

PZ170E User Manual  
E-481 High-Performance Piezo  
Amplifier/Controller  
Release: 1.2.0. Date: 03.06.2013



This document describes the following product:

- E-481.00  
High-Performance Piezo Amplifier/Controller  
with Energy Recovery, 1 Channel



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## About this Document

## Users of this Manual

This manual is designed to help the reader to install and operate the E-481 High-Performance Piezo Amplifier/Controller. 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-481 High-Performance Piezo Amplifier/Controller as well as the installation procedures which are required to put the system into operation.

## 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.



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### CAUTION

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

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### NOTE

Provides additional information or application hints.

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Any optional elements which might be mentioned in this documentation are described in their own manuals. Current releases can be downloaded from the PI Website as PDF files (<http://www.pi.ws>), obtained from your Physik Instrumente sales engineer or from [info@pi.ws](mailto:info@pi.ws) (<mailto:info@pi.ws>).

# Contents

1	Introduction	3
1.1	Overview .....	3
1.2	Intended Use .....	4
1.3	Safety Precautions.....	5
1.4	Additional Equipment.....	6
1.5	Unpacking .....	7
2	Operation	8
2.1	Calibrated System .....	8
2.2	Setup.....	8
2.3	Operating Elements.....	9
2.3.1	Front and Rear Panel Elements .....	9
2.3.2	Selection Pin for Output Voltage Range.....	10
2.4	Line Voltage Connection.....	12
2.5	Actuator Connection .....	13
2.5.1	Bipolar Piezo Actuators .....	13
2.5.2	Unipolar Piezo Actuators .....	13
2.5.3	Wiring Example.....	14
2.6	Temperature Sensor Connection .....	14
2.7	Control Signal Generation.....	14
2.7.1	Analog Operation.....	14
2.7.2	Remote Control via Computer Interface .....	15
2.7.3	Output Voltage Manipulation .....	15
2.8	Modes of Operation .....	16
2.8.1	Open-Loop Operation .....	16
2.8.2	Closed-Loop Operation .....	16
2.9	First Operation.....	17
2.10	Zero-Point Adjustment (with E-509 only).....	18
2.11	Protection Against Overheating .....	20
3	Maintenance	22
3.1	AC Power and Line Power Fuses .....	22
3.2	Cleaning .....	23
4	Software Download	24
5	Troubleshooting	25

6	Customer Service	26
7	Technical Data	27
7.1	Specifications .....	27
7.2	Frequency Response Diagram .....	28
7.3	Block Diagram .....	29
7.4	Signal Path with Servocontroller and PC-Interface Modules .....	30
7.5	Pin Assignments .....	32
7.5.1	2-Pin High-Voltage Connector .....	32
7.5.2	Temperature Sensor .....	33
8	Appendix	34
8.1	Protective Air Quality Requirements .....	34
8.2	How to Measure the Amplifier Output .....	34

# 1 Introduction

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## 1.1 Overview

The E-481 high-power piezo amplifier/controller is specifically designed for dynamic operation of high-capacitance PICA piezo actuators.

The E-481 is based on a novel design combining pulse width modulation and energy recovery. Instead of dissipating the reactive power in heat sinks, this energy is temporarily stored in inductive elements. Only the active power used by the piezo actuator has to be delivered. The energy not used by the actuator is returned to the amplifier and reused as supply voltage via a step-up transforming process. A peak sink and source current of up to 2000 mA is possible.

### Selectable Output Range

The output range can be set to positive, negative or bipolar, and provides a voltage swing of 1100 V in open-loop operation.

### Open-Loop and Closed-Loop Operation

E-481 amplifiers can be used to drive open- and closed-loop piezo positioning systems.

For open-loop piezo operation the amplifier output voltage is determined by the analog signal at the Control In socket combined with the DC-offset potentiometer setting. Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop. The control signal can be adjusted by various settings.

### Optional Servo Controller Upgrade

The E-481.00 allows easy installation of an optional E-509 sensor- / servo-controller module for closed-loop piezo position control. In this mode the amplifier is slaved to the E-509 servo controller. Depending on the attached piezo mechanics and feedback sensor, positioning accuracy and repeatability in the nanometer range and below are feasible.

### Computer Control

Control via PC by installing the E-517 digital piezo controller operation module is also possible.

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit technology providing enhanced system resolution.

### Thermal Piezo Protection Circuit

The E-481 features a temperature sensor input and control circuit to shut down the amplifier if the connected piezo actuator exceeds a maximum temperature threshold.

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## 1.2 Intended Use

Based on their design and realization, E-481 High-Performance Piezo Amplifier/Controllers are intended to drive capacitive loads, in the present case, piezoceramics (“piezo actuators”). E-481 must not be used for applications other than stated in this manual, especially not for driving ohmic (resistive) or inductive loads.

If upgraded with an E-509 servo-control module, E-481 can be operated in closed-loop mode using a position sensor (LVDT, SGS or capacitive 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-481s meet the following ambient conditions and classifications:

- Indoor use only
- Max. altitude for operation 3500 m
- Operating temperature range 5 °C to 40 °C
- Storage temperature range 0 °C to +70 °C
- Shipping temperature range -25 °C to +85 °C
- Max. relative humidity 80 % for temperatures up to 31 °C, decreasing linearly to 50 % relative humidity at 40 °C
- Line voltage fluctuations not greater than  $\pm 10\%$  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).
- Overvoltage category: II
- Protection class: I
- Degree of pollution: 2

## 1.3 Safety Precautions



### WARNING

On the “PZT Out” Lemo socket of the E-481, output voltages up to 1150 V can be present. These voltages will cause death or serious injury.

Working with the E-481 requires adequately trained and educated operating personnel.

Operate the piezo actuator on the “PZT Out” socket only when it is connected to a protective earth conductor.



### WARNING

Connect the AC power cord of the E-481 to the wall socket (100 to 120 V ~ or 220 to 240 V ~).

Two new line power fuses are required when changing the supply voltage. See p. 22 for more information.

To disconnect the system from the power supply completely, remove the power plug from the wall socket, or remove the power cord from the E-481.

