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PZ 70E User Manual

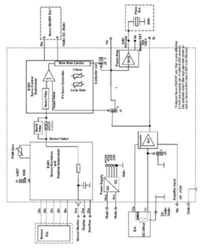
E-610 LVPZT Controller / Amplifier

Release: 6.2.1 Date: 2024-04-22

This document describes the following product(s)*:

- **E-610.L0**
  LVPZT Controller (OEM) for Inductive Sensors
- **E-610.S0**
  LVPZT Controller (OEM) for Strain Gauge Sensors
- **E-610.00**
  LVPZT Amplifier (OEM), Single-channel

* The E-610.C0 with capacitive sensor electronics is described in its own manual



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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-610 LVPZT Controller / Amplifier. It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts, piezoelectric drives and applicable safety procedures.
The manual describes the physical specifications and dimensions of the E-610 LVPZT Controller / Amplifier as well as the installation procedures which are required to put the associated motion system into operation.
This document is available as PDF file. Updated releases are available via FTP or email: contact your Physik Instrumente sales engineer or write to info@pi.ws.

Conventions

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

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 which might be delivered with E-610 LVPZT Controller / Amplifiers are described in their own manuals. Updated releases are available via FTP or email: contact your Physik Instrumente sales engineer or write to info@pi.ws.

E-801 User Manual, PZ117E
E-802 User Manual, PZ150E

The E-610 version with capacitive sensor processing is described in its own manual (PZ 72E).

Contents

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1 Introduction

1.1 Prescribed Use

Based on their design and realization, the E-610 LVPZT Controller / Amplifiers are intended to drive capacitive loads, in the present case, piezoceramic actuators. The E-610 must not be used for applications other than stated in this manual, especially not for driving ohmic (resistive) or inductive loads. E-610s with servo-controllers can be operated in closed-loop mode using the proper 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-610s 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-610s 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 ±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

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

1.2 General Description

E-610.00 amplifiers and E-610.x0 amplifier/controller modules are designed to drive and to control low-voltage piezoelectric translators (LVPZTs).

The E-610.00 is a single-channel amplifier with an average output power of 6 watts. The design is based on a controllable DC/DC converter, optimized for driving capacitive loads.

E-610.L0 and E-610.S0* are single-channel amplifiers and position controllers (LVPZT controller).

All modules can be operated from a single DC voltage from 12 to 30 V.

1.2.1 Servo-Control

Position feedback is the most effective way to suppress hysteresis and creeping effects; the piezo translators can then be controlled with an accuracy that is determined by the accuracy of the sensor used. Each module type supports a different type of position-control sensor:

- Strain gauge sensors (SGS), attached to the PZT stack or lever element
- Inductive sensors—either half-bridge sensors (IHB) or linear variable differential transformers (LVDT)

Capacitive sensor versions, offering the finest possible resolution, are also available and are described in a separate manual.

As an alternative, an externally processed sensor signal can be used.

The analog input signal (control signal) can either drive the power amplifier input directly, or be fed through a slew-rate limiter and notch filter and/or a servo-control circuit first. The maximum output voltage ranges from -30 to +130 V so as to support the full extension capability of PI low-voltage translators.

1.2.2 Applications

E-610 modules can be used for static and dynamic applications. High output stability and low noise assures stable micropositioning. Because LVPZT translators have high

* E-610.C0 is described in a separate user manual, PZ 72E

capacitances, the amplifiers are designed to supply appropriate high peak currents for dynamic applications. Excellent linearity and stability allows the use of E-610 modules in precision measurement and control systems.

Small size and compact design combined with excellent specifications make the E-610 series controller a preferred module for OEM users.

Although the modules were designed to drive PZT positioning elements, they can also be used to drive other systems which require controlled operating voltages.

1.2.3 Computer Control

Computer control of an E-610 can be realized using a DAC-board in a PC to generate the analog input signal. PI offers a driver set for NI LabVIEW which can be used with certain D/A boards. This driver set is compatible with the PI General Command Set (GCS) driver set for use with NI LabVIEW available for all newer controllers from PI. The Analog Controller Driver for use with NI LabVIEW (E-500.ACD) is free of charge, but requires the NI LabVIEW environment from National Instruments for operation. The PI Analog Controller supports all D/A converter boards from National Instruments that are compatible with DAQmx8.3. NI LabVIEW compatibility is given from version 7.1 upwards. Instructions for downloading the Analog Controller drivers is given in a Technical Note.

1.3 Safety Precautions

DANGER

Read This Before Operation:

E-610 modules are OEM amplifiers generating HIGH VOLTAGES for driving LVPZTs. The output power may cause serious injuries.

When working with these devices or using PZT products from other manufacturers we strongly advise you to follow the General Accident Prevention Regulations.

All work done with and on the modules described here requires adequate knowledge and training in handling High Voltages.

Be sure to connect pin 32a/c to a Protective Ground!

!

CAUTION

Electrostatic Hazard

Electronic components are sensitive to electrostatic electricity. Take appropriate electrostatic protection measures when removing modules.

Equipment Damage

Most piezo stages that can be connected to this controller can be damaged or destroyed by uncontrolled oscillation near the mechanical resonant frequency. If you observe resonance while configuring your system, switch off power to the actuators concerned immediately and check the settings and servo-control parameters.

2 Model Survey

2.1 Main Module

E-610 amplifier/controllers are designed as EURO-board plug-in modules which can be installed in a desktop chassis as well as in a 19"-rack-mount chassis. The following different models are available:

E-610.00	Single-board LVPZ amplifier module for OEM applications with integrated DC-DC power supply. This module consists of a mainboard with amplifier, power supply and heat sink.
E-610.L0	Single-board LVPZT controller module for OEM applications consisting of an amplifier, a sensor supply (AC excitation) and processing circuit, including preamplifier, demodulator, different filters and a proportional-integral (P-I) controller for open-loop \ closed-loop operation. This module is mainly used with LVDT sensors.
E-610.S0	Same main board as E-610.L0, but with a sensor excitation and processing submodule for strain gauge sensors (SGS).

The E-610.C0, the capacitive sensor version, is described in a separate manual.

22 Included Connector Set

Included with the E-610 module is a connector set designed to facilitate operating it in a user-provided housing. This set includes the following items:

- Solderable socket matching the 32-pin main connector, designed for installation completely inside the user housing. Because the connector standard includes types with more pins, the 32 pins used are all carry even number designations and are in rows “a” and “c”.
- Panel-mount coaxial socket (Lemo ERN.00.250.CTL) designed for bringing the PZT drive-voltage lines (on the 32-pin main connector) outside the user housing and interfacing with PI actuators and stages
- 4-conductor, panel-mount socket (Lemo ERA.0S.304.CLL) designed for bringing the sensor excitation and readout lines (on the main connector) outside the user housing and interfacing with PI actuators and stages (not included with amplifier-only version, E-610.00)

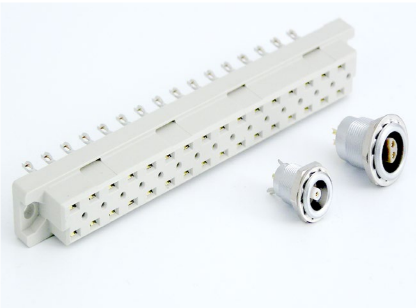


Fig. 1: Included connectors

See “LEMO Pin Assignments”, p. 32 for pinouts.

