PZ129E Operating Manual

E-651 / E-614 Controller / Amplifier

for Multilayer Bending Actuators

Release: 6.1.0 Date: 2019-11-18

This document describes the following Product(s):

- E-651.1S
  Piezo amplifier / servo controller for bending actuators, 1 channel, 0 to 60 V, strain gauge sensor, benchtop device
- E-651.2S
  Piezo amplifier / servo controller for bending actuators, 2 channels, 0 to 60 V, strain gauge sensor, benchtop device
- E-614.2BS
  Piezo amplifier / servo controller for bending actuators, 2 channels, 0 to 60 V, strain gauge sensor, OEM module

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For the E-651 / E-614, an EU Declaration of Conformity has been issued in accordance with the following European directives:

EMC Directive
RoHS Directive

The applied standards certifying the conformity are listed below.

Safety: EN 61010-1
EMC: EN 61326-1
RoHS: EN 50581

If an electrical operating device is designed to be integrated in another electrical operating device: The operator is responsible for a standards compliant integration of the electrical device into the overall system.

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1 Safety

1.1 Intended Use

The E-651 / E-614 is a laboratory device according to DIN EN 61010-1. It is intended to be used in interior spaces and in an environment which is free of dirt, oil and lubricants.

The E-651 / E-614 is designed and intended for driving of PICMA® multilayer bending actuators (i.e., capacitive loads) such as the PL-112 to PL-140, and P-871 from PI.

For closed-loop operation, the actuators must be equipped with strain gauge sensors, as this is the case with P-871 actuators.

The E-651 / E-614 must not be used for purposes other than those named in this user manual. In particular, the E-651 / E-614 must not be used to drive ohmic or inductive loads.

The E-651 / E-614 can be used for static as well as dynamic applications.

1.2 General Safety Instructions

The E-651 / E-614 is built according to state-of-the-art technology and recognized safety standards. Improper use can result in personal injury and/or damage to the E-651 / E-614.

- ➔ Only use the E-651 / E-614 for its intended purpose, and only use it if it is in a good working order.
- ➔ Read the user documentation (user manuals, Technical Notes).
- ➔ Immediately eliminate any faults and malfunctions that are likely to affect safety.

The operator is responsible for the correct installation and operation of the E-651 / E-614.

- ➔ Install the E-651 / E-614 near the power source so that the power plug can be quickly and easily disconnected from the
- ➔ mains.
- ➔ Use the supplied components to connect the E-651 / E-614 to the power source.
- ➔ If one of the supplied components for connecting to the power source has to be replaced, use a sufficiently dimensioned component.
- ➔ Only use cables and connections that meet local safety regulations.

Any resonant operation of the bending actuators should generally be avoided. Due to self-heating effects, the specified operating temperature range of the actuator could be exceeded rapidly and irreparable damage may occur.

- ➔ Power off the actuator immediately if you hear or see any resonant behavior. For the unloaded resonant frequency see the documentation of the actuator.

If an E-614 OEM module is operated without a housing, live parts will be accessible. Touching the live parts can result in minor injury. Electrical, magnetic and electromagnetic fields emitted by live parts can disturb the E-614 OEM module and/or the environment.

- ➔ Only operate the E-614 OEM module when it is installed in a shielded housing that securely encloses all live parts and fulfills the requirements of electromagnetic compatibility.
- ➔ Since parts of the circuit will store charge, precautions must also be taken when the E-614 OEM module is not powered. After switching off the E-614 OEM module, wait a minute before you touch parts of the E-614 OEM module to be sure that any residual voltage has dissipated.

If the E-651 benchtop device is operated with an open housing, live parts are accessible. Touching the live parts can result in minor injury.

- ➔ Only open the E-651 housing when you are authorized and have the corresponding qualifications.
- ➔ Before opening the housing, remove the E-651 from the power source by pulling the power plug.
- ➔ When operating with an open housing, do not touch any components in the housing aside from the adjustment elements mentioned in this user manual.

The E-651 / E-614 contains electrostatic-sensitive devices (ESD) that can be damaged if handled improperly.