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



### WARNING

Changing the output voltage range requires opening the case and must be carried out by authorized, qualified personnel only.

Disconnect unit from power supply completely before opening the case.



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## CAUTION

Place the E-481 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.

The device needs to be installed horizontally. Vertical mounting prevents internal convection.

Never cover the ventilation slots as this will impede ventilation.

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## CAUTION

Exposing piezo actuators to voltages too far outside their operating range will destroy the active element in the actuator. When changing the output voltage range, make sure that both the polarity and the voltage as seen by the piezo actuator are within the allowable range.

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## 1.4 Additional Equipment

The E-481 is upgradable with a servo-control module (E-509), and/or a digital piezo controller operation module (E-517, E-515 for display only). These modules come installed directly in the E-481 case. If the servo module and a piezo actuator are ordered with the system, your E-481 will be fully calibrated before being shipped.

Contact your PI sales engineer or write [info@pi.ws](mailto:info@pi.ws), if you want to upgrade your E-481. Any additional modules are described in their own separate manuals.

The following products are available:

E-509.C1A, E-509.S1	Sensor / Servo-Controller Module for capacitive or SGS position sensors respectively, 1 channel to eliminate drift and hysteresis from positioning operations.
E-517.i1	Digital Piezo Controller Operation Module; 24-bit D/A; TCP/IP, USB, RS-232, IEEE 488 (GPIB); 1 Channel; displays the current voltage and, if servo-module also present, the position of the PZT. DLL, COM, LabVIEW; convenient interactive user interface software for host PC is provided.
E-515.01	Display Module for PZT Voltage and Position, 1 channel

- E-500.ACD**      CD with Driver Set for Analog Controllers, available free of charge upon request  
 Computer control can be implemented using a DAC-board in a PC to generate the analog input signal. PI offers a LabVIEW driver set which can be used with certain D/A boards. This driver set is compatible with the PI General Command Set (GCS) LabVIEW driver set available for all newer controllers from PI.  
 The PI Analog Controller drivers support all D/A converter boards from National Instruments that are compatible with DAQmx8.3. LabVIEW compatibility is given from version 7.1 upwards. Connection of a sensor monitor signal from a sensor- or servo-module (e.g. E-509) is required.  
 The driver set is also available for download from the PI website.
- E-500.HCD**      Access to HyperBit Functionality for Enhanced System Resolution  
 (Supports certain D/A boards.)  
 PI's patented Hyperbit technology for providing position resolution higher than that of the D/A board is in the E-500.ACD driver set. Activating Hyperbit requires purchase of the password, which can be obtained from PI under Order No. E-500.HCD.

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## 1.5 Unpacking

Unpack the E-481 High-Performance Piezo Amplifier/Controller with care. Compare the contents against the items covered by the contract and against the packing list.

The following components are included:

E-481.00	Amplifier
3763	Line cord
000016103	Dummy plug for the temperature sensor socket (LEMO FFA.OS.303.CLAC32)
PZ170E	User manual (this document)
E500T0011	Technical Note for GCS LabVIEW driver set

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 case the product need be shipped again.

## 2 Operation

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### 2.1 Calibrated System

If a controller with an included servo module is ordered together with a piezo actuator, the system will be fully calibrated at PI according to your specifications before being shipped, and will come with a calibration information sheet.

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#### NOTES

Calibration should only be done by qualified authorized personnel after consultation with PI.

If you inform PI about your application, your E-481s 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.

Do not interchange controller (whole devices or individual modules) and/or piezo stages if they are matched and calibrated together. Respect the assignment of the piezo actuators to the individual controller channels, as indicated by the serial numbers on the labels affixed to the devices. With multi-axis stages respect the channel/axis assignments indicated by the cable labeling

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### 2.2 Setup

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#### CAUTION

Place the E-481 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.

The device needs to be installed horizontally. Vertical mounting prevents internal convection.

Never cover the ventilation slots as this will impede ventilation.

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The E-481 amplifier is suitable for mounting in a 19" rack.

## 2.3 Operating Elements

### 2.3.1 Front and Rear Panel Elements

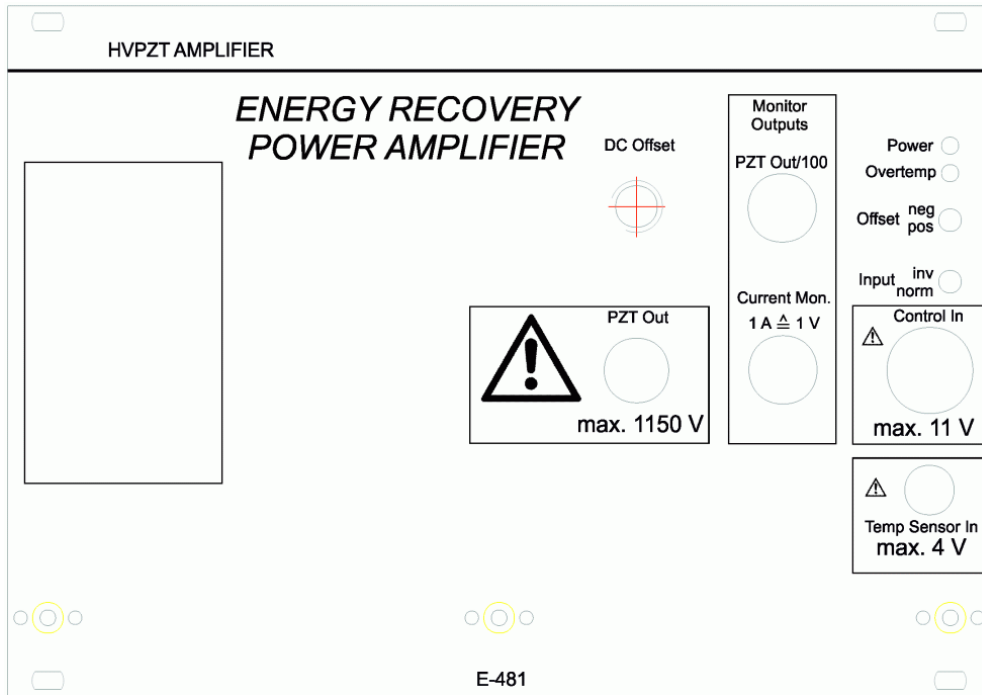





Figure 1: E-481 front panel

Element	Function
DC Offset	10-turn potentiometer for DC Offset (see p. 14 for details)
PZT Out 	LEMO socket, high-voltage output for the piezo actuator (pinout on p. 32, further details on p. 10 and p. 15). The maximum voltage swing is 1100 V.
PZT Out/100	BNC socket, monitor output for the voltage of the high-voltage output: 100 V output voltage correspond to 1 V monitor voltage
Current. Mon. 1A ≙ 1V	BNC socket, monitor output for the current of the high-voltage output: 1 A output current corresponds to 1 V monitor voltage
Power	LED, steady green during operation

