

Piezo Drivers / Servo Controllers For Nanopositioning Stages, Steering Mirrors & Piezo Actuators



Selection Guide: Single-Axis Piezo Controllers

Great Variety: Digital, Analog, Bench-Top & Card Type Controllers / Drivers

PI offers piezo drivers (amplifiers) for low voltage (~100 V) and high voltage (~1000 V) positioning systems. Controllers also

integrate position feedback circuitry for closed-loop operation. Digital controllers provide higher flexibility and allow parameter

changes on-the-fly as well as many advanced control, interfacing and linearization options. All models are available with a high-

bandwidth analog interface. Most analog controllers also have a digital interface option.

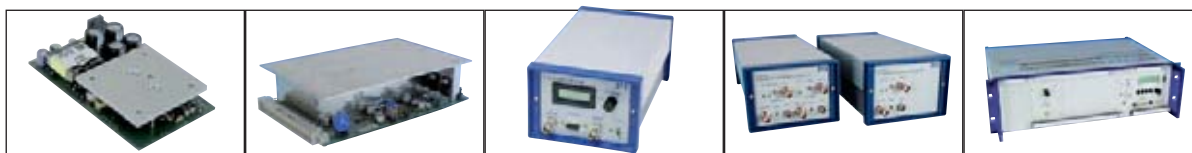
Models	Description	Voltage [V]	Power [W]	Digital Interface	Channels	Feedback Sensor	Page
E-753	Digital high-speed piezo controller & driver	-30 to 135	7.5	TCP/IP, RS-232	1	Capacitive	2-108
E-661	Piezo controller & driver w/ high-speed parallel port interface	-20 to 120	8	parallel, optoisolated	1	Capacitive	2-118
E-665	Piezo controller & driver with LED display, networkable	-20 to 120	36	20 Bit RS-232, 12 networkable	1	SGS, capacitive	2-116
E-625	Compact Piezo controller & driver, networkable	-20 to 120	14	20 Bit RS-232, 4 networkable	1	SGS, capacitive	2-114
E-621	Piezo controller & driver module, networkable	-20 to 120	14	20 bit RS-232, 12 networkable	1 to 12, networkable	SGS, capacitive	2-160
E-610	Piezo driver w/optional controller, OEM card	-20 to 120	14	-	1	- / SGS, capacitive	2-110
E-617	High power piezo driver modules w/ energy recovery	-30 to 135	to 280	-	1	-	2-112
E-660, E-660.OE	Piezo driver, desktop and solder-on units	5 to 110	2	-	1	-	2-119
E-462, E-462.OE	Piezo driver, desktop and solder-on units	10 to 1000	0,5	-	1	-	2-121
E-831	Piezo driver module, solderable.	-20 to 120	5	-	1	-	2-164
E-835	Piezo driver module for P-876 DuraAct™ patch transducers	-100 to 250	to 30	-	1	-	2-166
E-413	Compact piezo amplifier for DuraAct™ patch transducers and PICA™ Shear piezo actuators	±250	50	-	1	-	2-120
E-650	Driver, desktop or OEM module for bender actuators	0 to 60	18 / 8	-	1	-	2-122
E-651, E-614	Piezo controller / driver for bender actuators	0 to 60	1	-	1, 2	SGS	2-123
E-471, E-481	High-power amplifier / ultra high power amplifier with energy recovery	0 to ±1000 & bipolar	550, 2000	USB, TCP/IP, IEEE488, RS-232 (optional)	1	Optional	2-158 2-124



E-753 Digital high-speed piezo controller E-661 Controller / driver with parallel interface E-665 Controller / driver with display & 20 bit interface E-625 Compact controller / driver with 20 bit interface E-621 Controller / driver module with 20 bit interface



E-610 OEM amplifiers / controllers, Euro card E-617 High-power top-hat module w/ energy recovery E-660 100 V driver; E-462 1000 V driver E-660.OE OEM module E-462.OE OEM module E-831 OEM piezo driver module



E-835 Driver module for DuraAct™ patch transducers E-413 Amplifier for patch transducers and shear actuators E-650 Driver for benders E-651 Controller/driver for closed-loop benders E-471, E-481 High power amplifiers, 1000V, 550W / 2000W

Selection Guide: Multi-Axis Piezo Controllers

Digital, Analog, PCI Card, Bench-Top & Modular Controllers / Drivers

Piezo Controllers Overview

PI offers piezo drivers (amplifiers) for low voltage (~100 V) and high voltage (~1000 V) posi-

tioning systems. Controllers also integrate position feedback circuitry for closed-loop operation. Digital controllers provide higher

flexibility and allow parameter changes on-the-fly as well as many advanced control, interfacing and linearization options. All

models are available with a high-bandwidth analog interface. Most analog controllers also have a digital interface option.

Models	Description	Voltage [V]	Power [W]	Channels	Digital Interface	Sensor	Page
E-725	Digital piezo controller, 3 channels, static & dynamic linearization	-30 to 135	25	3/6	RS-232, USB, Ethernet	Capacitive	2-126
E-710	Digital piezo controller, 3-6 channels, static & dynamic linearization	-20 to 120	25	3, 4, 6	RS-232 & IEEE 448, Parallel	Capacitive	2-128
E-712	Digital piezo controller system, up to 6 axes	-30 to 135	6 / 200	3/6	Ethernet, USB, RS-232	Capacitive	2-140
E-761	Digital piezo controller, board, 3 channels, static & dynamic linearization	-20 to 120	5.3	3	PCI Bus	Capacitive	2-130
E-616	Controller for multi-axis piezo tip/tilt mirrors	-20 to 120	10	2	–	SGS	2-132
E-500- E-501	Chassis with P/S for amplifier, controller, interface modules see modular piezo controllers	module-dependent	6 to 200	3 to 12	Optional	Optional	2-142
E-536	Piezo controller system for PicoCube® positioning systems, 19" chassis	±250	50 / 100	2, 3	Optional	Capacitive	2-134
E-663	Driver, 3 channels, LED displays	-20 to 120	3 x 14	3	–	–	2-136
E-464	Driver, 3 channels, LED displays	0 to 1100	3 x 25	3	–	–	2-139
E-664	Piezo controller / driver for NanoCube® systems, LED displays	-20 to 120	3 x 14	3	–	SGS	2-137
E-760	NanoCube® piezo controller card for Hexapod controller & C-880 Controller	-20 to 120	3 x 9	3	ISA-bus card	SGS	2-138



E-725 Digital controller, 3 channels

E-710 Digital controller, 3 to 6 channels

E-712 Digital controller up to 6 channels

E-761 PCI board digital controller, 3 channels

E-500, E-501 Analog controller, up to 12 channels



E-616 Controller for piezo tip/tilt mirrors and platforms

E-536 PicoCube® piezo controller, 3 ch

E-663 Driver, 100 V, 3 ch.
E-464 Driver, 1000 V, 3 ch

E-664 NanoCube® controller, 3 channels

E-760 NanoCube® card for Hexapod controller upgrade

Modular piezo controllers: see p. 2-102

Accessories for PI piezo drivers / controllers see p. 2-168 ff

Selection Guide: Modular Piezo Controllers

Digital and Analog, Bench-Top and OEM, up to 12 Channels

PI offers low voltage (100 V) and high voltage (1000 V) piezo drivers. Drivers can be upgraded with servo-control modules for

closed-loop operation. Digital controllers provide higher flexibility and allow parameter changes on-the-fly as well as

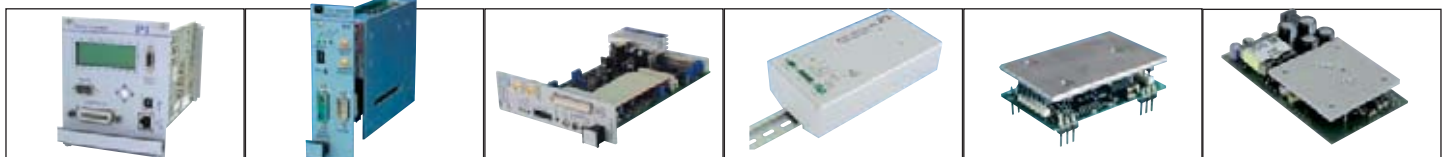
many advanced control and linearization options. All models are available with a high-bandwidth analog interface. Most

analog controllers also have a digital interface option.

Models	Description	Voltage [V]	Power [W]	Interface	Channels	Page
E-712	Digital Piezo Controller System, up to 6 axes	-30 to 135	6 / 200	Ethernet / USB / RS-232	3/6	2-140
E-500, E-501	19" and 9.5" Chassis with P/S for amplifier, controller, interface module	module dependent	module dependent	Optional, USB, TCP/IP, IEEE, RS-232	1, 2, 3, opt. to 12	2-142
E-470, E-471	High-power amplifier	3 to 1100 & bipolar	550	Optional, USB, TCP/IP, IEEE, RS-232	1-2	2-158
E-509	Sensor- / servo-controller module for E-500 / E-501, E-471, E-481	-	-	-	1, 2, 3	2-152
E-515, E-515.03	Display module (LED) for E-500 / E-501, E-471, E-481	-	-	-	1, 3	2-154
E-503	Amplifier module for E-500 / E-501	-20 to 120	3 x 14	-	1	2-146
E-504.00F	Amplifier module for E-500 / E-501 with energy recovery	-20 to 135	200	-	1	2-148
E-505	Amplifier module for E-500 / E-501	-20 to 120	200	-	1	2-147
E-508	Amplifier module for E-500 / E-501	3 to 1100 & bipolar	50	-	1	2-150
E-517	Interface module with D/A converter & LCD display. For E-500 / E-501, E-471, E-481	-	-	IEEE 488, RS-232, USB, TCP/IP	1, 3	2-156
E-621	Piezo controller / driver module with RS-232 interface, networkable, OEM, for E-500.621 rack	-20 to 120	14	20 bit RS-232	1 to 12, networkable	2-160
E-612	Controller card with high-speed parallel interface, for E-501.10 rack	-20 to 120	8	Parallel, opto-isolated	1 to 4, networkable	2-162
E-617	High-power OEM module with energy recovery for high dynamics applications	-30 to 135	<30 W	-	-	2-112
E-831	Piezo driver module, solderable	-20 to 120	5	-	1	2-164
E-835	Piezo driver module for P-876 DuraAct™ patch transducers	-100 to 250	to 30	-	1	2-166



E-712 Digital controller E-500 19" Chassis for driver, controller, interface modules E-500.621 up to 12 channels per rack E-471 HVPZT high- power amplifier, 550 W E-509 Sensor- / servo-controller module E-503, E-504, E-505, E-508 1 and 3 ch amplifier modules



E-517 Interface with D/A converter & LCD display E-621 Amplifier/ servo-controller module E-612 Controller card, parallel interface E-617 High power amplifier/ driver with energy recovery E-831 Solderable piezo driver module E-835 Driver module for DuraAct™ patch transducers

Single- and multi-axis piezo controllers see p. 2-100, p. 2-101
 Accessories for PI piezo drivers / controllers see p. 2-168 ff

Piezo Drivers & Controllers

Simple Control of High Performance Systems



PI offers the largest selection of digital and analog piezo drivers / linear amplifiers and piezo motion controllers worldwide.

The electronics play a key role for maximum performance of piezoelectric nanopositioning stages, steering mirrors and actuators. Ultra-low-noise, high-stability servo-controllers and linear amplifiers are essential, because piezoelectric actuators respond to even microvolt changes of the drive voltage with motion.

For industrial applications, where maximum throughput is crucial, PI offers digital control algorithms for dynamic linearization and reduced settling times. For dynamic high-power applications, PI's unique energy-recovery power amplifiers provide up to 2000 W of peak power!

All standard PI nanopositioning systems are fully CE and RoHS compliant.

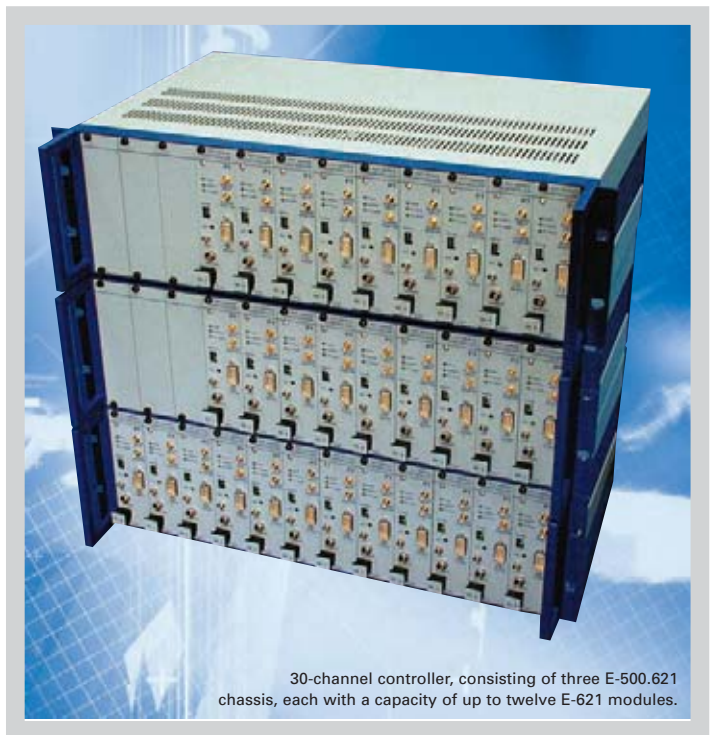
Analog and Digital Control for Your Choice

Analog controllers provide true real-time signal processing with very high resolution because no signal conversion is required. This can be advantageous in applications where the control signals are only available in analog form.

