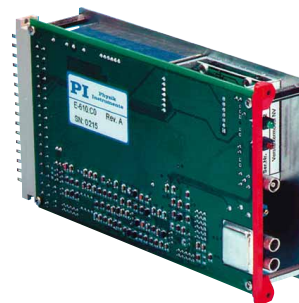**PI**

Piezo Nanopositioning Controllers

Analog Servo, Digital Interface Options

FAST

PRECISE

INDIVIDUAL

PI

Analog Piezo Nanopositioning Controllers

Single Axis Controllers

E-610 OEM module. One axis, open & closed-loop models

E-621 OEM Module. USB & RS-232 interfaces, 24 bit D/A converters. Additional analog interface. Network feature for up to 12 channels

E-625. Bench –Top Module. USB & RS-232 interfaces, 24 bit D/A converters. Additional analog interface. Network feature for up to 12 channels

Multi Axis Controllers

E-545 Economical controller for PInano™ piezo scanning microscope stages, 3-channels

E-500 Modular High-Power Piezo Controller System, 1 to 6 channels up to 200 W

E-664 Low-Cost Controller for NanoCube® XYZ piezo systems

E-536 Controller for PicoCube ultra-precision AFM scanner for picometer resolution

E-616 low-cost steering mirror controller module, 2 & 3 axis, bench top also available

30-channel controller consisting of E-621 piezo control modules and E-500.621 chasses

PI

E-610 Piezo Amplifier / Nanopositioning Controller Card
1-Channel OEM Piezo Driver Module with Optional Position Servo-Control
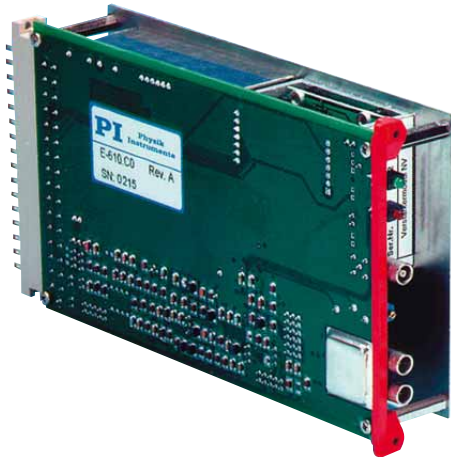
E-610 Single-channel OEM module with optional position servo control

- **Cost-Effective 1-Channel OEM Solution**
- **Closed-Loop and Open-Loop Versions**
- **Notch Filter for Higher Bandwidth**
- **Position Control with Strain Gauge or Capacitive Sensor**
- **18 W Peak Power**

The E-610 is an OEM amplifier & position servo-control board for low-voltage piezo actuators and positioning systems. It integrates a low-noise piezo amplifier which can output and sink peak currents of 180 mA in a voltage range of -20 to +120 V. Three versions are available: E-610.00 (only amplifier) and closed-loop versions E-610.S0 and E-610.C0 with additional components for position measurement and servo control.

Closed-Loop and Open-Loop Piezo Positioning

The units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and in position-controlled mode (closed-loop).

In closed-loop position control mode, displacement of the piezo is highly linear and proportional to the analog signal. The servo modifies the amplifier output voltage based on the position sensor signal. Thus, positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and on the sensor type.

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.

In open-loop (voltage-controlled) operation the output voltage is determined by an external analog signal. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors (see p. 2-104).

Remote Control via Computer Interface

For digital-interface computer control, consider the E-621 (see p. 2-160) and E-625 (see p. 2-114) instead.

Alternatively control via PC using a D/A board is possible. PI offers a LabVIEW driver set which can be used with certain D/A boards from National Instruments.
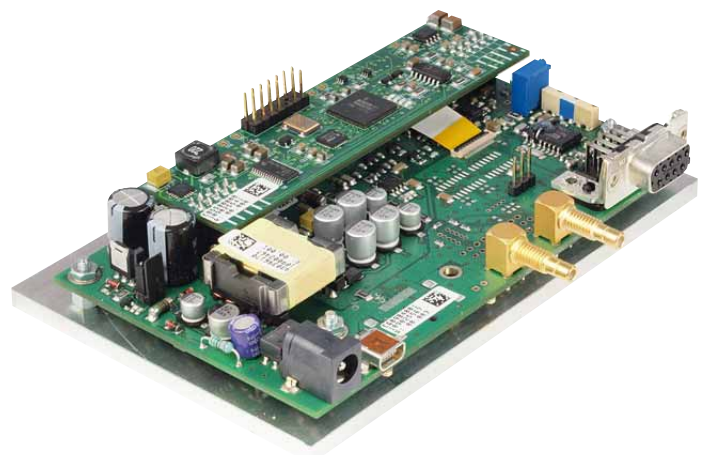
Operation / Contents of Delivery

A single stabilized voltage in the range of 12 to 30 V is sufficient to operate the E-610. An integrated DC/DC converter generates the piezo operating voltage and all other voltages used internally. All inputs and outputs (except capacitive sensor lines) are available on the male 32-pin rear connector. A matching female 32-pin connector is included in the contents of delivery to interface with your circuitry.