Element	Function
Overtemp	LED, lights up red if the temperature on the connected temperature sensor exceeds 85 °C, the high-voltage output is then deactivated (p. 25)
Offset	Toggle switch, inverts the sign of the DC-offset voltage (see p. 14 for details)
Input	Toggle switch, inverts the sign of the amplifier input signal (see p. 15 for details)
Control In 	BNC socket for external analog control signal, 11 V max. input swing in the range of -10 to +10 V (see p. 14 for details) Measurement category I
Temp Sensor In 	LEMO socket for a PT1000 temperature sensor (p. 14) or dummy plug, max. 4 V input Measurement category I
Overload Not shown in the figure above.	LED, lights red if malfunction occurs (p. 25)

The controls of the optional servo-control (E-509) and PC interface/display (E-517, E-515) modules are described in their own separate manuals.

The following elements are located on the rear side of the E-481:

- Line voltage connection (p. 12)
- Line power fuses (p. 22)
- On/off switch
- Selection pin for output voltage range (see below; accessible only when the rear panel is removed)

### 2.3.2 Selection Pin for Output Voltage Range

**WARNING**

Changing the output voltage range requires opening the case and must be carried out by authorized, qualified personnel only.

Disconnect unit from power supply completely before opening the case.



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## CAUTION

Make sure that the red selection pin is plugged. Otherwise the piezo actuator can be damaged due to improper grounding.

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## CAUTION

Exposing piezo actuators to voltages too far outside their operating range will destroy the active element in the actuator. When changing the output voltage range, make sure that both the polarity and the voltage as seen by the piezo actuator are within the allowable range.

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The following output voltage ranges are available:

0 to	1100 V (default)
-260 to	+780 V
-550 to	+550 V
+260 to	-780 V
0 to	-1100 V

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## NOTES

The labels inside of the case show the recommended nominal output voltage ranges. The available output voltage swing is as listed above (max. 1100 V).

The polarity of the output voltage can be inverted using the “Input” toggle switch on the E-481 front panel, see p. 15 for details.

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The default setting for the output range is “0... +1000 V”. This setting can be changed by moving an internal selection pin inside the case.

To change the output voltage range, proceed as follows:

- 1 Disconnect the E-481 from the power supply completely.
- 2 Remove the rear panel of the case.
- 3 Change the output voltage range by re-plugging the red selection pin (see figure below).
- 4 Remount the rear panel.

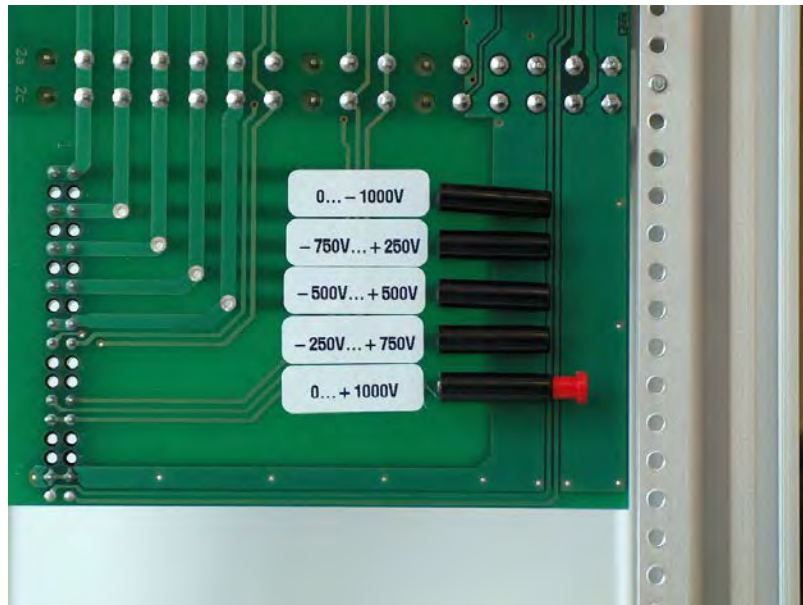


Figure 2: Selection of E-481 output voltage range

## 2.4 Line Voltage Connection

### WARNING

Connect the AC power cord of the E-481 to the wall socket (100 to 120 V ~ or 220 to 240 V ~).

To disconnect the system from the power supply completely, remove the power plug from the wall socket, or remove the power cord from the E-481.

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



Unless you request otherwise, upon delivery the E-481 will be set up for the voltage predominant in your country, either

100 to 120 V ~ / 50 — 60 Hz

or

220 to 240 V ~ / 50 — 60 Hz

To adapt the E-481 to a different line voltage, the two line power fuses must be replaced. See AC Power and Line Power Fuses (p. 22) for instructions and for the required fuse types.

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## 2.5 Actuator Connection



### WARNING

On the “PZT Out” socket of the E-481, output voltages up to 1150 V can be present. These voltages will cause death or serious injury.

Working with the E-481 requires adequately trained and educated operating personnel.

Operate the piezo actuator on the “PZT Out” socket only when it is connected to a protective earth conductor.

Connect your piezo actuator to the “PZT Out” socket of the E-481 amplifier.

If you order the actuator and controller together, and/or provide PI with sufficient information about your application, the actuator connector will be wired as required.

If you are connecting other actuators or wiring your own connector, read the discussion of actuator type carefully and any documentation that came with the actuator.

