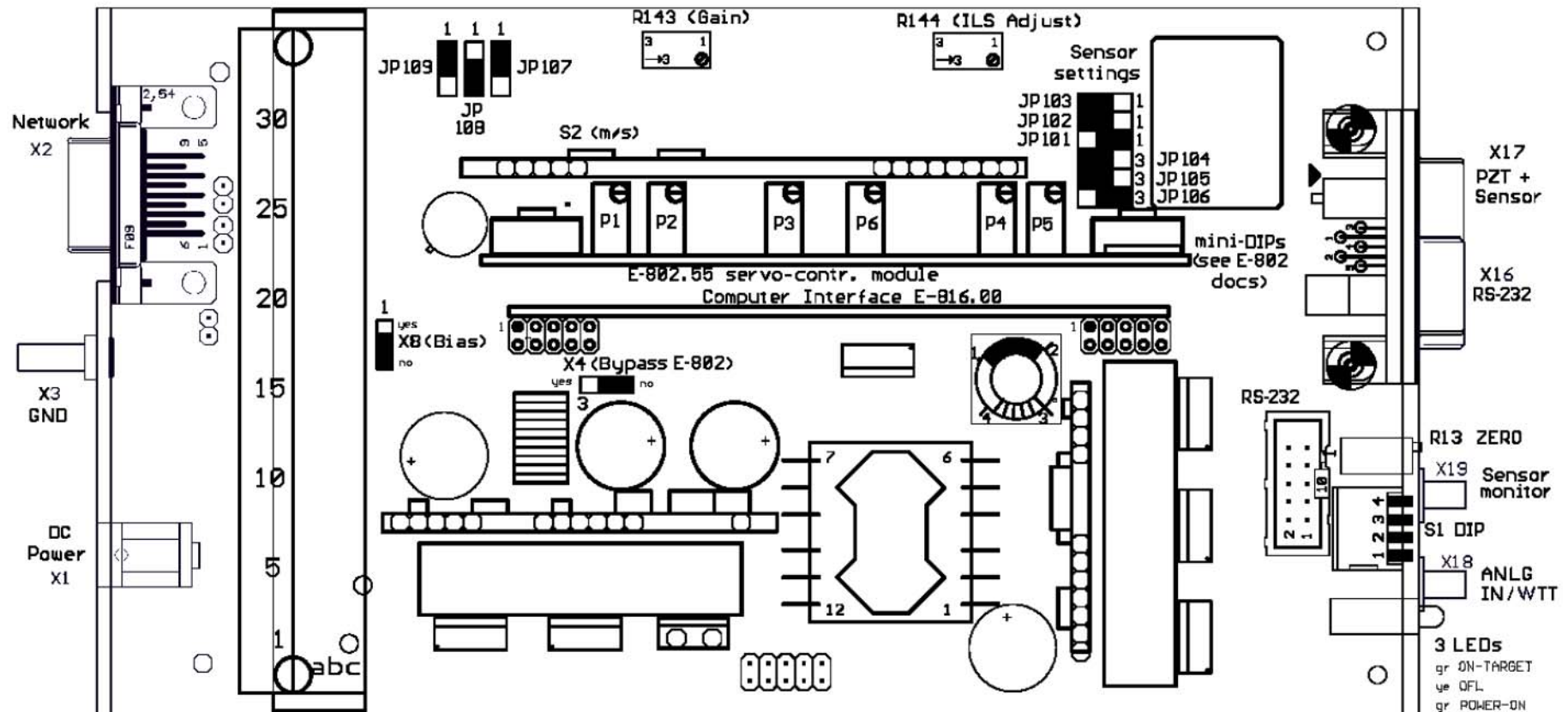


Fig. 4: E-625.CR (viewed from component side) component locations; adjustment elements shown in default settings

### 8.2.1 LEDs

Three LEDs are visible on the front panel:

ON TARGET	(green)	On target signal from E-802 submodule, indicates distance from target less than $\pm 0.19\%$ of range, TTL active-low
OVERFLOW	(yellow)	PZT output outside of -20 V to 120 V range
POWER ON	(green)	Unit powered up

### 8.2.2 Jumpers

Jumpers are also shown on the block diagram on p. 29.

#### X4 Servo mode, notch filter and slew rate bypass

- 1-2: E-802 submodule with servo-control, slew rate limitation and notch filter (E-802) is completely bypassed. No other combination of settings or commands can activate it.
- 2-3: Factory setting: the servo-control mode depends on other settings. With version 802.55, the slew rate limitation and notch filter are always ON, with earlier E-802 versions these functions are only active when servo-control is ON.