Additionally to classical piezo controllers, PI offers a wide range of digital servo controllers. The advantage of digital control is the possibility to use advanced control models and polynomial linearization to improve system response and accuracy significantly. Further advantages are integrated signal generators, trigger functions, system analysis, autocalibration and parameters that can be changed on-the-fly. High-resolution DA and AD converters, fast DSPs and real-time control algorithms allow fast processing for optimizing the system performance.

PI Digital Piezo Controllers—the Winning Margin in Precision

- 1 to 6 axes
- Network and synchronization capability for multi-axis applications
- Based on DSP (Digital Signal Processor) and/or embedded PC
- Optimized control and motion algorithms
- Modern interfaces: high-speed RS-232, remote operation via TCP/IP or USB
- Extensive software package
- All parameters can be changed on-the-fly
- Dynamic tuning with comfortable NanoCapture™ software
- Two notch filters per axis (standard) for higher dynamics
- Polynomial linearization provides to 0.01% linearity
- DDL: Dynamic linearization eliminates tracking errors
- Plug and Play, ID chip implemented in Sub-D connector of stage.
- Auto Zero function
- Automatic coordinate transformation for simple control of complex parallel-kinematics systems
- Freely programmable Trigger I/O
- Optional analog I/O



30-channel controller, consisting of three E-500.621 chassis, each with a capacity of up to twelve E-621 modules.

Operating Characteristics of Piezo Amplifiers

Power Requirements for Piezo (PZT) Operation

The operating limits of a piezo amplifier depend on the amplifier power, the amplifier design, and of course, the piezo's electrical capacitance. For dynamic applications, PZTs require high charge and discharge currents. Those requirements are best met by power amplifiers that can source and sink high peak currents. The average current is of secondary importance. For exact information on maximum operating frequency with a given PZT load refer to the individual operating limits graphs.

Open-loop operating limits data for all PI piezo power amplifiers in this catalog were taken after 15 minutes of continuous operation (PZT and amplifier) at room temperature. At power up, (cold conditions) maximum operating frequency is higher.

The indicated capacitance values are small-signal values for actual piezo actuators (measured at 1 V, 1000 Hz, 20 °C, no load). The capacitance of piezo ceramics changes significantly with amplitude, temperature, and load, up to approximately 200% of the unloaded small-signal capacitance at room temperature. See tutorial "Electrical Fundamentals" (p. 2-195) for more information.

Therefore the operating limits graphs actually reflect a much higher load to the amplifier than a standard capacitor of the same value would represent.

Adjusting Control Input

In order to achieve minimum distortion of the output waveform, it is important to ensure that the control input amplitude is reduced in proportion to the roll-off of the output voltage at higher frequencies.

Example: The E-503 (E-663) amplifier can drive a 23 μ F load at 100 V peak-to-peak (sinewave) up to approximately 15 Hz. At higher frequencies the output voltage drops off, e. g. to 80 V at 20 Hz. Therefore it would be important to reduce the input voltage amplitude to 8 V (gain = 10) at this frequency. Otherwise the amplifier will output a clipped distorted sinewave.

See "Introduction Flexure Stages" (p. 2-10) for more information on controller selection.

Application-Specific Settings

To achieve optimum performance each position servo-controller must be adjusted for displacement range, frequency response, settling time and optimum match with the position sensor. This adjustment is done at the factory and is included in

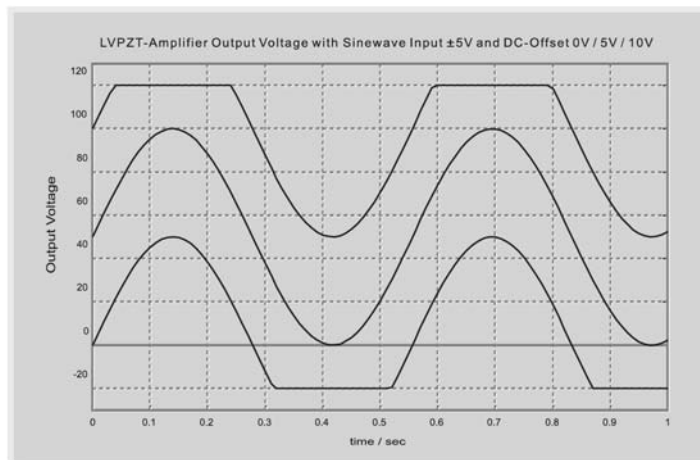
the price of the controller Test & Metrology (see p. 2-187).

To optimize the system settings, additional information about the desired operating bandwidth, the mass to be moved by the piezo and the spring constant of any preload or of the material the piezo pushes against is required.

The position servo-control portion of all analog PI piezo servo-controllers is identical, employing a proportional integral (P-I) algorithm specially optimized for piezo actuators. A differential term is not recommended with piezo actuators because it only increases the noise. One or several notch filters are used to greatly improve dynamics / bandwidth.

High System Bandwidth

All PI nanopositioning controllers (analog and digital) are equipped with one or more user-tunable notch filters. A controller with notch filter can be tuned to provide higher bandwidth because side-effects of system resonances can be suppressed before they affect system stability. For the most demanding step-and-settle applications, PI's exclusive Mach™ InputShaping® implementation is available as an option.



The diagram shows how the piezo amplifier input range can be varied with the DC-offset potentiometer. This principle is also valid for HVPZT amplifiers, where the typical input range is 0 to +10 V and the output range is 0 to 1000 V. The DC-offset potentiometer allows for continuous shifting of the input range between 0 V to +10 V and -10 V to 0 V.

Interfaces

Digital or Analog Interfacing?

Analog interfacing provides high bandwidth and remains the most common way of commanding piezoelectric motion systems. It is usually the choice when the control signal in the application is provided in analog form. A key advantage of analog interfacing is its intrinsic deterministic (real-time) behavior, contrasted to the difficulty of accurately timing high-bandwidth communications on present-day multitasking PCs.

However, when analog control signals are not available, or when a significant distance between the control signal source and the nanopositioning controller would affect signal quality, digital interfacing, which must not be confused with digital control, is the preferred choice.

Digital signals can be transferred through copper wires, or for complete EMI immunity, through optical fibers.

Supported Digital Interfaces

PI's controllers are equipped with fast TCP/IP, USB and RS-232 interfaces (for details and exceptions see data sheets). Positioning commands can be formulated directly in SI units (e.g. microns and microradians), a feature which facilitates pro-

gramming the system. In addition, parameters for the servo-loop, low-pass and notch filters are easily optimized and can be stored in non-volatile memory.

An optional parallel interface (PIO) bypasses the command parser and allows reading and writing up to 20,000 positions per second. Fast PCI interfaces offer transfer rates up to 1 MHz.

Interface Bandwidth vs. Timing

Piezo-driven stages can respond to a motion command on a millisecond or microsecond time scale.

That is why synchronization of motion commands and data acquisition have a high impact on the quality of many applications, like imaging or micromachining. The USB, for example, was designed to transfer huge blocks of data at high speeds, but exact timing was a much lesser concern. While insignificant in less responsive positioning systems, this kind of non-deterministic behavior may not be tolerable in high-speed tracking or scanning applications. Each motion command—comprising just a few bytes—must be transferred instantaneously and without latency. A lower-bandwidth bus with higher timing accuracy may perform better in many applications.

There are several factors that affect the response of a digital interface: the timing accuracy of the operating system on the controlling computer; the bus timing protocol; the bandwidth of the bus; and, the time it takes the digital interface (in the piezo controller) to process each command. Parallel-port interfaces do not require command parsing and offer the best combination of throughput and timing accuracy.

In addition to the interface properties, the bandwidth of the nanopositioning system (mechanics and servo) matters. A slow system (e.g. 100 Hz resonant frequency) will not benefit from a responsive interface as much as a high-speed mechanism.

Analog In- and Outputs

Optionally available analog inputs can be configured in a flexible way: either as a control input—the applied voltage can be connected with one of the available axes and is interpreted e.g. as a position value—or as an external sensor—e.g. used as an autofocus signal instead of an integrated sensor.

Optional analog outputs allow the control of external power amplifiers or can be used as monitor signal interfaces.

The individual data sheets for the controllers inform about number, voltage range (usually ± 10 V) and availability of the analog I/Os.



PI controllers are available with a number of different interfaces for highest flexibility. In addition to the modern Ethernet (TCP/IP) and USB, many industrial customers still appreciate the robust RS-232 protocol

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

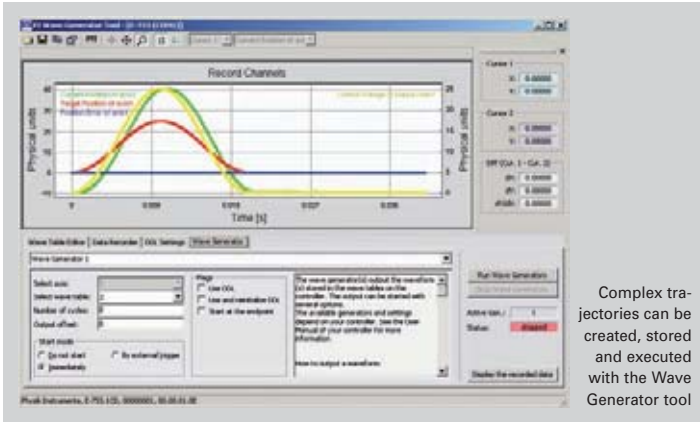
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Support of Controller-Specific Features



Complex trajectories can be created, stored and executed with the Wave Generator tool

Data Recorder: Data Acquisition and Output

The flexibly configurable data recorder enables simultaneous recording and read-out of input and output signals, such as for sensor positions or control voltages depending on time stamps or using trigger signals.

Wave and Profile Generator: Pre-Defined and Programmable Trajectory Profiles

Trajectory profiles of arbitrary, user-defined mathematical functions enable complex 2-axis motion. Depending on the controller used, either time and position data value pairs can be saved (Wave Generator) or complete trajectory profiles with velocity, acceleration and jerk (rate of change of acceleration) can be specified (Profile Generator). The functionality includes:

- Programming of complex functions
- Quick access to common functions (e.g. sine, ramps, triangle and square waves ...)
- Coordination of two axes, e.g. for applications requiring circular motion
- Saving of defined functions in the controller

All controller specific functionalities are available as DLL func-

tion calls and LabVIEW VIs, which enables their simple integration in external programs. Additional graphical user interfaces allow convenient selection and customization.

Improved Piezo Control: Dynamic Digital Linearization (DDL)

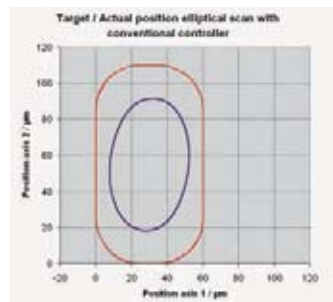
Conventional piezo controllers cannot completely avoid phase-shift and tracking errors in applications with rapid, periodic motion. This is due in part to the non-linear nature of the piezoelectric material, the finite control bandwidth and the inherent limitations of P-I (proportional-integral) servo-control, which only reacts when a position error is detected. The DDL option (ordering number E-710.SCN), available with recent digital piezo controllers such as E-753 (single-channel, see p. 2-108) or E-712 (multi-channel, see p. 2-140), solves this problem. This technology, developed by PI, reduces the error between the current and desired position to imperceptible values. The dynamic linearity and effectively usable bandwidth are thus improved by up to three orders of magnitude. DDL is of benefit to single- and multi-axis applications where motion follows a given trajectory repeatedly (see measurement curves).

Extensive Software Support

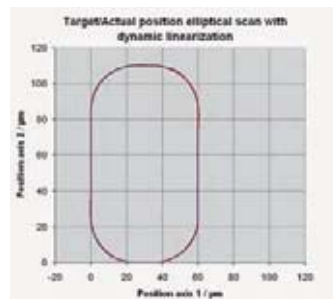
Digital controllers come with a large variety of software tools, such as the PIMikroMove™ graphic user interface or the Nano-Capture™ system analysis program. Additional LabVIEW drivers and DLL's for easy setup, system optimization and integration in application-specific programs are included. Comprehensive documentation, Online Help and sample code offer added value. Even analog systems can be controlled with PI's LabVIEW driver set, optionally with HyperBit functionality.

