Piezo Amplifiers and Controllers

STANDARD AND OEM SOLUTIONS

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Contents

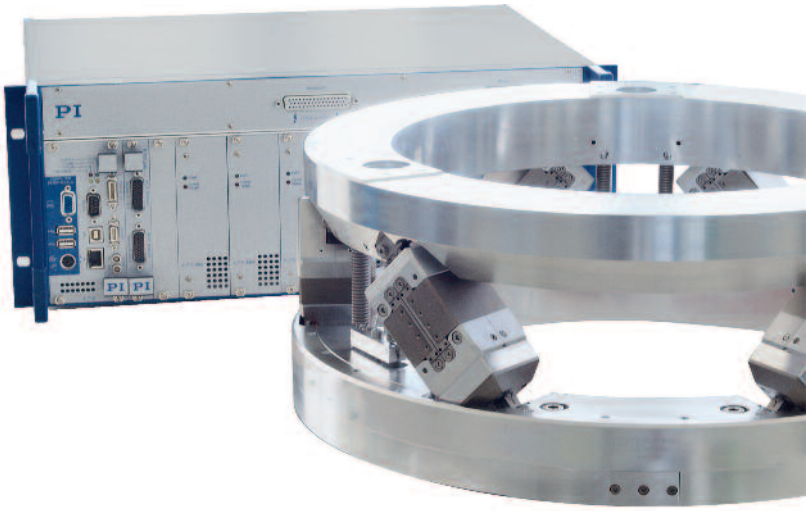
Piezo Technology and Precision Positioning

PRECISION MOTION CONTROL FOR SCIENCE AND INDUSTRY

Piezo, Nano, Positioning

PI offers the world's largest selection of positioning and drive systems for precision positioning in the accuracy range from a micrometer down to below a nanometer.

Piezo actuators are used in a wide range of integration levels, be it as direct drive or with lever amplification for greater travel, in single-axis and multi-axis positioners, with and without position measurement. Piezo stepping and ultrasonic drives as well as conventional motors, and their combinations, enable PI to provide custom-engineered positioning systems. The requirements of biotechnology, semiconductor industry, optical metrology or astronomy have one thing in common here: The high degree of precision required and PI as the supplier of the solution.



Modular, digital multi-axis controls with integrated coordinate transformation simplify the operation of complex parallel-kinematics systems, such as this Hexapod with NEXLINE® piezo stepping drives.

Just as Flexible as the Drive: The Control

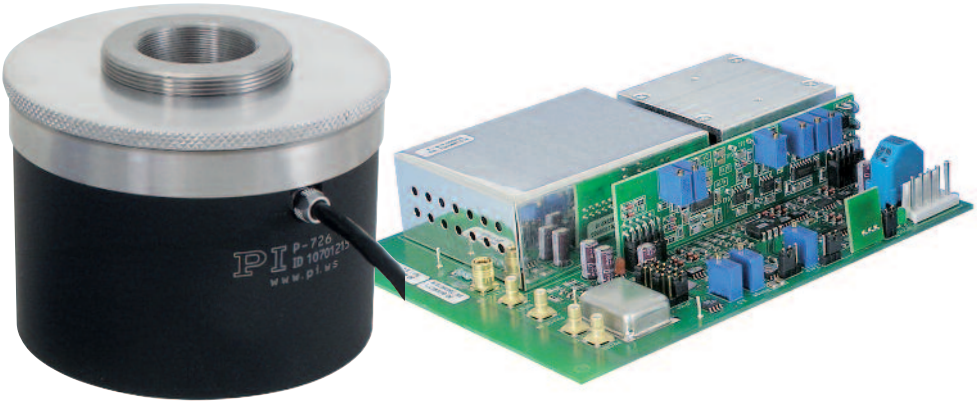
Fast settling or slow speed with high constancy, high positional stability, high resolution and high dynamics – the requirements placed on piezo systems vary greatly and need a control with a high degree of flexibility.

PI therefore offers a broad spectrum of piezo electronics from very versatile controllers to highly specialized ones: As an OEM board for integration, a plug & play bench-top device or in modular form to control almost any number of axes of motion.

Safety, Quality and Responsibility

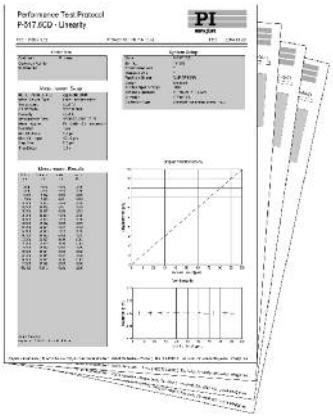
As far as PI is concerned, the certification of a quality management system is a commitment to continuously improve products and processes. Suppliers are integrated into the development process in order to transfer PI's high standards to them. PI's absolute commitment to quality leads it to train its own staff in Development and Production, provide laboratories for EMC – instrument safety tests and environmental tests, and also use the latest CAD and simulation tools. A commitment which is crucial for those working in the field of nanotechnology.

All PI products are subject to a unrelenting updating and development process which serves to continuously improve these products. Streamlined manufacturing processes together with the **Integrated Management System** (certification according to ISO 9001, ISO 14001 and OHSAS 18001) ensure high delivery reliability and quality "made in Germany".



High dynamics PIFOC® objective scanner and OEM controller. The power supply of the controller is usually integrated directly on the circuit board, the same applies to open OEM versions. The operation of the piezo system then only requires a stabilized voltage of 12 or 24 V.

Standardized Measurement Logs
The Good Feeling when Your Expectations Are Met



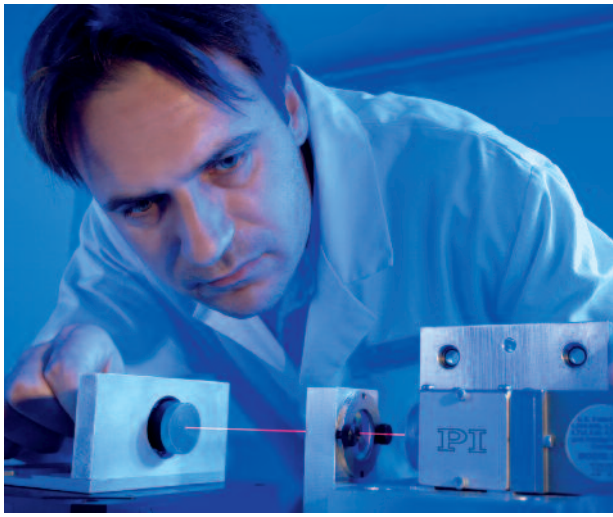
PI Nanopositioning systems are tested before shipping, the relevant log is included in the delivery.