- ➔ Avoid touching assemblies, pins and PCB traces.
- ➔ Before you touch the E-651 / E-614, discharge yourself of any electric charges, e.g., by wearing an antistatic wrist strap.
- ➔ Only handle and store the E-651 / E-614 in environments that dissipate existing static charges to earth in a controlled way and prevent electrostatic

charges (ESD protected workstation or electrostatically protected area, in short EPA).

➔ Before cleaning, disconnect the E-651 / E-614 from the power source by removing the mains plug.

1.3 Organizational Measures

User documentation (user manual, Technical Notes):

➔ Always keep this user documentation available by the E-651 / E-614.

➔ The latest versions of the user documentation are available from PI.

➔ Add all information given by the manufacturer to the user documentation, for example supplements or Technical Notes.

➔ If you pass the E-651 / E-614 on to other users, also turn over the user documentation as well as other relevant information provided by the manufacturer.

➔ Only use the device on the basis of the complete user documentation. Missing information due to an incomplete user documentation can result in minor injury as well as property damage.

➔ Only install and operate the E-651 / E-614 after having read and understood this user manual.

1.4 Personnel Qualification

The E-651 / E-614 may only be installed, started up, operated, and cleaned by authorized and qualified staff.

2 About this Document

This user manual contains information on the intended use of the E-651 / E-614.

It assumes that the reader has a fundamental understanding of basic servo systems as well as motion control concepts and applicable safety procedures.

2.1 Other Applicable Documents

Component	Document
E-801 Sensor Submodule	PZ117E User Manual
E-802 Servo-Control Submodule	PZ150E User Manual
E-614.2BS OEM module	E614T0003 Technical Note

2.2 Downloading Manuals

1 Open the website **www.pi.ws**.

2 Search for the product number (e.g., P-871) or the product family (e.g., PICMA® Bending) on the website.

3 Click on the product to open the product detail page.

4 Click on ***Downloads***.

The manuals are shown under ***Documentation***.

5 Click on the desired manual and fill in the inquiry form.

6 The download link will be sent to the e-mail address you entered.

If a manual is missing on our website or if there are problems in downloading:

➔ Contact our customer service department (p. 23).

3 Product Description

3.1 Control of Bending Actuators

The E-651 / E-614 is designed and intended for driving of PICMA® multilayer bending actuators such as the PL-112 to PL-140, and P-871 from PI.

The PICMA® bending actuators require full differential-voltage control with constant voltages of 0 V and +60 V and a variable voltage from 0 V to +60 V (see Fig. 1). Note that a control input voltage of 5 V corresponds to a PZT variable output of about +30 V, which puts the actuator in the middle position (i.e. deflection ≈ 0 µm).

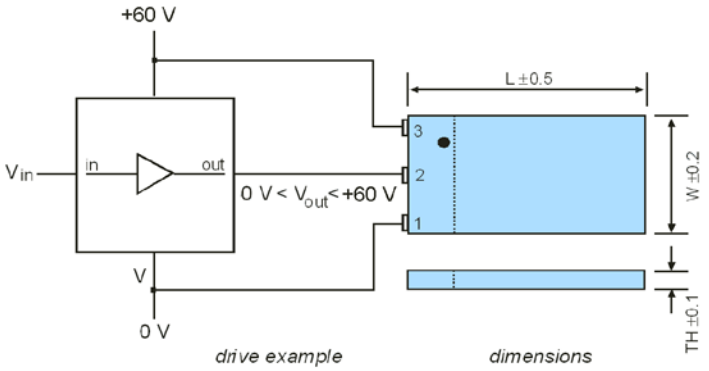


Fig. 1. PICMA® multilayer bending actuator with full differential-voltage control,
Pin assignment: 1 0 V [or GND]
2 0 V to +60 V
3 +60 V

3.2 Model Overview

E-651.1S	Piezo amplifier / servo controller for bending actuators, 1 channel, 0 to 60 V, strain gauge sensor, benchtop device
E-651.2S	Piezo amplifier / servo controller for bending actuators, 2 channels, 0 to 60 V, strain gauge sensor, benchtop device
E-614.2BS	Piezo amplifier / servo controller for bending actuators, 2 channels, 0 to 60 V, strain gauge sensor, OEM module Provides the same functionality as the E-651.2S 2-channel controller, but on a printed circuit board.