### 2.5.1 Bipolar Piezo Actuators

Here the output voltage swing is so chosen that the actuator sees both negative and positive high voltages. The output always has one lead at 0 V, and here the other is in a zero-crossing range, commonly  $\pm 500$  V.

### 2.5.2 Unipolar Piezo Actuators

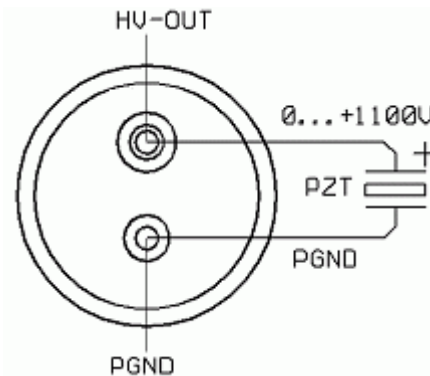
The notation of “positive” and “negative” polarity of piezo actuators does not refer to their direction of motion. Unipolar piezos of any polarity will elongate when a higher voltage is applied to their (+) than to their (-) terminal. “Positive” and “negative” refers to the sign of the voltage on the core of the cable.

All standard PI piezo actuators with 2-conductor LEMO connectors have positive polarity.



### 2.5.3 Wiring Example

In the wiring example shown at right, a “positive” piezo is connected so as to have 0 to +1100 V applied. To achieve this, the positive terminal (possibly labeled “+1100 V”) is connected to the variable HV-Out and the negative terminal to PGND.



## 2.6 Temperature Sensor Connection

E-481 amplifier modules are equipped with a temperature monitoring circuit to avoid overheating of the connected mechanics. It can be used with PT1000 temperature sensors.

Connect the PT1000 to the “Temp Sensor In” Lemo socket on the front panel of the E-481 (connection details on p. 33). When the mechanics connected to the E-481 does not feature a temperature sensor, the included dummy plug (order No. 000016103) must be used.

When a temperature of 85 °C is detected on the mechanics, the E-481 temperature monitoring circuit deactivates the high-voltage output of the amplifier (“PZT Out” socket), and the red “Overtemp” LED on the front panel lights up. See p. 20 for how to proceed in this case.

## 2.7 Control Signal Generation

### 2.7.1 Analog Operation

The E-481 can be operated by an analog control signal (“CONTROL OUT” in the signal path diagram on p. 31). The CONTROL OUT signal is the sum of the signal on the “Control In” BNC socket and the offset voltage set with the “DC Offset” potentiometer. Due to the constant amplifier gain of 100, the range of the CONTROL OUT signal is 1/100 of the output voltage range (p. 10). The signal may not have an active swing more than 11 V wide, or 10 V for Servo ON.

Output voltage (if in open-loop mode) or actuator position (closed-loop mode) are directly proportional to the CONTROL OUT signal.

### “Control In” signal

An external voltage can be applied to the “Control In” BNC socket. The signal applied to the “Control In” BNC socket can also be generated using a DAC-board in a PC. PI offers a LabVIEW driver set which can be used with certain D/A boards. This driver set is compatible with the PI General Command Set (GCS) LabVIEW driver set available for all newer controllers from PI. In addition, PI’s patented Hyperbit technology for providing position resolution higher than that of the D/A board is in the E-500.ACD driver set (see “Additional Equipment” p. 6).

### “DC Offset” potentiometer

Depending on the position of the potentiometer, a DC voltage between 0 and 10 V is made available. If you require a constant DC-offset (e.g. 0), make sure the knob stays at the required position.

Due to the constant gain of 100, the range of the CONTROL OUT signal is set to 1/100 of the output voltage range (p. 10). If the signal on the “Control In” BNC socket does not already have a range of 1/100<sup>th</sup> of the desired output voltage range, the following adjustments can be made in order to be able to use the full output voltage range:

- Shift with DC Offset: Use the DC-offset potentiometer to add a constant to the “Control In” signal so that CONTROL OUT is 1/100 of the desired output. The possible offset runs from 0 to 10 V or 0 to -10 V, depending on the offset polarity.
- Reverse the offset polarity: The “Offset” toggle switch changes the sign of the DC-offset voltage. “pos” provides offsets from 0 to 10 V, “neg” offsets from 0 to -10 V.

For closed-loop operation with an E-509 servo-control module, CONTROL OUT must be in the 0 to 10 V range.

## 2.7.2 Remote Control via Computer Interface

E-481 models equipped with an E-517 digital piezo controller operation module can be controlled from a host computer via TCP/IP, USB, RS-232 or IEEE488 interface. See the E-517 User Manual for details.

## 2.7.3 Output Voltage Manipulation

You can invert the polarity of the output voltage by inverting the polarity of the amplifier input signal (AMPLIFIER IN in the signal path diagram on p. 31; the output voltage is labeled “PZT HV OUT” there). To do this, use the “Input” toggle switch on the E-481 front panel:

- “inv” means that the polarity of the AMPLIFIER IN signal is inverted. Example: +1 V will be changed to -1 V and then amplified by 100 so that the output voltage will be -100 V.
- “norm” means that the polarity of the AMPLIFIER IN signal is not inverted. Example: +1 V will stay unchanged, and the resulting output voltage will be +100 V.

Note that depending on the system configuration, AMPLIFIER IN can result from different sources:

- No E-517 computer interface/display module and no E-509 servo-controller module present: AMPLIFIER IN is identical with the CONTROL OUT signal (= analog operation).
- E-517 computer interface/display module present: AMPLIFIER IN can result from CONTROL OUT (= analog operation) or from control input sent from a host computer via TCP/IP, USB, RS-232 or IEEE488 interface (= remote control via computer interface).
- E-509 servo-controller module present: Notch filter and slew rate limiter are applied to the CONTROL OUT or the control input sent from a host computer. AMPLIFIER IN is the result but in addition depends on the mode of operation:
  - Closed-loop operation: corrections are applied by the P-I servo-loop.
  - Open-loop operation: no corrections by the P-I servo-loop.

---

## 2.8 Modes of Operation

### 2.8.1 Open-Loop Operation

All E-481 versions can be operated in open-loop mode. Open-loop operation means that any control input provided by the user determines the output voltage directly.