3 Operating Modes

All units can be operated as simple power amplifiers, i.e. in voltage-controlled mode, where the PZT output voltage depends directly on input control voltage and DC offset potentiometer setting. This is also known as open-loop or servo-off operation.

Units with servo-controller (i.e. all except E-610.00) can also be operated in position-controlled mode. In position-controlled mode, the control input plus DC offset is interpreted as a target *position*, and the signal from the position sensor is used as input to a servo-control feedback loop. Position-controlled (closed-loop) mode permits elimination of drift and hysteresis.

In both open- and closed-loop modes, the units can be operated manually or via an external analog control input voltage, or by a combination of the two.

NOTE—Actuator Lifetime

The sum of input control voltage and DC-offset potentiometer setting should not exceed the -2 to 12 V range. In open-loop operation, -2 to 12 V control input will result in -20 to 120 V piezo output voltage. -3 to 13 V control input are possible and will result in -30 to 130 V output voltage, but working with increased output voltage will decrease actuator lifetime. See “Lifetime of PICMA® Actuators” on p. 35 for details.

3.1 Manual Offset Operation

In manual operation, the target voltage or position is controlled manually with an external 10 kΩ DC-offset potentiometer (not included). This potentiometer must be connected to pins 12a (-10 V), 14a (GND), and the wiper to pin 12c, and it must be activated with jumper J3 in position 1-2.

3.2 External Operation

For external operation, the offset potentiometer should be deactivated (jumper J3) and the target voltage or position is controlled by an external DC signal of -2 to 12 V.

See "Computer Control," p. 5, for information on PI support of external operation with a DAC card in a PC.

3.3 External Operation with DC Offset

For external operation with offset, the offset potentiometer (or equivalent) is activated and attached with jumper J3 in position 1-2 and an external DC signal is used on Control IN. The position of the potentiometer (wiper voltage) is added to the analog control input signal. The result must be in the -2 to +12 V range. With, for example, an offset setting of 5 V, the control input could range from -7 to +7 V.

3.4 Open-Loop (Voltage-Controlled) Operation

In open-loop mode, the position servo-control circuit is bypassed and the system works like an amplifier. In this mode, the PZT drive voltage is proportional to the control signal input in combination with the DC offset potentiometer, if installed and activated. (The sensor electronics works independently and outputs the current piezo position on "sensor monitor" even though that value is not used internally in open-loop mode, provided a sensor is connected to the appropriate main connector pins). The PZT output voltage can be monitored either directly (in parallel with the PZT) or on main connector pin 8a, which carries a high-impedance output of 1/100th the voltage of the PZT.

All modules have the analog input on pin 10c. With DC offset at zero, the nominal input voltage range is -2 to +12 V for a -20 to 120 V output voltage range.

If the input signal available is bipolar, set the external DC-offset potentiometer (or an equivalent divider) to an appropriate setting. When set, for example, to provide a 50 V output with 0 V input, a control input in the -5 to +5 V range will cover an output range of 0 to 100 V.

3.5 Closed-Loop (Position-Controlled) Operation

All E-610 models except the E-610.00 have position-sensor processing electronics for closed-loop operation. Closed-loop operation differs from open-loop operation in that the analog control input (plus any DC offset) is interpreted as a target position rather than a target voltage.

Depending on the sensor type, different sensor electronics are required: LVDT sensors require AC excitation and the sensor processing add-on board, E-801.2x, is installed. Strain gauge sensors work preferably with DC signals and use the E-801.1x add-on board instead.

Closed-loop operation offers both drift-free and hysteresis-free positioning. The servo-control electronics is implemented on a plug-in submodule, the E-802. See the E-802 User Manual for details.

In position-controlled mode, it is the output of the P-I (proportional integrated) controller that is used as input to the amplifier. The piezo position is refined until the final position is reached. In this controlled mode, the PZT position is directly proportional to the module's input signal while the PZT supply voltage may not be.

The operating voltage for the PZT must remain in the range from -30 to +130 V. If one of these limits is reached and the resulting expansion of the PZT does match that specified by the control signal, a TTL signal (overflow) is output on pin 26a.

PI's standard calibration procedure assures that the PZT reaches its nominal expansion value when the control input signal is +10 V.

To enable closed-loop mode do *both* of the following:

1. Set jumpers J1 and J2 on the main board to positions 2-3.

2. Connect pin 28a to pin 20a/c (Test GND). If pin 28a is not connected, then the unit works in voltage-controlled (open-loop) mode.

The notch filter and slew-rate limiter are also active. (Disabling servo mode will not always deactivate them. See the E-802 User Manual for details.)

4 Installation and Operation

4.1 General Instructions

DANGER

Read This Before Operation:

E-610 modules are OEM amplifiers generating HIGH VOLTAGES for driving LVPZTs. The output power may cause serious injuries.

When working with these devices or using PZT products from other manufacturers we strongly advise you to follow the General Accident Prevention Regulations.

All work done with and on the modules described here requires adequate knowledge and training in handling High Voltages.

Be sure to connect pin 32a/c to a Protective Ground!

!

CAUTION: Equipment Damage

Most piezo stages that can be connected to this controller can be damaged or destroyed by uncontrolled oscillation near the mechanical resonant frequency. If you observe resonance while configuring your system, switch off power to the actuators concerned immediately and check the settings and servo-control parameters.

Connector descriptions and pinouts are given at the end of this manual. All inputs and outputs are available on the main connector (p. 31).

On the main board of the E-610 modules a DC-DC converter is installed with a 12 to 30 VDC input voltage range. The converter generates -37 and +137 V for the power amplifier and +/-15 V for the sensor and servo-controller (if present).

NOTE

- When powering up the module, the DC-DC converter needs a peak current of about 1.5 A to start oscillating. The power supply should have a buffer capacitor, or the external power supply should be able to supply the 1.5 A for at least 1 second.

- The inputs and outputs of the DC-DC converter are not connected internally. Using a unipolar power supply, we recommend connecting the negative supply at pin 18a,c with the Test GND at pin 20a,c. This provides a defined GND level and helps to minimize noise.

4.2 E-610.00 Amplifier Modules

Make sure jumpers J1 and J2 on the main module are set to position 1-2 to disable the servo-control elements which are not present on this version. Optionally connect an external 10 k-ohm potentiometer to 12a, 12c and GND and make sure it is activated (J3 in position 1-2, see block diagram in Section 6).

Supply the board with the DC power in the 12 to 30 V range at pins 16a/c and 18a/c. The green power-on LED on the base board should light up. Check the LVPZT output voltage between pin 2a/c and 4a/c main connector without an LVPZT connected.

If you have connected the optional external potentiometer to offset the control input range, then this can be used to check the output voltage. Varying the offset from 0 to +10 V should make the output vary from 0 to +100 V.

If no external potentiometer is connected, drive the analog input (pin 10c) with a control voltage in the range of -2 to +12 V. The corresponding output should be -20 to +120 V.

4.3 E-610 Models with Servo-Control

NOTE: Calibration

If your unit is delivered with the PZT actuator that it is to drive, it will have been configured and calibrated with that actuator at the factory. Be careful not to interchange actuators and controllers if you have more than one. It should not be necessary to recalibrate the system unless hardware changes are made. It may be necessary to adjust the zero point if operating conditions such as load or temperature change greatly. For details see section “E-610 Calibration” beginning on page 16.