Simple, General Command Set Saves Time

General Command Set (GCS) is PI's universal command set for uniform control of nano- and micropositioning systems. All PI piezo, piezomotor and motor controllers including hexapods and hybrid systems support the command set. With GCS the control is independent of the used hardware, so that different devices can be controlled together or new devices can be used with minimum adaption efforts. See p. A-11 ff for details.



Elliptical scan with a XY piezo scanner and conventional P-I-servo controller. The outer curve shows the desired position, the inner curve shows the actual motion



The same scan as before but with a DDL controller. The tracking error is reduced to a few nanometers, desired and actual position cannot be distinguished in the graph

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages /
High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors /
Active Optics

**Piezo Drivers /
Servo Controllers**

Single-Channel

Multi-Channel

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E-753 Digital Piezo Controller High-Speed, Single-Axis Controller



E-753 Single-channel digital controller together with the PIHera® P-629.1CD nanopositioning stage with 1500 µm travel

- Next Generation Digital Controller Provides Higher Flexibility, Accuracy and Speed
- 100 kHz Sensor Sampling; 32-bit Floating Point DSP; 24-bit Low-Noise D/A Converters
- Ethernet (TCP/IP) Interface for Remote Control Capability, RS-232
- Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics
- Additional High-Bandwidth Analog Control Input / Sensor Input
- Digital I/O Lines for Task Triggering
- Extensive Software Support
- For Nanopositioning Systems with Capacitive Sensors

The E-753 next-generation digital piezo controller is the result of PI's 30+ years of experience with piezo motion control systems. It is ideal when it comes to meeting the most demanding accuracy and dynamic-performance requirements of nanopositioning systems of the highest precision class. The E-753 replaces the E-750 controller.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.001% of the travel range. During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with

Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000 and enables the spatial and temporal tracking during a dynamic scan.

Higher Velocity and Bandwidth for Dynamic Applications

The controller is perfectly suited for high-dynamics operation thanks to its high-resolution DA-converter and high-performance voltage amplifier. The high-speed processor with a sensor sampling rate of 100 kHz assures settling times in the millisecond range and below.

Flexibility for a Variety of Applications

PI nanopositioning systems which are equipped with an ID-chip and calibrated with a digital controller have the mechanics-related calibration and servo-control parameters stored in the chip. The controller automatically adapts to the connected mechanics by the appropriate use of this data, so that recalibration is not necessary when system components are replaced.

The integrated wave generator can save and output periodic

Ordering Information

- E-753.1CD**
High-Speed Single-Channel Digital Piezo Controller for Capacitive Sensors
- E-710.SCN**
DDL (Dynamic Digital Linearization) Firmware Upgrade
- E-753.IO**
Cable for Digital I/O Lines, 1.5 m, Solderable End

Ask about custom designs

motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created.

Simple System Integration

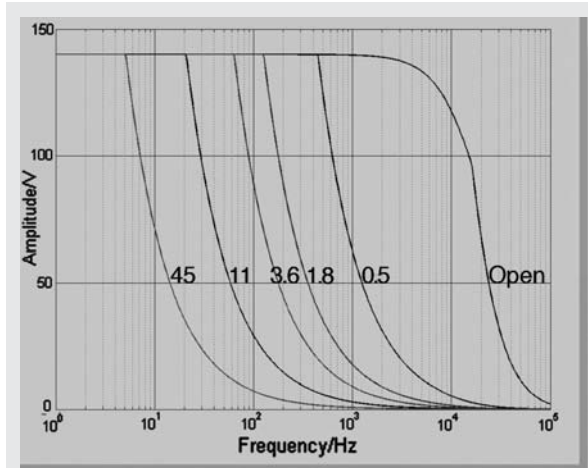
All parameters can be checked and reset via software. System setup and configuration is done with the included NanoCapture™ and PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. System programming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.



P-725 PIFOC® objective Z-positioner and E-753 controller constitute an optimal system for high-speed, high-resolution positioning and scanning.

Technical Data

Model	E-753.1CD
Function	Digital controller for single-axis piezo nanopositioning systems with capacitive sensors
Axes	1
Processor	DSP 32-bit floating point, 60 MHz
Sampling rate, servo-control	25 kHz
Sampling rate, sensor	100 kHz
Sensor	
Servo characteristics	P-I, two notch filters
Sensor type	Capacitive
Sensor channels	1
Sensor bandwidth	5.6 kHz
Sensor resolution	17-bit
Ext. synchronization	Yes
Amplifier	
Output voltage	-30 V to 135 V
Amplifier channels	1
Peak output power <5 ms	15 W
Average output power >5 ms	5 W
Peak current <5 ms	110 mA
Average current >5 ms	40 mA
Current limitation	Short-circuit-proof
Resolution DAC	24-bit
Interfaces and operation	
Communication interfaces	Ethernet, RS-232
Piezo connector	Sub-D special connector
Sensor connection	Sub-D special connector
Analog input	LEMO, ± 10 V, 18 bit
Digital input	2 x LEMO, TTL
Digital output	2 x LEMO, TTL
Command set	GCS
User software	NanoCapture™, PIMikroMove™
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave generator, trigger I/O, data recorder
Display	Status LEDs
Linearization	4th order polynomials, DDL (optional)
Separate protective ground connector	Yes
Miscellaneous	
Operating temperature range	5 to 50 °C
Overtemp protection	Deactivation of the piezo voltage output at 85 °C
Mass	0.9 kg (controller)
Dimensions	Controller: 264 x 125 x 48 mm (with rubber feet) Power supply: 174 x 95 x 58 mm (with rubber feet)
Power consumption	10 W max.
Operating Voltage	24 VDC from external power supply (included)



E-753 open-loop operating limits with various PZT loads. Graphs reflect the large signal-current limitation of the amplifier circuit, not the actual bandwidth.

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

Piezoelectrics in Positioning

Nanometrology

Micropositioning

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E-610 Piezo Amplifier / Controller

1-Channel OEM Piezo Driver Module with Optional Position Servo-Control



E-610.C0 for piezo positioning systems with capacitive sensors

- **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 amplifi-

er 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, -20 to 120 V
- E-610.C0**
Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -20 to V, Capacitive Sensor
- E-610.S0**
Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -20 to 120 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)

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages /
High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors /
Active OpticsPiezo Drivers /
Servo Controllers

Single-Channel

Multi-Channel

Modular

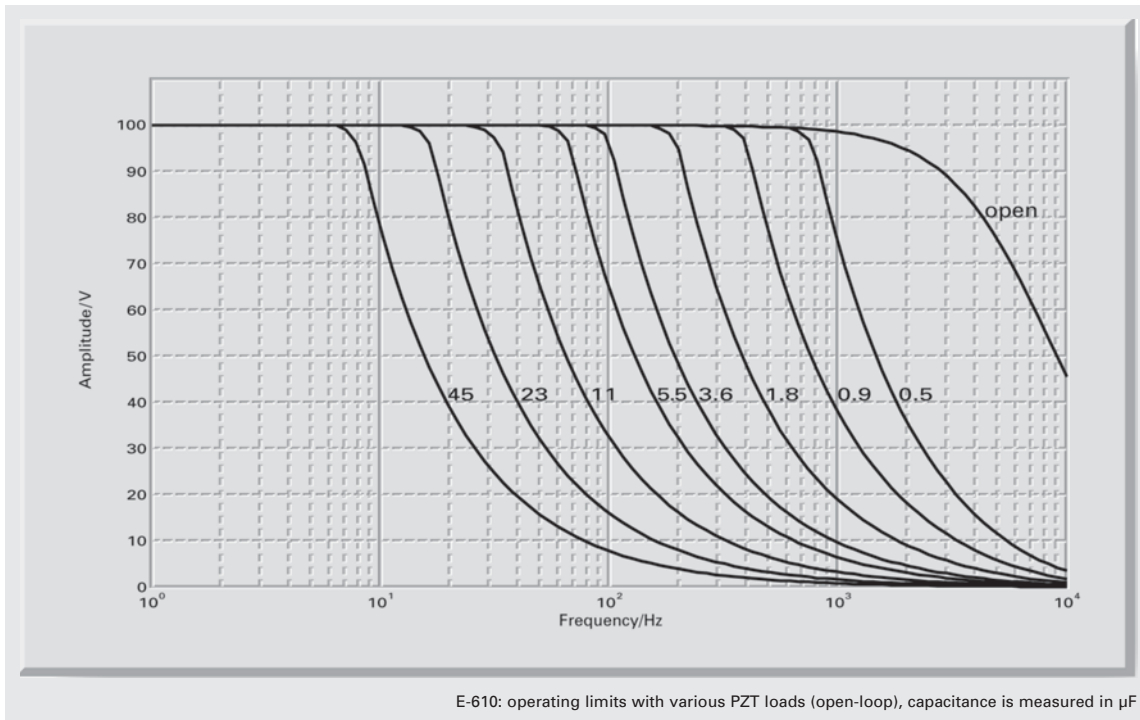
Accessories

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Nanometrology

Micropositioning

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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
Sensor		
Servo characteristics	–	P-I (analog), notch filter
Sensor type	–	Capacitive (.C0) / SGS (.S0)
Amplifier		
Control input voltage range	-2 to +12 V	-2 to +12 V
Output voltage	-20 to 120 V	-20 to 120 V
Peak output power	18 W (<15 ms)	18 W (.C0: <50 ms, .S0: <15 ms)
Average output power	10 W	10 W
Peak current	180 mA (<15 ms)	180 mA (.C0: <50 ms, .S0: <15 ms)
Average current	100 mA	100 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Noise, 0 to 100 kHz	1.6 mV _{rms}	0.5 mV _{rms} (.C0) / 1.6 mV _{rms} (.S0)
Voltage gain	10 \pm 0.1	10 \pm 0.1
Input impedance	100 k Ω	100 k Ω
Interfaces and operation		
Input / Output	32-pin (male) on rear panel (DIN 41612/D)	32-pin (male) on rear panel (DIN 41612/D)
Piezo connector	LEMO	LEMO
Sensor connection	–	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
Miscellaneous		
Operating temperature range	+5 to +50 °C	+5 to +50 °C
Dimensions	7HP/3U	7HP/3U
Mass	0.3 kg	0.35 kg
Operating Voltage	12 to 30 V DC, stabilized	12 to 30 V DC, stabilized
Current consumption, max.	2 A	2 A

E-617 High-Power Piezo Amplifier

Top-Hat & OEM Modules with Energy Recovery for High-Dynamics 24/7 Operation



The E-617.001 high-power piezo amplifier is intended for top-hat-rail mounting in switching cabinets

- Peak Power to 280 W
- High Currents to 2000 mA
- Energy Recovery for Low Power Consumption
- OEM Module and Top-Hat-Rail Versions

The E-617 is an exceptionally efficient, high-power, piezo amplifier for low-voltage piezo actuators. Providing peak power of up to 280 W and average power of 100 W, it can output and sink a peak current of 2000 mA. This allows driving high-capacitance piezo actuators at frequencies in the kilohertz range.

Energy Recovery Operating Principle

The working principle of the E-617 series is ideally suited for high-dynamics scanning and switching applications.

The innovative, efficient circuitry reduces power consumption and heat dissipation, especially in dynamic applications. 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.

Two models are available: The E-617.001 version is equipped for top-hat rail mounting which makes it ideal for automation and industry applications. The E-617.00F version is a compact module for chassis mounting.

High Performance with High Capacitive Loads

The E-617 amplifiers provide precision control of piezo actuators and positioning systems in open-loop operation with an analog control voltage amplified by the factor 12. Such analog operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential, but where commanding and reading the tar-

get position absolutely is either not important or carried out by external position sensors.

Power Supply / Contents of Delivery

Only one unipolar stabilized voltage in the range of 23 to 26 V is required to operate the E-617.

All connections of the E-617.001 top-hat rail module are conveniently provided on the front of the device. All inputs and outputs of the E-617.00F OEM module are via a 32-pin rear connector. Mating connectors are included.

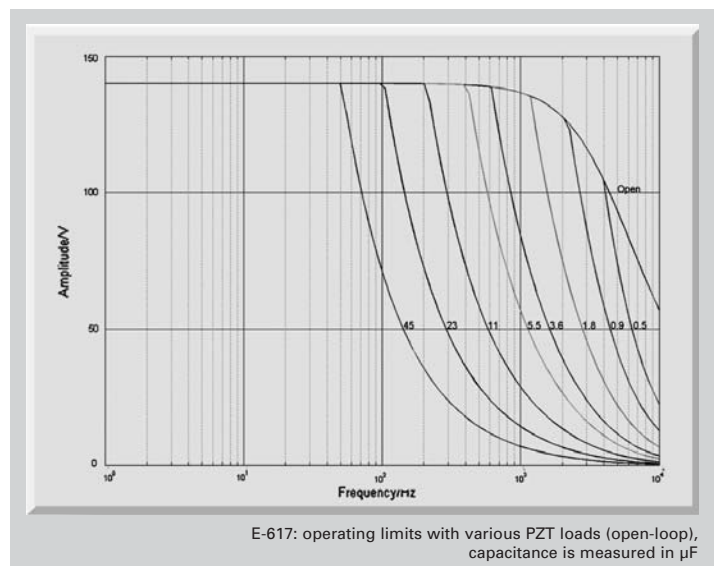
Remote Control via Computer Interface

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.