Ordering Information

E-610.00
Piezo Amplifier, 1 Channel, OEM Module, -30 to 130 V

E-610.C0
Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -20 to 120 V, Capacitive Sensor

E-610.S0
Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -30 to 130 V, SGS-Sensor

E-500.ACD
LabVIEW Driver Set for Analog Controllers

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution (Supports Certain D/A Boards)

An OEM version with a digital controller is available – the E-609
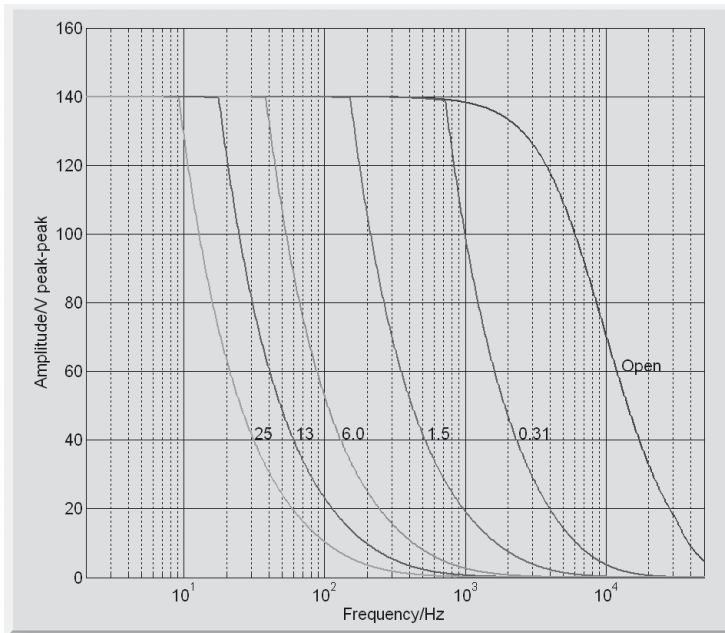
E-610.00 and E-610.S0: Operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-610.00	E-610.C0	E-610.S0
Function	Piezo Amplifier, 1 Channel, OEM Module	Piezo Amplifier / Servo-Controller, OEM Module	Piezo Amplifier / Servo-Controller, OEM Module
Sensor			
Servo characteristics	–	P-I (analog) + notch filter	P-I (analog) + notch filter
Sensor type	–	Capazitiv	SGS
Amplifier			
Control input voltage range	-2 to +12 V	-2 to +12 V	-2 to +12 V
Output voltage	-30 to 130 V	-20 to 120 V	-30 to 130 V
Peak output power	18 W (< 15 ms)	18 W (< 50 ms)	18 W (<15 ms)
Average output power	10 W	10 W	10 W
Peak current	180 mA (< 15 ms)	180 mA (< 50 ms)	180 mA (<15 ms)
Average current	100 mA	100 mA	100 mA
Current limitation	Short-circuit proof	Short-circuit proof	Short-circuit proof
Noise, 0 to 100 kHz	1.6 mV$_{rms}$	0.5 mV$_{rms}$	1.6 mV$_{rms}$
Voltage gain	10 ±0.1	10 ±0.1	10 ±0.1
Input independence	100 kΩ	100 kΩ	100 kΩ
Interfaces and operation			
Input / Output	32-pin (male) on rear panel (DIN 41612 / D)	32-pin (male) on rear panel (DIN 41612 / D)	32-pin (male) on rear panel (DIN 41612 / D)
Piezo connector	LEMO	LEMO	LEMO
Sensor connection	–	LEMO	LEMO
DC Offset	External potentiometer (not included), adds 0 to 10 V to Control In	External potentiometer (not included), adds 0 to 10 V to Control In	External potentiometer (not included), adds 0 to 10 V to Control In
Miscellaneous			
Operating temperature range	+5° to +50° C	+5° to +50° C	+5° to +50° C
Dimensions	7HP/3U	7HP/3U	7HP/3U
Mass	0.3 kg	0.35 kg	0.35 kg
Operating Voltage	12 to 30 V DC, stabilized	12 to 30 V DC, stabilized	12 to 30 V DC, stabilized
Current consumption, max.	2 A	2 A	2 A

Modular & Bench-Top Piezo Nanopositioing Controller
Digital and Analog Interfaces: USB, Fast 24-Bit D/A Converters, Analog Servo

E-625.CR Bench -Top Version

The E-621.CR module features
USB, RS-232 and Analog Interfaces

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

The E-621 is equipped with an RS-232 and USB interface and precision 24-bit converters for exceptional positional stability and resolution. It integrates a low-noise 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.

Closed-Loop and Open-Loop Piezo Positioning

The E-621 controller module provides precision control of piezo actuators and positioning systems both in closed-loop and open-loop operation. The piezo controllers comprise additional circuitry for position sensing and servo-control. Displacement of the piezo is controlled by an analog signal. Positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and sensor type.

High-resolution position sensors provide optimum positional stability and fast response in the nanometer range. Capacitive sensors measure position directly and without physical contact (direct metrology). Alternatively compact cost-effective strain gauge sensors (SGS) are available. The integrated notch filters (adjustable for each axis) improve stability and allow high-bandwidth operation closer to the resonant frequency of the mechanics.

In open-loop operation the output voltage is determined by an external analog signal. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth

are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors.

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.

Multi-Axis Network for up to 12 Channels

Up to twelve E-621s for capacitive or SGS sensors can be networked and controlled over a single PC interface. The different modules are connected in parallel (not daisy-chained) over the link. Only an additional 10 ms internal bus communications time is required to reach any of the units behind the one actually connected to the host PC.

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.
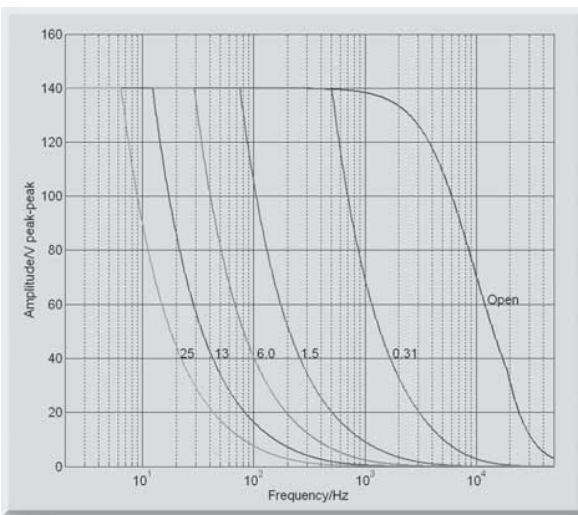
Software / GCS Command Set

The E-621 controller comes with Windows installation software, DLLs and LabVIEW drivers. 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.

