

## E-500 Series Piezo Controllers

### Modular & Flexible Nanopositioning System



# E-500 and E-501 Racks

## Modular Piezo Nanopositioning Controller, 1 - 12 Axes

### 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 nanopositioning systems and actuators. This includes piezo

amplifier and position servo controller modules for up to three channels with different features as well as display and interface modules. Flexible



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

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

#### 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!**

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).

#### 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

# Interface, Sensor & Servo 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

E-621.CR module for special E-500.621 chassis



- E-621.CR**  
Piezo Amplifier / Servo-Controller  
Module, 1 Channel, -30 to 130 V,  
Capacitive Sensor, USB, RS-232
- E-621.SR**  
Piezo Amplifier / Servo-Controller  
Module, 1 Channel, -20 to 120 V,  
SGS-Sensor, USB, RS-232
- E-500.621**  
19"-Chassis for up to twelve E-621  
Modules, Power Supply
- E-501.621**  
9,5"-Chassis for up to four E-621  
Modules, Power Supply

- 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-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

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

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

- 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

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

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

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



# E-517 Digital Piezo Controller Operation Module

## Wave Generator, Data Recorder, Display, Multiple Interfaces, for E-500 System



- 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
- Module for E-500 Piezo Controller Rack

### Ordering Information

**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

**Ask about custom designs!**

The E-517 is a microprocessor controlled interface and display module for the E-500 piezo controller system (see p. 2-142). It is equipped with low-noise, 24-bit D/A converters and can be controlled through four digital interfaces: TCP/IP, USB, RS-232 and IEEE 488 (GPIB).

Alternatively, stand-alone operation is possible by uploading macro command sequences to the internal non-volatile memory. For manual control a trackball interface is provided. An LCD display indicates position or operating voltages of the individual channels / axes.

### Wave Generator

The integrated wave generator can output periodic motion profiles. 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 and LabVIEW drivers are available for automated control.

### Technical Data

Model	E-517.i1	E-517.i3
Function	Digital operation module	Digital operation module
Channels	1	3
Processor	DSP 60 MHz	DSP 60 MHz
Sampling rate, sensor	25 kHz, 8-times oversampling	25 kHz, 8-times oversampling
Thermal drift	Stability: 0.2 mV	Stability: 0.2 mV
Linearity @ nominal range	0.01 %	0.01 %
Resolution	DAC: 24 bit, $\pm 12$ V ADC: 18 bit, sampling	DAC: 24 bit, $\pm 12$ V ADC: 18 bit, sampling
<b>Interfaces and operation</b>		
Interfaces/communication	Ethernet (TCP/IP), USB, RS-232, IEEE 488	Ethernet (TCP/IP), USB, RS-232, IEEE 488
I/O ports	1 trigger input 1 trigger output 5 V MDR14 connector	3 trigger inputs 3 trigger outputs 5 V MDR14 connector
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)
User software	PIMikroMove™	PIMikroMove™
Software drivers	Lab VIEW drivers, Windows and Linux Libraries (DLL)	Lab VIEW drivers, Windows and Linux Libraries (DLL)
Supported functionality	Wave generator, data recorder, macro programming	Wave generator, data recorder, macro programming
Display	LCD display for monitor signals (position and voltage), states and trackball menus	LCD display for monitor signals (position and voltage), states and trackball menus
Manual control	Operation via trackball	Operation via trackball
<b>Miscellaneous</b>		
Operating temperature range	+5 to +50° C	+5 to +50° C
Dimensions	21HP / 3U	21HP / 3U
Mass	0.37 kg	0.37 kg
Operating voltage	E-500 system	E-500 system

# E-509 Piezo Servo Module / Signal Conditioner

## 3-Channel Servo-Controller Module for E-500 Piezo Controller System



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

- Position Servo-Control for Piezo Mechanics with SGS or Capacitive Sensors
- 1-, 2- and 3-Channel Versions
- Improves Linearity
- Eliminates Drift and Hysteresis
- Notch Filter for Higher Bandwidth
- Increases Piezo Stiffness
- ILS Circuitry Maximizes Capacitive Sensor Linearity
- Plug-In Module for E-500 System
- Prepared for Interfaces / Display Modules (optional)

The E-509 module is both a signal conditioner for high-resolution capacitive and SGS displacement sensors and a servo-controller for closed-loop piezo nanopositioning mechanics. It compensates for the drift and hysteresis inherent in PZT materials and quickly adjusts the operating voltage on the PZT as soon as a change in force or load occurs. Single- and multi-channel versions for strain gauge and capacitive sensors are available.

### Nanometer-Precise Piezo Positioning

The proportional-integral (P-I) algorithm used by the E-509 servo-controller is optimized for piezo operation. Both P and I parameters as well as the control bandwidth can be set internally. The integrated notch filters (adjustable for each axis) improve the stability and allow

high-bandwidth operation closer to the piezomechanics' resonant frequency. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

### Two Types of Sensors

PI employs proprietary position sensors for fast response and optimum positioning reso-

### Ordering Information

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

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

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

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

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

**Ask about custom designs!**

lution 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.