#### X8 Provision for DC offset potentiometer (not included or described):

- 1-2 activated (do not activate without rewiring)
- 2-3 deactivated



#### JP101-JP106 Sensor Measurement Range

measurement range extension factor		no measurement	0.56	0.68	0.75	1.0	1.25	2.13	3
Jumper Position	JP103								
	JP102								
	JP101								
	JP104								
	JP105								
	JP106								

Fig. 5: E-625.CR sensor range jumper settings

The jumper group is shown as arranged on the main board (see component map, p. 30). Units are delivered set as required for the attached stages. With no information on the stage, PI usually sets units to 1.0.

JP107 - JP109 shift the voltage range of the sensor processing circuitry. They must remain as set at the factory, i.e. for use with an E-802 Servo-Control submodule (positive polarity, 0-10 V)

Position of the Jumper JP107		
Polarity of Output	Positive	Negative

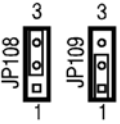
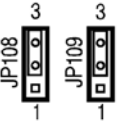
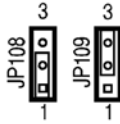
Typical Application	Using with PI's position control electronics	Using as a position detector	Special application
Position of Jumpers JP108 and JP109			
Voltage range of output	0V ~ 10V	-5V ~ +5V	-10V ~ 0V

Fig. 6: E-625.CR sensor processing output settings

### 8.2.3 Switches

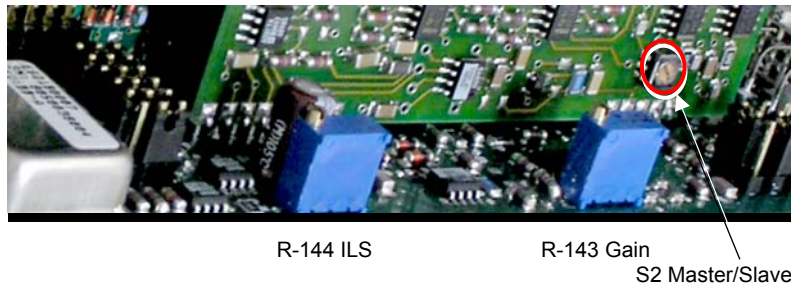
Switch block S1 is accessible through the front panel. (Do not confuse with the S1 damping control on the E-802 submodule, described in the E-802 User Manual).

sw1 (left switch)	ON (down)	Signal on Analog Input line used as analog input
	OFF (up)	Signal on Analog Input line not used as analog input
sw2	ON (down)	Computer interface submodule target used
	OFF (up)	Computer interface submodule target not used
sw3	ON (down)	Servo-on signal sent to servo submodule
	OFF (up)	Servo-on signal state depends on other control elements
sw4	ON (down)	Signal on Analog Input line used as wave table trigger
	OFF (up)	Signal on Analog Input line not used as wave table trigger

Unpredictable behavior may result if sw 1, 2 and 4 are set incompatibly. For admissible combinations, see E-625.CR Switch and Jumper Settings, p. 19.

Mini-DIP switches on the E-802.55 Servo-Control submodule: see the E-802 manual for description.

Switch S2 (master/slave) for capacitive sensor excitation synchronization (Do not confuse with the S2 mini DIP block on the E-802 submodule, described in the E-802 User Manual) in systems with multiple capacitive sensor units. One system remains as sensor master, the others must be set as slaves and the sync. lines of all must be bused together.



*Fig. 7: Sensor Master/Slave switch S2 (circled, near R-143 gain pot) on PCB soldered perpendicular to main board, shown in default Master position.*

### 8.2.4 Potentiometers

The calibration procedures involve setting a number of trim pots. The R13 Zero potentiometer is accessible through a hole in the front panel. It is necessary to open the case to adjust others, like R143 Sensor Gain and R144 ILS adjust, which are located on the main board, and the servo-control adjustments, which are on the E-802 submodule.

---

## 8.3 Sensor Synchronization

The sensor excitation frequency can be provided internally (S2 master setting) or externally (slave). On systems with multiple capacitive sensor units, synchronization is required. Set one unit to master, the rest to slave and make sure the sync lines of all and at least on ground line are bused (E-625.CR Network connector pins 7 and 8 and one of 1, 2, and 5).