Nanopositioning systems are an essential but costly component in applications. PI therefore individually tests and optimizes the static and dynamic parameters of every system. The measurement log is delivered with the system. The customer can therefore retrace the performance of the system at delivery and which system components belong together at any time.

PI continually invests in improving the testing methods and testing equipment in order to be able to supply systems of even higher quality.

Closed-loop nanopositioning systems are tested exclusively with high-quality calibrated interferometers. The test laboratories are insulated against seismic, electromagnetic and thermal effects, temperature stability is better than 0.25°C in 24 hours.

PI thus sets the standard in the testing and specification of nanopositioning products.



Service

Contact

If you have any further questions, please contact us at info@pi.ws or info@piceramic.de. Our technically experienced sales staff possesses a wide range of application knowledge and will provide you with expert advice.

The scope of supply of a PI system consisting of controller and stage includes everything required to operate it.

- External power supplies
- All power, communication and system cables
- The comprehensive operating manual in printed form
- Software CD with set-up function

When developing the instruments, top priority is given to the use of state of the art components. This ensures the systems have a **long availability and replaceability** even beyond the product lifecycle. All positioning systems from PI's standard range fulfill the CE and RoHS provisions.

Customized product developments and adaptations are an important part of our technical progress.

We therefore offer

- The complete range of our product spectrum from electronic components and complete devices as OEM circuit board through to the modular encased system.
- Production of small batches and large series
- Product development according to special product standards (national or market-specific standards such as the Medical Device Act, for example) and the corresponding certification
- Adaptation of the systems to special environmental conditions (vacuum, space, clean room)
- Copy-exactly agreements

The latest firmware, software and operating manual versions are available free of charge via the Internet. Firmware updates can easily be carried out via the standard interfaces of the controller.

PI offers comprehensive **software support.** PI software is included in the scope of supply for digital equipment and is used to start up the system and also to analyze and optimize the system's behavior. DLLs, LabVIEW drivers or the support of MATLAB make it easier to program the system.

PI software is, of course, compatible with the latest Microsoft operating systems and can also be operated under LINUX.

Stability and Precision

PIEZO AMPLIFIERS AND CONTROLLERS FOR NANOPOSITIONING

The characteristic properties of piezo actuators include the generation of large forces and fast response. In electrical terms a piezo element corresponds to a capacitance. A rapid change to the operating voltage brings about a rapid displacement of the actuator and thus a change in position. When the control voltage suddenly increases, the piezo actuator can achieve its nominal displacement in only a few microseconds. Requirement prerequisite for this is that the power supply provides sufficient current to charge the capacitance. In static operation, i.e. when a certain position is maintained, the stability of the power supply is also decisive. Noise or drifting must be avoided as far as possible.

Amplifier Electronics Determine Positional Accuracy and Dynamics

The control electronics are thus crucial for the performance of piezo actuators and nanopositioning systems or tip/tilt-mirrors which are based on them. High-stability amplifiers are required because piezoelectric actuators react to even the smallest change in voltage with a movement. The characteristics of the amplifier electronics used thus essentially determine the positional accuracy and dynamics which a piezo-driven nanopositioning system can achieve.

Precision in the Positioning or Switching Function: With or Without Servo Loop

At the same time, when selecting suitable amplifier electronics it is necessary to bear in mind that piezo actuators do not exhibit a linear relation between voltage increase and change in position. This is irrelevant e. g. for switching applications, like in injection valves, that manage quite well without closed-loop operation. The situation is different for accurate positioning tasks, where non-linear characteristics such as hysteresis, load variations and drift effects must be controlled by comparing the specified position (target value) with the position measured by the sensor (actual value). PI's closed-loop piezo positioning systems allow repeatabilities down to the sub-nanometer range, a non-linearity to below 0.01 % and bandwidths up to 10 kHz.

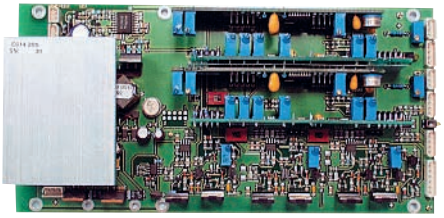
Modular Design for Flexibility

Up to three E-500 piezo amplifier modules can be installed in one E-500 chassis. A servo-control submodule for the closed-loop operation or a display and interface submodule can also be easily installed if required.

The powerful E-505 piezo amplifier module can output and sink peak currents of 2 A in a voltage range between -30 and 130 V.

Piezo amplifiers and controllers provide:

- High linearity
- Positioning with sub-nanometer accuracy
- High long-term stability
- Noise approx. 1 mV (RMS value)
- Low power consumption
- Notch filter for higher bandwidth
- Analog interfaces for fast direct commanding in real time
- Short-circuit proof



PI provides piezo amplifiers in a wide range of versions:
Boards, OEM and bench-top equipment, as well as special adaptations for the customer.

Product Examples for Analog Electronics

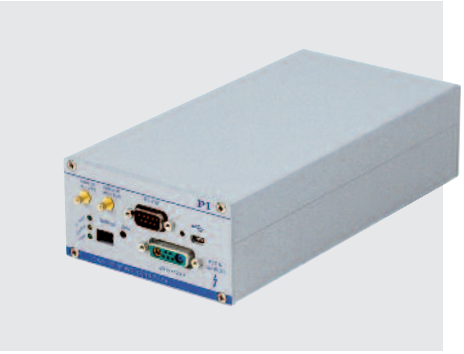
Each application has different requirements in relation to precision, peak current and voltage, dynamics and linearity, and so there is no universal control electronics which is equally well suited to all fields of application. PI therefore provides a large selection of digital and analog piezo linear amplifiers and piezo controllers.

High-Resolution Signal Processing in Real Time

The high-dynamic operation of piezo actuators demands that the charge of their capacitances can be quickly changed, which in turn requires very high peak currents. Analog piezo amplifiers and controllers from the PI range are the best option for a wide variety of applications, ranging from high-dynamics switching operation to closed-loop positioning. They do not require analog-to-digital conversion and therefore provide high-resolution signal processing in real time. Different designs, output voltages from 130 V to 1100 V, different bandwidths and interfaces ensure that a custom-made solution which is matched to the piezo actuator technology used can be found for every application. At the heart of these systems are very low-noise and high-linearity amplifier electronics.

Single-Channel Servo Controller E-610
The E-610 piezo amplifiers and servo controllers integrate a low-noise piezo amplifier which outputs and sinks peak currents of 140 mA in the low-voltage range.

- Cost-effective single-channel OEM solution
- Open-loop versions or closed-loop versions for SGS & capacitive sensors
- Notch filter for higher bandwidth
- 18 W peak power



Piezo Controller E-625 Provides Analog and Digital Interfaces
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 has an integrated low-noise piezo amplifier which can output and sink peak currents of 120 mA. Servo-controller versions for position sensing with capacitive or SGS sensors are available.