3.3 Scope of Delivery

PZ129E	User manual for E-651 / E-614, this document

E-651 benchtop devices only:

C-501.15050H	Wide-range, 15 V power supply, 50 W, with power cord (#3763)
E500T0011	Technical note for the analog driver for NI LabVIEW

E-614 OEM modules only:

E614T0003	Technical note showing the board's component and connection locations
PZ150E	User manual for the E-802 servo-controller submodule
PZ117E	User manual for the E-801 sensor submodule

3.4 Product View

This section describes the operating elements of the E-651 benchtop devices. A description of the E-614 OEM modules can be found in the E614T0003 technical note.

Fig. 2: E-651 front panel; elements for channel 2 are not present on single-channel models

Common elements:

ON (Power) LED	Power on/off indicator

Elements provided once per channel:

OFL LED	Lights up if the output voltage is outside the nominal output voltage range of the controller
SERVO ON/OFF	Switch for changing between open-loop (off) and closed-loop mode (on)
CONTROL IN	BNC connector for the analog control signal, -5 V to +5 V
SENSOR MONITOR	BNC connector for reading out the sensor signal (0 to 10 V) NOTICE → Do not apply any input voltage to the SENSOR MONITOR socket. This could cause damage to the electronics.
ZERO	This potentiometer shifts the output of the sensor processing circuitry
PZT & SENSOR	7-conductor LEMO connector with PZT outputs (constant +60 V and power-amp output 0 to +60 V), as well as sensor excitation (5 V DC) and sensor signal

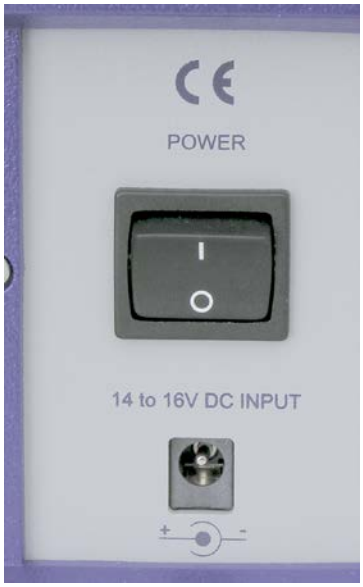


Fig. 3: E-651 rear panel details

POWER	ON/OFF switch
14 to 16V DC INPUT	Operating power input, socket for the barrel connector from the C-501.15050H power supply (included)

4 Operation

Note that upon delivery the system is ready for operation: all of PI's piezo positioning systems are delivered with performance test documents to verify the system performance, and calibration of the controller is done prior to delivery in our lab. Actuators and assigned controller channels are matched and should be kept together as a unit. The serial number of the assigned actuator is marked on the associated controller channel.

Normally, you do not need to calibrate the system. Only if the actuator, mechanical setup, cables to the bending actuator are replaced, or if a large change in operating temperature occurs, is recalibration necessary. Should you ever need to make a new full calibration, read “Calibration” on page 14.

4.1 Getting Started

This section gives instructions for the E-651 benchtop devices. Instructions for E-614 OEM modules can be found in the E614T0003 technical note.

➔ Do not interchange controller and/or actuators; they are matched and calibrated together. Respect the assignment of the actuators to the individual controller channels, as indicated by the serial numbers on the labels affixed to the devices.

Carry out the following steps to put the motion system into operation:

1. Connect the actuators to the proper controller channel(s) using the PZT & SENSOR socket(s). Handle the actuators with care and avoid any kind of mechanical shock.

2. Optionally: If you want to read out the sensor signal for a channel, connect a voltmeter (not included) to the appropriate SENSOR MONITOR socket.

3. With the POWER switch on the rear panel set to OFF, connect the controller to the C-501.15050H power supply (included) using the 14 to 16 VDC INPUT socket, and connect the power supply to the line power (100–240 VAC, 50/60 Hz).

4 Select the operating mode for each channel using the corresponding SERVO ON/OFF switch on the controller.
If SERVO is ON (closed-loop mode), the control input voltage is used as the target position value for the servo-control circuit, and determines the position of the bending. If SERVO is OFF (open-loop mode), the output voltage for the bending actuator is in direct linear relation to the control input voltage.