E-625 (top), E-665 and 12 x E-621
in an E-500 chassis (bottom)

E-621.CR: operating limits with various PZT loads (open-loop), capacitance is measured in µF

E-625.CR Bench -Top Version

Technical Data: Modular Card

Model	E-621.SR / E-621.CR
Function	Power amplifier & piezo controller
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (.CR)
Amplifier	
Control input voltage range	-2 to 12 V
Output voltage	-20 to 120 V / -30 to 130 V
Peak output power, <5 ms	12 W
Average output power	6 W
Peak current, <5 ms	120 mA
Average current	60 mA
Current limitation	Short-circuit-proof
Noise, 0 to 100 kHz	0.8 mV$_{rms}$
Voltage gain	10 ±0.1
Input impedance	100 kΩ
Interfaces and operation	
Interface / communication	USB, RS-232 (9-pin Sub-D connector, 9.6–115.2 kBaud), 24-bit A/D, 20-bit D/A
Piezo connector	LEMO ERA.00.250.CTL (.SR) / Sub-D special (.CR)
Sensor connection	LEMO EPL.0S.304.HLN (.SR) / Sub-D special (.CR)
Analog input	SMB
Sensor monitor output	SMB
Controller network	up to 12 channels, parallel
Command set	PI General Command Set (GCS)
User software	PIMikroMove™
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave table, 256 data points, external trigger, 16 macros
DC Offset	External potentiometer (not included), adds 0 to + 10 V to Control In
Miscellaneous	
Operating temperature range	+5 °C to +50 °C (10 % derated over 40 °C)
Overheat protection	Deactivation at 75 °C
Dimensions	7HP/3U
Mass	0.6 kg
Operating Voltage	12 to 30 V DC, stabilized
Current consumption, max.	2 A

Technical Data: Bench Top Version

Model	E-625.SR / E-625.CR
Function	Piezo Amplifier / Servo-Controller
Axes	1
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (.CR)
Amplifier	
Control input voltage range	-2 to 12 V
Min. output voltage	-20 to 120 V / -30 to 130 V
Peak output power, < 5 ms	12 W
Average output power	6 W
Peak current, < 5 ms	120 mA
Average current	60 mA
Current limitation	Short-circuit-proof
Noise, 0 to 100 kHz	0.8 mVrms
Voltage gain	10 ±0.1
Input impedance	100 kΩ
Interfaces and operation	
Interface / communication	USB, RS-232 (9-pin Sub-D connector, 9.6–115.2 kBaud), 24-bit A/D and 20-bit D/A E-625.S0 and E-625.C0 without interface
Piezo connector	LEMO ERA.00.250.CTL (.SR) / Sub-D Special (.CR)
Sensor connection	LEMO EPL.0S.304.HLN (.SR) / Sub-D Special (.CR)
Control input sockets	SMB
Sensor monitor socket	SMB
Controller network	up to 12 channels, parallel
Command set	PI General Command Set (GCS)
User software	PIMikroMove™
Software drivers	LabVIEW drivers, DLL's
Supported functionality	Wave table, 256 data points, external trigger, 16 macros
Miscellaneous	
Operating temperature range	+5 to +50 °C
Overheat protection	Deactivation at 75°C
Dimensions	205 x 105 x 60 mm
Mass	1.05 kg
Operating voltage	12 to 30 V DC, stabilized (power supply included)
Current consumption	2 A

E-665 Piezo Nanopositioning Controller with Display

36 W Power, Display, USB, RS-232 & Analog Interfaces, Analog Servo

Control of the E-665.SR piezo servo-controller is realized either via the digital high-speed interface or directly via the analog input

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

The E-665 is a bench-top piezo linear amplifier and position servo-controller with integrated high-speed 24-bit computer interface and a high-bandwidth analog interface. It integrates a low-noise piezo amplifier which can output and sink peak currents of 360 mA for low-voltage piezoelectric actuators (-20 to 120 V). Servo-controller versions for position sensing with capacitive or SGS sensors are available.

Closed-Loop Piezo Positioning

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 piezo controllers comprise additional circuitry for position sensing and servo-control. In closed-loop position control mode, displacement of the piezo is highly linear and proportional to the analog signal. The servo modifies the amplifier output voltage based on the position sensor signal. Thus, positioning accuracy and repeatability down to the subnanometer range is possible, depending on the piezo mechanics and on the sensor type.

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 datapoints internally. These values can then be output automatically (or under the control of an external signal). Thus, trajectory profiles can be repeated reliably and commanded easily.

Multi-Axis Network for up to 12 Channels

Up to twelve E-665s for capacitive or SGS sensors can be networked and controlled over a single PC interface. The different modules are connected in parallel (not daisy-chained) over the link providing higher data rates than possible with serial links.

Extensive Software Support

The controllers are delivered with Windows operating software.

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.