4.3.1 System Setup

The first step in installation is to connect the actuator and sensor. Sensors are connected to pins 24c, 26c, 28c, 30c (for details see the sensor wiring section beginning on page 32). You can use the included 4-conductor, panel-mount Lemo socket for interfacing to a matching connector on the mechanics (see p. 32 for details). Also connect the control input signal and/or offset potentiometer (if any), as well as any monitoring instruments you want to use.

The second step is to select the operating mode—either voltage-controlled (open-loop) or position-controlled (closed-loop). Connect pin 28a on the main connector to pin 14ac (GND) to enable closed-loop (servo ON) mode or leave pin 28a open for open-loop (servo OFF) mode. Note that with the E-802.55 model servo-control submodules, the notch filter and slew rate limiter stay on in open-loop, unless the submodule is jumpered out of the circuit (see block diagrams, p. 21 ff.). See the E-802 User Manual for details.

Operating the modules you should consider the following items:

Depending on the sensor type (E-610 model type), appropriate sensor processing is provided (DC for SGS, AC for LVDT):

E-610.L0 — Supports LVDT sensor. Sensor processing is implemented on the E-801 submodule, which is described in detail in a separate User Manual. On the E-801, AC signals from the sensor are amplified in a dual stage preamplifier, settable between medium- and high-gain to optimize piezo performance.
An analog output signal is available at the output of the demodulator which is directly proportional to the piezo expansion. This signal can be fine-tuned as to amplitude and zero point with trim pots See the E-801 User Manual for details.

E-610.S0 — Supports SGS sensor. Sensor processing is implemented on the E-801 submodule, which is described in detail in a separate User Manual. One the E-801, DC signals are amplified in a preamplifier stage which outputs an analog signal directly proportional to the PZT expansion. Again, gain and zero point can be adjusted with trim pots.

With 0 DC offset and servo-control ON, an analog input signal of +10 V should cause the PZT to expand to its nominal value. At zero input, the sensor monitor voltage at main connector 22a should also measure zero. If not, perform the Electrical Zero-Point Calibration described on p. 17) to correct it. At the nominal PZT expansion, pin 22a should measure around +10 V.

In cases where the piezo drives a mechanical system up to its mechanical resonance, the additional induced phase shift could result in unstable operation if the feedback loop were closed. To suppress such critical resonance an optional notch filter can be activated on the main board. By default, it is bridged by zero-ohm resistor, R35.

Most dynamic applications require the power amplifier to deliver a short peak current higher than the average value. Because of the limited power of the transistors, this peak is limited to about 5 ms in length. After this time the current decreases to the average value.

There may be cases where the control signal calls for an even higher peak current, but the required current cannot be supplied. To avoid such non-linearities, a slew rate limitation is added to the control circuit. This feature guarantees wide signal bandwidth without overdriving the power amplifier.

There are additional potentiometers for optimizing closed-loop operation. See the “E-610 Calibration” Section for details.

4.3.2 User Electronics and Sensor Monitor Signal

If you are connecting your own electronics to the sensor monitor signal (main connector, p. 32), 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.

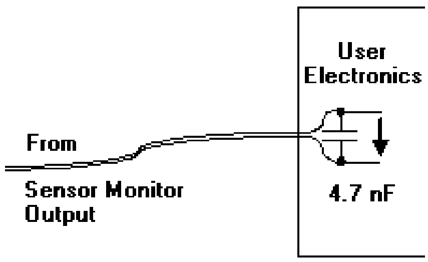


Fig. 2: Electronics on Sensor Monitor line with required input capacitance

5 E-610 Calibration

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

The servo controller is calibrated prior to shipment in our labs. 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.

The system is ready for operation upon delivery. PZTs and their assigned controllers are matched and should be considered as a unit. The serial numbers of the PZTs installed are marked on the individual modules.

Some calibration steps, however, must be performed in any case, either to compensate different loading and mounting details or to tune dynamic behavior for stable operation.

NOTE

For some calibration steps the heat sink (cover plate) has to be removed to make certain test points or components on the add-on modules available.

5.1 Equipment Needed for Calibration

Zero-point adjustment requires a voltmeter. Static displacement calibration requires an external expansion gauge with appropriate resolution (e.g. 0.01 µm for a P-841.30 actuator) and a precision voltmeter. Access to adjustment elements on the submodules while the system is in operation is necessary, so an extension connector may be required.

5.2 Preparations

Mount the PZT actuator 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 modules.

5.3 LVDT Mechanical Zero-Point Adjustment

LVDT sensors have a mechanical zero point adjustment. SGS sensors are permanently affixed and cannot be shifted mechanically.

Models connected to LVDT sensors also may need to have the mechanical zero-point of the sensor adjusted. LVDT sensor readout is based on differential measurement of the inductive excitation of two secondary coils with a common, moving, ferrite core. The first step of the alignment procedure is to balance the bridge by moving the ferrite core (probe) to the zero position.

To verify the balance of the bridge, display the sinusoidal voltages on connector X18 pin 9 (main connector pin 26c) and pin 4 (main connector 28c) on a 2-channel oscilloscope. If the bridge is balanced properly, both sine curves have the same amplitude and phase.

If there is any deviation, move the LVDT mechanically until both curves become identical.

5.4 Electrical Zero-Point Calibration

Electrical zero-point calibration has the goal of making the point of zero expansion coincide with the point of zero control input voltage.

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.

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 arising due to improper match of actual and desired expansion windows.

The adjustment procedure is as follows (see section “On-Board Components” on p. 23 for location of adjustment elements):

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

2. Make sure that jumper J4 is correctly set: 1-2 for SGS, 2-3 for LVDT.

3 Make sure the control input is 0 V.

4 If there is a DC-Offset potentiometer installed and activated, make sure it is in the 0 V position (usually full counterclockwise).

5 Connect +15 V and GND to the E-610 module. Note that for starting the module, a current of at least 1500 mA is required; otherwise the internal oscillator will not start. Only 400 mA are required after start up.

6 If you use your own LVDT sensors, adjust the sensor mechanical zero position (LVDT core position). For details see the section 5.3 on page 17.

7 Set the module to voltage-controlled (servo OFF, open-loop: J1, J2 in positions 1-2).

8 Now exercise the PZT over the nominal expansion range by applying analog signals 0-10 V to pin 10c. Then set the PZT to 0 with 0 V at 10c.

9 Read the voltage at pin 22a (sensor monitor). Adjust the P406 zero potentiometer so that the reading is in the range of 0 to +1 V (+1 V is recommended for increased actuator lifetime). The zero point is now close enough to allow going into servo mode.

10 Set the unit to servo ON.

11 Again using the zero potentiometer, adjust until the PZT monitor out (or the PZT voltage itself) is 0 V. Because servo-control is now active, the sensor monitor signal will not change: the servo-controller will cause PZT actuator motion to maintain the position.

5.5 Static Gain Adjustment

It should only be necessary to readjust the static gain if system components have been exchanged or altered. Before doing so, reading the detailed description of the sensor-processing system is recommended (E-801 Sensor Submodule User Manual).

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

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

The static gain adjustment procedure is as follows (location of adjustment elements on the submodules is described in the E-801 Sensor Submodule and the E-802 Servo Submodule User Manuals; location of mainboard elements in Section 6.3 beginning on p. 23):

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.

