Controllers for Piezo (Flexure) Actuators

Digital, Analog, High Power, Affordable
The E-709 opens up the possibilities of digital control for piezo-driven nanopositioning systems for the same price as analog controllers. It was designed for piezo actuators and nanopositioning stages which are equipped with cost effective measuring systems such as strain gauges or piezoresistive sensors. The advantage: higher precision, more control options and very simple operation. In addition, PI provides the full functionality of its comprehensive software packages free of charge! The E-709 can also be used for applications providing analog control signals. In addition to a variety of digital interfaces an analog input and output are also included. A software command allows the analog input to be interpreted as position control signal or as a sensor value. The analog output can be configured for the control of external amplifiers or for the output of position values.

Digital Linearization for Strain Sensors: 10 x More Precise!
For the first time, the E-709 nanopositioning controller opens up the advantages of digital control to compact systems with strain sensors. These sensors are based on the strain of metal foils or semiconductor films (piezoresistive sensors) and are used when space limitations prevent the use of the more advanced capacitive sensors, or where the requirements in terms of resolution or temperature stability are not as critical. The limited linearity of these strain sensors can be improved by digital controllers, which use additional linearization algorithms to minimize the deviation between target and actual position. This improves the accuracy by up to one order of magnitude and achieves linearity values of up to 0.02%.

Flexibility: Software Configurable Servo Parameters
All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.

OEM Versions at an Even Lower Price
E-709 controllers are also offered without case. A lower cost version sold as the E-609 is available for purely analog control signals (e.g. autofocus) to be integrated easily.

Ordering Information
E-709.PRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, Piezoresistive Sensors, Bench-Top
E-709.SRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, SGS-Sensor, Bench-Top
E-709.PR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, Piezoresistive Sensors
E-709.SR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, SGS-Sensor
The E-709 is also available for capacitive sensor-equipped positioning systems.

The target position is controlled via an analog signal, allowing system components with analog output (e.g. autofocus) to be integrated easily.
## Technical Data

<table>
<thead>
<tr>
<th>Modell</th>
<th>E-709.SR</th>
<th>E-709.SRG</th>
<th>E-709.PR</th>
<th>E-709.PRG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Digital controller for single-axis piezo nanopositioning systems (.SR, .PR: OEM board)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Channels</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Processor</strong></td>
<td>DSP 32-bit floating point, 150 MHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Servo characteristics</strong></td>
<td>P-I, two notch filters, sensor linearization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sampling rate, servo control</strong></td>
<td>10 kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sampling rate, sensor</strong></td>
<td>10 kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sensor</strong></td>
<td>Metal foil strain gauge sensors (.SR, .SRG), Piezoresistive sensors (.PR, .PRG)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Linearization</strong></td>
<td>5th order polynomials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sensor bandwidth</strong></td>
<td>5 kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sensor resolution</strong></td>
<td>16 bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ext. synchronization</strong></td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Amplifier

- **Output voltage**: -30 V to +130 V
- **Peak output power**: 10 W (<5 ms)
- **Average output power**: 5 W (>5 ms)
- **Peak current**: 100 mA (<5 ms)
- **Average current**: 50 mA (>5 ms)
- **Current limitation**: Short-circuit-proof
- **Resolution DAC**: 17 bit

### Interfaces and operation

- **Communication interfaces**: USB, RS-232, SPI
- **Piezo / sensor connector**: Sub-D 9-pin
- **I/O connector**: HD-Sub-D 26-pin, 1 analog control input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 1 analog output, 5 digital outputs (LVTTL, 3 predefined, 2 programmable)
- **Command set**: PI General Command Set (GCS)
- **User software**: PIMikroMove, NanoCapture
- **Software drivers**: LabVIEW drivers, DLLs
- **Supported functionality**: Wave generator, data recorder, auto zero, trigger I/O
- **Display**: Status LED, overflow LED

### Miscellaneous

- **Operating temperature range**: 8 to 50 °C (over 40 °C, max. power av. power derated)
- **Dimensions**: 160 x 96 x 33 mm
- **Mass**: 260 g (.SR/.PRI), 470 g (.SRG/.PRG)
- **Operating voltage**: 24 VDC
- **Power consumption**: 24 W max.
E-625 Controller for Closed-Loop Piezo Linear Actuators
Compac  e Top Device with igh-Speed Interf ace

■ Integrated 24-Bit USB Interface
■ Network Capability with up to 12 Channels
■ 120 mA Peak Current
■ Position Control with Strain Gauge or Capacitive Sensor
■ Notch Filter for Higher Bandwidth
■ Table for User-Defined Curves
■ Additional Analog Interface

The single-channel E-625 piezo controller is equipped with a RS-232 and USB interface and precision 24-bit A/D converters for exceptional positional stability and resolution. It integrates a low-noise integrated piezo amplifier which can output and sink peak currents of 120 mA for low-voltage piezoelectric actuators. Servo-controller versions for position sensing with capacitive or SGS sensors are available.

PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the resonant frequency of the mechanics.

Multi-Axis Network for up to 12 Channels
Up to twelve E-625 for capacitive or SGS sensors can be networked and controlled over a single PC interface. The different units are connected in parallel (not daisy-chained) over the link providing higher data rates than possible with serial links. Between the individual E-625s, parallel networking is realized via optional E-625.CN cables.

High-Resolution Digital Interface
The digital interface includes high-precision 24-bit A/D converters for optimum position stability and resolution and supports fast communication with the host-computer.

Waveform Memory
The built-in wave table can store user-defined data points internally. These values can then be output automatically (or under the control of an external signal) and programmed for point-by-point or full-scan triggering. Thus, trajectory profiles can be repeated reliably and commanded easily.

Extensive Software Support
The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control. The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.

Ordering Information

E-625.CR
Piezo Amplifier / Servo-Controller, 1 Channel, -30 to 130 V, Capacitive Sensor, USB, RS-232

E-625.SR
Piezo Amplifier / Servo-Controller, 1 Channel, -30 to 130 V, SGS-Sensor, USB, RS-232

E-625.CN
Network Cable for Networking of Two E-625

E-625.C0
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, -30 to 130 V, Capacitive Sensor

E-625.S0
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, -30 to 130 V, SGS-Sensor

Ideal system configuration:
E-625.CR with P-725 PIFOC® microscope objective positioner

E-625: operating limits with various PZT loads (open-loop), capacitance is measured in μF

E-625.CR compact piezo servo-controller
## Technical Data

<table>
<thead>
<tr>
<th>Model</th>
<th>E-625.SR / E-625.CR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Piezo Amplifier / Servo-Controller</td>
</tr>
<tr>
<td><strong>Axes</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Sensor</strong></td>
<td></td>
</tr>
<tr>
<td>Servo characteristics</td>
<td>P-I (analog), notch filter</td>
</tr>
<tr>
<td>Sensor type</td>
<td>SGS (.S) / capacitive (.C)</td>
</tr>
<tr>
<td><strong>Amplifier</strong></td>
<td></td>
</tr>
<tr>
<td>Control input voltage range</td>
<td>-2 to 12 V</td>
</tr>
<tr>
<td>Min. output voltage</td>
<td>-30 to 130 V</td>
</tr>
<tr>
<td>Peak current, &lt; 5 ms</td>
<td>120 mA</td>
</tr>
<tr>
<td>Average current</td>
<td>60 mA</td>
</tr>
<tr>
<td>Current limitation</td>
<td>Short-circuit-proof</td>
</tr>
<tr>
<td>Noise, 0 to 100 kHz</td>
<td>0.8 mVrms</td>
</tr>
<tr>
<td>Voltage gain</td>
<td>10 ±0.1</td>
</tr>
<tr>
<td>Input impedance</td>
<td>100 kΩ</td>
</tr>
<tr>
<td><strong>Interfaces and operation</strong></td>
<td></td>
</tr>
<tr>
<td>Interface / communication*</td>
<td>USB, RS-232 (9-pin Sub-D connector, 9.6–115.2 kBaud), 24-bit A/D and 20-bit D/A</td>
</tr>
<tr>
<td>Piezo connector</td>
<td>LEMO ERA.00.250.CTL (.SR) / Sub-D Special (.CR)</td>
</tr>
<tr>
<td>Sensor connection</td>
<td>LEMO EPL.0S.304.HLN (.SR) / Sub-D Special (.CR)</td>
</tr>
<tr>
<td>Control input sockets</td>
<td>SMB</td>
</tr>
<tr>
<td>Sensor monitor socket</td>
<td>SMB</td>
</tr>
<tr>
<td>Controller network</td>
<td>up to 12 channels, parallel</td>
</tr>
<tr>
<td>Command set*</td>
<td>PI General Command Set (GCS)</td>
</tr>
<tr>
<td>User software*</td>
<td>PIMikroMove</td>
</tr>
<tr>
<td>Software drivers*</td>
<td>LabVIEW drivers, DLL’s</td>
</tr>
<tr>
<td>Supported functionality*</td>
<td>Wave table, 256 data points, external trigger, 16 macros</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>+5 to +50 °C</td>
</tr>
<tr>
<td>Overheat protection</td>
<td>Deactivation at 75°C</td>
</tr>
<tr>
<td>Dimensions</td>
<td>205 x 105 x 60 mm</td>
</tr>
<tr>
<td>Mass</td>
<td>1.06 kg</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>12 to 30 V DC, stabilized (power supply included)</td>
</tr>
<tr>
<td>Current consumption</td>
<td>2 A</td>
</tr>
</tbody>
</table>

* E-625.S0 and E-625.C0 without interface
The E-481 high-power piezo amplifier/controller is specifically designed for dynamic operation of high-capacitance PICATM PZT actuators.