Ordering Information

- E-617.001**
High-Power-Piezo Amplifier with Energy Recovery, 1 Channel, -30 to 135 V, 100 W, Top-Hat Rail
- E-617.00F**
High-Power-Piezo Amplifier with Energy Recovery, OEM-Module, 1 Channel, -30 to 135 V, 100 W

The same functionality and specifications are available in the E-504 amplifier module. see p. 2-148.



E-617: operating limits with various PZT loads (open-loop), capacitance is measured in μF



E-617.00F high-power piezo amplifier OEM module

Technical Data

Model	E-617.001	E-617.00F
Function	High-Power-Piezo Amplifier with Energy Recovery, 1 Channel, -30 to 135 V, for Top-Hat Rail mounting	High-Power-Piezo Amplifier with Energy Recovery, OEM-Module, 1 Channel, -30 to 135 V
Amplifier		
Input voltage	-3 to +12 V	-3 to +12 V
Output voltage	-30 to +135 V	-30 to +135 V
Peak output power <5 ms	280 VA	280 VA
Average output power >5 ms	Equivalent to 100 W reactive power	Equivalent to 100 W reactive power
Peak current, <5 ms	2000 mA	2000 mA
Average current, >5 ms	1000 mA	1000 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	12 ±0.1	12 ±0.1
Amplifier bandwidth, small signal	3.5 kHz	3.5 kHz
Ripple, noise, 0 to 100 kHz	<30 mV _{rms} <100 mV _{pp}	<30 mV _{rms} <100 mV _{pp}
Capacitive base load (internal)	2.5 µF	2.5 µF
Suggested capacitive load	>3 µF	>3 µF
Output impedance	0.5 Ω	0.5 Ω
Amplifier resolution	1 mV	1 mV
Amplifier classification	class D (switching amp), 100 kHz	class D (switching amp), 100 kHz
Input impedance	100 kΩ	100 kΩ
Interfaces and operation		
Piezo connector	Phoenix-plug connector MINI-COMBICON 3-pin IMC1.5/3-ST-3.81	LEMO ERA.00.250.CTL (front); DIN 41612 32-pin (rear)
Analog input	Phoenix-plug connector MINI-COMBICON 6-pin IMC1.5/6-ST-3.81	SMB
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
Miscellaneous		
Operating temperature range	+5 to +50 °C (10% derated over 40 °C)	+5 to +50 °C (10% derated over 40 °C)
Dimensions	205 x 105 x 60 mm	7HP/3U
Mass	1 kg	0.35 kg
Operating voltage	23 to 26 VDC, stabilized, on Phoenix plug MINI-COMBICON 3-pin IMC1.5/3-ST-3.81	23 to 26 VDC, stabilized, on 32-pin rear connector
Max. power consumption	<30 W	<30 W

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

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E-625 Piezo Servo-Controller & Driver

Compact Bench-Top Device with High-Speed Interface



E-625.SR (left) and E-625.CR compact piezo servo-controllers

- **Optionally Integrated 20-Bit High-Speed RS-232 Interface**
- **Network Capability with up to 12 Channels**
- **12 W Peak Power**
- **Position Control with Strain Gauge or Capacitive Sensor**
- **Notch Filter for Higher Bandwidth**
- **Table for User-Defined Curves**
- **Additional Analog Interface**

The single-channel E-625 piezo controller is equipped with a high-speed RS-232 interface and precision 20-bit D/A and A/D converters for exceptional positional stability and resolution. It integrates a low-noise integrated piezo amplifier which can output and sink peak currents of 120 mA for low-voltage piezoelectric actuators (-20 to 120 V). Servo-controller versions for position sensing with capacitive or SGS sensors are available. PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth

operation closer to the resonant frequency of the mechanics.

Multi-Axis Network for up to 12 Channels

Up to twelve E-625 for capacitive or SGS sensors can be networked and controlled over a single RS-232 interface. The different units are connected in parallel (not daisy-chained) over the link providing higher data rates than possible with serial links. Between the individual E-625s, parallel networking with optional E-625.CN cables is used.

High-Resolution Digital Interface

The RS-232 digital interface includes high-precision 20-bit D/A and A/D converters for optimum position stability and resolution and supports fast communication with the host computer, with up to 300 bidirectional read/write operations per second.

Waveform Memory

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

Extensive Software Support

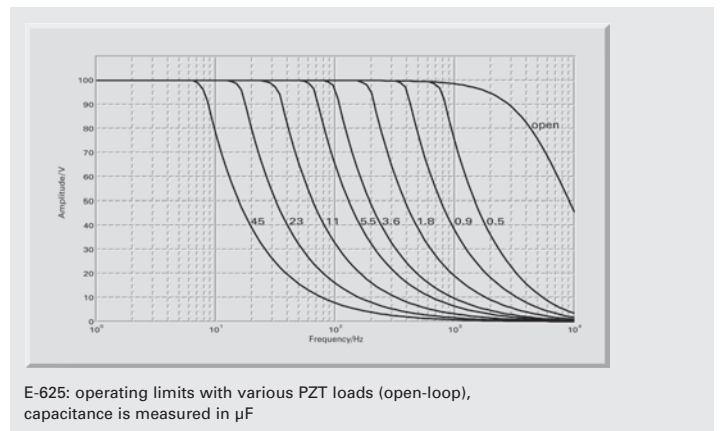
The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control.

The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the pro-

Ordering Information

- E-625.CR**
Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, Capacitive Sensor, RS-232
- E-625.SR**
Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, SGS-Sensor, RS-232
- E-625.CN**
Network Cable for Networking of Two E-625
- E-625.C0**
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, Capacitive Sensor
- E-625.S0**
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, SGS-Sensor

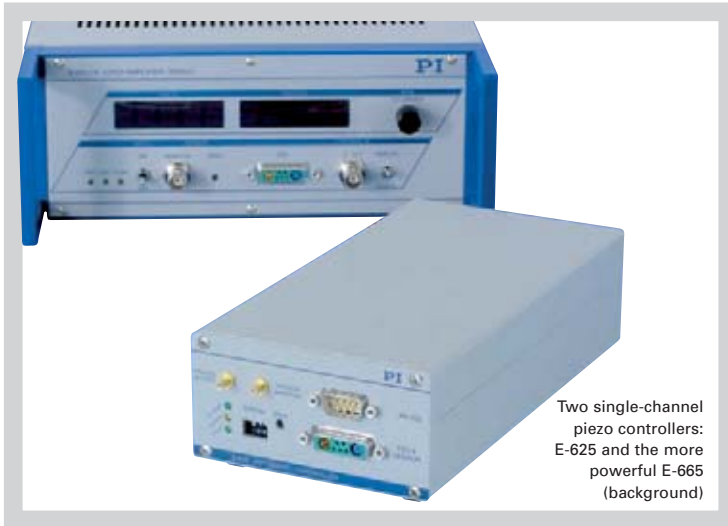
gramming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.



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



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



Technical Data

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)
Sensor resolution	20-bit
Amplifier	
Control input voltage range	-2 to 12 V
Min. output voltage	-20 to 120 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	RS-232 (9-pin Sub-D connector), 20 bit ADC/DAC, 9.6–115.2 kBaud 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
Supported functionality	Wave table, 64 data points, 100 Hz, external trigger
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
Current consumption	2 A

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

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Multi-Channel

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E-665 Piezo Amplifier / Servo Controller

Display, Analog & Digital Interface



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 20-Bit High-Speed RS-232 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 20-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 sub-nanometer range is possible, depending on the piezo mechanics and on the sensor type.

High-Resolution Digital Interface

The RS-232 digital interface includes high-precision 20-bit D/A and A/D converters for optimum position stability and resolution and supports fast communication with the host computer, with up to 300 bi-directional read/write operations per second.

Waveform Memory

The built-in wave generator 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.

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 RS-232 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. Comprehensive DLLs and LabVIEW drivers are available for automated control.

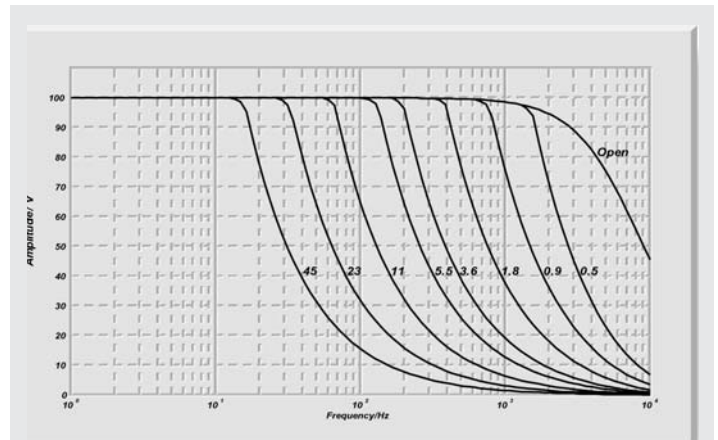
The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis position-

Ordering Information

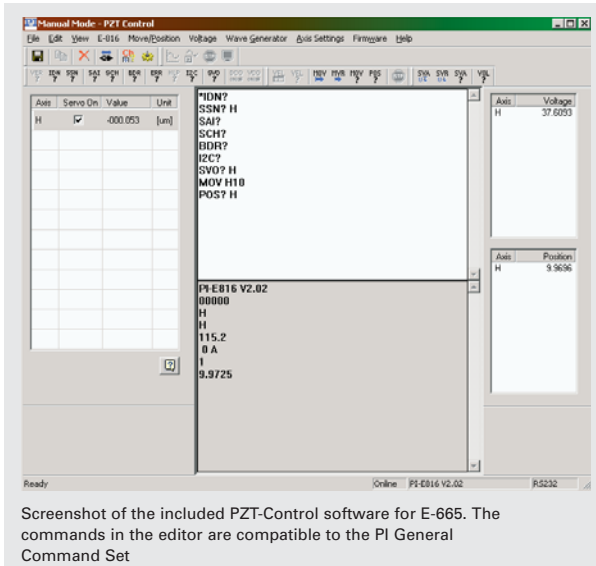
- E-665.CR**
Piezo Amplifier / Servo-Controller, 1 Channel, RS-232, -20 to 120 V, Capacitive Sensor
- E-665.SR**
Piezo Amplifier / Servo-Controller, 1 Channel, RS-232, -20 to 120 V, SGS-Sensor
- E-665.C0**
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, Capacitive Sensor
- E-665.S0**
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, SGS Sensor

ing 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), Windows dynamic link libraries (DLL) and COM objects



E-665: operating limits with various PZT loads (open-loop), capacitance is measured in μF



Screenshot of the included PZT-Control software for E-665. The commands in the editor are compatible to the PI General Command Set

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	RS-232 (9-pin Sub-D connector), 20 bit ADC/DAC, 9.6 - 115.2 kBaud
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
Supported functionality	Wave table, 64 data points, 100 Hz, external trigger
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
Overheat protection	Deactivation at 85 °C
Dimensions	236 x 88 x 273 mm + handles
Mass	2.5 kg
Operating voltage	90-120 / 220-240 VAC, 50-60 Hz (linear power supply)
Max. power consumption	50 W

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

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6-Axis

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E-661 Piezo Controller with Parallel Interface

For Maximum Command-Throughput Capacity



E-661.CP high-speed bench-top controller with parallel interface

- 10 μ s High-Speed Parallel Command Port
- Additional Analog Interface
- For Piezo Stages with Capacitive Sensors
- Notch Filter for Higher Bandwidth
- Integrated Piezo Power Amplifier
- OEM Modules and Multi-Channel System Available

The compact, high-speed E-661 piezo controller is designed for nanopositioning systems with integrated capacitive position feedback sensors. It possesses a low-noise integrated piezo amplifier providing -20 to 120 V with 80 mA sink and source capability. The E-661 comes with a metal case for EMI protection and an external power supply.

High-Speed Interface

The controller features a high-speed parallel command port with optical coupled inputs and extra low-noise, linear, 16-bit D/A converters. Real-time position feedback is realized via a special trigger option. Additionally a broadband analog interface is installed (0 to 10 V).

Nanometer Resolution in Milliseconds

This high-performance controller is designed for nanopositioning

tasks with highest precision and maximum turnover. Positioning with nanometer precisions and settling times of a few milliseconds are achieved in combination with the P-726 (see p. 2-32) objective positioners or P-753 (see p. 2-16) LISA™ actuators. More and more high-tech branches require “nanometer accuracy within milliseconds”. This is the case in microscopy/pharmaceutical research or quality testing for read/write heads, where every millisecond saved raises the throughput and helps reduce costs.