The GCS commands are available at the controller terminal, in macros and in the form of a universal driver set for LabVIEW (VIs) or Windows dynamic link libraries (DLL).
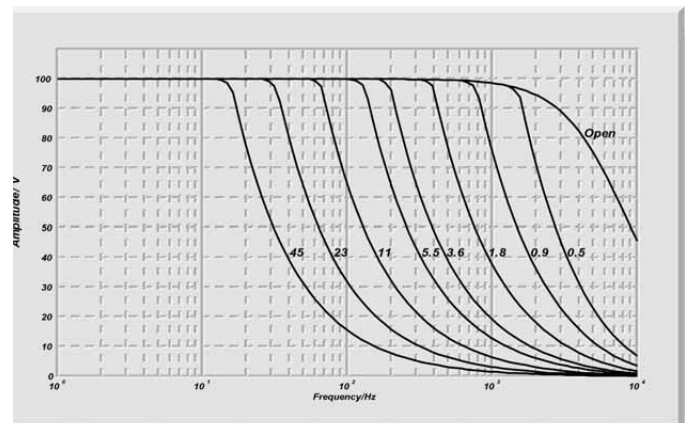
E-665: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-665.SR, E-665.CR
Function	Piezo amplifier & position servo-controller with digital interface
Axes	1
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (CR)
Amplifier	
Control input voltage range	-2 to +12 V
Min. output voltage	-20 to 120 V
Peak output power, < 20 ms	36 W
Average output power	12 W
Peak current, < 20 ms	360 mA
Average current	120 mA
Current limitation	Short-circuit-proof
Noise, 0 to 100 kHz	0.5 (.SR) / 4.0 (.CR) mV$_{rms}$
Voltage gain	10 ±0.1
Input impedance	100 kΩ
Interfaces and operation	
Interface / communication	USB and RS-232 (9-pin Sub-D connector, 9.6–115.2 kBaud), 24-bit A/D, 20-bit D/A
Piezo connector	LEMO ERA.00.250.CTL (.SR) / Sub-D special (.CR)
Sensor connection	LEMO EPL.0S.304.HLN (.SR) / Sub-D special (.CR)
Analog input	BNC
Sensor monitor socket	BNC
Controller network	up to 12 channels, parallel
Command set	PI General Command Set (GCS)
User software	PIMikroMove™
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave table, 256 data points, external trigger, 16 macros
Display	2 x 4½-digits, LED
DC Offset	10-turn pot., adds 0 to 10 V to Control In
Miscellaneous	
Operating temperature range	5 to 50 °C (10 % derated over 40 °C)
Overheat protection	Deactivation at 85 °C
Dimensions	236 x 88 x 273 mm + handles
Mass	2.5 kg
Operating voltage	100–120 / 220–240 VAC, 50–60 Hz (linear power supply)
Max. power consumption	50 W

PI

E-664 Low-Cost NanoCube® XYZ Nanopositioning Controller

For XYZ-Piezo System P-611.3S

E-664 Controller for NanoCube®
XYZ nanopositioning systems
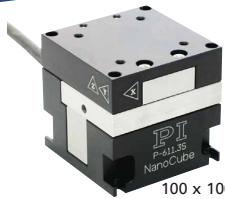
NanoCube® XYZ-nanopositioning system,
100 x 100 x 100 µm closed-loop travel range, resolution 1 nm

- ■ **Integrated Amplifier with 3 x 14 W Peak Power**
- ■ **Position Servo-Control with Notch Filter for Higher Bandwidth and Stability**
- ■ **3 Displays for Voltage / Position**
- ■ **Cost-Effective Controller for P-611.3S NanoCube® Nanopositioning Systems**
- ■ **Manual and External Control**

The E-664 is a bench-top amplifier & position servo-controller that is especially designed for the P-611.3S NanoCube® XYZ nanopositioning system (see p. 2-52). Three integrated low-noise amplifiers and control circuitry for strain gauge position sensors allow closed-loop position resolution down to 2 nm and dynamic operation.

The combination of the E-664 servo-controller and P-611.3S NanoCube® piezo stage makes for a very cost-effective precision 3D nanopositioning system.

Closed-Loop and Open-Loop Piezo Positioning

The E-664 servo controller can be operated both in closed-loop (position-control) and in open-loop (voltage-control) mode. In closed-loop mode, piezo displacement is proportional to the analog signal applied to the BNC control-input socket. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the piezo-mechanics resonant frequency. In open-loop operation the output voltage is determined by the analog control signal at the BNC Control Input socket, optionally combined with the DC-offset potentiometer . V ol-tage controlled operation (in contrast to position-controlled operation) is used in applications where the fastest possible response and very high resolution with maximum bandwidth are essential, and/or when commanding and reading the target position in absolute values is either not important or accomplished with an external feedback loop (see p. 2-104). The precision

10-turn potentiometers can also be used alone to set the output voltages manually.

Versatile I/O Supports Automation

On-target and overflow status information is displayed separately for every channel. This information is also present on a 14-pin I/O connector on the rear panel that also carries the analog control input and sensor monitor lines.

Remote Control via Computer Interface

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.

Technical Data

Model	E-664.S3
Function	Power amplifier & position servo controller for P-611.3S NanoCube® nanopositioning system
Axes	3
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS
Amplifier	
Input voltage	-2 to +12 V
Output voltage	-20 to 120 V
Peak output power per channel <5 ms	14 W
Average output power per channel >5 ms	6 W
Peak current per channel <5 ms	140 mA
Average current per channel >5 ms	60 mA
Current limitation	Short-circuit-proof
Voltage gain	10 ±0.1
Ripple, noise, 0 to 100 kHz	<1 mVrms
Interfaces and operation	
Piezo connector	25-pin sub-D connector
Sensor connector	25-pin sub-D connector
Control Input sockets	3 x BNC (rear), I/O connector
I/O ports	14-pin connector for on-target and overflow status, Control In and sensor monitor outputs
Display	3 x 3½-digits, LED
Miscellaneous	
Operating temperature range	5 to 50°C
Overtemp protection	Deactivation at 75°C
Dimensions	236 x 88 x 273 mm + handles
Mass	3 kg
Operating voltage	90–120 / 220–240 VAC, 50–60 Hz (linear power supply)
Max. power consumption	60 W