5 Connect a control-input voltage source (-5 V to +5 V DC) to the CONTROL INPUT socket for each controller channel.

6 Power up the E-651 controller using the POWER switch on the rear panel. The POWER LED on the front panel lights up.

7 Deflect the actuator(s): apply a control input voltage in the range from -5 V to +5 V to the channel(s).
You can monitor the actuator deflection with the SENSOR MONITOR signal (see step 2; 0 V to 10 V), even when the system is in open-loop mode.
If the output voltage corresponding to the control input signal is outside the output voltage range (0 to 60 V), the OFL (overflow) LED for the channel lights and remains on as long as the overflow condition persists.

4.2 Operating Modes

E-651 / E-614 controller/amplifiers can be operated in closed-loop or open-loop mode.

The position signal is available in either operating mode in the form of a sensor monitor signal from 0 to 10 V. Note that +5 V corresponds to mid-position of the actuator.

4.2.1 Closed-Loop Operation

In closed-loop mode, it is the **deflection** (position) of the actuator that is controlled by the control input signal, which is processed by the E-802 servo-control submodule (see section 4.3.2).

A channel of an E-651 benchtop device is in closed-loop mode if the corresponding SERVO switch on the front panel is set to ON.

For information on E-614 OEM modules, see the E614T0003 technical note.

4.2.2 Open-Loop Operation

In open-loop mode the variable output voltage for the actuator is controlled by the control input signal (this output voltage for the actuator is in direct linear relation to the control input voltage).

A channel of an E-651 benchtop device is in open-loop mode if the corresponding SERVO switch on the front panel is set to OFF.

For information on E-614 OEM modules, see the E614T0003 technical note.

4.3 On-Board Submodules

Each E-651 / E-614 channel is equipped with submodules for sensor processing (E-801) and servo-control (E-802).

4.3.1 E-801 Submodule for Strain Gauge Sensor Processing

This submodule is used for excitation and evaluation of one strain gauge sensor (SGS). It is designed as a plug-in submodule to be used on different PCBs.

The submodule supplies the strain gauge with a DC voltage and generates a signal proportional to the expansion changes of the strain gauge. Located on the submodule is a sensor gain adjustment and settings for a low-pass filter.

See the SGS portions of the E-801 User Manual (PZ117E) for details.

4.3.2 E-802 Position Servo-Control Submodule

The E-802 submodule produces an analog control signal for the power amplifier driving the actuator. 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 (target) and the sensor signal (current position) to generate the amplifier control signal using an analog proportional-integral (P-I) algorithm.

For calibration procedures, see “Calibration” and the E-802 Servo-Control Submodule User Manual (PZ150E).

5 Calibration

Note that upon delivery the system is ready for operation: all of PI's positioning systems with a piezo actuator are delivered with performance test documents to verify the system performance, and calibration of the controller is done prior to delivery in our lab. Actuators and assigned controller channels are matched and should be kept together as a unit. The serial number of the actuator assigned to each channel is marked on the individual controller.

Normally there is no need for you to recalibrate the system. Only exchanging the actuator, the mechanical setup, replacing the cables on the actuator or making a large change in the operating temperature, may make recalibration necessary.

The only procedure which is necessary from time to time is the zero-point adjustment (see below). All other calibration procedures—static gain adjustment[1] and dynamic calibration[2]—require special equipment and should only be done by qualified personnel and are required only in special circumstances. See the user manuals for the sensor processing and servo-control submodules (E-801 and E-802) for details regarding those procedures.

5.1 Equipment Needed

Zero-point adjustment requires a voltmeter and a small straight-bladed screw driver.

5.2 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. If an overflow condition occurs (OFL LED lights up for the channel), it can often be prevented by re-adjusting the ZERO point.