Single and Multi-Channel Systems

The same performance is available in modular form as the E-612.C0 (see p. 2-162). Up to four E-612.C0 piezo amplifier modules can be installed in one E-501.10 chassis for a multi-channel system. An internal address bus allows control of all modules over a single parallel command port.

Ordering Information

E-661.CP
Piezo Controller with High-Speed Parallel Interface, -20 to 120 V, Capacitive Sensor

Model	E-661.CP
Function	High-Speed Piezo Controller
Channels	1
Capacitive sensor circuit	
Clock frequency	1.6 MHz
Bandwidth	1.5 kHz
Amplifier	
Output voltage	-20 to +120 V
Average output power	8 W
Average current	80 mA
Current limitation	Short-circuit proof (5 minutes to shutdown)
Bandwidth (no load)	>500 Hz
Digital circuit	
Data	16-bit
Input level	TTL
Timing	THmin 10 μ s; TLmin 10 μ s
Input current	10 mA
On-target indication	On: target position $\pm 0.025\%$ to 0.2%, jumper-selectable
Analog input / output	
Control input voltage	-2 to 12 V
Input impedance	27 k Ω , 1 nF
Sensor monitor output	
Voltage range	-12 to +12 V (jumper-selectable)
Output impedance	10 Ω (10 nF)
Bandwidth	1.5 kHz
Connectors	
Digital interface	25-pin sub-D
Piezo	LEMO ERA.00.250
Sensor	LEMO EPL.00.250
Sensor monitor output	SMB
Analog input	SMB
Power consumption	15 V, 2 A (external power supply included)
Dimensions	125 x 50 x 262 mm

E-660 Piezo Driver

OEM Module / Bench-Top



E-660.OE OEM Version

E-660.00 Bench-top piezo driver

- Compact Single-Channel Piezo Driver
- Output Voltage Range 5 to 110 V
- 12 V Battery or External PS Operation

The E-660.00 piezo driver is a low-cost amplifier for low-voltage piezo actuators and positioning stages. It can output and sink a peak current of 20 mA and an average current of 10 mA. The E-660 is designed for static and low-level dynamics applications. The low operating current of only

150 mA @ 12 V makes the unit suitable for battery operation.

Voltage-Controlled Piezo Operation

This precision piezo driver is designed for voltage-controlled piezo operation in both dynamic and static mode. Its output voltage is determined by the analog control signal at the BNC Control Input socket, optionally combined with the DC-offset potentiometer. Voltage-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 external position feedback.

Ordering Information

E-660.00
Piezo Amplifier, 5 to 110 V,
Bench-Top

E-660.OE
Amplifier Module, 5 to 110 V,
OEM Version

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

Compact OEM Version

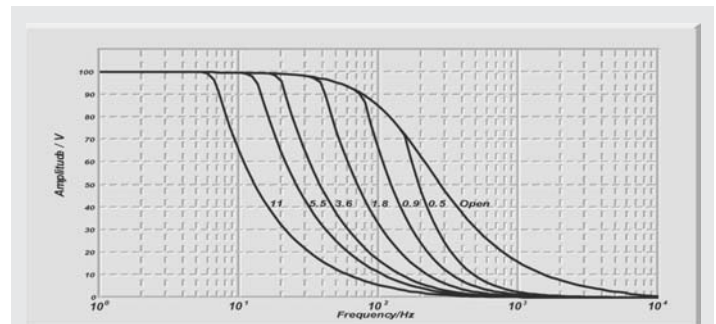
The E-660.OE version is fully enclosed in a metal case and designed for mounting on circuit boards. All inputs and outputs are via 8 header pins located on the bottom of the module. This OEM module does not provide manual controls.

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

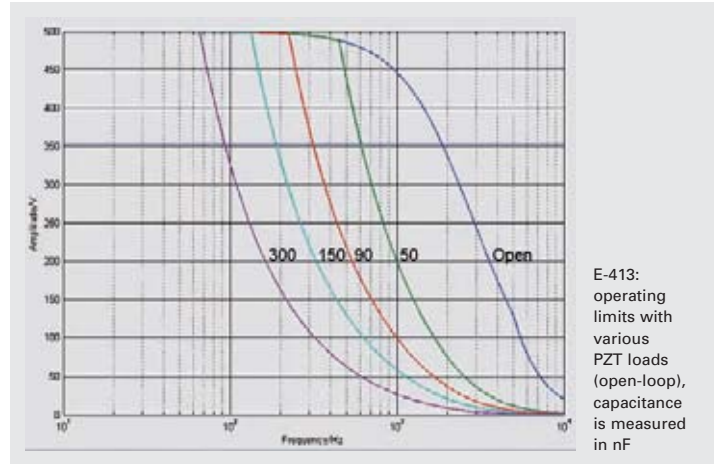
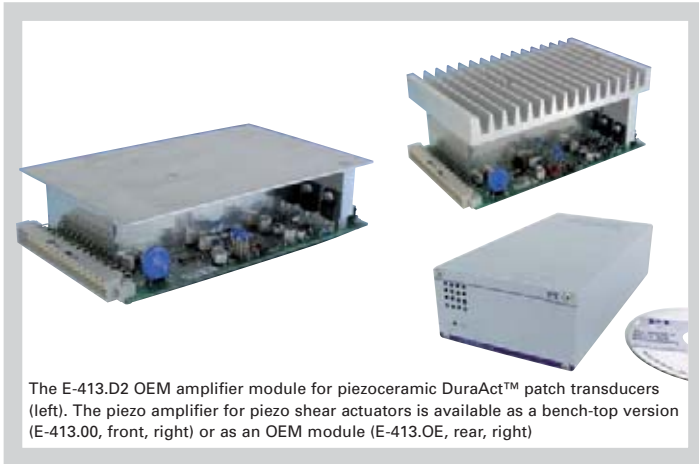
Model	E-660.00	E-660.OE	Unit
Function	Power amplifier	Power amplifier	
Channels	1	1	
Amplifier			
Input voltage	0 to +11	0 to +11	V
Output voltage	5 to 110	5 to 110	V
Peak output power	2	2	W
Average output power	1	1	W
Peak current, < 5 ms	20	20	mA
Average current, >5 ms	10	10	mA
Current limitation	Short-circuit-proof	Short-circuit-proof	
Voltage gain	10 ±0.1	10 ±0.1	
Ripple, noise, 0 to 10 kHz	5	5	mVrms
Input impedance	100	10	kΩ
Interfaces and operation			
Piezo connector	LEMO ERA.00.250.CTL	Header pins	
Control Input sockets	BNC	Header pins	
DC-Offset	1-turn pot., adds 10 to 0 V to Control In	–	
Miscellaneous			
Operating temperature range	5 to +50	5 to +50	°C
Dimensions	160 x 90 x 60	67 x 41 x 20	mm
Mass	0.5	0.25	kg
Operating voltage	10 to 15 VDC, stabilized	10 to 15 VDC, stabilized	V
Max. power consumption	3	3	W



E-660: operating limits with various PZT loads (open-loop), capacitance is measured in μF

E-413 DuraAct™ & PICAShear™ Piezo Driver

Bipolar Operation for Patch Transducers and Shear Actuators



- Peak Power to 50 W
- OEM Module / Bench-Top for PICAShear™ Actuators
- OEM Module for DuraAct™ Piezoelectric Patch Transducers

Technical Data

Model	E-413.00	E-413.OE	E-413.D2
Function	Power amplifier for PICAShear™ piezo actuators, bench-top	Power amplifier for PICAShear™ piezo actuators, OEM module	Power amplifier for DuraAct™ piezoelectric patch transducers, OEM module
Amplifier			
Input voltage range	-5 to +5 V	-5 to +5 V	-2 to 8 V
Output voltage range	-250 to 250 V	-250 to 250 V	-100 to 400 V
Amplifier channels	1	1	1
Peak output power	50 W (<3 ms)	50 W (<3 ms)	50 W (<5 ms)
Average output power	<12 W (>3 ms)	<12 W (>3 ms)	<6 W (>5 ms)
Peak current	100 mA (<3 ms)	100 mA (<3 ms)	100 mA (<5 ms)
Average current	24 mA (>3 ms)	24 mA (>3 ms)	12 mA (>5 ms)
Current limitation	Short-circuit proof	Short-circuit proof	Short-circuit proof
Voltage gain	50 ±0.1	50 ±0.1	50 ±0.1
Ripple, noise, <10 kHz	100 mV _{P-P} @100 nF	100 mV _{P-P} @100 nF	100 mV _{P-P} @100 nF
Amplifier resolution	<10 mV	<10 mV	<10 mV
Input impedance	100 kΩ	100 kΩ	100 kΩ
Interface and operation			
Piezo connector	Conec sub-D 5W1 with HV (rear)	DIN 41612, 32-pin. (rear)	DIN 41612, 32-pin. (rear)
Control input voltage	SMB connector (rear)	DIN 41612, 32-pin. (rear)	DIN 41612, 32-pin. (rear)
Miscellaneous			
Operating temperature range	+5 to +50 °C (10% derated over 40 °C)	+5 to +50 °C (10% derated over 40 °C)	+5 to +50 °C (10% derated over 40 °C)
Dimensions	220 x 105 x 54 mm	14HP / 3U	7HP / 3U
Mass	1.14 kg	0.8 kg	0.4 kg
Operating voltage	24 V / 2 A	24 V / 2 A	24 V / 1 A
Power consumption	48 W	48 W	24 W

Ordering Information

E-413.D2
Piezo Amplifier for DuraAct™ Patch Transducers, -100 to +400 V

E-413.00
Piezo Amplifier for PICAShear™ Actuators, -250 to +250 V, Bench Top

E-413.OE
Piezo Amplifier for PICAShear™ Actuators, -250 to +250 V, OEM Module

Accessories:
E-500.ACD
LabVIEW Driver Set for Analog Controllers (Supports Certain D/A Boards)

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

E-462 PICA™ Piezo Driver

Compact, Bench-Top or OEM Module



E-462.00 Bench-top piezo amplifier

- **Single-Channel Piezo Driver**
- **Output Voltage Range 10 to 1000 V**
- **12 V Battery or External PS Operation**
- **For Static or Quasi-Static Operation**
- **DC-Offset Potentiometer for Input-Signal Bias & Manual Control**

Technical Data

Model	E-462.00	E-462.OE
Function	Power amplifier for PICA™ high-voltage PZTs	Power amplifier for PICA™ high-voltage PZTs
Amplifier		
Channels	1	1
Output voltage	10 to 1000 V	10 to 1000 V
Average output power	0.3 W	0.3 W
Peak output power < 5ms	0.5 W	0.5 W
Max. average output current	0.3 mA	0.3 mA
Peak output current < 5 ms	0.5 mA	0.5 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Ripple, noise 0 to 100 kHz	50 mV _{RMS} 50 (100 nF) mV _{P-P}	
Voltage gain	100 ±1	200 ±1
Control input voltage	0 to +10 V	0 to +5 V
Input impedance	10 kΩ	10 kΩ
Frequency response	Static and quasi-static applications only	Static and quasi-static applications only
Interface and operation		
PZT voltage output socket	LEMO EGG.0B.701.CJL1173	LEMO PHG.0B.701.CJL1173 D42
Control input socket	BNC	Header pins
DC-Offset	1-turn pot., adds 0 to +10 V to Control input	–
Miscellaneous		
Dimensions	160 x 90 x 60 mm	67 x 41 x 20 mm
Mass	0.5 kg	0.25 kg
Operating voltage	10 to 15, stabilized VDC	10 to 15, stabilized VDC
Max. operating current	80 mA	80 mA
Operating temperature range	+5 to +50 °C (over 40 °C, max. av. power derated 10%)	+5 to +50 °C (over 40 °C, max. av. power derated 10%)
Power supply	Wall-plug unit	–

The E-462.00 piezo driver is a low-cost amplifier / driver for PICA™ high-voltage PZTs. It can output a peak current of 0.5 mA and is specially designed for static and quasi-static applications. Because the unit requires an operating current of only 80 mA @ 12 V, battery operation is possible.

Analog Control

E-462 amplifiers are designed to provide precise control of open-loop piezo positioning systems. The amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting.

PCB-Mount Version for OEMs

The E-462.OE version is fully enclosed in a metal case and

Ordering Information

- E-462.00**
HVPZT Piezo Amplifier, 1000 V
- E-462.OE**
HVPZT Piezo Amplifier Module, 1000 V, OEM Version
- E-500.ACD**
LabVIEW™ Driver Set for Analog Controllers (Supports Certain D/A Boards)
- E-500.HCD**
HyperBit™ Functionality for Enhanced System Resolution
- Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" section (page 2-168 ff).
- Ask about custom designs!**

designed for mounting on circuit boards. All input connections are via 6 header pins located on the bottom. The HV output is via a coaxial cable with LEMO connector. This OEM module does not provide manual controls. If dynamic (>1 Hz) PZT operation is required, please consider the E-464 (see p. 2-139) (3-channel bench-top amplifier), E-470 (see p. 2-158) or E-508 (see p. 2-150) amplifiers (modular systems with sensor / servo option).