Model	E-509.C1A/E-509.C2A/E-509.C3A	E-509.S1/E-509.S3
Function	Signal conditioner & servo-controller for piezo mechanics	Signal conditioner & servo-controller for piezo mechanics
Channels	1/2/3	1/3
<b>Sensor</b>		
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter
Sensor type	Capacitive	SGS
Sensor channels	1 / 2 / 3	1 / 3
Sensor bandwidth	0.3 to 3 kHz (selectable with jumper); up to 10 kHz on request	0.3; 1; 3 kHz
Noise factor	0.115 ppm/Hz <sup>1/2</sup>	
Thermal drift	<0.3 mV / C°	<3 mV / C°
Linearity	<0.05%	<0.2%
<b>Interfaces and operation</b>		
Sensor connection	LEMO EPL.00.250.NTD	LEMO ERA.0S.304.CLL
Sensor monitor output	0–10 V	0–10 V
Sensor monitor socket	LEMO 6-pin FGG.0B.306.CLAD56	BNC (1-ch.) / 3-pin. LEMO (3-ch.)
Supported functionality	ILS (Integrated Linearization System)	ILS (Integrated Linearization System)
Display	Overflow LED	Overflow LED
<b>Miscellaneous</b>		
Operating temperature range	+5 to +50 °C	+5 to +50 °C
Dimensions	7HP/3U	7HP/3U
Mass	0.35 kg	0.35 kg
Operating Voltage	E-500 System	E-500 System
Max. power consumption	4 to 8 W	4 to 8 W

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# E-503 Piezo Amplifier Module

## 3 Channels, for E-500 Piezo Controller System



E-503.00 Piezo amplifier module

- Module for E-500 Piezo Controller Rack
- 3 x 140 mA Peak Current
- Output Voltage Range -30 to 130 V
- Prepared for Position Servo-Control Upgrade (optional)
- Prepared for Interfaces / Display Modules (optional)

The E-503 is a piezo driver module for low-voltage piezo actuators and positioners. It contains three independent amplifiers that can output and sink a peak current of 140 mA in the -30 to 130 V voltage range. For frequency response with selected capacitive loads, see graph below. The piezo ampli-

fier module is designed to work in the E-500 Controller system (see p. 2-142).

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

### Modular Design for Flexibility: Optional Servo Controller Upgrade

The E-503 amplifier module can be installed in the E-500 / E-501 controller chassis. The modular design makes the E-500 piezo controller system very flexible. An optional E-509 piezo servo-controller module can be installed along with the E-503 amplifier module, for closed-loop piezo position control. In this configuration, the E-503 output voltage is set by the servo-control loop.

### Voltage Controlled Piezo Positioning

In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input optionally combined with the DC-offset potentiometer. Open-loop operation is ideal for applications where fast response and very

### Ordering Information

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

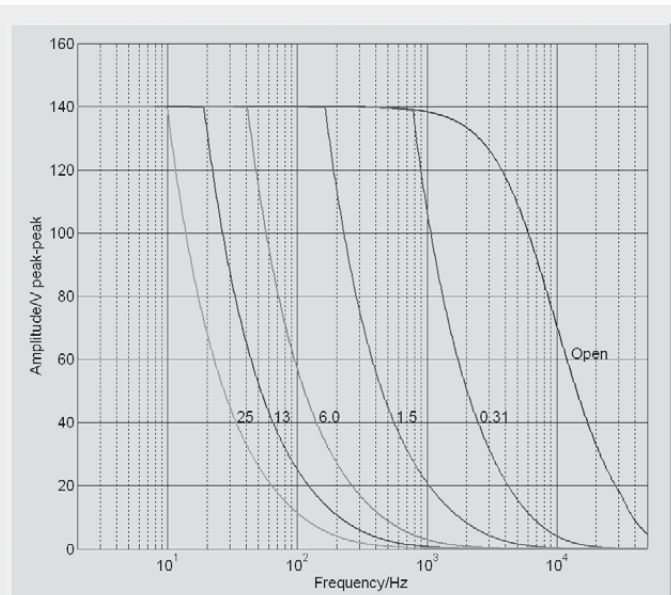
**E-503.00S**  
Piezo Amplifier Module,  
-30 to 130 V, 2 Channels,  
Modified E-503.00 for S-330, S-334,  
S-340 Tip/Tilt Systems, with  
One Fixed Voltage of +100 V,  
Two Variable Voltages

**Ask about custom designs**

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. The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