- Integrated 24 bit USB interface
- Network capability with up to 12 channels
- 12 W peak power
- Position control for strain gauges & capacitive sensors
- Notch filter for higher bandwidth
- Internal table stores user-defined curves
- Additional broadband analog interface

Servo-Controller OEM Custom Model with Position Control
Specifically matched to the application: Small package and interfaces to customer specifications. The functionality is derived from the E-610 standard model.

- Cost-effective 1-channel OEM solution
- Fixed notch filters for higher bandwidth
- Position servo-control for strain gauge sensors
- 8 W peak output power
- Power supply integrated on the circuit board
- Power can be uprated

Powerful Computer Interface, Networkable
The E-621 is equipped with an RS-232 interface and precision 24 bit D/A and A/D converters for exceptional positional stability and resolution. It has an integrated low-noise piezo amplifier which can output and sink peak currents of 120 mA. Servo-controller versions for position sensing with capacitive or SGS sensors are available.

- Analog electronics with digital interfaces
- One interface to host several channels

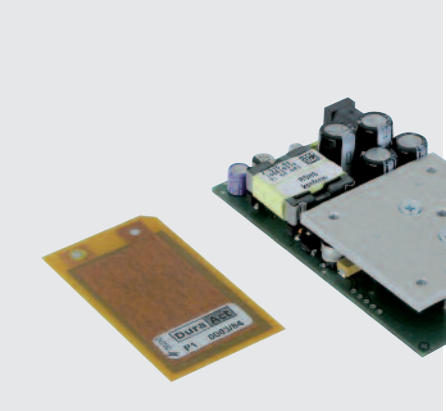
- Modular design
- Integrated 24 bit USB interface
- Up to 12 channels in one rack, networkable
- Up to 12 W peak output power
- Position control for strain gauges & capacitive sensors
- Notch filter for higher bandwidth
- Additional broadband analog interface
- Table for user-defined curves

E-831 Miniature Module
- Open-loop control
- Separate power supply for up to three electronics with up to -30 / +130V output voltage
- Bandwidth up to several kHz
- For capacitances of up to 20 µF

E-660 OEM Module for Quasi-Static Control
- +5 to +110 V
- Plug-in contacts for installation on circuit board
- Power supply included; battery operation possible

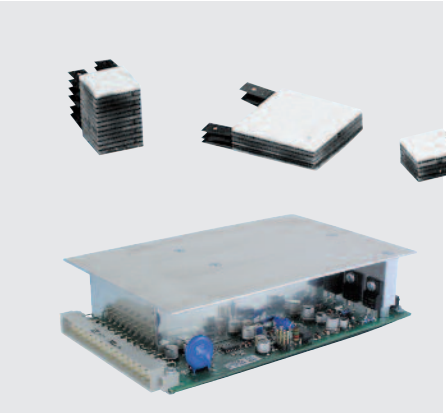
Piezo Actuators Out of the Ordinary?

AMPLIFIERS AND CONTROLLERS FOR PATCH TRANSDUCERS, BENDER ACTUATORS, SHEAR ACTUATORS



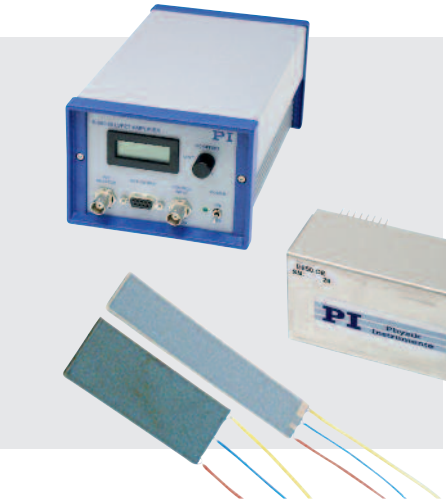
Bipolar Operation for Piezoelectric DuraAct Patch Transducers
DuraAct elements can be used as actuators, sensors or energy harvesters.

- OEM module E-835
- Peak output power up to 30 W
- Output voltage range -100 to +250 V
- Compact: 87 x 50 x 21 mm
- High bandwidth of up to 4 kHz and more



E-413 Piezo Amplifier for DuraAct and PICA Shear
Shear actuators offer high linearity, high dynamics and stiffness.

- Output voltage range -100 to +400 V or ± 250 V
- Peak output power up to 50 W
- OEM module / bench-top for PICA shear actuators
- OEM module for piezoelectric DuraAct patch transducers



E-650 Piezo Amplifier for Multilayer Bender Actuators
Bender actuators with multilayer construction provide large travel ranges with medium forces, e.g. for dynamic switching applications.

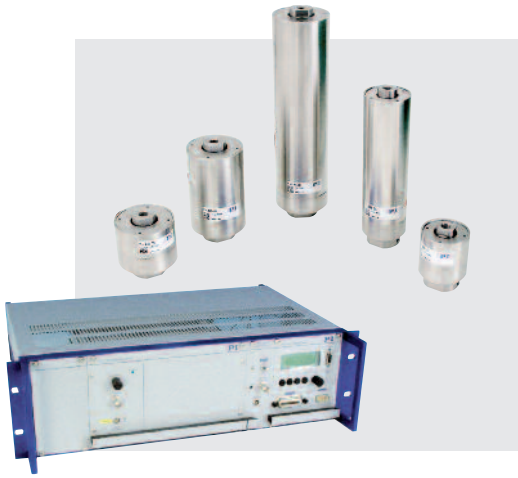
- Specifically designed to drive multilayer bimorph actuators without position sensor
- Output voltage range 0 to 60 V
- Dual-channel bench-top version or OEM version for soldering onto circuit board
- Up to 18 W peak output power

Piezo Actuators Out of the Ordinary?

AMPLIFIERS AND CONTROLLERS FOR HIGH-VOLTAGE, HIGH-LOAD ACTUATORS, BIPOLAR CONTROL

E-421, E-471 Modular High-Power Piezo Amplifier / Controller
High-load piezo actuators are designed for dynamic operation. They achieve force generation of up to 30,000 N.

- Peak output power 550 W
- Output voltage 3 to 1,100 V & bipolar
- Optional: Position control, digital interfaces, display



E-536 PicoCube® Piezo Controller: High Dynamics and Resolution in up to Three Axes
PicoCube® scanner and positioning systems provide sub-nanometer accuracy in up to three axes, e.g. for scanning force microscopy.