Computer Control

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.

E-650 Piezo Driver for Multilayer Bender Actuators OEM Module / Bench-Top



- Specifically Designed to Drive Multilayer Bimorph Actuators Without Position Sensor
- Bench-Top and OEM Versions
- Up to 18 W Peak Power
- Voltage Display

E-650.00 is a bench-top piezo driver, especially designed for low-voltage, multilayer piezo bender actuators (bimorphs) such as the PL112 to PL140 (see p. 1-94). It is equipped with a special circuit that can provide one fixed voltage and a variable voltage in the range of 0 to 60 V for differential piezo oper-

ation. The driver can output and sink a peak current of 300 mA. A 3½-digit display shows the piezo voltage.

Voltage-Controlled Piezo Operation

This precision piezo driver is designed for voltage-controlled piezo operation in both dynam-

ic and static mode. Its output voltage is determined by the analog control signal at the BNC Control Input socket, optionally combined with the DC-offset potentiometer. Voltage-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 external position feedback. The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

Compact OEM Version

The E-650.OE is the OEM version of the E-650.00. It provides peak output power of 8 W. The electronics are fully enclosed in a metal case. All inputs and outputs are via 8 header pins located on the bottom of the module. The E-650.OE is not intended for manual operation.

Ordering Information

- E-650.00**
Piezo Driver for Bender Actuators, 0 to 60 V, Bench-Top
- E-650.OE**
Piezo Driver Module for Bender Actuators, 0 to 60 V, OEM Version

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-650.00	E-650.OE
Function	Power amplifier	Power amplifier
Amplifier		
Input voltage	0 to +10 V	0 to +10 V
Output voltage	0 to 60 V, plus fixed reference voltage of 60 V	0 to 60 V, plus fixed reference voltage of 60 V
Peak output power	18 W	8 W
Average output power	6 W	4 W
Peak current, < 5ms	300 mA	140 mA
Average current, >5 ms	100 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	6 ±0.1	6 ±0.1
Amplifier bandwidth, large signal	600 Hz @ 1000 nF load, 6 kHz @ no load	200 Hz @ 1000 nF load, 3 kHz no load
Input impedance	100 kΩ	100 kΩ
Interfaces and operation		
Piezo connector	9-pin sub-D connector	Header pins
Control input sockets	BNC	Header pins
Display	3½-digit LCD	-
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Dimensions	160 x 125 x 50 mm	70 x 42 x 30 mm
Mass	0.7 kg	0.15 kg
Operating voltage	90–240 VAC, 50–60 Hz, (external switching P/S, included)	±15 V, 315 mA max., stabilized

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E-651 – E-614 Piezo Amplifier / Servo Controller

Piezo Controller for Closed-Loop Multilayer Bender Actuators



E-651 dual- and single-channel controllers for closed-loop piezo benders

- Controller for Closed-Loop Multilayer Bimorph Actuators
- Bench-Top & OEM-Board Versions
- 1- and 2-Channel Versions

Technical Data

Models	E-651.1S	E-651.2S
Function	Piezo amplifier & servo controller for multilayer bender actuators, bench-top	Piezo amplifier & servo controller for multilayer bender actuators, bench-top
Channels	1	2
Sensor		
Servo characteristics	P-I (analog)	P-I (analog)
Sensor type	SGS	SGS
Sensor bandwidth	Low-pass filter cut-off frequency: 100 Hz / 5 kHz selectable	Low-pass filter cut-off frequency: 100 Hz / 5 kHz selectable
Amplifier		
Input voltage	-5 to +5 V	-5 to +5 V
Output voltage	0 to 60 V, plus fixed reference voltage of 60 V	0 to 60 V, plus fixed reference voltage of 60 V
Peak output power per channel, < 5 ms	1 W	1 W
Average output power per channel, >5 ms	0.5 W	0.5 W
Peak current per channel	6 mA	6 mA
Average current per channel	18 mA	18 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	6	6
Input impedance	100 k Ω	100 k Ω
Interfaces and operation		
Piezo / sensor connector	LEMO EPG.0B.307.HLN	LEMO EPG.0B.307.HLN
Analog input	BNC	BNC
Sensor monitor output	0 to +10 V for nominal displacement	0 to +10 V for nominal displacement
Sensor monitor socket	BNC	BNC
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overtemp protection	Deactivation at 75 °C	Deactivation at 75 °C
Dimensions	125 x 90 x 265 mm	125 x 90 x 265 mm
Mass	1.36 kg	1.45 kg
Operating voltage	14 to 16 V DC (C-890.PS wide-range power supply included)	14 to 16 V DC (power supply C-890.PS included)
Power consumption	15 W	15 W

E-651 is a bench-top piezo controller, especially designed for low-voltage, multilayer piezo bender actuators equipped with strain gauge sensors such as the P-871 (see p. 1-84). One and two channel versions are available.

The E-614.2BS OEM board provides the same functionality as the E-651.2S two-channel controller in a smaller package.

Closed-Loop and Open-Loop Piezo Positioning

In closed-loop position control mode, displacement of the piezo bender is proportional to the analog signal applied to the BNC control input socket. The

Ordering Information

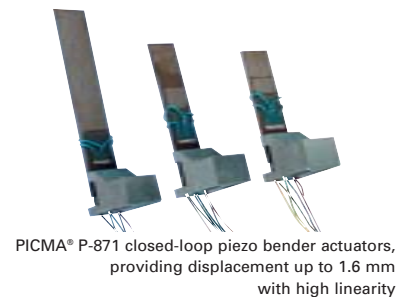
- E-651.1S**
Piezo Amplifier / Servo Controller for Bender Actuators, 1 Channel, 0 to 60 V, DMS-Sensor, Bench-Top
- E-651.2S**
Piezo Amplifier / Servo Controller for Bender Actuators, 2 Channels, 0 to 60 V, DMS-Sensor, Bench-Top
- E-614.2BS**
Piezo Amplifier / Servo Controller for Bender Actuators, 2 Channels, 0 to 60 V, DMS-Sensor, OEM Board

controller is calibrated in such a way that ± 5 V input corresponds to maximum nominal deflection.

The E-651 can also be operated as piezo driver (open-loop, or voltage-controlled mode). The output voltage is then determined directly by the analog input signal in the -5 to +5 V range. Multiplying by the gain factor of 6, an output voltage range of 0 to 60 V results.



E-614.2BS two-channel OEM controller board



PICMA® P-871 closed-loop piezo bender actuators, providing displacement up to 1.6 mm with high linearity

E-481 PICA™ Piezo High-Power Amplifier/Controller

2000 W and Energy Recovery for High Efficiency



E-481.00 high-power amplifier, optionally available with E-509 servo-controller and E-517 interface and display module

- **Peak Power 2000 W**
- **Energy Recovery**
- **Output Voltage 0 to ±1000 V or Bipolar**
- **Overheat Protection for Piezo Actuators with Temperature Sensor**
- **Optional Position Servo-Control Modules**
- **Computer Interface & Display Modules**

The E-481 high-power piezo amplifier/controller is specifically designed for dynamic operation of high-capacitance PICA™ PZT actuators.

The E-481 is based on a novel design combining pulse width modulation and energy recovery. Instead of dissipating the reactive power in heat sinks, this energy is temporarily stored in inductive elements. Only the active power used by the piezo actuator has to be delivered. The energy not used by the actuator is returned to the amplifier and reused as supply voltage via a step-up transforming process. A peak sink and source current of up to 2000 mA is possible.

Selectable Output Range

The output range can be set to positive, negative or bipolar, and provides a voltage swing of 1100 V in open-loop operation.

Open-Loop and Closed-Loop Operation

E-481 amplifiers can be used to drive open- and closed-loop piezo positioning systems.

For open-loop piezo operation the amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting. Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop. The Control In signal can be adjusted by various settings.

Optional Servo Controller Upgrade

The E-481.00 allows easy installation of an optional E-509

(see p. 2-152) sensor- / servo-controller module for closed-loop piezo position control. In this mode the amplifier is slaved to the E-509 servo controller. Depending on the attached piezo mechanics and feedback sensor, positioning accuracy and repeatability in the nanometer range and below are feasible.

Computer Control

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

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Thermal Piezo Protection Circuit

The E-481 features a temperature sensor input and control circuit to shut down the amplifier if the connected piezo ceramic exceeds a maximum temperature threshold.

Ordering Information

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

Note

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

Upgrades

Sensor / Servo-Control Modules

E-509.C1A

Sensor / Servo-Controller Module, Capacitive Sensor

E-509.S1

Sensor / Servo-Controller Module, SGS-Sensor

Interface / Display Modules

E-517.i1

Interface-/Display Module, 24 Bit D/A Ethernet, USB, RS-232, 1 Channel

E-515.01

Display Module for PZT Voltage and Position

E-500.ACD

LabVIEW with Driver Set for Analog Controllers

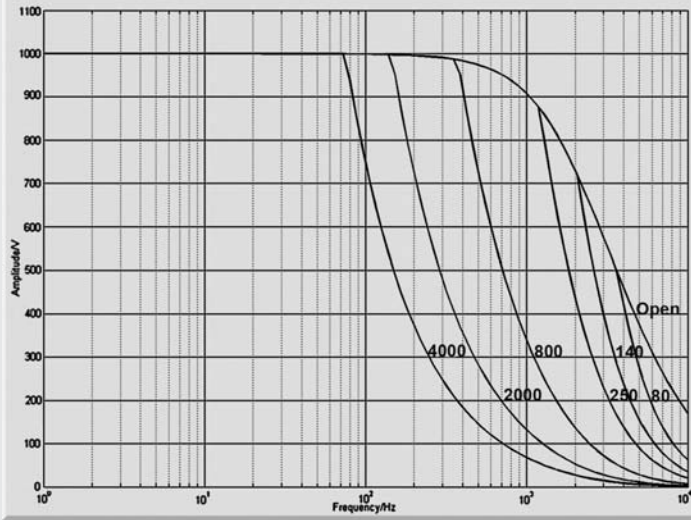
E-500.HCD

Hyperbit™ Functionality for Enhanced System Resolution

Supports Certain D/A Boards.

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" section, (p. 2-168 ff).

Ask about custom designs!



E-481: operating limits with various PZT loads, capacitance is measured in nF

Technical Data

Model	E-481.00
Function	Power amplifier for PICA™ high-voltage PZTs
Amplifier	
Output voltage	0 to 1100 V (default) (Selectable -260 to +780 V -550 to +550 V +260 to -780 V 0 to -1100 V)
Amplifier channels	1
Average output power	equivalent to 630 VA reactive power
Peak output power <5 ms	2000 VA
Average current	>600 mA
Peak current <5 ms	2000 mA
Amplifier bandwidth, small signal	5 kHz (660 nF), 1 Hz (3.4 μ F)
Amplifier bandwidth, large signal	1.4 kHz (660 nF), 350 Hz (3.4 μ F)
Ripple, noise	150 mV _{RMS} 0 to 100 kHz
Current limitation	Short-circuit-proof
Voltage gain	+100
Control input voltage	Servo off: $\pm 1/100$ of selected output range Servo on: 0 to 10 V
Input impedance	100 k Ω
Interface and operation	
PZT voltage output socket	LEMO EGG.0B.701.CJL1173
Control input socket	BNC
PZT temperature sensor	Max 85 °C, high voltage output is automatically deactivated if PZT temperature out of range
DC Offset	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous	
Operating voltage	100–120 or 220–240 VAC, 50–60 Hz (fuse change required)
Operating temperature range	+5 to +50 °C (over 40 °C, max. av. power derated 10%)
Weight	8.6 kg
Dimensions	288 x 450 x 158 mm

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages /
High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors /
Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

Piezoelectrics in Positioning

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E-725 Digital Piezo Controller For 3-Axis High-Speed Precision Positioning Systems



Ordering Information

E-725.3CD
Digital Multi-Channel Piezo Controller, 3-Channel, Sub-D Connector for Capacitive Sensors

E-725.3CM
Digital Multi-Channel Piezo Controller, for PicoCube™ and Capacitive Sensors

Ask about custom designs

- For Nanopositioning Systems with Capacitive Sensors
- 3-Channel Version
- Powerful Digital Controller: DSP 32-bit Floating Point, 225 MHz; 20 kHz Sampling Rate; 24-bit DAC
- Communication via Ethernet, USB, RS-232
- 4th Order Polynomial Linearization for Mechanics & Electronics
- Dynamic Digital Linearization (DDL) Option for Improved Path Accuracy
- Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics
- Additional High-Bandwidth Analog Control Input / Sensor Input
- Optional High-Speed Parallel I/O Interface
- Flexible Wave Generators
- Digital I/O Lines for Task Triggering
- Extensive Software Support

The E-725 digital piezo controller is a compact, high-performance drive electronics for nanopositioning systems with up to three axes. High-power amplifiers permit dynamic scans even for piezo systems with large range or direct drive. State-of-the-art processor technology optimizes the operating parameters for improved linearity and tracking accuracy. High-resolution D/A converters provide for nanopositioning that deserves this name.