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

3 Set servo mode to SERVO OFF
(J1 and J2 in pos. 1-2).

4 Make sure the DC-Offset potentiometer (if installed and activated) is still set to zero.

5 Set control input to 0 V.

6 Connect +15 V and GND to the E-610 module.

NOTE

For starting the module, a current of at least 1500 mA is required; otherwise the internal oscillator will not start. Only 400 mA are required after start up.

7 Scan the control input voltage from 0 V to +10 V and read the PZT displacement using the external gauge. With +10 V the external gauge should show the PZT at about nominal expansion. Adjust with the sensor gain trim potentiometer (see Fig. 3 and component maps beginning on page 23). Sensor gain is now close enough to allow switching servo ON.

8 Set servo ON.

9 Adjust the sensor monitor signal to exactly 10.000 V using the gain adjustment potentiometer on the E-802 servo submodule (different versions of this submodule

exist, see the E-802 User Manual for gain adjustment on your unit).

10 Adjust the PZT position to the nominal expansion value using the sensor gain adjustment. Now, because servo ON, the sensor monitor value will not change!

11 Repeat the last two steps until you get stable readings.

If the Gain settings have been changed, the zero-point adjustment starting with section 5.4 should be repeated, and then the static gain rechecked.

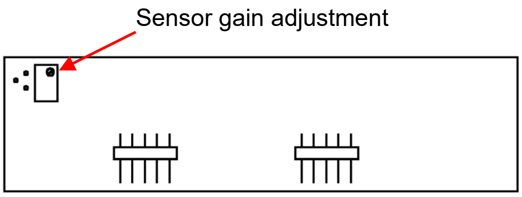


Fig. 3: Sensor gain on E-801 sensor excitation and readout submodule. Most versions in circulation have the sensor gain adjustment as shown. See the E-801 User manual for more details.

5.6 Dynamic Calibration

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

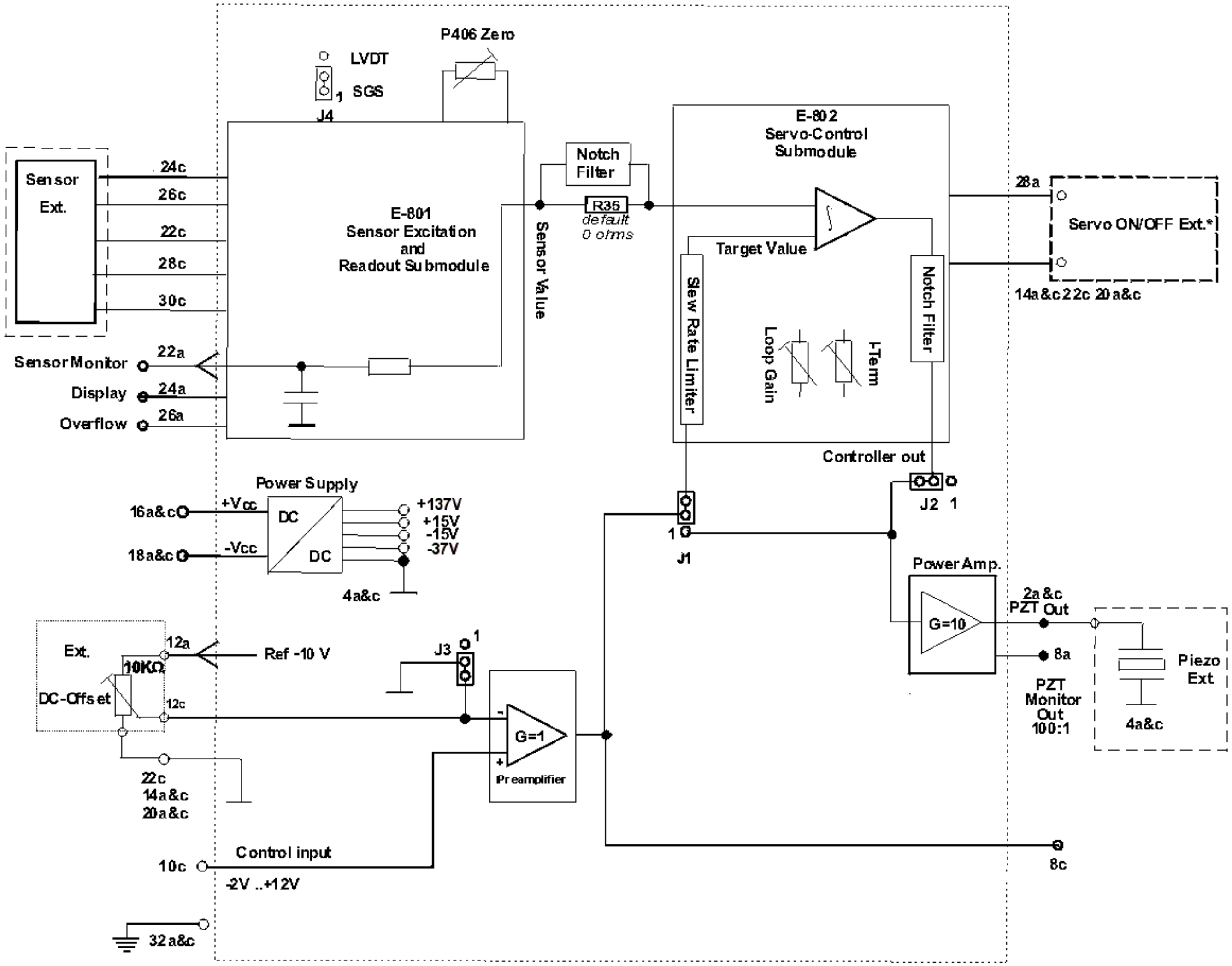
6 Electronics

The basic circuit design of the amplifier and controller modules is shown in the drawings on the following pages. Input signals at main connector pin 10c and the signal from the external DC-offset potentiometer are combined in the preamplifier stage. Depending on the model/configuration, the resultant signal will be used either as input for the amplifier or as input signal for the position servo-control circuit.

6.1 Block Diagram E-610.L0, E-610.S0

For more detailed information on the E-801 sensor processing submodules, see the E-801 User manual.

For more detailed information on the E-802 servo-control submodules, see the E-802 User Manual.



*External Servo ON/OFF (pin 28a) is only effective if J1/J2 are properly set. In older E-802 versions, 28a switches notch filter and slew-rate limiter as well as servo-control.

Fig. 4: E-610.L0, E-610.S0. Note that the control input on pin 10c can be -3 to 13 V which will result in -30 to 130 V output voltage, but working with increased output voltage will decrease actuator lifetime. See “Lifetime of PICMA® Actuators” on p. 35 for details.

6.2 Front Panel

The green LED indicates that the module is powered up and in operation. The yellow LED lights when an overflow condition occurs: i.e. an attempt to drive the PZT voltage under -30 or over +130 V.