---

## 8.4 E-802 Position Servo-Control Board

The E-802 is a small plug-in PCB that processes the control signal for the amplifier driving the piezoelectric translators. Slew rate limitation, notch filter and servo-control loop are all implemented on the E-802.

The servo-loop logic compares the control voltage input and the sensor signal to generate the amplifier control signal using an analog proportional-integral (P-I) algorithm.

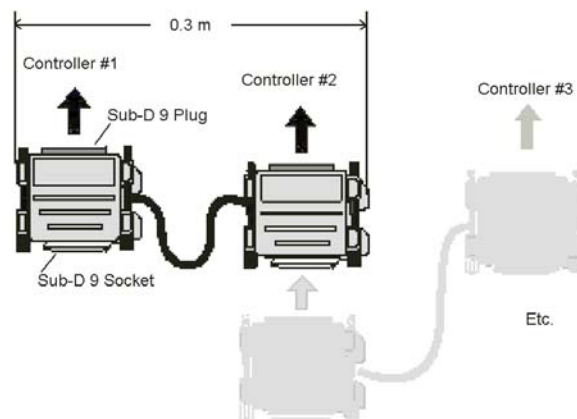
For calibration procedures, see "Servo-Control Static Gain Calibration", p. 24 and "Servo-Control Dynamic Characteristics", p. 27. The E-802 submodule is described in detail in a separate user manual.

## 8.5 Power Supply

E-625s come with a wide-range (100-240 VAC) 15 V power supply with a detachable line-power cord and a straight female cord plug (Tiny Q-G® Miniature Connector) matching the power connector in the controller. Replacements can be ordered from PI under E-661.PS

## 8.6 Network Cable

To network E-625s, a way of busing the required network lines is required. This can be done with E-625.CN cables (not included), which have piggyback sub-D connectors allowing more than one cable to be plugged into a single E-625. Because of length restrictions, at most 3 cables can be used.



*Fig. 8: E-625.CN networking cable*

## 9 Old Equipment Disposal

In accordance with EU directive 2002 / 96 / EC (WEEE), as of 13 August 2005, electrical and electronic equipment may not be disposed of in the member states of the EU mixed with other wastes.

To meet the manufacturer's product responsibility with regard to this product, Physik Instrumente (PI) GmbH & Co. KG will ensure environmentally correct disposal of old PI equipment that was first put into circulation after 13 August 2005, free of charge.

If you have such old equipment from PI, you can send it to the following address postage-free:

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





# 10 Technical Data

## 10.1 Specifications

Model	E-625.CR
Channels	1
Output voltage range	-20 to +120 V
Peak output current	140 mA (5 ms max.)
Max. average output current	60 mA
Max. average output power	6 W
Control input voltage range	-2 to 12 V
Voltage gain	10±0.1
Input impedance	> 100 kΩ
Bandwidth	see frequency diagram
Ripple of Uout	20 mVpp at low frequencies, 40 mVpp (spikes) at 30 kHz
Dimensions	205 x 105 x 60 mm
Weight	1.05 kg
Operating voltage range	12 to 30 VDC, max. ripple 50 mV pp (15 V recommended); E-661.PS takes 100-240 VAC, 47-63 Hz and provides 15 VDC
Operating current	2 A max.
Sensor type	Capacitive
Sensor excitation	100 kHz
Sensor monitor	0 to +10 V for nominal expansion
Controller output range	+/- 14.5 V
Overflow signal	TTL, active when amplifier output reaches limit
Computer interface	RS-232, 9-pin sub-D (male)
Sensor monitor	SMB connector
Analog input / wave table trigger connector	SMB
PZT output and sensor input connector	Sub-D special