- Output voltage -250 / +250 V, for PicoCube® P-363 systems
- Versions:
  - Peak output power up to 3 x 100 W for high-dynamics operation
  - Minimal noise below 3 mVpp for high-resolution positioning

E-616 Multi-Channel Amplifier for Piezo Tilt Mirror
Fast tilting about two axes and linear positioning for laser beam control.

- OEM electronics with coordinate transformation
- Three integrated amplifiers provide up to 10 W peak output power
- Closed-loop and open-loop versions
- Closed-loop control for parallel-kinematics designs (three and four struts)
- Compact and cost-effective design for OEMs or bench-top
- Integrated power supply

Piezo Actuators Out of the Ordinary?

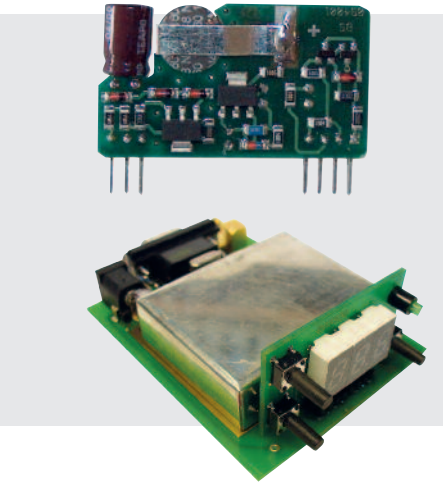
AMPLIFIERS AND CONTROLLERS FOR BENDERS, EVALUATION OF PIEZORESISTIVE SENSORS, SHAKER AND PUMPING APPLICATIONS

E-545 PInano® Piezo Controller
PInano® positioning systems for high-resolution microscopy provide coarse as well as fine positioning.

- 3 channels with 14 W peak power, USB interface
- TCP/IP, USB and RS-232 interfaces
- Low-noise 24-bit D/A converter
- 25 kHz sample rate
- Notch filter for higher bandwidths
- Wave generator with programmable trigger I/O
- Integrated linearization for piezoresistive sensors

OEM Shaker Electronics for Ultrasonic Transducers
The voltage range can be matched to the displacement required.

- Compact dimensions: 35 x 65 x 50 mm
- Bandwidth up to 20 kHz
- Power up to 5 W
- 24/7 operation



Driving Micropumps
Piezo elements are ideal drives for miniaturized pumping and dosing systems.

- Compact OEM electronics
- Suitable for circuit board mounting (lab-on-a-chip)
- Frequency and amplitude control
- Also available with display

Dynamics and Precision for Switching Applications

HIGH CURRENTS MEAN FAST RISE TIMES

Fast switching cycles require very dynamic charging and discharging of the piezo capacitance at a rate of some tens of kilohertz. The dynamics are limited solely by the charging or discharging time which the electronics can master. Correspondingly high currents provide fast rise and decay times of around a few tens of microseconds. Various power classes are available to suit the repetition rates required.

The piezo actuator heats up if it is subjected to permanently large currents in dynamic operation. PI recommends a temperature sensor be used on the actuator for such applications. If a certain temperature limit is exceeded, the power supply is automatically interrupted.

The powerful E-505.10 piezo amplifier module is available for the **modular E-500 piezo controller system,** which has been optimized especially for high-dynamics switching applications. It integrates a low-noise piezo amplifier which can output and sink peak currents of 10 mA for low-voltage piezoelectric actuators (-30 to 130 V).

Technical data:

- 1000 W peak power with 10 A peak current
- Bandwidth, small signal > 15 kHz
- Noise 1.0 mV rms
- Closed-loop operation (optional)
- Fast interface module for digital communication (optional)

Powerful E-505.10 piezo amplifier module

Powerful Duo for Continuous Applications

Continuous applications such as those in testing units for injection valves place particularly high demands on the dynamics. The modular E-618 system provides a range of options for the optimum setting up of such applications. A bandwidth of 15 kHz is possible with a peak power of 3,200 W and peak currents up to 20 A. A further addition is the evaluation for a temperature sensor at the actuator. The amplifier can be upgraded to a piezo controller by means of plug-in modules with position control. Digital interfaces are available as optional extras.

Actuators for High-Dynamics Applications

The motion or displacement of the piezo actuator is based on pure solid state effects. The dynamics that can be achieved are therefore usually limited by the electronics, and not by the mechanical design. Continuous operation with high power and high dynamics nevertheless requires the corresponding cables and contacts. PICMA® actuators with patented, meander-shaped external electrodes supply the electric current evenly to the internal electrodes. The contact itself remains electrically stable and mechanically flexible even at high currents of up to 20 A, thus supporting a particularly dynamic control.

PICMA® actuators with patented, meander-shaped external electrodes for up to 20 A charging current

Piezo actuator with integrated preload for up to 300 N tensile load, connection for protective air and temperature sensor. 10 µm travel at up to 7 kHz

E-618 high-power piezo amplifier

Application examples

- Material testing and precision engineering
- Shock tests
- Machine testing
- Switches
- Acceleration tests
- Structure analysis
- Active vibration damping
- Injection valve control

Solutions for High-Dynamics 24/7 Operation

SWITCHED AMPLIFIERS WITH ENERGY RECOVERY

Piezo actuators are often used for the particularly precise machining of materials, e.g. in mechanical engineering for fine positioning in milling machines and lathes. These applications require large forces and high dynamics. The piezo actuators are dimensioned to provide these large forces, i.e. piezo actuators with high capacitance are used. Particularly high currents are used to charge or discharge the actuators with the dynamics needed. Similar characteristics are necessary to control valves.

Energy Recovery Minimizes Energy Consumption in Continuous Operation

Since these applications often operate around the clock, seven days a week, the energy consumption of the amplifier is important. PI's answer is a switched amplifier electronics, where the pulse width of the input signal is modulated and thus the piezo voltage ist controlled (PWM). This results in a particularly high efficiency. A patented circuit for energy recovery is also integrated: It stores a portion of the energy which flows back as the piezo discharges in a capacitive store, and makes it available again for the next charging process. This makes it possible to achieve energy savings of up to 80% . Moreover, the amplifier does not heat up as much and thus does not impact as much on the actual application.

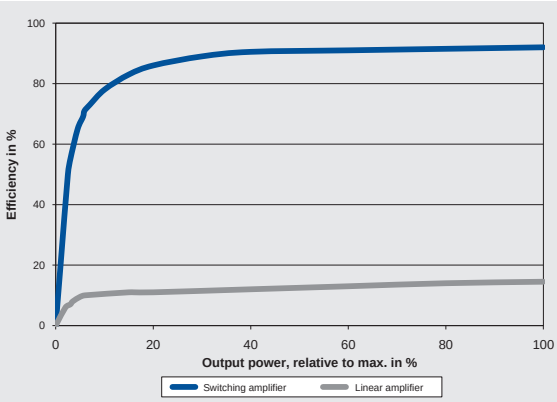
In contrast to conventional Class D – switched amplifiers, PI's switched amplifiers for piezo elements are current and voltage controlled. This patented system means they are also suitable for applications in the field of active vibration control, where it is important that they be adapted to the dynamic range required at the time.