The zero-point of each channel is adjusted with the appropriate ZERO potentiometer (E-651: ZERO potentiometer for each

[1] The objective of static gain adjustment is to ensure that the actuator expands to its nominal expansion in "positive" direction when a control signal input of +5 V is applied (with DC-offset disabled).
[2] Dynamic calibration optimizes step response and suppresses resonance, overshoot, and oscillation.

channel accessible through the front panel, p. 8; E-614: R132 for channel 1, R133 for channel 2). This potentiometer shifts the output of the sensor processing circuitry and hence the values on the sensor monitor output (E-651: front panel; E-614: MON-DMS1 and MON-DMS2 test points) and sensor-input lines of the servo-loop submodule.

For the operating elements of the E-651 benchtop devices see p. 8.

For the location of the potentiometers, connectors, switches and jumpers of the E-614 OEM board see the E614T0003 technical note.

To adjust the zero-point for a channel proceed as follows:

1. Before powering up the system, make sure the 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 actuators are always connected to the same controller channels.
2. Make sure the analog control input (E-651: front panel; E-614: connector X20) is at 0 V.
3. Set the channel to open-loop mode (E-651: SERVO OFF; E-614: EC/VC switch to VC)
4. E-614 only: close jumper X7 (channel 2) and X10 (channel 1) to disable any DC offset potentiometer.
5. Power up the system.
6. Deflect the actuator over its full range by sweeping the control input signal over the range of -5 V to +5 V.
7. Hold the control input signal at -5 V.
8. Adjust the ZERO potentiometer so that the sensor-monitor signal is 0 V.

Normally the zero-point adjustment can be finished at this point. Now you can switch the channel to closed-loop mode and deflect the actuator over the full range by applying a control input voltage of -5 to +5 V. The overflow LED should not light up. If the overflow LED does light, repeat steps 2 to 8.

Failure of the zero-point re-adjustment (i.e. overflow LED still lights up) could indicate a serious problem. See "Calibration" for information on how to proceed.

6 Troubleshooting

6.1 Typical Problems

Problem	Possible Causes	Solutions
Actuator does not move	Cables not connected or connected to wrong socket	Check the connecting cables
	Cable is defective	Contact our customer service department (p. 23).
	Bending actuator defective	Replace actuator with a working one, to test a new combination of actuator and controller (note that if you want to use the new actuator in regular operation a fully recalibration of the system is required) and contact our customer service department (p. 23).
	Control input voltage source defective	Repair or replace voltage source
	Controller will not power up	Check POWER LED (with E-614 not included), power supply and line voltage connection
Overflow LED lights up	Commanded output voltage outside the allowed range (0 to +60 V)	Re-adjust the zero-point (see p. 14). If this is not successful, contact our customer service department (p. 23).
	Control input signal outside the allowed range (-5 V to +5 V)	Use a suitable control input signal

6.2 Opening the E-651 Housing

Should it ever be necessary to open the E-651 housing, e.g. for a static gain adjustment procedure, proceed as follows:

1. Switch off the controller and disconnect the power supply.
2. Use a Torx 8 driver to unscrew the 2 screws in the blue frame on the rear panel and carefully remove the rear panel.
3. Use the Torx 8 driver to unscrew the 2 screws in the blue frame on the front panel. Carefully remove the front panel, which also pulls the PCB out of the housing (the rear panel must be turned and pulled carefully through the housing too).
4. Reconnect the power supply to the socket on the rear panel. Keep the system powered down.

Note that some adjustment elements on the main board and on the E-801 and E-802 submodules are covered with sealing lacquer. Damage to the seal will void the warranty except in consultation with PI.

7 Technical Data

7.1 Specifications

	E-651.1S	E-651.2S / E-614.2BS
Function	Piezo amplifier and position controller for multilayer bending actuators, benchtop device	Piezo amplifier and position controller for multilayer bending actuators E-651.2S: benchtop device E-614.2BS: OEM module
Channels	1	2
Sensor		
Controller type	P-I (analog)	P-I (analog)
Sensor type	SGS	SGS
Sensor bandwidth	Low-pass filter frequency: 300 Hz / 1 kHz / 3 kHz selectable	Low-pass filter frequency: 300 Hz / 1 kHz / 3 kHz selectable
Amplifier		
Input voltage range	-5 to 5 V	-5 to 5 V
Min. output voltage	0 to 60 V, additional fixed voltage of 60 V	0 to 60 V, additional fixed voltage of 60 V
Max. output power (<5 ms)	1 W	1 W / channel
Average output power	0.5 W	0.5 W / channel
Peak current (<5 ms)	36 mA	36 mA / channel
Average output current	18 mA	18 mA / channel
Current limitation	Short-circuit proof	Short-circuit proof
Voltage gain	6	6
Input impedance	100 kΩ	100 kΩ