## 10.2 Frequency Response Diagram

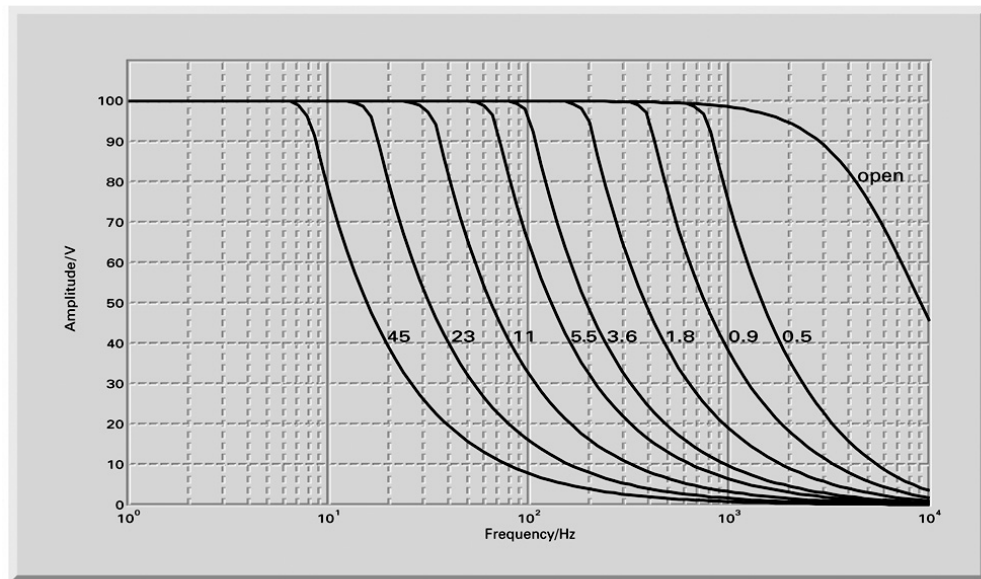
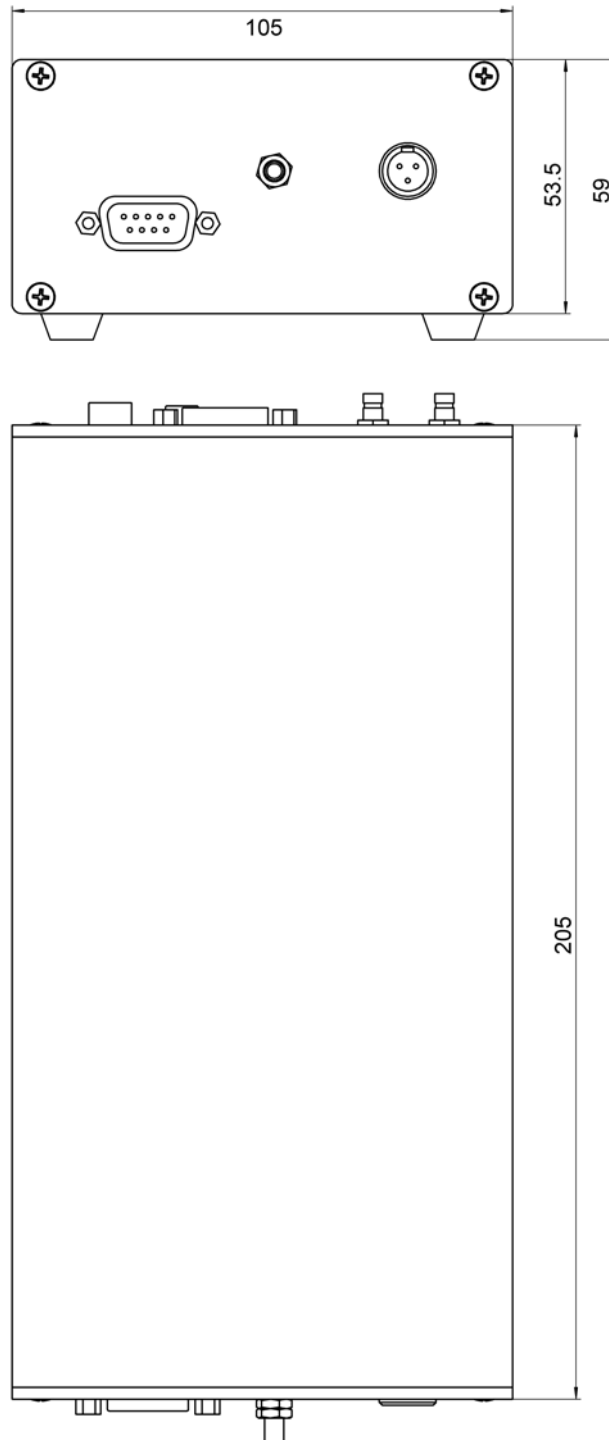


Fig. 9: E-625 open-loop frequency response with various PZT loads. Values shown are capacitance in  $\mu\text{F}$ , measured in actual PZT

## 10.3 Dimensions



*Fig. 10: E-625 dimensions in mm*

## 11 Pin Assignments



Fig. 11: E-625.CR front panel

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### 11.1 Analog IN / WTT

SMB coaxial, GND on outer line; depending on switch settings, interpreted either as target position or voltage ( -2 to +12 V on inner line), or as wave table trigger signal (TTL).