E-616 Low Cost Nanopositioning Controller for Piezo Tip/Tilt Mirrors
Flexible Multi Channel OEM Electronics with Coordinate Transformation

The E-616 OEM controller and the S-334 fast steering mirror system providing a tip/tilt range of up to 60 mrad

Ordering Information

E-616.SS0
Multi Channel Servo-Controller / Driver for Piezo Tip/Tilt Mirror Platforms with SGS and Differential Drive

E-616.S0
Multi Channel Servo-Controller / Driver for Piezo Tip/Tilt Mirror Platforms with SGS and Tripod Drive

The E-616 is a special controller for piezo based tip/tilt mirrors and tip/tilt platforms. It contains two servo controllers, sensor channels and power amplifiers in a compact unit. The controller works with high-resolution SGS position sensors used in PI piezo mechanics and provides optimum position stability and fast response in the nanometer and µrad-range respectively . A high output power of 10 W per channel allows dynamic operation of the tip/tilt mirrors for applications such as (laser) beam steering and stabilization.

Tripod or Differential Piezo Drive? One for All!

PI offers two basic piezo tip/tilt mirror designs. Both are parallel-kinematics designs where the individual piezo actuators affect the same moving platform. With the tripod design (e. g. S-325, see p. 2-92) the platform is driven by three piezo actuators placed with 120° spacing. The differential drive design (S-330, see p. 2-88 or S-334, see p. 2-90) with two orthogonal axes and a fixed pivot point is based on two pairs of actuators operating in

push / pull-mode. The differential evaluation of two sensors per axis provides an improved linearity and resolution.

Internal Coordinate Transformation Simplifies Control

Parallel-kinematics require the transformation of the commanded tilt angles into the corresponding linear motion of the individual actuators. In the E-616.S0, this is taken care of by an integrated circuit, eliminating the need of additional external hardware or software. Additionally with the E-616.S0 all actuators can be commanded by an offset-voltage simultaneously. As a result a vertical movement, for example for optical path tuning, is obtained.

Simple Setup and Operation

To facilitate integration, setup and operation the E-616 features both front and rear panel connections: The 25 pin sub-D piezo & sensor connector is located on the front, along with offset trim pots and LEDs for Power and Overflow . A 32 pin rear connector allows commanding and reading the sensor and amplifier monitor outputs.

- ■ **Three Integrated Amplifiers Provide up to 10 W Peak Power**
- ■ **Closed-Loop and Open-Loop Versions**
- ■ **Internal Coordinate Transformation Simplifies Control of Parallel Kinematics Designs (Tripod & Differential Drive)**
- ■ **Compact and Cost-Effective Design for OEMs**

E-616 Bench top controller
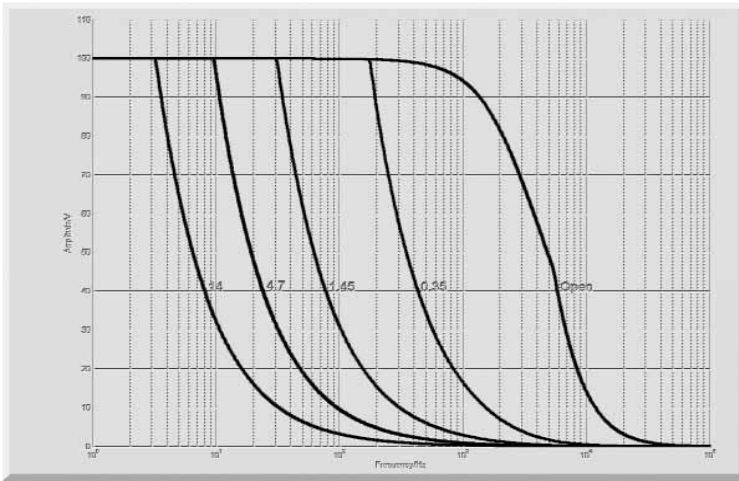
E-616: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-616.S0	E-616.SS0
Function	Controller for parallel-kinematics piezo tip/tilt mirror systems with strain gauge sensors, tripod design	Controller for parallel-kinematics piezo tip/tilt mirror systems with strain gauge sensors, differential design
Tilt axes	2	2
Sensor		
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter
Sensor type	SGS	SGS
Sensor channels	3	2
External synchronization	200 kHz TTL	200 kHz TTL
Amplifier		
Control input voltage range	-2 V to +12 V	-2 V to +12 V
Output voltage	-20 V to +120 V	-20 V to +120 V
Amplifier channels	3	3
Peak output power per channel	10 W	10 W
Average output power per channel	5 W	5 W
Peak current	100 mA	100 mA
Average current per channel	50 mA	50 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	10	10
Amplifier bandwidth, small signal	3 kHz	3 kHz
Amplifier bandwidth, large signal	See frequency diagram	See frequency diagram
Ripple, noise, 0 to 100 kHz	<20 mVpp	<20 mVpp
Amplifier resolution	<1 mV	<1 mV
Interfaces and operation		
Piezo / sensor connector	25-pin sub-D connector	25-pin sub-D connector
Analog input	32-pin connector	32-pin connector
Sensor monitor output	0 to +10 V for nominal displacement	0 to +10 V for nominal displacement
Sensor monitor socket	32-pin connector	32-pin connector
Display	Power-LED and sensor OFL display	Power-LED and sensor OFL display
Miscellaneous		
Operating temperature range	5 °C to 50 °C	5 °C to 50 °C
Overheat protection	Max. 75 °C, deactivation of the piezo voltage output	Max. 75 °C, deactivation of the piezo voltage output
Dimensions	160 mm x 100 mm x 10 TE	160 mm x 100 mm x 10 TE
Mass	700 g	700 g
Operating voltage	12 to 30 V DC	12 to 30 V DC
Power consumption	30 W	30 W