Interfaces and operation	E-651.1S	E-651.2S	E-614.2BS
Piezo / sensor connector	LEMO EPG.0B.307.HLN	LEMO EPG.0B.307.HLN	Separate pin headers for piezo output and sensor
Analog input / control input socket	BNC	BNC	Pin header
Sensor monitor output	0 to 10 V for nominal displacement	0 to 10 V for nominal displacement	0 to 10 V for nominal displacement
Sensor monitor socket	BNC	BNC	Pin header
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	5 to 50 °C
Overheat protection	Deactivation at 75 °C	Deactivation at 75 °C	Deactivation at 75 °C
Dimensions	125 mm × 90 mm × 265 mm	125 mm × 90 mm × 265 mm	100 mm × 40 mm × 200 mm
Mass	1.36 kg	1.45 kg	0.3 kg
Operating voltage	14 to 16 V DC (power adapter in the scope of delivery)	14 to 16 V DC (power adapter in the scope of delivery)	14 to 16 V DC

7.2 Maximum Ratings

The E-651 / E-614 is designed for the following operating data:

Maximum Operating Voltage	Operating Frequency	Maximum Power Consumption
16 V	⎓	E-651.1S 20 W E-651.2S: 25 W E-614.2BS: 25 W

7.3 Ambient Conditions and Classifications

The following ambient conditions and classifications must be observed for the E-651 / E-614:

Area of application	For indoor use only
Maximum altitude	2000 m
Relative humidity	Highest relative humidity 80% for temperatures up to 31°C Decreasing linearly to 50% relative humidity at 40°C
Operating temperature	5 to 50 °C
Storage temperature	0°C to 70°C
Transport temperature	–25°C to +85°C
Overvoltage category	II
Protection class	I
Degree of pollution	2
Degree of protection according to IEC 60529	IP20

7.4 Pin Assignment

For the pin assignment of the connectors on the E-614 OEM board see the E614T0003 technical note.

7.4.1 E-651 PZT & SENSOR connector

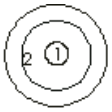
LEMO connector EPG.0B.307.HLN

Pin	Function
1	GND (actuator)
2	Sensor input (-)
3	Sensor input (+)
4	GND (SGS)
5	+ 60 V
6	Variable output voltage (actuator control)
7	SGS reference voltage

7.4.2 C-501.15050H Power Supply

3.34A @+15VCD output,
100-240 VAC input

1: Center pin, +15VDC, 2.1 mm diameter
2: GND



8 Cleaning

E-651 bench-top units only:

1 Disconnect the E-651 from the power source.

2 Wait a minute to be sure that any residual voltage has dissipated.

3 Clean the housing surfaces of the E-651 using mild detergents or disinfectant solutions. Prevent cleaning fluid from penetrating the housing.

9 Customer Service

For inquiries and orders, contact your PI sales engineer or send us an email (mailto:service@pi.de).

➔ If you have any questions concerning your system, provide the following information:

- Product and serial numbers of all products in the system
- Firmware version of the controller (if applicable)
- Version of the driver or the software (if applicable)
- Operating system on the PC (if applicable)

➔ If possible: Take photographs or make videos of your system that can be sent to our customer service department if requested.

Only PI service personnel must repair the E-651 / E-614.

The latest versions of the user manuals are available for download on our website.

10 Old Equipment Disposal

In accordance with EU law, electrical and electronic equipment may not be disposed of in EU member states via the municipal residual waste.

Dispose of your old equipment according to international, national, and local rules and regulations.

In order to fulfil its responsibility as the product manufacturer, Physik Instrumente (PI) GmbH & Co. KG undertakes environmentally correct disposal of all old PI equipment made available on the market after 13 August 2005 without charge.

Any old PI equipment can be sent free of charge to the following address:

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