Temperature Monitoring Protects the Piezo Actuator

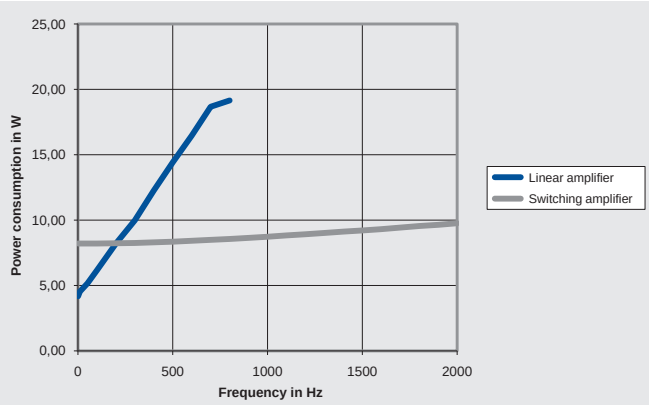
The energy loss in the piezo itself is low – very little waste heat is generated. This cannot be neglected in continuous operation, however. The appropriate electronics can therefore evaluate the signals of a temperature sensor on the piezo. The ceramic is thus protected from overheating and premature aging. Possible fissures, which could cause flashovers, can be prevented.

Applicable Patents

German Patent No. 19825210C2
International Patent No. 1080502B1
US Patent No. 6617754B1



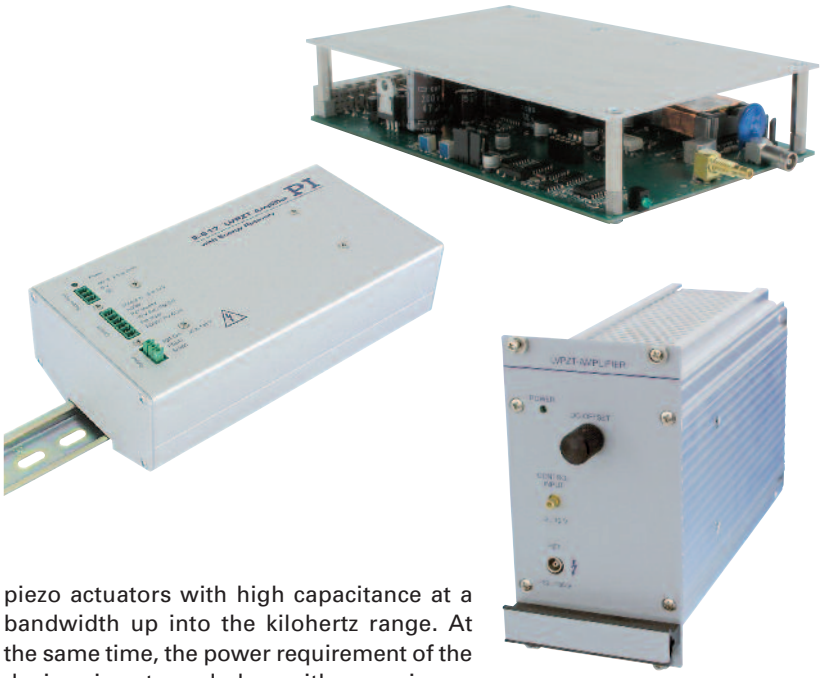
For the same output power PI amplifiers with patented energy recovery consume only around 20 % of the power consumed by a corresponding linear amplifier.



Power consumption of a piezo amplifier with linear and switched power stage at the piezo output, capacitive load 1 µF. The measured values show clearly that the pulse-width modulated amplifier allows significantly higher dynamics than the amplifier operating in conventional linear mode. The linear amplifier reaches the upper limit of its power consumption at frequencies of up to around 700 Hz whereas the switched amplifier only reaches this limit far above 2 kHz.

Product Examples: Particularly Powerful, Dynamic and Economical

Three models of switched amplifier with integrated energy recovery are available. The E-617.001 (left in picture) is designed for installation on a top-hat rail and is therefore ideally suited for use in automation and industry. The E-617.00F (center) is a compact OEM module designed for installation in a chassis. The E-504 power amplifier module (right) supplements the modular E-500 piezo controller series. A position control and digital interfaces or a display can be integrated as optional extras.



Technical data:

- Peak output power 280 W
- High average output power 100 W
- Peak current of up to 2 A
- Output voltage range -30 to 130 V
- Bandwidth up to 3.5 kHz

These piezo amplifiers thus make it possible to have dynamic operation of low-voltage piezo actuators with high capacitance at a bandwidth up into the kilohertz range. At the same time, the power requirement of the devices is extremely low with a maximum of 30 W.

The principle of energy recovery is also available for **high-voltage actuators** with a voltage swing of up to 1,100 V in unipolar or bipolar control. The modular high-power E-481 piezo amplifier / controller provides a peak power of 2,000 W and peak currents of up to 2 A.

An evaluation of a temperature sensor is integrated to protect the piezo actuator from thermal overload. Piezo current and voltage can be tapped via monitor connections. The E-481 is available with the option of position control, digital interfaces, or display.

E-481 high-power piezo amplifier
Digital linearization algorithms can also be implemented to improve the open-loop positioning accuracy in this high-power version with 2 kW and 2 A. Linearity values of around 99% are then achieved.

Application examples

- Valve control (e.g. pneumatics)
- Injection valves
- High-dynamic scanning
- Milling machines
- Laser beam control
- Active vibration damping

Linearized Amplifiers for Piezo Displacement Without Hysteresis

CHARGE CONTROL

For dynamic applications:

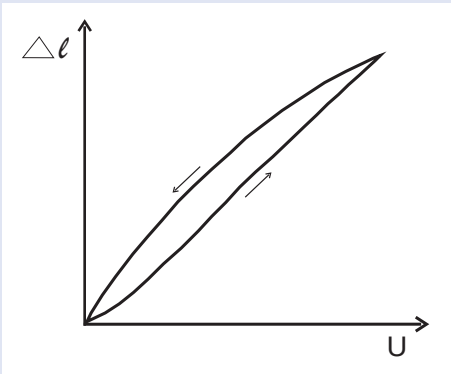
- Active vibration damping
- Adaptronics
- Fast mechanical switches
- Valve control (e.g. pneumatics)
- Dosing

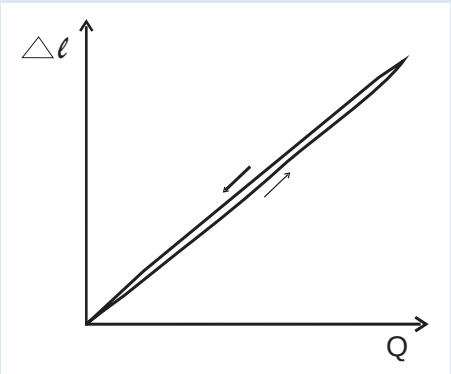
Dynamic scanning is a typical field of application for piezo actuators or nanopositioning systems. Two different methods can be distinguished here: Step and settle mode, where a position can repeatedly be approached with precision, and ramping mode, where the piezo displacement has a particularly linear characteristic. The first case requires a closed servo-loop to ensure that the positions are repeatedly approached with reliability, and the step size is kept constant.