### Technical Data

Model	E-503.00	E-503.00S
Function	Power amplifier	Power amplifier
Channels	3	2
<b>Amplifier</b>		
Control input voltage range	-2 to +12 V	-2 to +12 V
Output voltage	-30 bis 130 V	-30 bis 130 V; one additional fixed voltage of +100 V
Peak current per channel, <5 ms	140 mA	140 mA
Average current per channel, >5 ms	40 mA	40 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	10 ± 0.1	10 ± 0.1
Input impedance	100 kΩ / 1 nF	100 kΩ / 1 nF
<b>Interfaces and operation</b>		
Piezo connector	LEMO ERA.00.250.CTL	LEMO ERA.00.250.CTL
Analog input	BNC	BNC
DC Offset	10-turn pot., adds 0 to 10 V to Control In	10-turn pot., adds 0 to 10 V to Control In
<b>Miscellaneous</b>		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overheat protection	Deactivation at 85 °C	Deactivation at 85 °C
Dimensions	14HP/3U	14HP/3U
Mass	0.9 kg	0.9 kg
Operating Voltage	E-500 System	E-500 System
Max. power consumption	40 W	40 W



E-503: operating limits with various PZT loads (open-loop), capacitance is measured in μF

# E-505 Piezo Amplifier Module, 2000 mA Peak Current

## High Power, E-500 Piezo Controller System



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

- Up to 10 A Peak Current
- Output Voltage Range -30 to 130 V
- Module for E-500 Piezo Controller Rack
- Prepared for Position Servo-Control Upgrade (optional)
- Prepared for Interfaces / Display Modules (optional)

The E-505 piezo amplifier module is designed to work in the E-500 Controller system (see p. 2-142). It features a low-noise, high-power amplifier for low-voltage piezo actuators and po-

sitioners, that can output and sink a peak current of up to 2000 mA in the -30 to 130 V voltage range. The E-505 units are designed to provide high-resolution operation of piezo actua-

tors and positioning systems in voltage-controlled mode (open-loop) and optionally in position-controlled mode (closed-loop).

For switching applications the E-505.10 version provides a peak output current of up to 10 A.

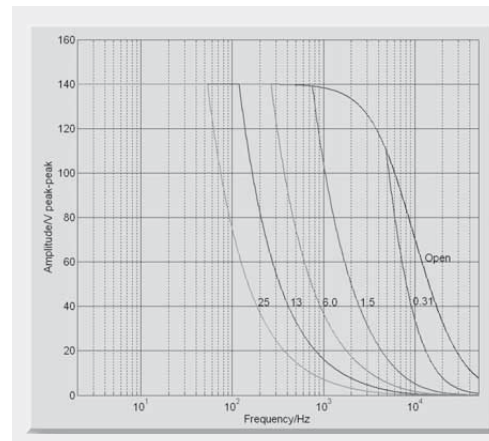
For frequency response with selected capacitive loads, see graph below.

### Ordering Information

**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



E-505: operating limits with various PZT loads (open-loop), capacitance is measured in  $\mu\text{F}$

### Technical Data

Model	E-505.00	E-505.10	E-505.00S
Function	Power amplifier	Power Amplifier for Switching Applications*	Offset Voltage Supply for Tip/Tilt Systems
Channels	1	1	1
<b>Amplifier</b>			
Control input voltage range	-2 to +12 V	-2 to +12 V	-
Output voltage	-30 to +130 V	-30 to +130 V	100 V
Peak current	2 A (<3 ms)	10 A (<200 $\mu\text{s}$ )	2 A (<5 ms)
Average current	215 mA	215 mA	300 mA
Current limitation	Short-circuit-proof	Short-circuit-proof	Short-circuit-proof
Noise, 0 to 100 kHz	0.6 mVrms	1.0 mVrms	<0.7 mVrms
Voltage gain	10 $\pm$ 0.1	10 $\pm$ 0.1	-
Input impedance	1 M $\Omega$ / 1 nF	1 M $\Omega$ / 1 nF	-
<b>Interfaces and operation</b>			
Piezo connector	LEMO ERA.00.250.CTL	LEMO ERA.00.250.CTL	LEMO ERA.00.250.CTL
Analog input	BNC	BNC	-
DC-Offset	10-turn pot., adds 0 to 10 V to Control In	10-turn pot., adds 0 to 10 V to Control In	-
<b>Miscellaneous</b>			
Operating temperature range	+5 to +50 $^{\circ}\text{C}$	+5 to +50 $^{\circ}\text{C}$	+5 to +50 $^{\circ}\text{C}$
Overheat protection	Deactivation at +85 $^{\circ}\text{C}$	Deactivation at +85 $^{\circ}\text{C}$	Deactivation at +85 $^{\circ}\text{C}$
Dimensions	14HP/3U	14HP/3U	14HP/3U
Mass	0.9 kg	0.9 kg	0.9 kg
Operating Voltage	E-500 System	E-500 System	E-500 System
Max. power consumption	55 W	55 W	55 W

\* For piezo actuators with special high-current layout

### Modular Design for Flexibility: Optional Servo Controller Upgrade

Up to three E-505 amplifier modules can be installed in one E-500 chassis. The flexible, modular design of the E-500 piezo servo-controller system allows easy installation of an optional E.509 sensor- / servo-controller module for closed-loop operation. The output voltage is then set by the servo-control loop. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.