With the E-725.3CM, PI for the first time offers a digital controller for the P-363 PicoCube™ (see p. 2-66), a fast precision scanner for atomic force microscopy.

Optional interfaces and analog in- and outputs make it possible to process external sensor or control values.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to better than 0.01% for capacitive sensors, typically 10 times better than achievable with conventional controllers.

More than just a Controller – Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can

be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

This control algorithm enables the spatial and temporal tracking during a dynamic scan. 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. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Extensive Software Support

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

Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-Chip can be operated in any combination, supported by the AutoCalibration function of the controller. Individual stage data and optimized servo-control parameters are stored in the ID-Chip and are read out automatically by the digital controllers.

Technical Data

Model	E-725.3CD	E-725.3CM	Tolerance
Function	Digital Controller for Multi-Axis Piezo Nanopositioning Systems with Capacitive Sensors	Digital Controller for Multi-Axis Piezo Nanopositioning Systems with Capacitive Sensors	
Axes	3	3	
Processor	DSP 32-bit floating point, 225 MHz	DSP 32-bit floating point, 225 MHz	
Sampling rate, servo-control	20 kHz	20 kHz	
Sampling rate, sensor	20 kHz	20 kHz	
Sensor			
Servo characteristics	P-I, two notch filters	P-I, two notch filters	
Sensor type	Capacitive	Capacitive	
Sensor channels	3	3	
Sensor bandwidth (-3 dB)	5.6 kHz	5.6 kHz	max.
Sensor resolution	18 bit	18 bit	
Ext. synchronization	Yes	Yes	
Amplifier			
Output voltage	-30 to 135 V	-250 to 250 V	±3 V
Amplifier channels	4	4	
Peak output power per channel	25 W	47 W	max.
Average output power per channel*	10 W	10 W	max.
Peak output current per channel	190 mA	190 mA	max.
Average output current per channel*	120 mA	60 mA	max.
Current limitation	Short-circuit proof	Short-circuit proof	
Resolution DAC	24 bit	24 bit	
Interfaces and operation			
Communication interfaces	Ethernet, USB, RS-232	Ethernet, USB, RS-232	
Piezo / sensor connector	Sub-D special connector	Sub-D special connector	
Analog input	1 x Lemo, ±10 V, 18 bit	1 x Lemo, ±10 V, 18 bit	
Digital input / output	MDR20; 2 x IN, 8 x OUT	MDR20; 2 x IN, 8 x OUT	
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)	
User software	NanoCapture™, PIMikroMove™	NanoCapture™, PIMikroMove™	
Software drivers	LabVIEW driver, DLLs	LabVIEW driver, DLLs	
Supported functionality	Wave-Gen, Trigger I/O	Wave-Gen, Trigger I/O	
Display	LEDs for Power, On Target, Error, Cmd	LEDs for Power, On Target, Error, Cmd	
Linearization	4th order polynomial, DDL (Dynamic Digital Linearization)	4th order polynomial, DDL (Dynamic Digital Linearization)	
Separate protective ground connector	Yes	Yes	
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	
Overheat protection	Max. 71 °C, deactivation of the piezo voltage output	Max. 71 °C, deactivation of the piezo voltage output	
Mass	3.5 kg	3.6 kg	
Dimensions	263 x 89 x 302 mm (with handles)	263 x 89 x 302 mm (with handles)	
Power consumption	70 W	70 W	max.
Operating voltage	24 VDC from external power supply (included)	24 VDC from external power supply (included)	

* The total output power of all 4 amplifier channels should not exceed 34.5 W to avoid overcurrent (E-725 is equipped with a 3.15 AM fuse).

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

Piezoelectrics in Positioning

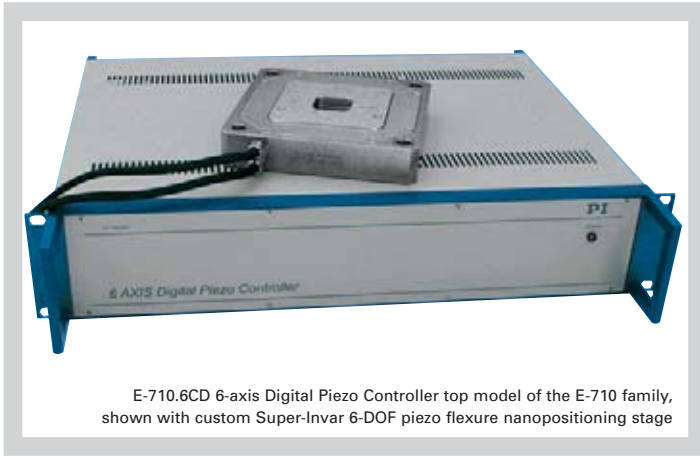
Nanometrology

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E-710 Digital Piezo Controller

3 to 6 axes, for highest precision



E-710.6CD 6-axis Digital Piezo Controller top model of the E-710 family, shown with custom Super-Invar 6-DOF piezo flexure nanopositioning stage

- **For Nanopositioning Systems with Capacitive Feedback Sensors**
- **All Control Parameters Software-Settable**
- **3-, 4- & 6-Channel Versions**
- **Firmware Linearization: Dynamic Digital Linearization (DDL) Option Improves Scanning Linearity**
- **Coordinate Transformation for Parallel-Kinematics / Parallel-Metrology Systems**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Interface Options: High-Speed Parallel I/O Interface and Analog Inputs**
- **Notchfilter for Higher Bandwidth**
- **Extensive Software Support**
- **Option: Digital Sensor-Signal Transmission over 15 m and More**

E-710 digital piezo controllers offer sophisticated functionality in a variety of configurations. Based on powerful 32-bit DSPs (digital signal processor) they include integrated, low-noise power amplifiers for piezo actuators and excitation/read-out electronics for extremely high-resolution capacitive position sensors. E-710s provide up to 8 piezo driver channels, 7 sensor channels and the processing power for coordinated control of up to 6 logical axes, e.g. for parallel kinematics systems.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.001% of the travel range. The high-speed processor with a sensor sampling rate of 25 kHz, assures settling times in the millisecond range and below. The controller is perfectly suited for high-dynamics operation, thanks to its high-resolution DA-converters and high-performance voltage amplifiers.

More than just a Controller—Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

This control algorithm enables the spatial and temporal tracking during a dynamic scan. The integrated wave generator can save and output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Sensor-Signal Transmission up to 15 m

A remote sensor interface box is available for applications where the distance between the mechanics and electronics is greater than 10 m. This DST option (digital sensor-signal transmission), includes a compatible E-710 controller. It is designed to reduce the interference that begins to degrade performance when the analog sensor excitation and readout signal paths exceed 10 m. The connection between the sensor box and the controller can be up to 15 m (longer distances on request), as the digital signals it carries are far more robust.

Simple System Integration

All parameters can be checked and reset via software. System setup and configuration is done with the included NanoCapture™ and PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. System program-

Ordering Information

See Ordering Numbers / Interface Options on next page

Options and Accessories

E-710.SCN

DDL (Dynamic Digital Linearization) Firmware Upgrade

E-710.3X3

Extension Cable for E-710.3CD, 3 Sub-D Connectors, 3 m

E-710.3X5

Extension Cable for E-710.3CD, 3 Sub-D Connectors, 5 m

E-710.1X3

Extension Cable for E-710, 1 Sub-D Connectors, 3 m

E-710.DST4

DST Cable (Digital Signal Transmission) for E-710.6SD, 8 m

ming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.

Ordering Information / Interface Options

Channels	Connector (piezomechanics)	Base Model	Parallel I/O Interface	Analog Input*	Analog Input* + Parallel I/O Interface	DST** + Analog Input*
3	1 x Special Sub-D, 3 ch.	E-710.3CD	E-710.P3D	E-710.A3D	E-710.APD	incl. Parallel I/O Interface E-710.APS
4	4 x LEMO	E-710.4CL	E-710.P4L	-	-	-
	4 x Special Sub-D, 1 ch. 1 x Special Sub-D, 3 ch. + 1 x Special Sub-D, 1 ch.	E-710.4CD E-710.C4D	E-710.P4D E-710.4PD	-	-	-
6	2 x Special Sub-D, 3 ch.	E-710.6CD	-	Standard	-	Analog input on DST box E-710.6SD

*LEMO connector

**Digital Signal Transmission



The digital sensor-signal transmission (DST) allows a distance up to 15 m between positioning unit and controller

Technical Data

Model	E-710.3CD / E-710.P3D / E-710.A3D E-710.APD / E-710.APS	E-710.4CD / E-710.4CL / E-710.C4D E-710.4PD / E-710.P4D / E-710.P4L	E-710.6CD / E-710.6SD
Function	Digital piezo controller for multi-axis nanopositioning systems with capacitive sensors	Digital piezo controller for multi-axis nanopositioning systems with capacitive sensors	Digital piezo controller for multi-axis nanopositioning systems with capacitive sensors
Axes	3	4	6
Processor	32-bit, floating-point DSP	32-bit, floating-point DSP	2 x 32-bit, floating-point DSP
Sampling rate, servo-control	200 μ s / 5 kHz	200 μ s / 5 kHz	200 μ s / 5 kHz
Sampling rate, sensor	50 μ s / 20 kHz	50 μ s / 20 kHz	40 μ s / 25 kHz
Sensor			
Servo characteristics	P-I, two notch filters	P-I, two notch filters	P-I, two notch filters
Sensor type	Capacitive	Capacitive	Capacitive
Sensor channels	3	4	6
Sensor resolution	16 bit	16 bit	16 bit
Ext. synchronization	Yes	Yes	Yes
Amplifier			
Output voltage	-20 to 110 V	-20 to 110 V	-20 to 110 V
Amplifier channels	4	4	8
Peak output power per channel,	25 W	25 W	25 W
Average output power per channel	6 W	6 W	6 W
Peak current per channel, <20 ms	200 mA	200 mA	200 mA
Average current per channel, >20 ms	60 mA	60 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof	Short-circuit-proof
Resolution DAC	20 bit	20 bit	20 bit
Interfaces and operation see separate table			
Communication interfaces	RS-232; IEEE 488 Parallel I/O (E-710.Pxx / .xPx only)	RS-232; IEEE 488; Parallel I/O (E-710.Pxx / .xPx only)	RS-232; IEEE 488
Command set	GCS	GCS	GCS
User software	PI MikroMove™, PZTControl™, NanoCapture™	PI MikroMove™, PZTControl™, NanoCapture™	PI MikroMove™, PZTControl™, NanoCapture™
Software drivers	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs
Supported functionality	Wave generator, data recorder	Wave generator, data recorder	Wave generator, data recorder
Display	Power LED	Power LED	Power LED
Linearization	4th order polynomials, DDL (optional)	4th order polynomials, DDL (optional)	4th order polynomials, DDL
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	5 to 50 °C
Dimensions	450 x 88 x 343 mm + handles	450 x 88 x 343 mm + handles	450 x 88 x 343 mm + handles
Mass	7 kg	7 kg	7 kg
Operating voltage	90–120 or 220–264 VAC, 50–60 Hz	90–120 or 220–264 VAC, 50–60 Hz	90–120 or 220–264 VAC, 50–60 Hz
Max. power consumption	60 W	60 W	120 W

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages /
High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors /
Active OpticsPiezo Drivers /
Servo Controllers

Single-Channel

Multi-Channel

Modular

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E-761 Digital Piezo Controller

Cost-Efficient PCI Board for Piezo Stages with up to 3 Axes



E-761 Digital Piezo Controller in PCI-Board Format

- For Piezo Stages with Capacitive Sensors
- High-Speed PCI Interface
- 3 Logical Axes, 4 Piezo Amplifiers
- Additional High-Bandwidth Analog Interface
- 32-Bit Digital Filters
- Notch Filter for Higher Bandwidth
- 24-Bit Ultra-Low-Noise DAC Converters
- Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics
- Coordinate Transformation for Parallel-Kinematics / Parallel-Metrology Systems
- Extensive Software Support

E-761 digital piezo controllers offer advanced control technology in a cost-effective PCI-board format. They were designed to run piezo stages with up to three logical axes. The E-761 incorporates four instrumentation-class, 24-bit digital-analog converters (DAC) behind ultra-low-noise power amplifiers, and is based on a specialized 32-bit digital signal processor (DSP) with proprietary firmware.

Having PCI-board format, the E-761 digital controller can be easily installed in any commercial or industrial PC, allowing for easy integration with other devices such as frame grabbers. The PCI interface with its high bandwidth makes possible a very fast communication between software and

controller. This is a definite plus in time-critical applications or when controlling several axes.

Additionally, the E-761.3CT version offers three digital output lines for a variety of triggering tasks.