6.3 On-Board Components

6.3.1 Component Locations for E-610.00

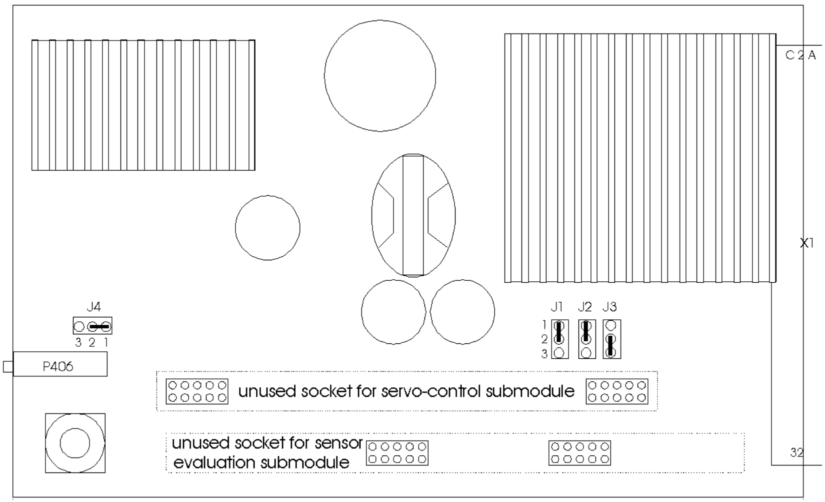


Fig. 5: Component Locations for E-610.00

6.3.2 Component Locations for E-610.L0

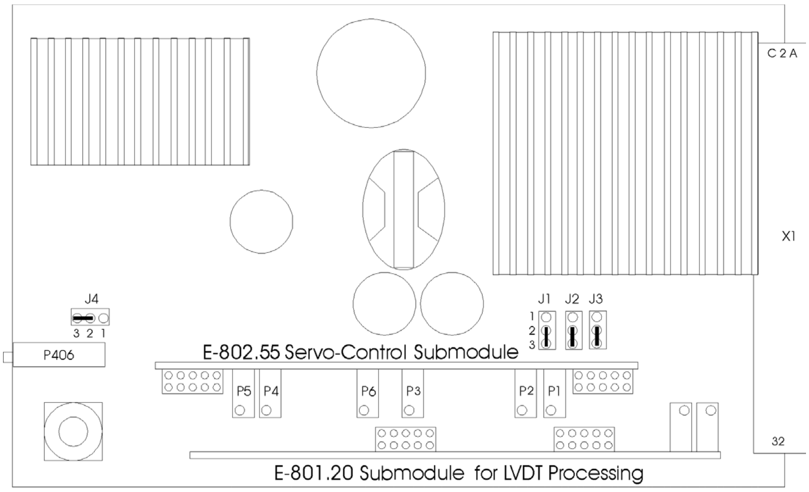


Fig. 6: E-610.L0 layout: older equipment may have other submodule versions: see the submodule User Manuals for details

6.3.3 Component Locations for E-610.S0

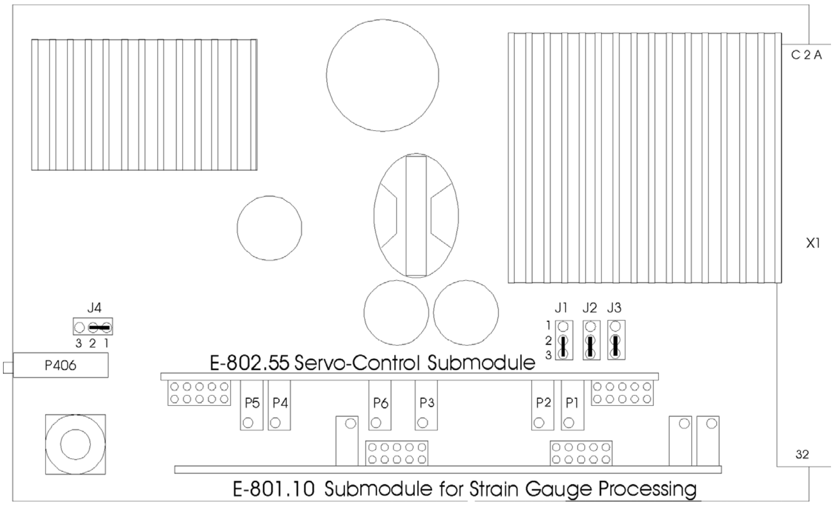


Fig. 7: E-610.S0 layout: older equipment may have other submodule versions: see the submodule User Manuals for details

6.3.4 Adjustment Elements

J1 & J2:	1-2 (both): bypass E-802 (servo-control, slew rate limiter and notch filter) completely 2-3 (both): use E-802
J3:	1-2: external potentiometer activated 2-3: external potentiometer deactivated
J4:	1-2: DC sensor excitation (SGS sensors only) 2-3: AC sensor excitation (required for LVDTs)

6.4 Submodules

Servo-control and LVDT/SGS sensor evaluation and excitation functions are implemented in plug-in submodules. E-801 submodules interface to these sensors, while E-802 modules perform servo-control.

It should not be necessary to remove or replace the submodules, but if you ever do so, note that the submodule component sides face each other as shown above.

6.4.1 E-802 Position Servo-Control Boards

The E-802 submodule 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 (target) and the sensor signal (actual position) to generate the amplifier control signal using an analog proportional-integral (P-I) algorithm.

For calibration procedures, see Section 5 and the E-802 Servo-Control Submodule User Manual.

6.4.2 Sensor Excitation and Evaluation

On all but the amplifier-only version, an E-801 submodule provides sensor excitation and readout. E-801.1x submodules provide DC sensor excitation and can be used with strain gauge sensors (SGS) only. E-801.2x submodules provide AC sensor excitation and are primarily for LVDT sensors, although they can be used with SGS sensors if necessary.

Should you ever need to make any adjustments on the sensor submodules, refer to the E-801 User manual for more details.

7 Technical Data

7.1 Board and Amplifier Section (all models)

Channels:	Single-channel
Output voltage range:	-30 to +130 V*
Peak output current:	140 mA (5 ms max.)
Max. average output current:	60 mA
Max. average output power:	6 W (with forced-air cooling > 10 m3/h)
Control input voltage range:	-2 to 12 V*, shiftable with DC offset
Voltage gain:	10+/-1%
Input impedance:	> 100 kΩ
DC-offset adjustment range:	100 volts wide, adds 0 to +10 V to Control In
Bandwidth:	See frequency response curves (Figure below)
Ripple of Uout:	20 mVpp at low frequencies 40 mVpp (spikes) at 30 kHz
Input connector:	BNC (E-610.00 only)
PZT output connector (not on board)	Panel-mount, 2-conductor LEMO ERN.00.250.CTL included for user installation
Dimensions:	EURO-board: 160 x 100 x 35.6 mm
Main connector:	32 pin DIN 41612 D Eurocard connector

* -2 to 12 V is the recommended control input range, resulting in -20 to 120 V piezo output voltage. -3 to 13 V control input are possible and will result in -30 to 130 V output voltage, but working with increased output voltage will decrease actuator lifetime. See “Lifetime of PICMA® Actuators” on p. 35 for details.

Power Requirements:

Max. power consumption:	15 W
Operating voltage range:	12 to 30 VDC, max. ripple 50 mV pp (15 V recommended)
Operating current:	2 A max.