# E-506 Linearized Piezo Amplifier with Charge Control

## Charge Control for High Dynamics



E-506.10 charge-controlled Piezo driver module

### Ordering Information

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

**Ask about custom designs!**

additional position feedback is not required.

The E-506.10 piezo amplifier module is designed to work in the E-500 Controller system (s. p. 2-142). 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 130 V voltage range.

### Piezo Over Temperature Protection

The E-506 can evaluate a temperature sensor on the piezo actuator in order to protect the actuators, especially when used in dynamic applications. Automatic switch-off then reliably prevents the pre-set temperature threshold from being exceeded.

For frequency response with selected capacitive loads, see graph below.

- **Highly Linear Amplifier Module**
- **280 W Peak Power**
- **Output Voltage Range -30 to 130 V**
- **Module for E-500 Piezo Controller Rack**
- **Prepared for Position Servo-Control Upgrade (optional)**
- **Prepared for Interfaces / Display Modules (optional)**

The E-506.10 piezo amplifier module uses a charge control principle. Here, the input signal controls the amount of electrical charge which is transferred to the piezo actuator. The result is a highly precise, linear displacement of the piezo actuator in high-dynamics operation.

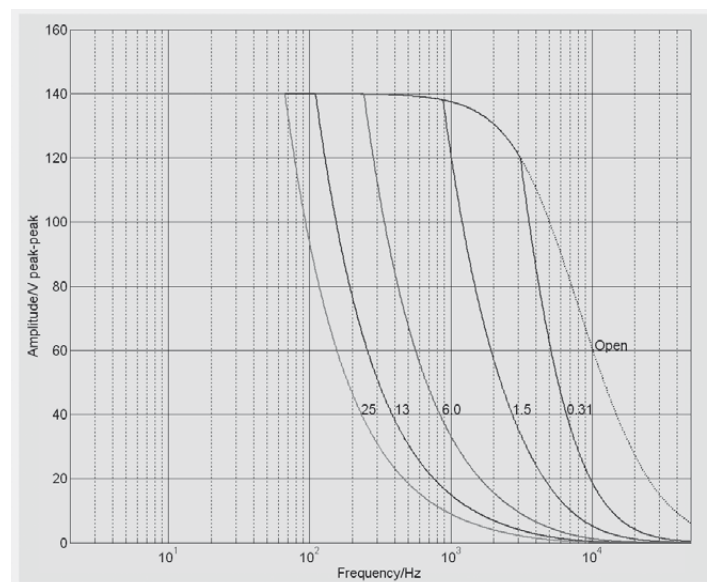
The typical hysteresis which piezo actuators show when operated with a voltage-controlled piezo amplifier can such be reduced to 2% only. An

### Minimum frequencies\* for charge-controlled operation

Capacitance (piezo actuator)	f <sub>trans</sub>
0.33 µF	250 mHz
1.06 µF	80 mHz
6.2 µF	9 mHz
14 µF	4 mHz

\* Voltage-controlled operation for lower frequencies

E-506.10: operating limits with various PZT loads (open-loop), capacitance is measured in µF. The minimum capacitive load is 0.3 µF



## Technical Data

<b>Model</b>	<b>E-506.10</b>	
Function	Linearised amplifier module, charge-controlled	
Channels	1	
<b>Amplifier</b>		
Input voltage	-2 to +12 V	
Output voltage*	-30 to 130 V	
Peak output power, < 2.5 ms	280 W	max.
Average output power	30 W	max.
Peak current, < 2.5 ms	2 A	
Average current	215 mA	
Current limitation	Short-circuit-proof	
Ripple, noise	<0.6 mV <sub>rms</sub>	
Reference capacitance (adjustable)	1 to 280 µF	
Input impedance	1 MΩ / 1 nF	
<b>Interfaces and operation</b>		
Piezo connector (voltage output)	LEMO 2-pin EGG.0B.302.CLL	
Analog input	BNC	
DC Offset	10-turn pot., adds 0 to 10 V to Control In	
Piezo temperature sensor (input)	PT 1000; LEMO socket; deactivation of the piezo voltage output at 150°C	
<b>Miscellaneous</b>		
Operating temperature range	+5 to +50 °C	
Dimensions	14HP / 3U	
Mass	0.9 kg	
Operating voltage	E-500 System	
Power consumption	55 W	max.