---

### 11.2 Sensor Monitor

SMB coaxial, GND on outer line, 0 to 10 V on inner line

---

### 11.3 Computer Interface

Sub-D 9 male, industry-standard RS-232. See the E-816 Computer Interface Submodule User Manual for interfacing information.

---

### 11.4 PZT and Sensor Connector

Special sub-D (X17) carrying both PZT drive and sensor lines.

- A1 PZT out
- A2 Sensor probe
- 1 ID-chip (not supported)
- 2 AGND target and ID GND
- 3 PZT GND (tied to case)
- 4 n.c.
- 5 Sensor target

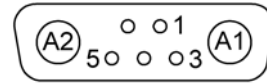


Fig. 12: E-625.CR rear panel

## 11.5 Network

Sub-D 9 female with the following pinout:

- |             |   |
|-------------|---|
| Pin 1,2 & 5 | GND   |
| Pin 3       | SCL (I <sup>2</sup> C networking)*                                  |
| Pin 4       | SDA (I <sup>2</sup> C networking)*                                  |
| Pin 7       | 100 kHz (networking with cap. sensors)                              |
| Pin 8       | 3.2 MHz (networking with cap. sensors)                              |
| Pin 6       | On-target output signal (within 0.19% of range),<br>TTL, active-low |
| Pin 9       | n.c.  |

\*The SCL and SDA bus lines are limited to a maximum length of 1 m and a maximum capacitance of 300 pF.

A cable with convenient piggy-back sub-D 9-pin connectors is available as E-625.CN for networking E-625s (see p. 35).

---

## 11.6 Power Connector

Pin 1 Power supply GND  
Pin 2 12 to 30 VDC (15 V  
recommended), stabilized  
Pin 3 n.c.



*Fig. 13: E-625 Power connector, viewed from outside case.*

---

## 11.7 Ground Stud

Because grounding is not assured over the power connection, the ground stud must be connected to a protective ground. Note that it, the metal case, and the PZT output ground are the same, but are not tied directly to the DC in or logic grounds.

# 12 Appendix

## 12.1 Internal 32-Pin Connector

The pinout of this internal connector is provided for informational purposes only.

Pin	Function	Pin	Function
<b>2a</b>	PZT output	<b>2c</b>	PZT output
<b>4a</b>	PZT GND (tied to case)	<b>4c</b>	PZT GND (tied to case)
<b>6a</b>	RS-232/RTS	<b>6c</b>	RS-232/CTS
<b>8a</b>	On-Target (TTL, active low)****	<b>8c</b>	RS-232/RX
<b>10a</b>	RS-232/TX	<b>10c</b>	Analog input / wave table trigger input (use depends on sw1 and sw4 settings)
<b>12a</b>	Pot* 10 kOhm (-10V)	<b>12c</b>	Pot* wiper
<b>14a</b>	Pot* 10 kOhm (GND)	<b>14c</b>	Pot* 10 kOhm (GND), also Test GND
<b>16a</b>	+VCC supply	<b>16c</b>	+VCC supply
<b>18a</b>	-VCC supply	<b>18c</b>	-VCC supply
<b>20a</b>	100 kHz in/out**	<b>20c</b>	nc (reserved)
<b>22a</b>	Monitor, sensor	<b>22c</b>	nc (reserved)
<b>24a</b>	3.2 MHz in/out**	<b>24c</b>	nc (reserved)
<b>26a</b>	Overflow (TTL, active-low)	<b>26c</b>	nc (reserved)
<b>28a</b>	Servo ON/OFF select	<b>28c</b>	nc (reserved)
<b>30a</b>	GND for RS-232	<b>30c</b>	nc (reserved)
<b>32a</b>	I <sup>2</sup> C SCL-signal***	<b>32c</b>	I <sup>2</sup> C SDA signal***

\* DC-offset pot is not included or described with this product. It is deactivated by jumper X8.

\*\* Cap. sensor networking sync lines are output if S2 set to Master, input if S2 set to Slave; they also appear on the Network connector.

\*\*\*The SCL and SDA bus lines are limited to a maximum length of 1 m and a maximum capacitance of 300pF; they appear on the Network connector.

\*\*\*\*On target signal from E-802 submodule, indicates distance from target less than  $\pm 0.19\%$  of range, TTL active-low