Front-Panel LEDs

Green	Power on
Yellow	Overflow (PZT out > 130 V or < -30 V)

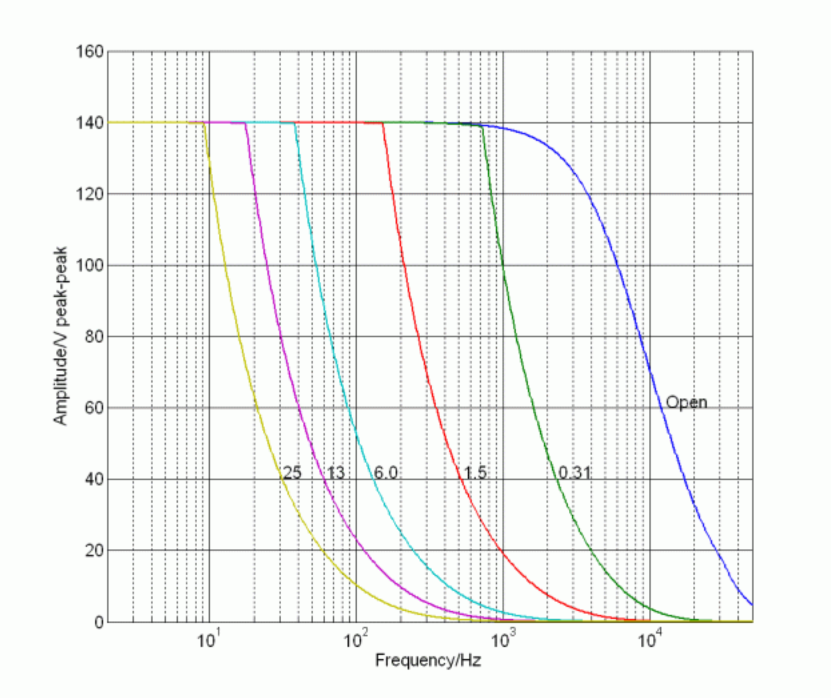


Fig. 8: E-610 open-loop frequency response with various PZT loads. Values shown are capacitance in µF.

7.2 LVDT Sensor Processing (E-610.L0 only)

Implemented on E-801.2x sensor processing submodule; see E-801 User Manual for more details.

Sensor type:	LVDT, Inductive probes
Sensor excitation:	10 Vpp standard, max 25 Vpp 20 to 20,000 Hz, 50 mA
Preamplifier gain:	10, 100, selectable
Sensor monitor output:	0 to +10 V for nominal expansion
Display output:	0 to max. 2 V, adjustable
Sensor connector (not on board)	Panel-mount, 4-conductor LEMO ERA.0S.304.CLL included for user installation

7.3 SGS Sensor Processing (E-610.S0 only)

Implemented on E-801.1x sensor processing submodule; see E-801 User Manual for more details.

Sensor type:	Strain gauge (SGS)
Sensor excitation:	5 VDC, adjustable
Low pass cut off frequency:	300 Hz (Selectable 1 kHz/3 kHz)
Sensor monitor output:	0 to +10 V for nominal expansion
Display output:	0 to max 2 V adjustable
Sensor connector (not on board)	Panel-mount, 4-conductor LEMO ERA.0S.304.CLL included for user installation

8 Dimensions

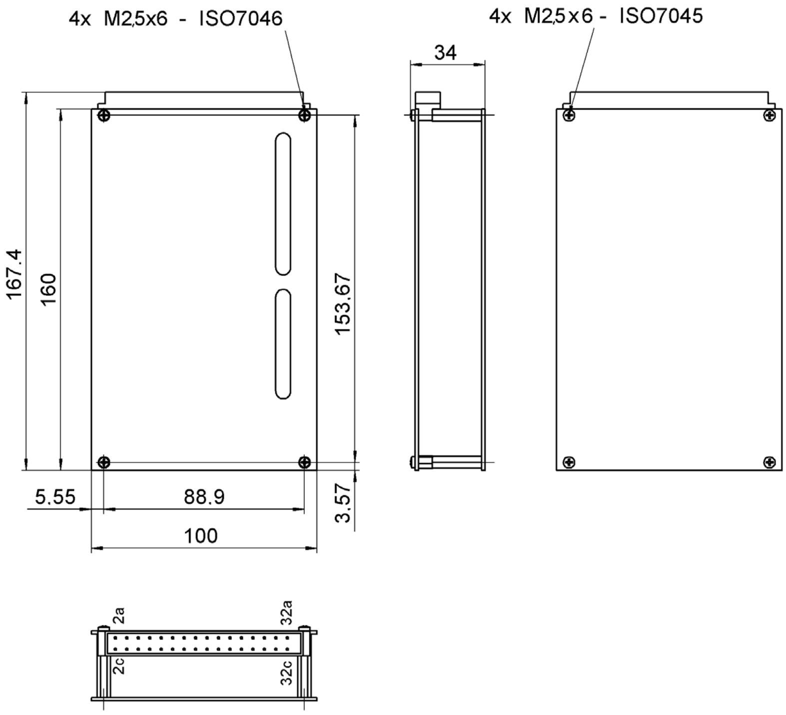


Fig. 9: E-610.00, E-610.S0 and E-610.L0 dimensions in millimeters

9 Pin Assignments

9.1 System Connection Summary

For operation, at least the following elements must be connected:

	Main Connector	Lemo Connector (if used)	Only for
Supply power, 12-30 VDC	+ 16a&c; – 18a&c		
PZT out	2 a&c		
PZT GND	4a&c		
Sensor excitation	24c, 30c (GND)	pin 1, pin 4	closed-loop
Sensor readout	26c, 28c	pin 2, pin 3	closed-loop
Control in	10c		*
DC-offset pot	12a 12c & 14ac		*
GND	22c, 20a&c, 14a&c		
Protective GND	32a&c		

*The DC-offset pot may be missing (deactivate with X4) or the Control In signal shorted, but not both.

9.2 32-Pin Main Connector

Because the DIN 41612 connector standard includes types with more pins, the 32 pins of the “D” version all carry even number designations and are in rows “a” and “c”.

PZT output, LEMO center*	a	2	c	PZT output*
PZT GND, LEMO shield*	a	4	c	PZT GND*
nc	a	6	c	nc
Monitor PZT out (100:1)	a	8	c	Internal use
Internal use	a	10	c	Amplifier input
10 kOhm pot (-10 V)	a	12	c	Pot wiper
10 kOhm pot (GND) & test GND	a	14	c	Pot 10 kOhm (GND) & test GND
+VCC supply	a	16	c	+VCC supply
-VCC supply	a	18	c	-VCC supply (connect to 20c for minimum noise)
Test GND	a	20	c	Test GND
Sensor monitor[1]	a	22	c	Sensor monitor GND, Test GND
Display sensor (adjust.)[1]	a	24	c	Sensor excitation, see wiring diagram, 4-line LEMO pin 1*
Overflow (TTL)[1]	a	26	c	Sensor readout signal, see wiring diagram, connect to 4-line LEMO pin 2*
Servo OFF/ON select[1]	a	28	c	Sensor readout signal, see wiring diagram, LEMO pin 3*
Internal use[1]	a	30	c	Sensor excitation GND, see wiring diagram, LEMO pin 4*
Protective GND	a	32	c	Protective GND

*Separate panel-mount LEMO socket(s) are included which can be used to bring the stage/actuator connection line outside the user housing and interface to PI actuators/stages. See Section 9.3 for details.

[1] Not applicable for E-610.00 amplifier-only versions

9.3 LEMO Pin Assignments

If desired, the included panel-mount LEMO socket(s) can be used to interface to plug(s) on the stage or actuator. If used, they should be wired as indicated below. Use coaxial/shielded cable and keep runs as short as possible.