\* Max. 85 °C, deactivation of the piezo voltage output (internal overtemp protection)

## Minimum frequencies\* for charge-controlled operation

Capacitance (piezo actuator)	f <sub>trans</sub>
0.33 µF	250 mHz
1.06 µF	80 mHz
6.2 µF	9 mHz
14 µF	4 mHz

\* Voltage-controlled operation for lower frequencies

# E-504 High Power Energy Recovery Piezo Driver

## High Power through Energy Recovery, E-500 Piezo Controller System



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

- **Peak Power 280 W**
- **High Average Output Power 100 W**
- **Very Energy Efficient Through Energy Recovery**
- **Output Voltage Range -30 to 130 V**
- **Module for E-500 Piezo Controller Rack**
- **Prepared for Position Servo-Control Upgrade (optional)**
- **Prepared for Interface / Display Modules (optional)**

The E-504 power amplifier extends the E-500 modular piezo controller system with a high-output amplifier for low-voltage actuators and positioners.

The innovative, efficient energy recovery circuitry reduces power consumption and heat dissipation, especially in dynamic applications. This makes possible peak output currents up to 2000 mA and a peak power of 280 W, with an average output power of up to 100 W.

### Working Principle

Charge is transferred to the piezo actuator using low-loss PWM techniques. When the actuator is discharged, the

energy not consumed is fed through the energy recovery circuitry for reuse in the next charging cycle.

The working principle of the E-504 series is perfectly qualified for high-dynamics scanning and switching applications. For applications where static position stability in the sub-nanometer range is essential, the E-505 (see p. 2-147) amplifier module is recommended.

### Modular Design for Flexibility: Optional Servo-Controller Upgrade

Up to three E-504 amplifier modules can be installed in one E-500 controller chassis. The flexible, modular design of the E-500 piezo controller sys-

tem allows easy installation of an optional E-509 sensor- / servo-controller module for closed-loop operation. The output voltage of the E-504 is then set by the servo-control loop. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

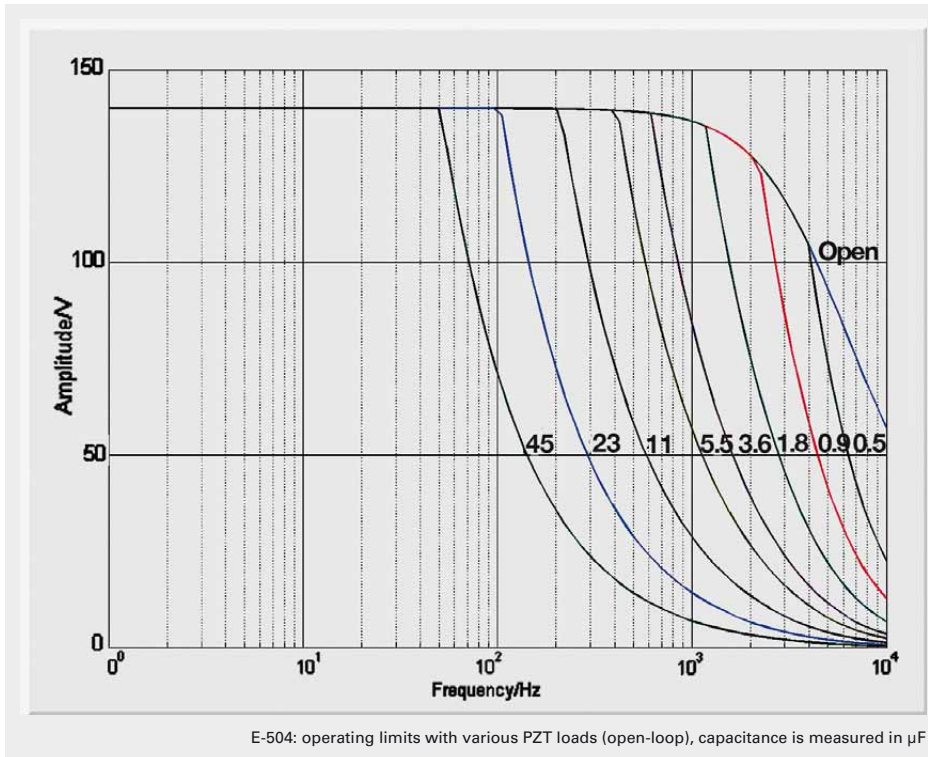
### Open-Loop Operation

In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input, optionally combined with the DC-offset potentiometer. 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. The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

The same functionality and specifications are available in the E-617 amplifier module. (see p. 2-112).