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 Input 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 In signal can be adjusted by various settings.

Selecteable 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.

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
The E-517 computer interface/display module can also be installed in the E-481.

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 ceramic exceeds a maximum temperature threshold.

Ordering Information
E-481.00
HVPZT Piezo Amplifier / Controller, Energy Recovery, 1100 V, 2000 W, 19"

Note
Requires Piezo Actuators with Option P-177.50, Temperature Sensor and Protective Air

Upgrades
Sensor / Servo-Control Modules
E-509.C1A
Sensor / Servo-Controller Module, Capacitive Sensor
E-509.S1
Sensor / Servo-Controller Module, SGS-Sensor

Interface / Display Modules
E-517.I1
Interface-/Display Module, 24 Bit D/A Ethernet, USB, RS-232, 1 Channel
E-515.01
Display Module for PZT Voltage and Position
E-500.ACD
LabView with Driver Set for Analog Controllers
E-500.HCD
Hyperbit™ Functionality for Enhanced System Resolution
Supports Certain D/A Boards.

Ask about custom designs!

High-load piezo actuators P-235.1S, .4S and .9S, P-225.8S and .1S (from left) with CD for size comparison
**Technical Data**

<table>
<thead>
<tr>
<th>Model</th>
<th>E-481.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Power amplifier for PICATM high-voltage PZTs</td>
</tr>
<tr>
<td><strong>Amplifier</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Output voltage | 0 to 1100 V (default)  
| | (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 | 2000 VA |
| Average current | >600 mA |
| Peak current | 2000 mA |
| Amplifier bandwidth, small signal | 5 kHz (660 nF), 1 Hz (3.4 µF) |
| Amplifier bandwidth, large signal | 1.4 kHz (660 nF), 350 Hz (3.4 µF) |
| Ripple, noise | 150 mV_RMS  
| 0 to 100 kHz | 2000 mV_P-P (100 nF) |
| 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** | |
| PZT voltage output socket | LEMO EGG.0B.701.CJL1173 |
| Control input socket | BNC |
| PZT temperature sensor | Max 85 °C, high voltage output is automatically deactivated if PZT temperature out of range |
| DC Offset | 10-turn pot., adds 0 to +10 V to Control IN |
| **Miscellaneous** | |
| Operating voltage | 100–120 or 220–240 VAC, 50–60 Hz (fuse change required) |
| Operating temperature range | +5 to +50 °C (over 40 °C, max. av. power derated 10%) |
| Weight | 8.6 kg |
| Dimensions | 288 x 450 x 158 mm |
E-500 · E-501 Modular Piezo Controller
Flexible System for Piezo Actuators and Nanopositioners

The E-500 modular piezo controller system offers a broad choice of control modules for nanopositioning systems and actuators. This includes piezo amplifier and position servo controller modules for up to three channels with different features as well as display and interface modules. Flexible configuration makes the system adaptable to a wide range of applications.

E-500 systems are assembled to order, tested, and, if a servo-controller is present, calibrated with the associated piezo mechanics.

Remote Control via Computer Interface
Installing the E-517, computer interface/display module (see p. 2-156) with 24-bit resolution makes possible control from a host PC.

Optionally, digital control via an external 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.

Two chassis are available:
The E-500.00 19” chassis for Piezo Controller System, 1 to 3 Channels

Ordering Information

<table>
<thead>
<tr>
<th>Model</th>
<th>E-500.00</th>
<th>E-501.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channels</td>
<td>1, 2, 3 (up to 3 amplifier modules)</td>
<td>1, 3 (1 amplifier module)</td>
</tr>
<tr>
<td>Dimensions</td>
<td>450 x 132 x 296 mm + handles</td>
<td>236 x 132 x 296 mm + handles</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>90–264 VAC, 50–60 Hz</td>
<td>90–120 / 220–264 VAC, 50–60 Hz</td>
</tr>
<tr>
<td>Max. power consumption</td>
<td>180 W</td>
<td>80 W</td>
</tr>
</tbody>
</table>

Technical Data

- Up to 3 Axes, Custom Systems up to 12 Axes and More
- Choice of Amplifier Modules for Low-Voltage and High-Voltage, 14 to 400 W Peak Power
- Choice of Position Servo Control Modules for SGS & Capacitive Sensors, 1 to 3 Channels
- Choice of PC Interface / Display Modules
- 19- & 9½-Inch Chassis

The newest release for data sheets is available for download at www.pi.ws Cat120E Inspirations2009 08/10.18
Program Overview

- Piezo Ceramic Actuators & Motors
- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Nanometrology Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapod 6-Axis Positioners / Robots
- Micropositioning Stages & Actuators
- Photonics Alignment Systems, Solutions for Telecommunications
- Motor Controllers
- Ultrasonic Linear Motors

Request or download the complete PI Nanopositioning & Piezo Actuator Catalog

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