### 2.8.2 Closed-Loop Operation

Closed-loop operation requires a position sensor and a servo module (e.g. E-509). Closed-loop operation means that the user commands the piezo position. The output voltage required to reach this target position is calculated internally by the servo-loop, based on the given target and the feedback of the position sensors (see E-509 User Manual PZ77E).

Note: In closed-loop operation up to 10% of the output voltage range may be required for compensating nonlinearity and drift.

---

## 2.9 First Operation

The following instructions refer to analog operation (p. 14) of the system. If your E-481 is equipped with an E-517 digital piezo controller operation module and you want to control the system via the computer interface, perform only steps 1 to 3 of the instructions below and then operate the system as described in the E-517 User Manual.

- 1 Make sure that the E-481 is connected to line power but powered down—line cord socket and On/Off switch are on the rear panel, see “Line Voltage Connection” p. 12) for details.
- 2 If your piezo actuator is equipped with a PT1000 temperature sensor, connect it to the “Temp Sensor In” socket of the E-481. If no temperature sensor is present, connect the included dummy plug (Part No. 000016103).
- 3 Make sure that the “Input” toggle switch on the E-481 front panel is in the “norm” position (i.e. the polarity of the output voltage is not inverted).
- 4 Connect the piezo actuator to the E-481 “PZT Out” high-voltage output and to a protective earth conductor.
- 5 For closed-loop systems (E-509 servo module present; see also the E-509 User Manual):
  - 5.1 Connect the sensor cable to the corresponding socket on the servo module.
  - 5.2 Deactivate servo-control (set “SERVO” toggle switch on the servo module “OFF”).
  - 5.3 If you are using the sensor monitor signal, connect your appropriate electronics to the SENSOR MONITOR socket on the servo module.
- 6 Turn the DC offset potentiometer full counterclockwise (CCW)  
If a negative DC-offset is required: set the DC offset to negative polarity with the “Offset” toggle switch.
- 7 Power up the E-481 using the On/Off switch on the rear panel. The green “Power” LED will light up.
- 8 Command the first motion of the piezo actuator by turning the offset potentiometer full clockwise (CW) to run the actuator over the nominal travel range, then turn the potentiometer back full CCW

If an E-517 digital piezo controller operation module or an E-515 display module is installed, watch the voltage and, if an E-509 servo module is present, the position on the display to check whether the system is operating properly.

Make sure that the full voltage swing is attained.

- 9 When an E-509 servo module is installed, the sensor monitor signal will show a voltage from about 0 to 10 V proportional to the piezo extension.  
Example: A piezo actuator with a nominal travel of 100  $\mu\text{m}$  shows a sensor monitor signal of 1.5 V at 15  $\mu\text{m}$ . For an actuator with 30  $\mu\text{m}$  nominal travel, 1.5 V at sensor monitor would correspond to 4.5  $\mu\text{m}$  (15% of 30  $\mu\text{m}$ )
- 10 If an external analog signal is used, connect the signal source to the "Control In" BNC socket. If the signal range is not 1/100 of the output voltage, adjustments can be made (see p. 14).

If you have a closed-loop system, follow up by performing a zero-point adjustment.

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## 2.10 Zero-Point Adjustment (with E-509 only)

The zero-point adjustment of the E-509 servo module becomes necessary when the application conditions (particularly load, temperature) of the piezo actuator have changed. Proper zero-point adjustment of the sensor ensures that the full output voltage swing can be used in closed-loop operation without reaching the output voltage limits of the amplifier and causing an overflow condition (see E-509 User Manual, PZ77E).

Equipment needed: For zero-point adjustment in analog operation, an adjustable voltage source is needed which is able to output 1/100 of the selected output voltage range. Furthermore, a precision voltmeter is required.

If an E-517 digital piezo controller operation module is present in the system, zero-point adjustment can be performed without additional equipment; see the E-517 user manual for further information. Adjustment is possible in "Online" mode (= remote control from PC) as well as in "Offline" mode (= analog operation) (p. 15). However, "offline" and "online" modes must not be mixed during the adjustment.

How to perform zero-point adjustment in analog operation:

- 1 Make sure the piezo actuator is mounted in the same way and with the same load as during normal operation in the application.

- 2 Make sure that the external analog control signal is 0 V and turn the DC offset potentiometer full CCW.
- 3 Set the SERVO toggle switch on the front panel of the servo module to OFF.
- 4 Connect a voltmeter to the SENSOR MONITOR socket of the servo module.
- 5 Power up the system.
- 6 Turn the offset potentiometer full clockwise and than back full counterclockwise (0 V) to exercise the piezo actuator.
- 7 Adjust the ZERO potentiometer on the servo module until a sensor-monitor signal of 0 V is measured by the voltmeter on the SENSOR MONITOR socket of the servo module.
- 8 Switch to closed-loop operation (SERVO ON).

---

## CAUTION

If your piezo actuator starts oscillating (humming noise), immediately switch to open-loop operation (SERVO OFF)! The actuator can be irreparably damaged by resonant oscillation. Adjust the settings of the servo control parameters (potentiometers on E-509 servo module; see E-509 User Manual) before switching to closed-loop operation again.

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If a display module is present, the position display of the piezo actuator will now jump to “0”.

Connect a voltmeter to the monitor signal on the “PZT Out/100” BNC socket, or watch the output voltage on the display module, if present. Adjust the ZERO potentiometer on the E-509 module to obtain the following value for the output voltage at the zero point of the sensor:

Selected output voltage range	Output value at zero point
0 to 1000 V	50 V
-250 to +750 V	-200 V
-500 to +500 V	-450 V (positive piezo polarity) +450 V (negative piezo polarity)
+250 to -750 V	200 V
0 to -1000 V	-50 V

This is the output value corresponding to the low end of the piezo actuator travel range.

To check the output voltage range, command the maximum extension with either a DC voltage on “Control In” or with the “DC Offset” potentiometer, or a combination of the two. In doing so, read the monitor signal on the “PZT Out/100” BNC socket, or watch the output voltage on the display module, if present..

If the full output voltage range is attainable, the zero-point adjustment is finished. If not, repeat the adjustment with a slightly different value for the zero point.