### Ordering Information

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



## Technical Data

<b>Model</b>	<b>E-504.00F</b>
<b>Function</b>	Power amplifier with energy recovery, 1 channel
<b>Amplifier</b>	
Control input voltage range	-2 to +12 V
Output voltage	-30 V to 130 V
Peak output power <5 ms	280 W
Average output power	Equivalent to 100 W reactive power
Peak output current <5 ms	2000 mA
Average current	1000 mA
Current limitation	Short-circuit-proof
Voltage gain	$10 \pm 0.1$
Ripple, noise, 0 to 100 kHz	5 mV <sub>RMS</sub> 20 mV <sub>P-P</sub>
Output impedance	$0,5 \Omega / 2,5 \mu\text{F}$
<b>Interfaces and operation</b>	
Piezo connector	LEMO ERA.00.250.CTL
Analog input	SMB
DC-Offset	10-turn pot., adds 0 to +10 V to Control In
<b>Miscellaneous</b>	
Operating temperature range	+5 to +50°C
Dimensions	One 14T slot wide, 3H high
Mass	0.9 kg
Operating voltage	E-500 System
Max. power consumption	<30 W



# E-621 Piezo Servo-Controller & Driver

## Modules with Fast 24-Bit Interface



E-621.CR module

- **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,

**Ordering Information**

**E-621.CR**  
Piezo Amplifier / Servo-Controller Module, 1 Channel, -30 to 130 V, Capacitive Sensor, USB, RS-232

**E-621.SR**  
Piezo Amplifier / Servo-Controller Module, 1 Channel, -20 to 120 V, SGS-Sensor, USB, RS-232

**E-500.621**  
19"-Chassis for up to twelve E-621 Modules, Power Supply

**E-501.621**  
9,5"-Chassis for up to four E-621 Modules, Power Supply

trajectory profiles can be repeated reliably and commanded easily.

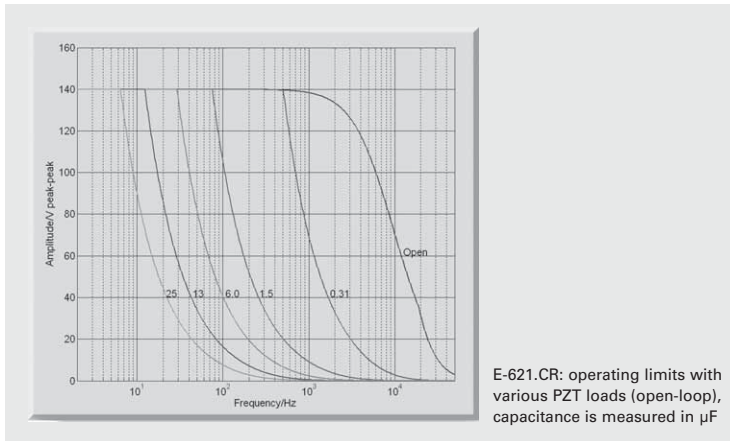
### Software / GCS Command Set

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.



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

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## Technical Data

<b>Model</b>	<b>E-621.SR / E-621.CR</b>
Function	Power amplifier & piezo controller
<b>Sensor</b>	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (.CR)
<b>Amplifier</b>	
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 <sub>rms</sub>
Voltage gain	10 $\pm$ 0.1
Input impedance	100 k $\Omega$
<b>Interfaces and operation</b>	
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
<b>Miscellaneous</b>	
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

# E-508 PICA™ High Voltage Piezo Amplifier Module, 1100 V

## High-Power Module with 1100 V Output Voltage, E-500 Piezo Controller System



E-508.00 Piezo amplifier plug-in module

cision 10-turn potentiometer can also be used alone to set the output voltage manually.

### OEM Version for Fast Switching Applications

The E-508.OE is the high-current OEM version, especially designed for switching applications. It can output a peak current of 400 mA for 5 ms. The E-508.OE is directly controlled by an analog signal.

For extensions, adapter cables and connectors, see "Accessories" in the piezo electronics chapter (see p. 2-168 ff).

### Ordering Information

**E-508.00**  
HVPZT Piezo Amplifier Module, +3 to +1100 V, 1 Channel

**E-508.OE**  
HVPZT Piezo Amplifier Module, OEM Version, 400 mA Peak Current

**Ask about custom designs!**

- Peak Power up to 400 W
- Output Voltage Range 3 to ±1100 V or bipolar
- Plug-In Module for E-500 System
- E-508.OE for Switching Applications
- Prepared for Position Servo-Control Upgrade (optional)
- Prepared for Interfaces / Display Modules (optional)

The E-508 plug-in module is a piezo driver / amplifier for the E-500 / E-501 piezo controller systems suitable for PICA™ piezo actuators (HVPZT). Its low-noise, 4-quadrant amplifiers can output and sink peak currents of 50 mA (E-508.OE: up to 400 mA) over an 1100 V range. The units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and optionally in position-controlled mode (closed-loop).