E-545 Nanopositioning Controller for PInano™ XYZ Piezo Stages

TCP/IP, USB, RS-232 & High Bandwidth Analog Interfaces. Analog Servo

E-545 PI nano™ series nanopositioning stage controller

- **Low-noise 24-bit D/A Converter**
- **Sample Rate 25 kHz**
- **Linearization for Piezoresistive Sensors**
- **Notch Filter for Higher Bandwidth**
- **TCP/IP, USB und RS-232 Interfaces**
- **3 x 14 W Peak Power**
- **Wave Generator with Programmable Trigger-I/O**

The E-545 controller is ideally suited for the PI nano™ stage series P-545 for super-resolution microscopy. The controller meets all demands for this applications and provides useful additional functionality.

USB Interface

The microprocessor controlled interface is equipped with low-noise, 24-bit D/A converters and can be controlled through three digital interfaces: TCP/IP, USB oder RS-232.

Alternatively, stand-alone operation is possible by uploading macro command sequences to the internal non-volatile memory.

Wave Generator

The integrated wave generator can output periodic motion pro-files. In addition to sine and triangle waves, arbitrary, user-defined motion profiles can be created and stored.

Extensive Software Support

The controllers are delivered with Windows operating software. Comprehensive DLLs, LINUX and LabVIEW drivers are available for automated control.

Technical Data

Model	E-545.3RD
Function	Piezo Servo-Controller for PI nano™ stages
Axes	3
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	Piezoresistive sensors
Amplifier	
Min. output voltage min.	-20 to 120 V
Peak output power, < 5 ms	14 W
Average current	6 W
Peak current, < 5 ms	140 mA
Average current	60 mA
Current limitation	Short-circuit-proof
Voltage gain	10 ±0.1
Interfaces and operation	
Interface / communication	Ethernet (TCP/IP), USB, RS-232
Piezo system connector	Sub-D 25
Command set	PI General Command Set (GCS)
User software	PIMikroMove™
Supported functionality	Wave generator, data recorder, macro programming
Miscellaneous	
Operating temperature range	+5 to +50 °C
Overheat protection	Deactivation at 85°C
Operating Voltage	12 to 30 VDC, stabilized
Current consumption	2 A

E-500 and E-501 Racks
Modular Piezo Nanopositioning Controller for High Power Amps
Analog Servo, Digital & Analog Interfaces

Configuration example: E-500 Chassis with optional modules:
E-505, 200 W High-Power piezo amplifier (3 x), E-509.S servo-controller,
E-517.i3 24-bit interface / display module

Configuration example: E-501 chassis with optional modules:
E-503 piezo amplifier, E-509.C2A servo-controller for capacitive position sensors,
E-517.i3 24-bit interface / display module

- ■ **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 E-500 modular piezo controller system offers a broad choice of control modules for nanopositoning 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

30-channel controller consisting of 3 E-500.621 chassis, each of which can accomodate up to 12 E-621 modules

HyperBit™ technology providing enhanced system resolution.

Two chassis are available:

The E-500.00 19'' rackmount chassis provides operating voltages for all compatible modules including amplifiers, servo-controllers, display and interface modules (see system configuration see p. 2-144).

Ordering Information

E-500.00
19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

E-501.00
9½"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

E-500.ACD
LabVIEW Driver Set for Analog Controllers

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution (Supports Certain D/A Boards)

Ask about custom designs!

Technical Data

Model	E-500.00	E-501.00
Function	19"-Chassis for Piezo Controller System: Amplifier Modules, Sensor- / Servo-Control Modules, Interface / Display Modules	9.5"-Chassis for Piezo Controller System: Amplifier Modules, Sensor- / Servo-Control Modules, Interface / Display Modules
Channels	1, 2, 3 (up to 3 amplifier modules)	1, 3 (1 amplifier module)
Dimensions	450 x 132 x 296 mm + handles	236 x 132 x 296 mm + handles
Operating voltage	90–264 VAC, 50–60 Hz	90–120 / 220–264 VAC, 50–60 Hz
Max. power consumption	180 W	80 W

Available Modules for E-500 and E-501 Racks

E-509 3-channel servo-controller module for nanopositioning systems with strain gauge sensors

E-509.C1A
Sensor / Piezo Servo-Control Capacitive Sensor, 1 Channel

E-509.C2A
Sensor / Piezo Servo-Control Capacitive Sensors, 2 Channels

E-509.C3A
Sensor / Piezo Servo-Control Capacitive Sensors, 3 Channels

E-509.S1
Sensor / Piezo Servo-Control SGS Sensor, 1 Channel

E-509.S3
Sensor / Piezo Servo-Control SGS-Sensors, 3 Channels

- **High-Speed Analog Servo for Piezo with Capacitiv & SGS**
- **1-, 2- and 3-Channel Versions**
- **Improves Linearity, Increases Piezo Stiffness**
- **Eliminates Drift and Hysteresis**
- **Notch Filter for Higher Bandwidth**
- **ILS Circuitry Maximizes Capacitive Sensor Linearity**

The E-517 piezo display and D/A converter module, provides USB and TCP/IP connectivity

E-517.i1
Interface / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, Single Channel

E-517.i3
Interface / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

- **Low-Noise 24-bit D/A Converter**
- **Sample Rate 25 kHz**
- **TCP/IP, USB, IEEE 488 and RS-232 Interfaces**
- **6-Digit Display for Voltage and Position**
- **1- & 3-Channel Versions**
- **Wave Generator with Programmable Trigger-I/O**