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## 2.11 Protection Against Overheating

To protect the system against overheating, the high-voltage output on the “PZT Out” socket is deactivated automatically in the following cases:

- A PT1000 temperature sensor connected to the E-481 detects a temperature of 85 °C on the mechanics. In this case, the red “Overtemp” LED on the front panel lights up.
- The internal temperature sensor of the E-481 detects a temperature of 85 °C at the electronics. In this case, the red “Overtemp” LED on the front panel does **not** light up.

If the high-voltage output has been deactivated, the piezo actuator will no longer move.

Proceed as follows when the high-voltage output has been deactivated:

1. Turn off the E-481 for a cooling phase.
2. Wait until the temperature has dropped on the mechanics and/or inside the electronics. This can take several minutes.
3. Power up the E-481 again.

---

## NOTES

To avoid overheating of the piezo actuator, you can reduce the maximum operating frequency and output voltage. The maximum operating frequency and output voltage (travel) depend on operating conditions such as thermal coupling (single- or double-ended, with or without air cooling) length-to-diameter ratio and, of course, on the driving waveform. For protective-air quality requirements see p. 34.

The maximum possible frequency for a particular system should be determined after the system is set up with the defined operating conditions by slowly running the system up to the point where the controller performs a thermal shutdown. It is important to take proper account of the time constant of the PT1000 temperature sensor, the mechanical characteristics of the system, and the amplifier parameters.

---

Permanent deactivation of the high-voltage output due to overheating may indicate hardware failure.



## 3 Maintenance

### WARNING

Before cleaning the E-481, changing the AC fuses and removing or installing modules, disconnect it from the power supply completely. To do this, remove the power plug from the wall socket, or remove the power cord from the E-481.



### 3.1 AC Power and Line Power Fuses

Unless otherwise requested, the unit will be set up for the power predominant in your country. New line-power fuses are required when changing the supply voltage.

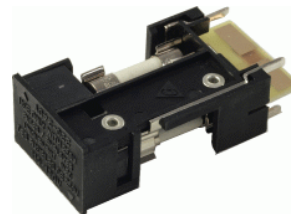
### CAUTION

Both fuses are active and have to be checked if there is a fault and replaced when changing the supply voltage.



Indication of valid voltage value must be located here.

*Figure 3: Position of the line fuses and fuse carrier, only one of two fuses visible*



*Figure 4: Fuse carrier*

To access the line power fuses, proceed as follows:

- 1 Switch off the E-481 and remove the line cord.

- 2 Wait a minute to be sure that any residual voltage has dissipated.
- 3 Carefully pull out the fuse carrier (see figures above) using a tool with a small flat tip, e.g. a flat-bladed screwdriver.
- 4 Be sure to replace both fuses with fuses of the type appropriate for the new voltage:  
220 to 240 V ~: 2 x 2 A HT, 250 Vac  
100 to 120 V ~: 2 x 4 A HT, 250 Vac  
  
H = High breaking  
T = Time lag  
  
Note that IEC fuses are cited: other fuse standards may require higher nominal current rating.
- 5 Rotate the fuse carrier so that the valid voltage setting (“110-120 V” or “220-240 V”) can be read in normal orientation (see Figure 3 on p. 22 for the required location of the valid voltage indication).
- 6 Reinstall the fuse carrier.

---

## 3.2 Cleaning

The outside surface of the case can be cleaned using mild detergents or disinfectant solutions. Organic solvents must not be used.

## 5 Troubleshooting

Positioner does not move.

Cables not connected properly:

- Check the connecting cables.
  
- Note the required voltage range for the analog signal at “Control In”. The control input range is basically one one-hundredth of the output voltage.(see p. 14 for more information).

The “Overtemp” LED lights.

- The connected PT1000 temperature sensor is reporting 85 °C and the high-voltage output has thus been shut off. Turn off the controller. Wait until the temperature has dropped before powering the controller up again.

“Overload” LED lights.

Indicates an overload condition of the amplifier, possibly caused by a malfunction or short circuit.

- Turn off the controller. After a few minutes the controller should be ready to be powered up again.  
If the failure reoccurs, disconnect the piezo actuator and turn on the controller again.  
If the “Overload” LED does not light up, the failure was caused by the piezo actuator. If the “Overload” LED does light up again, the failure was caused by the controller. Please contact PI (see below).

# 7 Technical Data

## 7.1 Specifications

	E-481.00												
Function	Power amplifier for PICA high-voltage PZTs												
Amplifier													
Output voltage	<table border="0"> <tr> <td>0 to</td> <td>1100 (default) V</td> </tr> <tr> <td>(Selectable</td> <td></td> </tr> <tr> <td>-260 to</td> <td>+780 V</td> </tr> <tr> <td>-550 to</td> <td>+550 V</td> </tr> <tr> <td>+260 to</td> <td>-780 V</td> </tr> <tr> <td>0 to</td> <td>-1100 V)</td> </tr> </table>	0 to	1100 (default) V	(Selectable		-260 to	+780 V	-550 to	+550 V	+260 to	-780 V	0 to	-1100 V)
0 to	1100 (default) V												
(Selectable													
-260 to	+780 V												
-550 to	+550 V												
+260 to	-780 V												
0 to	-1100 V)												
Amplifier channels	1												
Average output power	equivalent to 630 VA reactive power												
Peak output power per channel, < 5 ms	2000 VA												
Maximum output power													
Average current	>600 mA												
Peak current	2000 mA												
Amplifier bandwidth, small signal	5 kHz (660 nF), 1 kHz (3.4 μF)												
Amplifier bandwidth, large signal	1.4 kHz (660 nF), 350 Hz (3.4 μF)												
Ripple, noise	150 mV <sub>RMS</sub>												
0 to 100 kHz	2000 (100 nF) mV <sub>P-P</sub>												
Current limitation	Short-circuit-proof												
Voltage gain	+100												
Control input voltage	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V												
Input impedance	100 kΩ												
Interface and operation													
Output voltage socket	LEMO EGG.0B.701.CJL1173												
Control input socket	BNC												
Piezo actuator temperature sensor	Max 85 °C, high voltage output is automatically deactivated if piezo actuator temperature out of range												
DC Offset	10-turn pot., adds 0 to +10 V or -10 to 0 V to Control In												