Ramping mode, with its linear piezo displacement, can also be realized via position feedback and servo loop, of course. The servo loop then determines the dynamics of the overall system. However, in some cases this significantly reduces the number of cycles per unit of time. This can be avoided with an alternative amplifier principle; the so-called charge control.

Charge and Displacement

Charge control utilizes the fact that, for piezos, the relation between electrical charge and displacement is considerably more linear than the relation between voltage applied and displacement. The deviation in the first case amounts to only around 2 %, while it is about 10 to 15 % for voltage control (see diagrams below). With charge control it is therefore often possible to achieve the necessary precision without servo loop. This improves the dynamics and costs less. It is not only high-dynamic applications which benefit from charge control, the benefit is also felt at very low operating frequencies. However, it is unsuitable for tasks where positions have to be held over longer periods, because the positional drift of the piezo actuator is not compensated.





Typical displacement characteristic of piezo actuators as a function of the voltage applied (left) and charge (right). The hysteresis is significantly reduced by controlling the charge applied.

The E-506.10 piezo amplifier module is designed to work in the E-500 controller system. It features a low-noise high-power amplifier for low-voltage piezo actuators and positioners that can output and sink a peak current of up to 2A in the -30 to +130V voltage range.

- Highly linear amplifier module with charge control
- 280 W peak output power
- Piezo overtemperature protection
- Optional extras: Position control, digital interfaces, display

The electric circuit requires the piezo systems to have a ground-free construction and corresponding connections.

Digital Controllers

PRECISION, DYNAMICS AND EASE OF OPERATION

Digital controllers have advantages over analog amplifier electronics which are particularly relevant to high-precision positioning tasks: All motion parameters can be specifically influenced by calculation algorithms. This increases the precision and the dynamic characteristics.

Software for Easy Operation

The digitalization of all process steps means the process parameters can be easily accessed using software. As soon as the load changes, for example, the software allows digital controllers to change servo parameters immediately.

In addition, PI software offers diagnostic tools and assistance with the adjustment of settings, such as the graphic display of step responses for the optimization of parameter settings.

Digital Data Processing

Digital processing improves the system performance:

Linearization of the Electronics

All digital PI controllers for nanopositioning operate in the same way. It is thus possible to operate any piezo mechanical system that has been fine-tuned to a digital control with other controllers without loss of performance. The adjustment data required is stored on the stage's ID chip and processed by the controller when the system is first started up.

Servo Control Loop and Control Characteristics

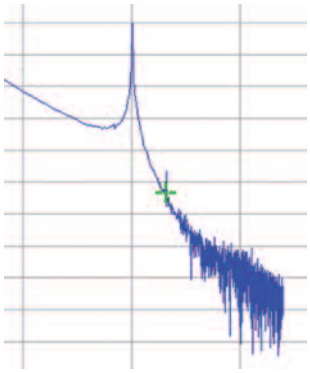
The controller compensates the deviation between the actual position and the target position. PID controllers are typically used for this. Depending on the application, however, different controlling methods in combination with linearization algorithms can achieve better results. Digital filters prevent undesired excitations, suppress noise and thus increase the resolution of the systems.

Linearization of the Mechanical System

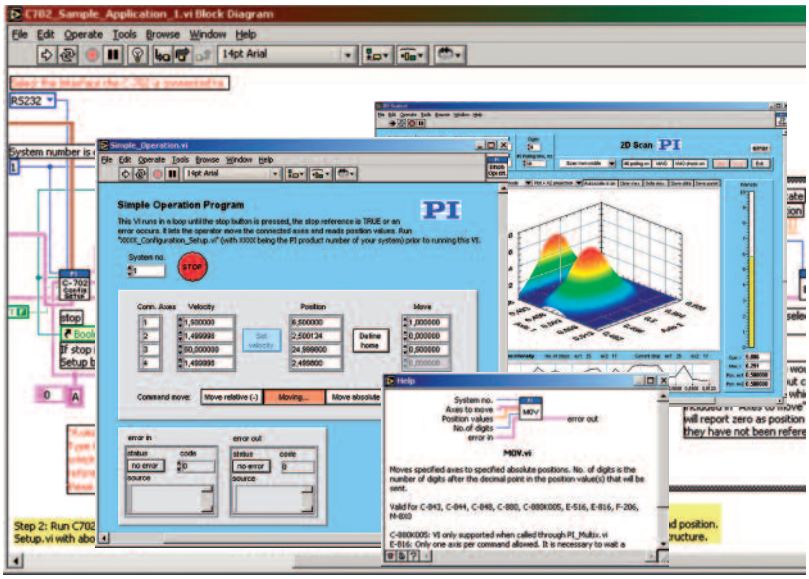
The linearity of the entire system is one criterion for its positioning accuracy. Piezo actuators have a non-linearity of 10 to 15% of the travel range, which has to be compensated for by the target values supplied and the closed-loop control so that the system reaches the position with maximum accuracy. Digital controllers reduce the non-linearity of the motion to a value below 0.001% by using polynomials of higher order in the calculation – in a travel range of 100 µm this value corresponds to an accuracy of below one nanometer.

Dynamic Linearization

The Dynamic Digital Linearization (DDL) reduces the deviation of periodic trajectories even while the motion is being carried out. This is important for scanning applications that have to identify a particular position and have to accurately reach this position again, or for applications where there must be no deviation from the trajectory for specific processing steps.