### Modular Design for Flexibility: Optional Servo Controller Upgrade

Up to three E-500 piezo amplifier modules can be installed in one E-500 chassis. The flexible, modular design of the E-500 piezo controller system allows easy installation of an optional E.509 sensor- / servo-controller

module for closed-loop operation. The output voltage is then set by the servo-control loop. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

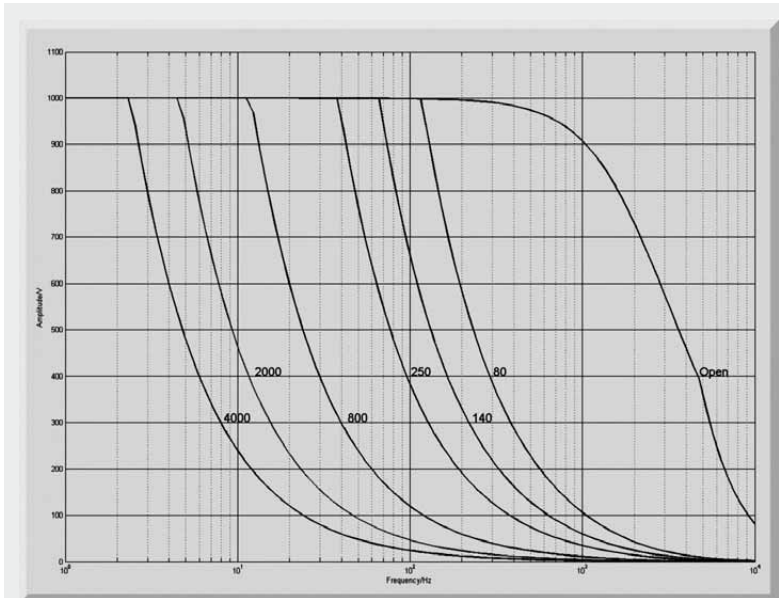
### Voltage Controlled Piezo Positioning

In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input optionally combined with the DC-offset potentiometer. 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). The pre-



The E-508.00 plug-in module (right) and the E-508.OE, OEM module optimized for switching applications

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E-508: operating limits with various PZT loads (open-loop), capacitance is measured in nF

## Technical Data

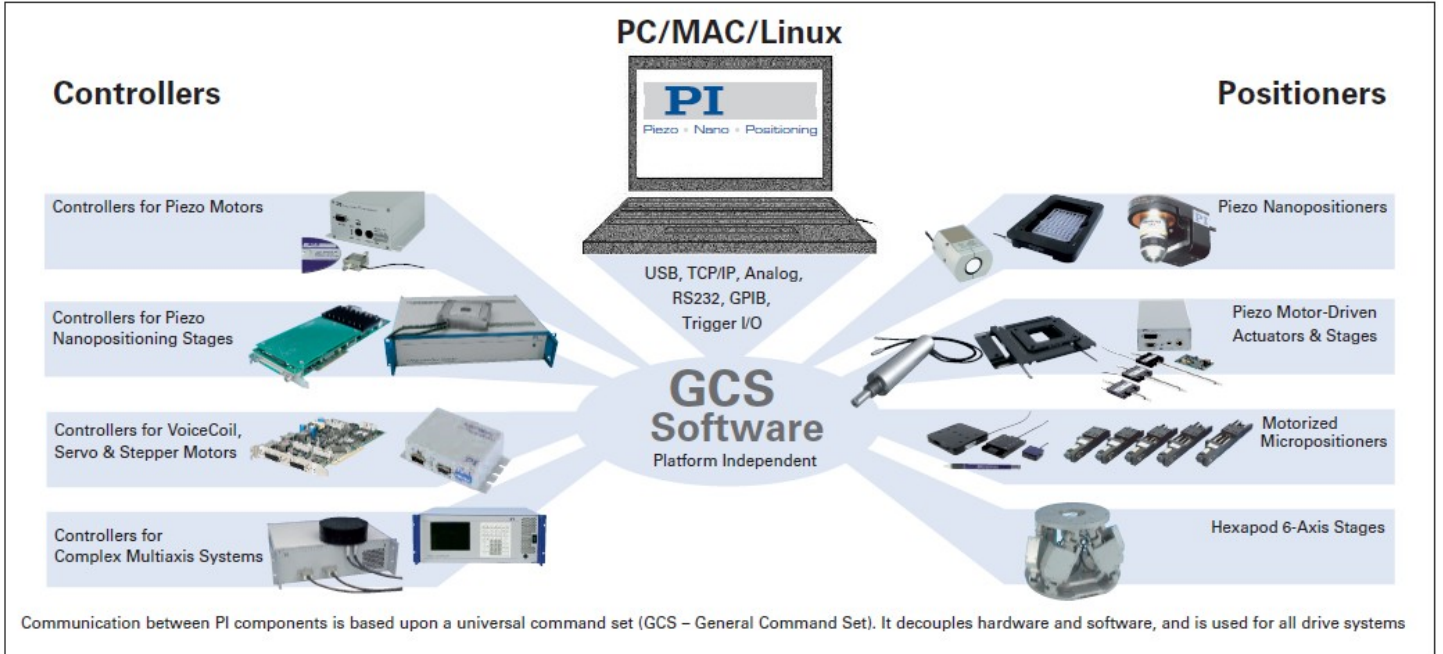
Model	E-508.00	E-508.OE	Unit
Function	Power amplifier for PICA™ high-voltage piezos	Power amplifier for PICA™ high-voltage piezos	
<b>Amplifier</b>			
Output voltage	3 to +1100 (Standard) (-260 to +780 -550 to +550 +260 to -780 -3 to -1100) (jumper selectable)	3 to +1100 (Standard) (-260 to +780 -550 to +550 +260 to -780 -3 to -1100) (factory-settable)	V
Amplifier channels	1	1	
Average output power	13	13	W
Peak output power, <5 ms	50	400	W
Average current	12	12	mA
Peak current, <5 ms	50	400	mA
Amplifier bandwidth, small signal	6	10	kHz
Amplifier bandwidth, large signal	50 (200 nF)	50 (200 nF)	Hz
Ripple, noise 0 to 100 kHz	5 50 (100 nF)	20 200 (100 nF)	mV <sub>RMS</sub> mV <sub>P-P</sub>
Current limitation	Short-circuit-proof	Short-circuit-proof	
Voltage gain	+100 ±1, -100 ±1 (selectable)	+100 ±1, -100 ±1 (selectable)	
Control input voltage	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V	
Input impedance	100	100	kΩ
<b>Interfaces and operation</b>			
Piezo voltage output	LEMO EGG.0B.701.CJL.1173	LEMO EGG.0B.701.CJL.1173	
Input	BNC SMB		
DC-Offset	10-turn pot., adds 0 to 10 V to Control In	-	
<b>Miscellaneous</b>			
Operating voltage	E-500 System	E-500 System	
Operating temperature range	+5 to +50 °C (10 % derated over 40 °C)	+5 to +50 °C (10 % derated over 40 °C)	°C
Mass	0.75	0.75	kg
Dimensions	14 HP/3 U	14 HP/3 U	