Miscellaneous	
Operating voltage	100 to 120 or 220 to 240 V ~, 50 — 60 Hz (fuse change required)
Overvoltage category	II
Protection class	I
Operating temperature range	+5 to +40 °C
Storage temperature range	0 to +70 °C
Shipping temperature range	-25 to +85 °C
Altitude for operation	Max. 3500 m
Mass	8.6 kg
Dimensions	288 x 450 x 158 mm

## 7.2 Frequency Response Diagram

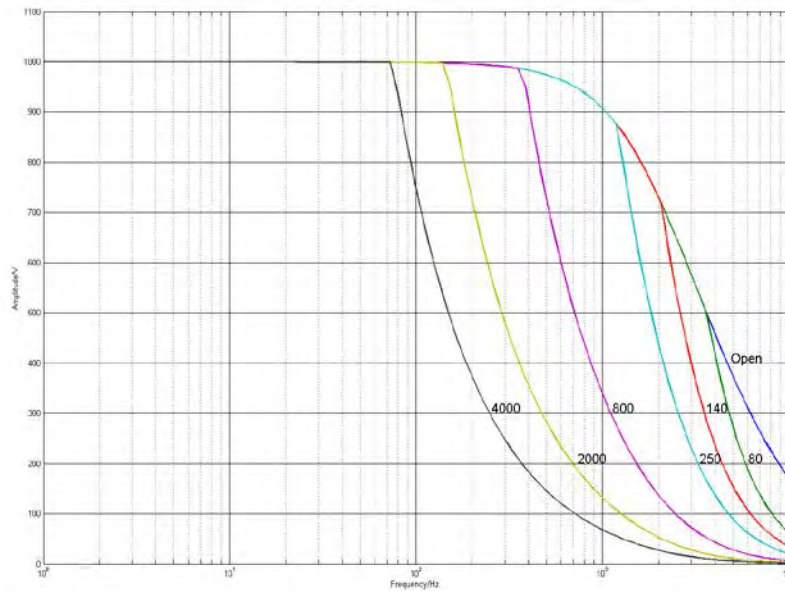


Figure 5: E-481, operating limits with various piezo loads. Values shown are capacitance in nanofarads



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## **7.4 Signal Path with Servocontroller and PC-Interface Modules**

The block diagram below shows the signal path for E-481 closed-loop versions upgraded with an E-517 digital piezo controller operation module. The E-481 open-loop versions and models without E-517 module are equipped with dummy modules instead. The purpose of these dummies is to complete the internal circuitry and the front panel of the chassis.

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### **CAUTION**

If your E-481 contains dummy modules: Do not operate the E-481 when the dummy modules are removed. Without the dummy module(s), the system will malfunction because no control signal can be fed into the amplifier module due to the broken circuit.

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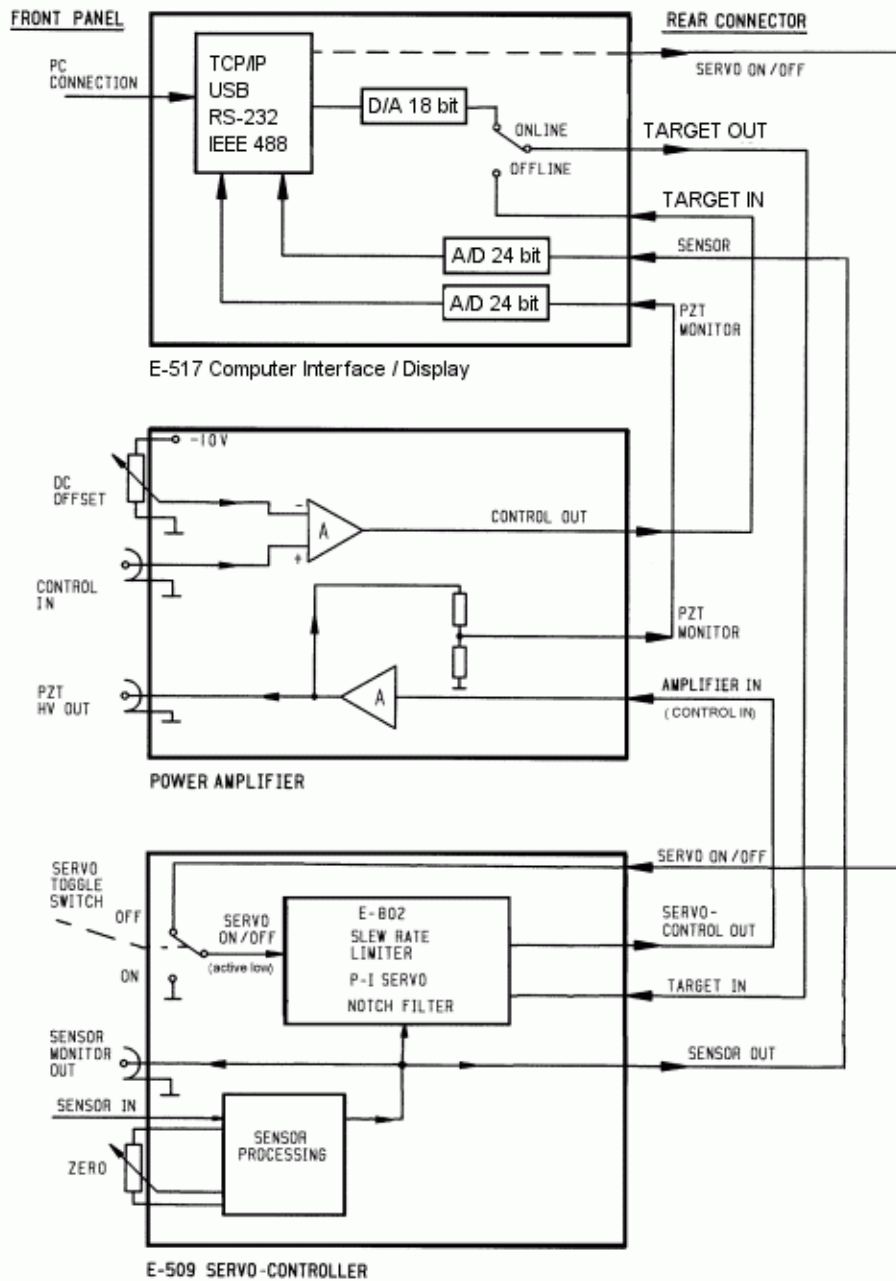


Figure 7: Interconnections between E-517 digital piezo controller operation module, power amplifier (E-481) and E-509 servo module



## 7.5 Pin Assignments

### 7.5.1 2-Pin High-Voltage Connector

#### WARNING

On the “PZT Out” Lemo socket of the E-481, output voltages up to 1150 V can be present. These voltages will cause death or serious injury.