Coaxial- LEMO Connector, ERN.00.250.CTL

For PZT output drive voltage:

Center from main connector pin 2 a or c,
Shield from main connector pin 4 a or c

4-conductor LEMO ERA.0S.304.CLL:

For SGS or LVDT sensor connection (not with E-610.00):

pin 1	from main connector pin 24c, sensor excitation
pin 2	from main connector pin 26c, sensor signal
pin 3	from main connector pin 28c, sensor signal
pin 4	from main connector pin 30c, sensor excitation GND
shield	from main connector pin 22c

9.4 Sensor Wiring Information

9.4.1 LVDT Sensor Description/Wiring

LVDT sensor excitation and signal processing is implemented on an E-801 submodule. Consult the E-801 User Manual for details and information on the various E-801 versions in use.

Sensors working on the principle of LVDTs have usually a bobbin with a primary winding, two secondary windings and a moving core. If an AC current is applied to the primary winding, it produces a magnetic field which is concentrated by the soft iron or ferrite core. The magnetic field then passes through the two secondary windings and induces a voltage in each. If the core is moved from the central position one secondary winding receives more magnetic flux than the other thus the induced voltages are different and proportional to the movement. LVDT transducers normally operate at 3 to 5 Vrms and at frequencies between 1 and 20 kHz and have a typical current consumption between 10 and 50 mA.

The output signal from an LVDT can be expressed as a sensitivity in mV output voltage per volts of the supply voltage and per millimeter displacement. Typical LVDT output sensitivity is in the range of about 100 to 250 mV/V/mm depending on the type.

LVDTs have to be used in conjunction with E-610.L0 modules.

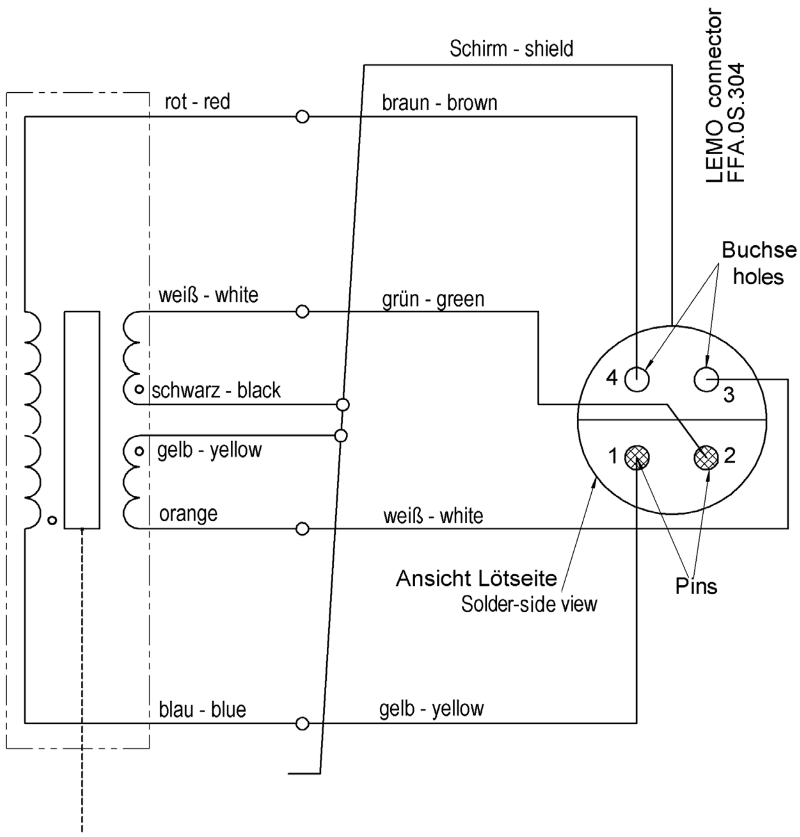


Fig. 10: Linear Variable Differential Transformer Type SMI and M6DI

9.4.2 SGS Sensor Description and Wiring

SGS sensor excitation and signal processing is implemented on an E-801 submodule. Consult the E-801 User Manual for details and information on the various E-801 versions in use.

Strain gauge sensors can be used to measure the expansion of piezo translators. In most of the standard products, two strain gauges are attached on opposite sides of the ceramic stack. Together with two bridge completion resistors, the strain gauges are wired in diagonal positions to form a Wheatstone bridge. The bridge is balanced if all four elements have the same resistance. Small tolerances can be compensated in the electronics.

The resistance of the strain gauges depends on the expansion of the piezo elements. The measuring bridge outputs a signal of about 1 mV / V at full expansion. The bridge completion resistors are mounted inside the LVPZT casing to minimize cable influence and temperature sensitivity. Only in some very small elements, where no space is available, are the resistors placed on the controller board (see jumper J401).

All LVPZTs having 60 µm expansion or more, two strain gauges and resistors are connected in series to measure with higher accuracy.

Some special strain gauges with four active elements (two Poisson gauges) are available on request.

Correct wiring of the strain gauges can be tested easily by measuring the total bridge resistance at the LEMO connector between pin 1,4 (supply) and pin 2,3 (outputs). The value should be about 700 ohm for smaller LVPZTs and about 1400 ohm for the larger ones.

Strain Gauge sensors should be used with the Module E-610.S0 but can also be operated with E-610.L0 module taking into account some restrictions.

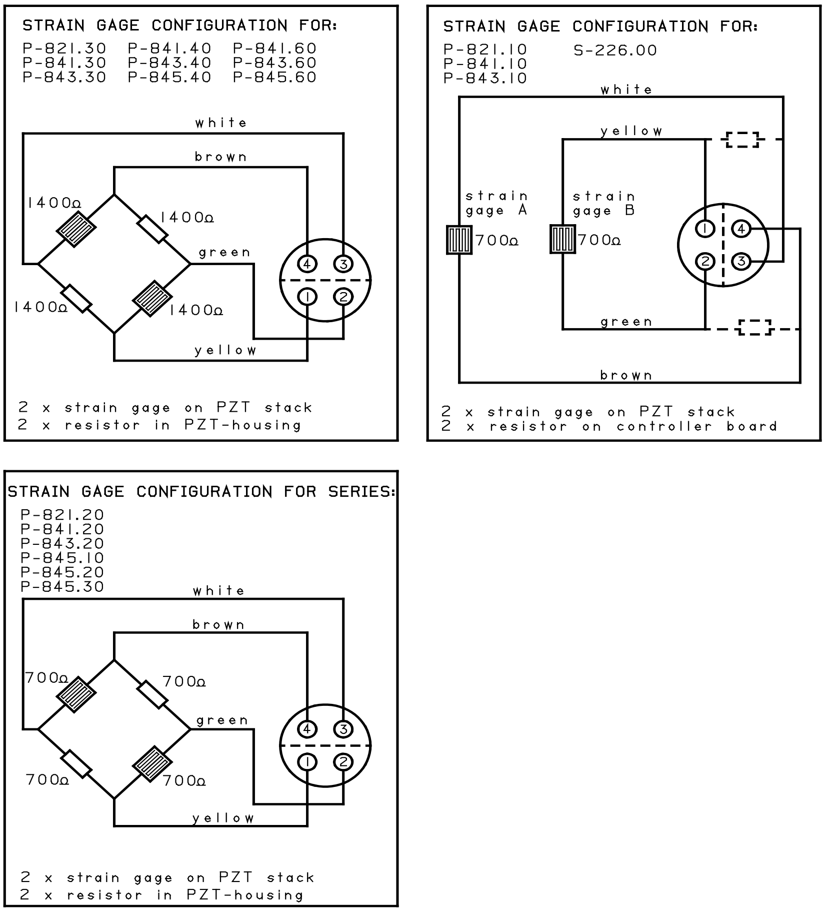


Fig. 11: Strain gauge wiring variants

10 Appendix: Piezoelectric Positioning Topics

10.1 Lifetime of PICMA® Actuators

The following factors which can have an impact on the actuator lifetime must be taken into consideration: Applied voltage, temperature and relative humidity.