Software from PI for ease of operation and performance optimization of piezo systems: The adjustment tool for parameters shows the frequency response of a nanopositioning stage in the Bode plot



Rapid access to the full functionality

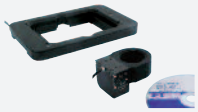
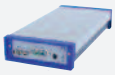
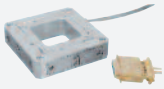
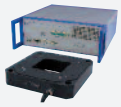
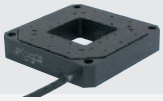
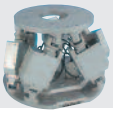
Product Overview and Systems

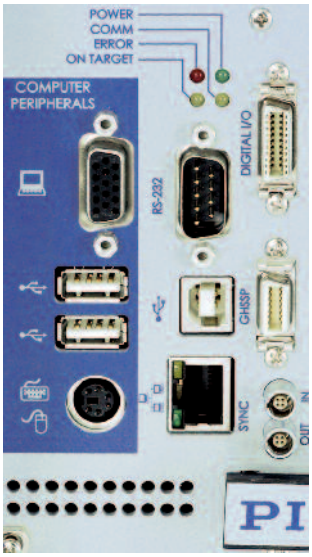
Additional Functions of Digital Controllers*

Computing power and memory, which go hand in hand with digital controllers, allow useful additional functions to be implemented

- **Software access** to all motion parameters and the graphic display of the effects
- **Coordinate transformation** for parallel kinematics for simple commanding in Cartesian coordinates
- **Macro memory** to store and retrieve motions which can be externally triggered
- **Function generator and waveform memory** for the retrieval of predefined trajectories and the generation of customized wave forms
- **Data recorders** record sensor and control data for subsequent processing.
- The **ID Chip** allows the flexible exchange of controllers and nanopositioners without having to adjust the operational parameters again

*Not all controllers have all the functions. The individual ranges of functions are listed in the respective datasheets.

Drives		Controller platform	
Nanopositioning systems with 1 axis		E-753	
Nanopositioning systems with up to 3 axes, low-power requirement		E-761	
Nanopositioning systems with up to 3 axes		E-725	
Nanopositioning systems with up to 6 axes		E-712	
PICOCUBE® high-speed scanner		E-712	
NEXLINE® heavy-duty nanopositioning drive		E-755 E-712	
NEXLINE® parallel-kinematic with up to 3 axes		E-712	
Positioning systems with NEXACT® nanopositioning drive (with encoder analysis)		E-861	
Positioning systems with DC-servo motors and encoder analysis / PILine® ultrasonic piezo drives with encoder analysis / stepper motors		C-863 C-867 C-663	
Hexapods/ parallel kinematics with any drives		Digital Hexapod controller	



The standard interfaces for digital nanopositioning controllers are RS-232, USB and TCP/IP. On top of this, PI provides additional digital I/O lines as well as options for analog interfaces or a PIO for real-time commanding.

“High-End” or “Low-Cost”? Controller Performance Made to Measure

Ideal for all Power Classes

The most important requirement is that analog input signals are converted quickly and with high resolution for the subsequent processing. Information which is lost during conversion is lost forever. The same applies to the generation of the output signal: The best algorithms are useless if the output signal cannot be genera ted with high resolution.

PI therefore uses A/D and D/A converters with at least 20 bit resolution in the most powerful controllers for multi-axis high-resolution positioning systems. This means that analog signals are resolved into more than one million data points.

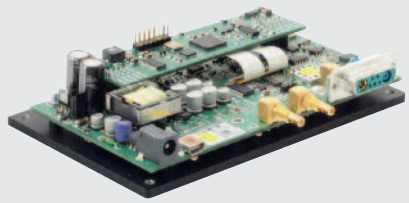
At the same time, the incoming volumes of data must be processed rapidly to achieve results similar to those of conventional analog controllers in terms of real time. This requires fast processors: Modern DSPs or powerful PC solutions, depending on the task the controller has to fulfill.

A cycle is thus completed in 0.02 milliseconds, for example; this corresponds to a servo rate of 50 kHz. Updated sensor data and control signals are then provided accordingly.

Low-Cost Digital Technology – This is no Contradiction!

PI provides a number of low-cost digital controllers and thus achieves accuracies ranging from one to ten nanometers. The single-channel E-709 supports both strain gauge sensors (metal foils and piezoresistive) and capacitive sensors. The D/A conversion is 16 bit, the 32 bit processor with 150 MHz clock-pulse rate allows a servo rate of 10 kHz – i.e. position recalculations are carried out 10,000 times per second. The amplifier provides 5 W continuous power for the dynamic operation of conventional nanopositioning systems such as the P-721 PIFOC® objective scanner, for example.

The digital linearization algorithms noticeably improve the performance of piezo positioning systems equipped with strain gauge sensors (SGS).



The same technology is contained in the E-609 piezo controller and in the E-709 digital servo controller. In the E-609, PI uses a digital controller in a device with pure analog control input. The E-709 additionally provides the commanding via SPI, USB and RS-232 interfaces.

Digital E-712 Piezo Controller System for Nanopositioning

Modular System for Maximum Precision for up to Six Axes

- Maximum precision for up to 6 axes, and Hexapod control
- 600 MHz processor; servo update rate up to 50 kHz; high-stability 20-bit D/A converter
- Real-time operating system for optimum tracking accuracy
- ID-Chip support for automatic calibration of the controller to the piezo mechanical system
- Ethernet, USB, RS-232, optional high-bandwidth analog inputs and outputs
- Comprehensive software package
- Modular design for maximum flexibility in meeting customer requirements

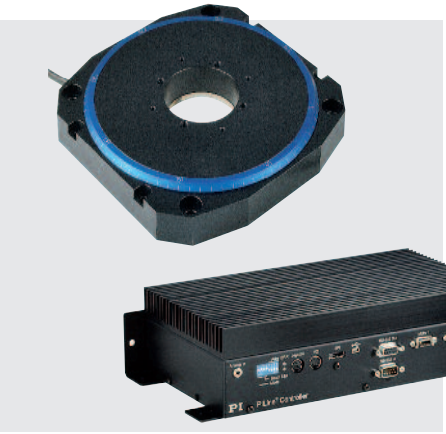
Digital Out of the Ordinary: Controllers for Piezo Stepping and Ultrasonic Drives

E-861 Controller/Driver for PiezoWalk® NEXACT® Linear Drives and Positioners
Piezo stepping drives combine large force, dynamics and unlimited travel.

- Networkable for multi-axis operation
- Complete system with controller, integrated power amplifiers and software; parameters changeable on-the-fly
- High performance at low cost
- I/O for automation, joystick for manual operation, stand-alone functionality
- OEM version for open-loop operation

E-712 Digital Piezo Controller System
Modular design for several axes.

- Amplifier modules for different drive concepts: Piezo actuators, NEXLINE® and NEXACT® piezo stepping drives.
- Maximum precision for Hexapod control as well
- Up to 13 channels in 19'' chassis
- Evaluation of capacitive and incremental position sensors
- Real-time data transfer via fast parallel interfaces
- Real-time operating system for synchronization with system components



C-867 Controller for PILine® Piezo Linear Drives
PILine® piezo ultrasonic motors are particularly compact and fast.