## Software Tools

For LabView, C++, VB, Matlab, Image Acquisitong Packages, NI DAC Cards, .....

PI provides high-level, robust, easy-to-use software tools for fast, seamless integration of motion systems into application control software

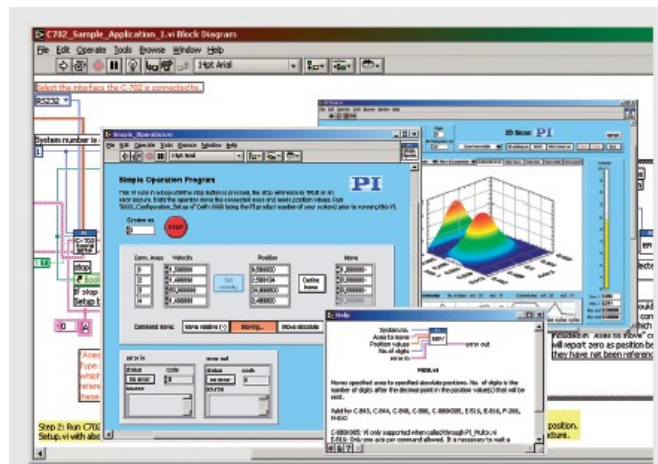


The high quality of positioning systems is made apparent in daily operation by PI software. Starting with simple commissioning, through convenient operation with a graphical interface, to quick and simple integration in customized programs with high performance, PI software covers all aspects important to an application.

devices are identical in syntax and function. Through the use of the GCS command set with its convenient functions, the orientation phase and application development process is significantly accelerated. The GCS commands are available at the controller terminal, in macros and in the form of a universal driver set for LabVIEW (VIs), Windows dynamic link libraries (DLL) and Linux libraries. This facilitates the development of custom macros, as well as integration with programming languages like LabVIEW, C++ or MATLAB.

### Universal Command Set Simplifies Commissioning and Programming

For uniform operation of nano and micropositioning systems, the universal PI General Command Set (GCS) is used. GCS operation is independent of the controller or drive principle used, so that several positioning systems can be controlled together, or new systems can be introduced with a minimum of programming effort. With GCS the development of custom application programs is simplified and less prone to errors, because the commands for all supported



Easy integration in LabView. Quick access to the full functionality Contact PI for our extensive library of software examples!

**PI piezo stages & controllers are compatible with all major image acquisition software packages such as, Metamorph™, μManager™, Slidebook™, Simple PCI™, NIS Elements™, ImagePro™.**

For more information on PI software support, go online or request the PI software brochure



Software and manuals can be downloaded, from the PI Support server

### Software Updates Online

PI supports users with free updates, detailed online help and well structured manuals which ease initiation of the inexperienced but still answer the detailed questions of the professional.

### Supported Operating Systems

- Microsoft Windows Vista
- Microsoft Windows XP
- Microsoft Windows 2000
- Linux

## Program Overview

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- 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
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