The E-509.E3 module offers sensor signal read-out and servo control for three channels

E-509.E3
PISeca™ Sensor / Piezo Servo-Control Module for Single-Electrode Capacitive Sensor Probes, 3 Channels

E-509.E03
PISeca™ Modular Signal Conditioner Electronics for Single Electrode Capacitive Sensors, 3 Channels

- **E-509.E03: 3-Channel Signal Conditioner Module**
- **E-509.E3: 3-Channel Sensor Module with Additional Servo Controllers for Piezo Positioning Systems**
- **Integrated Linearization System (ILS) for Maximum Linearity**

Available Power Amp Modules for E-500 and E-501 Racks

E-505.00 is a high-performance amplifier module for the piezo servo-controller system E-500

E-505.00
Piezo Amplifier Module, 2 A, -30 to 130 V, 1 Channel

E-505.10
Piezo Amplifier Module for Switching Applications, 10 A, -30 to 130 V, 1 Channel

E-505.00S
Offset Voltage Supply for Tip/Tilt Systems, One Fixed Voltage of +100 V

- ■ **Up to 10 A Peak Current**
- ■ **Output Voltage Range -30 to 130 V**

E-503.00 Piezo amplifier module

E-503.00
Piezo Amplifier Module, -30 to 130 V, 3 Channels

E-503.00S
Piezo Amplifier Module, -30 to 130 V, 2 Channels, Modified E-503.00 for S-330, S-334, S-340 Tip/Tilt Systems, with One Fixed Voltage of +100 V, Two Variable Voltages

- ■ **3 x 140 mA Peak Current**
- ■ **Output Voltage Range -30 to 130 V**

E-504.00F High-power amplifier module with energy recovery

E-504.00F
High-Power-Piezo Amplifier Modul 1 Channel, 280 W Peak Power, 100 W Average Power, -30 to 130 V

- ■ **Peak Power 280 W**
- ■ **High Average Output Power 100 W**
- ■ **Very Energy Efficient Through Energy Recovery**
- ■ **Output Voltage Range -30 to 130 V**

E-506.10 charge-controlled Piezo driver module

E-506.10
High Linearity Piezo Amplifier Module, 30 W Average Output Power, -30 to 130 V, 1 Channel

- ■ **Highly Linear Amplifier Module**
- ■ **280 W Peak Power**
- ■ **Output Voltage Range -30 to 130 V**

E-536 PicoCube® Nanopositioning Piezo Controller

High Dynamics, High Resolution, for up to 3 Axes

E-536.3C 3-channel PicoCube® Controller

- **For P-363 PicoCube® Systems**
- **Peak Power 3 x 100 W**
- **Ultra-Low Noise**
- **Output Voltage ±250 V**

those in the PicoCube®, with resolutions down to 0.1 nm.

Computer Control

Control via PC is possible by installing the E-517, 24-bit interface/display module.

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.

Ordering Information

E-536.3C
PicoCube® Piezo Controller,
3 Channels, Capacitive Sensors

E-536.30
PicoCube® Piezo Controller,
3 Channels, Open-Loop

E-536.3CH
PicoCube® Piezo Controller,
3 Channels, High-Resolution,
Capacitive Sensors

E-536.30H
PicoCube® Piezo Controller,
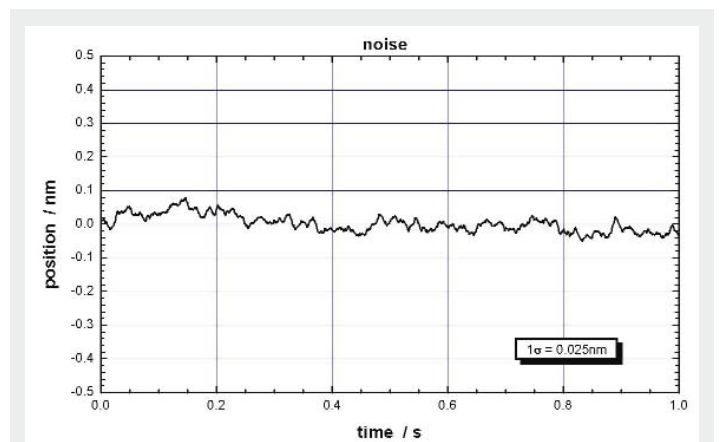3 Channels, High-Resolution,
Open-Loop

E-517.i3
Interface- / Display Module, 24 Bit
D/A, TCP/IP, USB, RS-232,
3 Channels

E-500.HCD
Hyperbit™ Functionality for
Enhanced System Resolution

(Supports certain D/A boards.)

P-363.2CD and .3CD (background) PicoCube™, high-performance piezo positioning- and scanning systems or AFM/STM and nanomanipulation.

The E-536 is a controller for the P-363 PicoCube® pico-positioning system providing three ultra-low-noise amplifier channels for piezo shear actuators. The controller design meets the special requirements of the high-speed, ultra-high-perform - ance PicoCube® XY(Z) piezo stages (see p. 2-66) of ±250 V for both static and dynamic applications.

The high-performance E-536.3x can output and sink peak currents up to 200 mA featuring a small-signal bandwidth of 10 kHz. The E-536.3xH ultra-high-resolution models provide a position resolution below 0.03 nm at a peak power of 50 W . Both models are available with or without a servo module for closed-loop or open-loop operation.

Superior Resolution and High Dynamics

Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwith are essential. Here, commanding and reading the traget position in absolute values is either not important or carried out by external position sensors. Together with the P-363 PicoCube® a resolution of 0.05 nm or better is achieved.