- Broadband encoder inputs for high speed and high resolution
- PID servo-control with dynamic parameter switching
- Integrated power driver piezo motor with frequency control
- USB, RS-232 and analog interfaces (e.g. for a joystick)
- 4 + 4 programmable TTL I/Os for flexible automation
- Data recorder
- Extensive software support, LabVIEW, DLL, macro programming, etc.

Selection Criteria for Piezo Amplifiers and Controllers from PI

Choosing the right piezo controller depends on the actual application situation. A wide variety of criteria such as limitations to the installation space available, single-axis or multi-axis solutions, or the necessity of having PC control determine which amplifier or controller is the right one.

A number of analog and digital controllers are available for nanopositioning tasks:

Your application requires ...	Which Piezo servo controller is suitable?
Frequent load changes or changes to the mode of operation	Set parameters easily with software: All digital ones from PI, including the E-609 series
Reasonably priced	Digital: E-709 or E-609; Analog: E-610, E-625, E-621)
3 to 6 channels	Digital: E-725, E-710, E-712; Analog: E-500, E-612
More than 6 channels	Networkable controllers such as E-621, E-625, E-665; modular controller such as E-712, E-500
Resolution	Digital high-end solutions from PI such as E-753, E-712, E-725; Every analog one
Optimum dynamic linearity	Digital high-end solutions from PI with DDL option
Long-term stability (thermal)	All piezo controllers and amplifiers from PI
Linearity / accuracy	All digital ones from PI, including the E-709 series: Digitalization polynomials up to 5th order; additional DDL option
Position control by means of analog input signal	All analog ones; Digital ones E-709, E-609, E-753 or E-712 with analog IN option
Real-time commanding	Digital ones with PIO-option; SPI-interface (standard for E-709!), TCP/IP for transmission rates up to 1 kHz; all controllers with analog I/O
Control in real-time or with high servo rates	All analog ones; E-712, E-753, E-725
Fast, non-periodic motion in several axes, tracking	E-712
Virtual axes and multi-axis synchronization	Digital multi-axis controllers such as E-712, E-725
Digital communication interfaces; user-defined periodic motion profiles; data recorder	All digital ones; E-625, E-621, E-665; Modular controller with E-517 digital operation module
Stand-alone functionality with macros	Modular controller with E-517 digital operating unit
Trigger I/Os	All digital ones; E-625, E-621, E-665; Modular controllers with E-517 digital operating unit

Your application is highly dynamic ...	Which high-power piezo amplifier is suitable?
Positioning with sub-nanometer accuracy and outstanding stability	E-505 amplifier module in the E-505 controller system; For long-term stability position control with capacitive or strain gauge sensors as an optional extra
Dynamic scanning with high linearity	E-506 linearized amplifier with charge control for maximum dynamics; E-505 power amplifier with position control
Dynamic scanning in continuous operation	E-617, E-504 switched amplifier with energy recovery for minimum energy consumption
Dynamic scanning in continuous operation, high capacitive loads	E-618 with particularly large charging current up to 20 A for very steep rising edges E-505.10 amplifier with large charging current up to 10 A
Fast switching, low number of cycles	E-505.10 amplifier with large charging current up to 10 A E-617, E-504 switched amplifier with energy recovery

For more information

A complete description of the products presented in this overview can be found on our website at www.pi.ws and in the **PI Main Catalog,** which we will be pleased to send to you on request.

Detailed information on digital piezo controllers is available in our current brochure **„Digital Control – Best Performance for Positioning Systems“.**

Well-presented basic knowledge on the subject of **Piezoactuators in Nanopositioning** can also be found at www.pi.ws and on the website of our subsidiary PI Ceramic (www.piceramic.de).

PI

PI General Catalog

Request it now!

The 530 page hardbound catalogue from PI is the most comprehensive reference book on the fundamentals of nano-positioning, piezo systems and micro-positioning technology yet. The catalog contains 200 product families, with more than 1000 drawings, graphs, images and technical diagrams.

Headquarters

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
Auf der Römerstraße 1
76228 Karlsruhe/Palmbach
Tel: +49 (721) 4846-0
Fax: +49 (721) 4846-1019
Email: info@pi.ws
www.pi.ws

PI Ceramic GmbH
Lindenstraße
07589 Lederhose
Tel: +49 (36604) 882-0
Fax: +49 (36604) 882-4109
Email: info@piceramic.de
www.piceramic.de

Subsidiaries

USA (East) & CANADA

PI (Physik Instrumente) L.P.
16 Albert St.
Auburn, MA 01501
Tel: +1 (508) 832 3456
Fax: +1 (508) 832 0506
Email: info@pi-usa.us
www.pi-usa.us

USA (West) & MEXICO

PI (Physik Instrumente) L.P.
5420 Trabuco Rd., Suite 100
Irvine, CA 92620
Tel: +1 (949) 679 9191
Fax: +1 (949) 679 9292
Email: info@pi-usa.us
www.pi-usa.us

JAPAN

PI Japan Co., Ltd.
Akebono-cho 2-38-5
Tachikawa-shi
Tokyo 190-0012
Tel: +81 (42) 526 7300
Fax: +81 (42) 526 7301
Email: info@pi-japan.jp
www.pi-japan.jp

PI Japan Co., Ltd.
Hanahara Dai-Ni Building #703
4-11-27 Nishinakajima,
Yodogawa-ku, Osaka-shi,
Osaka 532-0011
Tel: +81 (6) 6304 5605
Fax: +81 (6) 6304 5606
Email: info@pi-japan.jp
www.pi-japan.jp

UK & IRELAND

PI (Physik Instrumente) Ltd.
Trent House, University Way,
Cranfield Technology Park,
Cranfield, Bedford MK43 0AN
Tel: +44 (1234) 756 360
Fax: +44 (1234) 756 369
Email: uk@pi.ws
www.physikinstrumente.co.uk

ITALY

Physik Instrumente (PI) S. r. l.
Via G. Marconi, 28
20091 Bresso (MI)
Tel: +39 (02) 665 011 01
Fax: +39 (02) 610 396 56
Email: info@pionline.it
www.pionline.it

FRANCE

PI France S.A.S.
244 bis, avenue Marx Dormoy
92120 Montrouge
Tel: +33 (1) 55 22 60 00
Fax: +33 (1) 41 48 56 62
Email: info.france@pi.ws
www.pifrance.fr

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
Building No. 7-106
Longdong Avenue 3000
201203 Shanghai
Tel: +86 (21) 518 792 98
Fax: +86 (21) 687 900 98
Email: info@pi-china.cn
www.pi-china.cn