Working with the E-481 requires adequately trained and educated operating personnel.

Operate the piezo actuator on the “PZT Out” socket only when it is connected to a protective earth conductor.



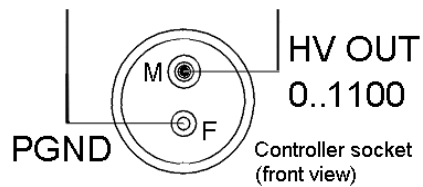
Type: LEMO EGG.0B.701.CJL.1173

Pin assignments:

HV OUT: High-voltage output

PGND: Power ground

Housing: Cable shield, for protective ground



### 7.5.2 Temperature Sensor

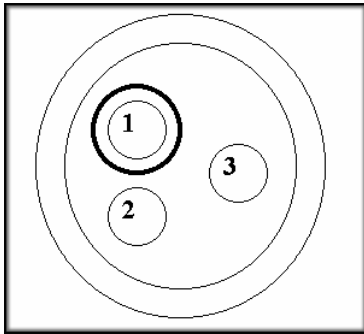


Figure 8: Temperature sensor connector, view from solder side

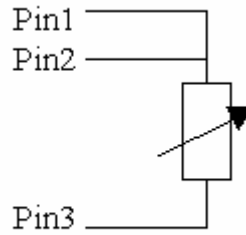


Figure 9: Temperature sensor diagram

Pin assignment:  
Pin 1: Temp\_SA  
Pin 2: Temp\_S  
Pin 3: GND/PE  
Housing: Shield/GND/PE

## 8 Appendix

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### 8.1 Protective Air Quality Requirements

Optionally the PICA piezo actuators P-212, P-216, P-225 and P-235 can be ordered with the P-177.50 option "Dynamic applications (with E-481): temperature sensor and protective air for PICA HVPZT".

The protective air must meet the following requirements:

Temperature at least 3 C° (5.5 F°) above dew point

Residual oil content < 0.03 mg/m<sup>3</sup>, measured at 7 bar (102 psi) and 20°C (68°F)

Particulates < 0.01 mg / m<sup>3</sup>

These requirements can generally be met by running compressed air conformant to ISO 8573.1 Quality Class 4 through a dryer and microfilter with 99.9999% effectiveness.

Maximum pressure in the translator must not exceed 0.5 bar (7.3 psi).

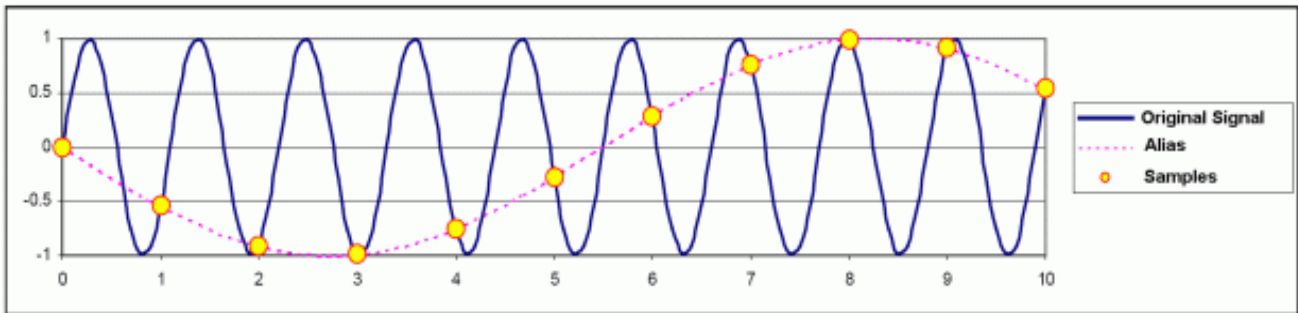
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### 8.2 How to Measure the Amplifier Output

The innovative, efficient circuitry of the E-481 reduces power consumption and heat dissipation, especially in dynamic applications. Working with an internal switching frequency of 100 kHz, charge is transferred to the piezo actuator using low-loss PWM techniques. The ripple of the amplifier output is <100 mV<sub>pp</sub> at 100 kHz. But when measuring the amplifier output signal with low sampling rate and small bandwidth (e.g. with a digital oscilloscope), aliasing will occur and distort the measurement result. In digital signal processing, aliasing refers to an effect that the signal reconstructed from samples is different than the original continuous signal when the sampling rate is too low. With the E-481 amplifier output, this means that a low-frequency signal seems to be measured which is not present at all.

Example:

When a 91 Hz signal is sampled with 100 Hz sampling rate, the result seems to be a 9.1 Hz signal (see figure below).



*Fig. 1: Signal digitization with too low sample rate (time in 1/100 s): Original signal = 91 Hz and sampling rate = 100 Hz; the result is mistaken as a 9.1 Hz signal ("Alias")*

To avoid aliasing, the sampling rate must be at least twice as high as the highest frequency in the signal to be sampled (according to the Nyquist–Shannon sampling theorem). I.e. with an amplifier switching frequency of 100 kHz, the sampling rate must be 200 kHz or higher. If the sampling rate provided by your oscilloscope is not high enough, use a low-pass filter at the oscilloscope input to eliminate frequencies above 100 kHz. Alternatively, you can use an analog oscilloscope or perform high-resolution measurements in the lower frequency range.

When following those instructions, you will obtain valid measurement results.