The effect of each individual factor on the lifetime can be read off the diagrams shown below. The lifetime calculated in hours simply results as the product of all three values read off the diagrams.

The impact that the applied voltage has, is particularly important. With decreasing voltage the lifetime increases exponentially. This must always be taken into consideration in an application. The recommended maximum range of the control input voltage for E-610 therefore is -2 to 12 V, resulting in a piezo voltage range of -20 to 120 V. A control input range of -3 to 13 V is possible (results in -30 to 130 V piezo voltage), but will reduce the actuator lifetime accordingly.

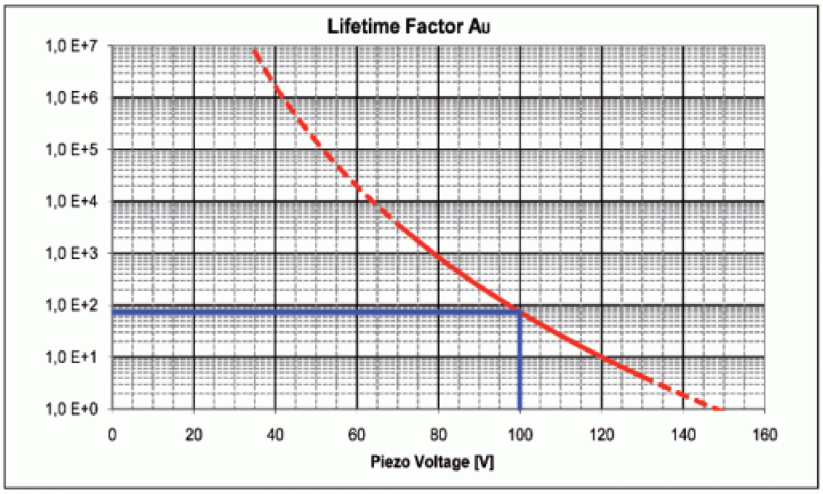


Fig. 12: Interdependency between the mean MTTF of a PICMA® actuator and the value of the voltage applied

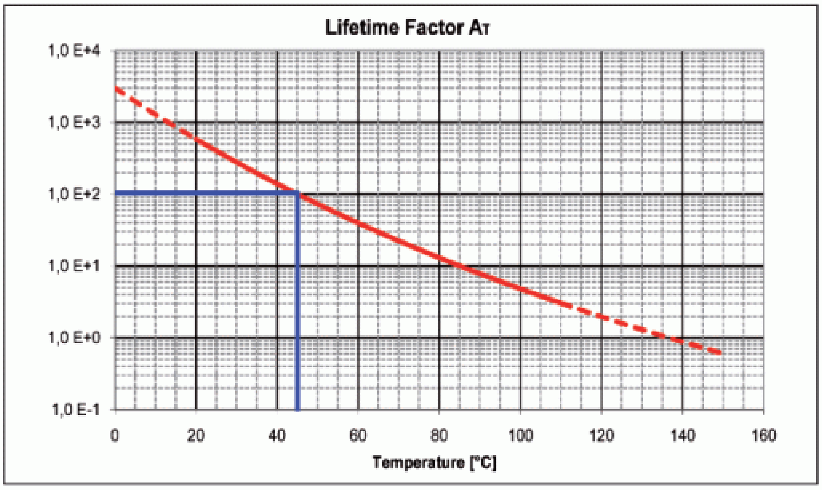


Fig. 13: Interdependency between the mean MTTF of a PICMA® actuator and the ambient temperature

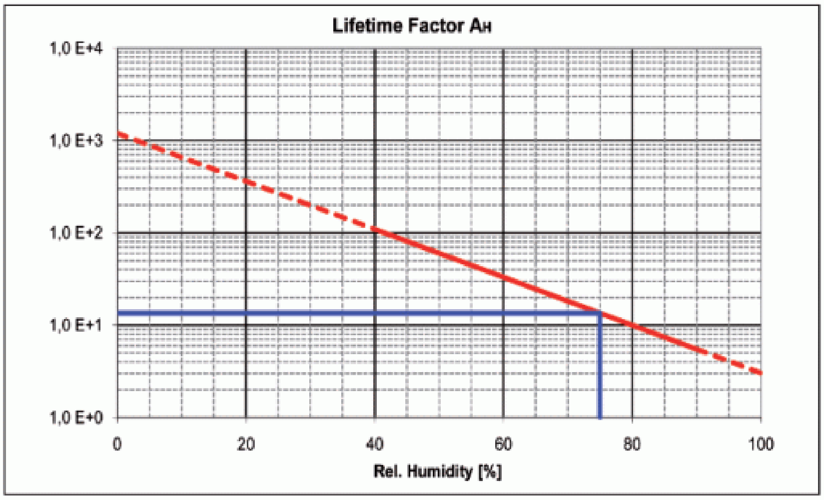


Fig. 14: Interdependency between the mean MTTF of a PICMA® actuator and the relative humidity

Example

The simple formula MTTF = A_U * A_T * A_F provides a quick estimate of the reliability in hours. In concrete terms: The values for 75% RH (A_F=14), 100 VDC (A_U=75) and 45 °C (A_T=100) result in an approximate MTTF of 105,000 h, i.e. more than 11 years (see markings on the diagrams).

Read the “Tutorial: Piezoelectrics in Positioning” in the PI Catalog for detailed information.

10.2 Sensors for Low-Voltage PZT Translators

Low-voltage piezoelectric translators are available with integrated position sensors. Most of the piezo-driven stages and tip/tilt mirror systems are also equipped with internal sensors.

Three main classes of sensors are used: strain gauge sensors (SGS), linear variable differential transformers (LVDT) and capacitive sensors (E-610.C0 version for capacitive sensors is described in User Manual PZ 72E).

Depending on the sensor type, different sensor excitation methods are used: LVDT require an AC supply and readout while SGS sensors can be excited with either AC or DC signals, (but with different performance). In general, strain gauges should be used with DC signals for best performance, although in a few applications AC-supplied strain gauges will perform with acceptable accuracy.

Using SGS sensors with an AC supply, the impact of cable length, arrangement and other properties can become a major source of limited sensor resolution. Due to these reasons, we recommend operating SGS sensors with DC voltages, i.e. with the E-610 model equipped with the appropriate sensor submodule.

11 EC Declaration of Conformity

For the E-610 Low-Voltage Piezo Amplifier/ Controller Module, an EC Declaration of Conformity has been issued in accordance with the following EMC standards and normative documents:
Low Voltage Directive
EMC Directive
RoHS Directive

The applied standards certifying the conformity are listed below.
Safety (Low Voltage Directive): EN 61010-1
EMC: EN 61326-1
RoHS: EN IEC 63000