Excellent Position Accuracy with Capacitive Sensors

The E-536.3C versions have integrated sensor electronics and servo-controllers for closed-loop position control. Position feedback is provided by capacitive sensors, like
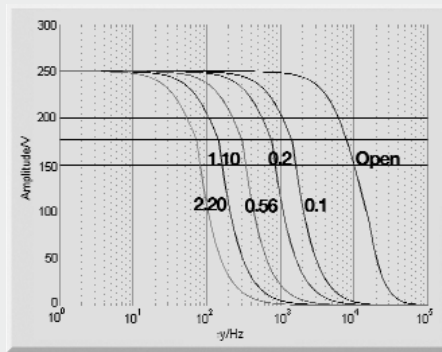
Positional noise measurement of E-536 amplifier driving a P-363 pico-positioning system in open loop shows 1-sigma resolution of 25 picometers (0.025 nm). Measured with ultra-high-resolution capacitive sensor
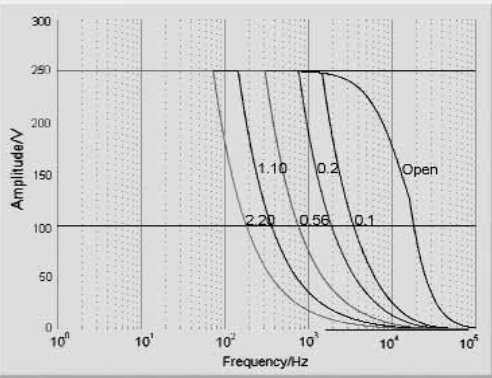
E-536.3x: operating limits with various PZT loads, capacitance is measured in µF

E-536.3xH: operating limits with various PZT loads, capacitance is measured in µF

Technical Data

Model	E-536.3C / E-536.30	E-536.3CH / E-536.30H
Function	Power amplifier & servo-controller for P-363 PicoCube®	Power amplifier & servo-controller for P-363 PicoCube®
Amplifier		
Output voltage	-250 to +250 V	-250 to +250 V
Amplifier channels	3	3
Average output power per channel	10 W, limited by temperature sensor	6 W, limited by temperature sensor
Peak output power per channel, <3 ms	100 W	50 W
Average current	30 mA	15 mA
Peak current per channel, <3 ms	200 mA	100 mA
Amplifier bandwidth, small signal	10 kHz	2 kHz
Amplifier bandwidth, large signal, @ 100 nF	0.2 kHz	0.125 kHz
Ripple, noise, 0 to 100 kHz	0.8 mV$_{RMS}$, <5 mV$_{P-P}$ (100 nF)	0.5 mV$_{RMS}$, <3 mV$_{P-P}$ (100 nF)
Current limitation	Short-circuit proof	Short-circuit proof
Voltage gain	+50	+50
Input impedance	100 kΩ	100 kΩ
Sensor*		
Servo characteristics	Analog proportional-integral (P-I) algorithm with notch filter	Analog proportional-integral (P-I) algorithm with notch filter
Sensor type	capacitive sensors	capacitive sensors
Sensor channels	3 / -	3 / -
Sensor bandwidth	1.5 kHz	1.5 kHz
Sensor Monitor output	0 to +10 V	0 to +10 V
Interfaces and operation		
PZT output sockets	LEMO EGG.0B.701.CJL.1173	LEMO EGG.0B.701.CJL.1173
Sensor target and probe sockets	LEMO EPL.00.250.NTD	LEMO EPL.00.250.NTD
Control Input sockets	SMB	SMB
Sensor Monitor socket	LEMO FGG.0B.306.CLAD56	LEMO FGG.0B.306.CLAD56
Control Input voltage	Servo off: -5 to +5 V, Servo on: 0 to +10 V	Servo off: -5 to +5 V, Servo on: 0 to +10 V
DC Offset	10-turn pot., adds 0 to +10 V to Control IN	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous		
Operating voltage	115 VAC / 50-60 Hz or 230 VAC / 50-60 Hz	115 VAC / 50-60 Hz or 230 VAC / 50-60 Hz
Mass	8.1 kg / 7.8 kg (with E-516 module)	8.1 kg / 7.8 kg (with E-516 module)
Dimensions	450 x 132 x 296 mm + handles	450 x 132 x 296 mm + handles

*only E-536.3Cx with capacitive sensors
Interfaces / communication: RS-232, TCP/IP, USB (with optional E-517 computer interface and display module only)
Operating temperature range: +5 °C to +50 °C (over 40 °C, max. av . power derated 10 %), high-voltage output is automatically deactivated if temperature is too high by internal temperature sensor (75 °C max.)

PI

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

USA (East) & CANADA

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

JAPAN

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

CHINA

**Physik Instrumente
(PI Shanghai) Co., Ltd.**
Building No. 7-301
Longdong Avenue 3000
201203 Shanghai, China
Tel: +86 (21) 687 900 08
Fax: +86 (21) 687 900 98
info@pi-china.cn
www.pi-china.cn

FRANCE

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

GERMANY

**Physik Instrumente (PI)
GmbH & Co. KG**
Auf der Römerstr. 1
D-76228 Karlsruhe/Palmbach
Tel: +49 (721) 4846-0
Fax: +49 (721) 4846-100
info@pi.ws · www.pi.ws

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
info@pi-usa.us
www.pi-usa.us

PI Japan Co., Ltd.
Hanahara Dai-ni Building, #703
4-11-27 Nishinakajima,
Yodogawa-ku, Osaka-shi
J-Osaka 532
Tel: +81 (6) 6304 5605
Fax: +81 (6) 6304 5606
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
uk@pi.ws
www.physikinstrumente.co.uk

ITALY

Physik Instrumente (PI) S.r.l.
Via G. Marconi, 28
I-20091 Bresso (MI)
Tel: +39 (02) 665 011 01
Fax: +39 (02) 873 859 16
info@pionline.it
www.pionline.it