Improved Trajectory Accuracy Through Parallel Metrology

Digital controllers have a number of advantages over conventional analog piezo controllers. Sensor and actuator axes need not be parallel to each other, or to the orthogonal logical axes used to command the system. The flexible coordinate transformation algorithm permits operation of complex, multi-axis, parallel metrology stages (e. g. 3-axis Z-tip-tilt-stages).

With parallel motion metrology, the controller compensates the undesired off-axis motion of each actuator automatically using the others (active trajectory control). High-end nanopositioning systems with active trajectory control can attain motion accuracies in the sub-nanometer range.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.001% of the travel range.

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

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

Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-chips can be operated in any combination, supported by the controller's AutoCalibration function. Individual stage data and optimized servo-control parameters are stored in the ID-Chips and are read out automatically by the digital controller.

Simple System Integration

All parameters can be set and checked by software. System setup and configuration is done with the included

Ordering Information

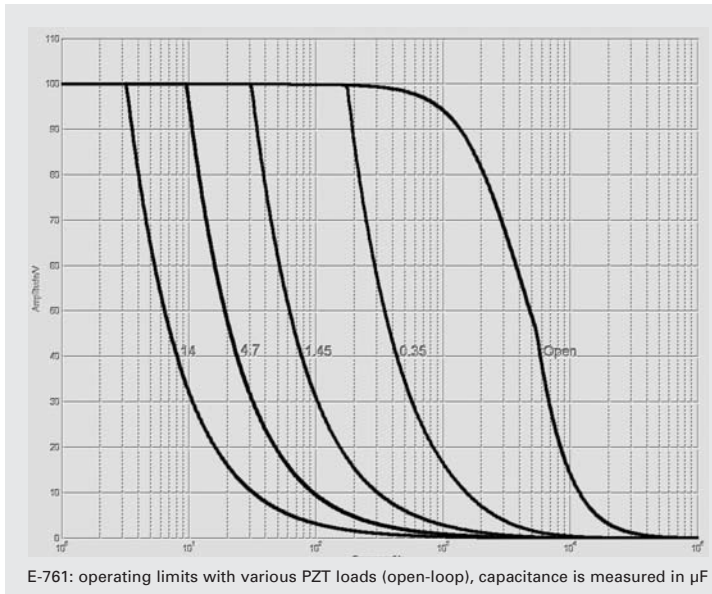
E-761.3CD
Digital Piezo Nanopositioning Controller, 3 Axes, Sub-D-Special, PCI Board

E-761.00T
Trigger Output Bracket for E-761.3CD

E-761.3CT
Digital Piezo Nanopositioning Controller, 3 Axes, Sub-D-Special, PCI Board, Trigger Output

Ask about custom designs!

NanoCapture™ and PZTControl™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. All PI controllers use the same command set, a significant advantage during application software development, system upgrade or when operating a variety of different controllers from one application.



Technical Data

Model	E-761.3CD	E-761.3CT
Function	Digital piezo controller and power amplifier, PCI board	Digital piezo controller and power amplifier, PCI board, trigger output
Axes	3	3
Processor	32-bit, floating-point DSP	32-bit, floating-point DSP
Sampling rate, servo-control	40 μs / 25 kHz (sensor-oversampling factor 4)	40 μs / 25 kHz (sensor-oversampling factor 4)
Sensor		
Servo characteristics	P-I, two notch filters	P-I, two notch filters
Sensor type	Capacitive	Capacitive
Sensor channels	3	3
Sensor resolution	16-bit	16-bit
Ext. synchronization	Yes	Yes
Amplifier		
Output voltage	-20 to 120 V	-20 to 120 V
Amplifier channels	4	4
Peak output power per channel,	5.3 W	5.3 W
Average output power per channel	1.7 W	1.7 W
Peak current per channel, <20 ms	50 mA	50 mA
Average current per channel, >20 ms	10 mA	10 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Resolution DAC	24-bit	24-bit
Interfaces and operation		
Interface / communication	PCI connector	PCI connector
Piezo / sensor connector	Sub-D special	Sub-D special
Control Input sockets	LEMO	LEMO
Digital output	-	3 x TTL
Command set	GCS	GCS
User software	NanoCapture™, PZTControl™	NanoCapture™, PZTControl™
Software drivers	LabVIEW drivers, Windows and Linux Libraries (DLL)	LabVIEW drivers, Windows and Linux Libraries (DLL)
Supported functionality	Wave generator	Wave generator, trigger output
Display	Status LED for piezo voltage	Status LED for piezo voltage
Linearization	4th order polynomial	4th order polynomial
Miscellaneous		
Operating temperature range	+5 to +50 °C (derated 10% over 40 °C)	+5 to +50 °C (derated 10% over 40 °C)
Overtemp protection	Deactivation at 60 °C	Deactivation at 60 °C
Dimensions	287 x 108 x 25 mm (2 slots)	287 x 108 x 25 mm + 122 x 45x 26 mm (3 slots)
Mass	0.56 kg	0.56 (PCI-board only)
Operating voltage	5 V	5 V
Power consumption	20 W, 4 A max.	20 W, 4 A max.

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

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E-616 Controller for Multi-Axis Piezo Tip/Tilt Mirrors and Platforms Flexible Multi Channel OEM Electronics with Coordinate Transformation



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

- **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**

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 μ rad-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

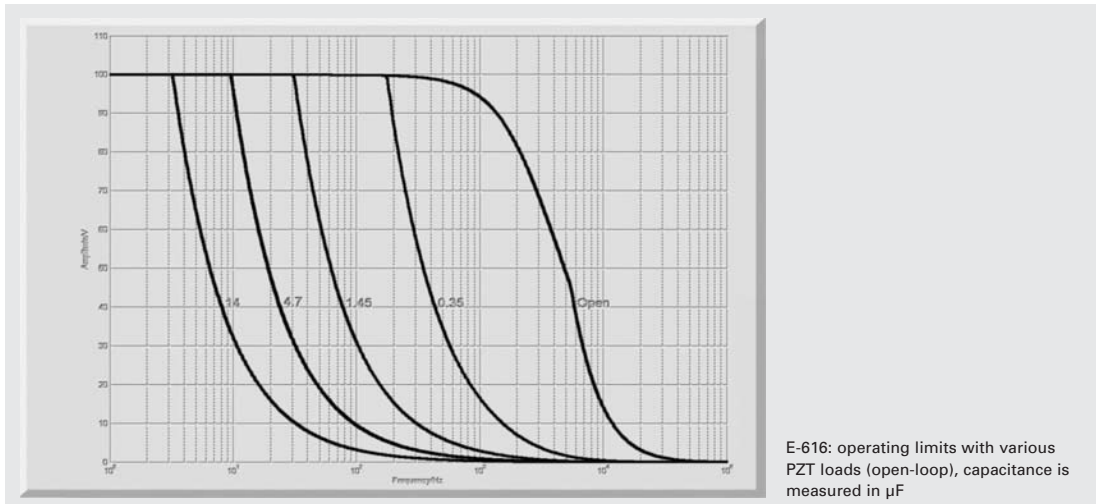
push / pull-mode. The differential evaluation of two sensors per axis provides an improved linearity and resolution.

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.



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

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

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E-536 PicoCube® 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

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-performance PicoCube® XY(Z) piezo stages (see p. 2-74) 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 bandwidth are essential. Here, commanding and reading the target 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

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

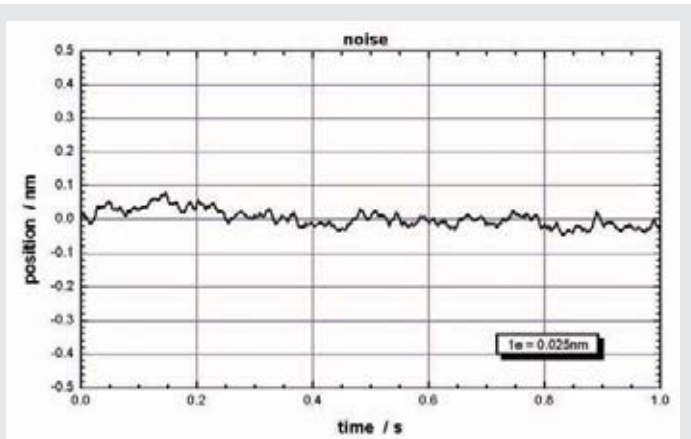
E-517.i3
Interface- / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

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

(Supports certain D/A boards.)



E-536 controller with P-363 PicoCube® pico-positioning system



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

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages /
High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors /
Active OpticsPiezo Drivers /
Servo Controllers

Single-Channel

Multi-Channel

Modular

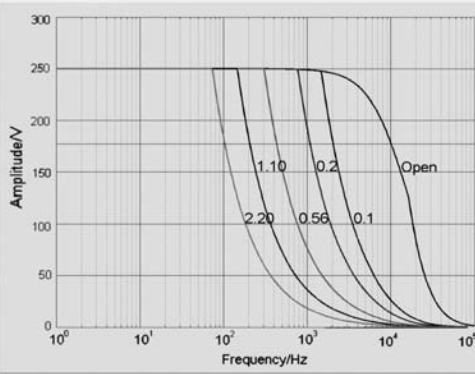
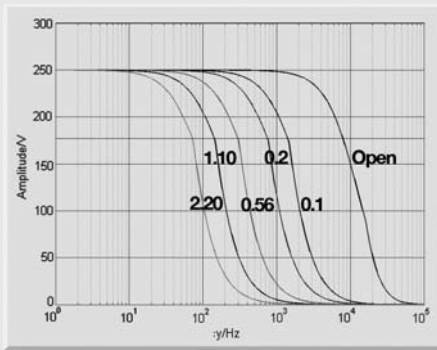
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E-536.3x: operating limits with various PZT loads, capacitance is measured in μF E-536.3xH: operating limits with various PZT loads, capacitance is measured in μF

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 k Ω	100 k Ω
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.)

E-663 Three-Channel Piezo Driver For Open-Loop Piezo Systems and Actuators Without Position Sensors



E-663.00 bench-top device

- 3 Independent Channels
- 3 x 14 W Peak Power
- Output Voltage Range -20 to 120 V
- High-Bandwidth Analog Control Interface
- Precision 10-Turn Potentiometers for Manual Control
- 3 LED Voltage Displays

The E-663.00 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 -20 to +120 V voltage range. Three 3½-digit LED displays show the output voltage of each individual channel.

Voltage-Controlled Piezo Operation

This precision piezo driver is designed for voltage-controlled piezo operation in both dynamic and static modes. 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. Voltage 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 potentiometer can also be used alone to set the output voltage manually.

Remote Control via Computer Interface

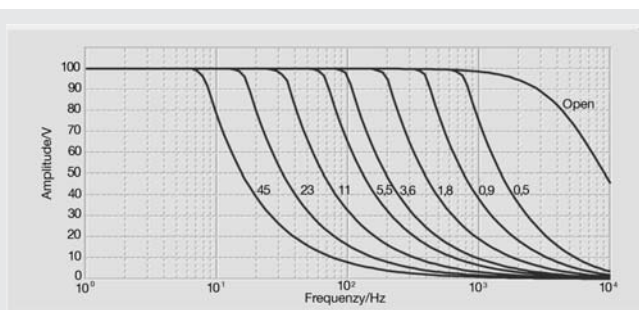
Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyper-Bit™ technology providing enhanced system resolution.

Ordering Information

E-663.00
Piezo Amplifier, 3 Channels,
-20 to 120 V, Bench-Top

Technical Data

Model	E-663.00	Tolerance
Function	Power amplifier	
Channels	3	Max.
Amplifier		
Input voltage	-2 to +12 V	
Min. output voltage	-20 to 120 V	
Peak output power per channel	14 W	Max.
Average output power per channel	6 W	Max.
Peak current per channel	140 mA	<5 ms
Average current per channel	60 mA	>5 ms
Current limitation	Short-circuit-proof	
Noise, 0 to 100 kHz	<1 mVrms	
Voltage gain	10 ±0.1	
Input impedance	100 kΩ	
Interfaces and operation		
Piezo connector	3 x LEMO ERA.00.250.CTL	
Control input socket	3 x BNC	
Display	3 x 3 1/2 -digit, LED	
DC-Offset	3 x 10-turn pots, adds 0 to 10 V to Control In	
Miscellaneous		
Operating temperature range	5 to +50°C	
Dimensions	236 x 88 x 273 mm + handles	
Mass	4.6 kg	
Operating voltage	90–120 / 220–240 VAC, 50–60 Hz (linear power supply)	
Power consumption	60 W	Max.



E-663: operating limits with various PZT loads (open-loop), capacitance is measured in μF

E-664 NanoCube® Piezo Controller

For XYZ-Nanopositioning System P-611.3S



E-664 Controller for NanoCube®
XYZ nanopositioning systems

- **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 propor-

tional 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. Voltage 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

Ordering Information

E-664.S3
NanoCube® Piezo Controller,
3 Channels, SGS-Sensors,
-20 to 120 V

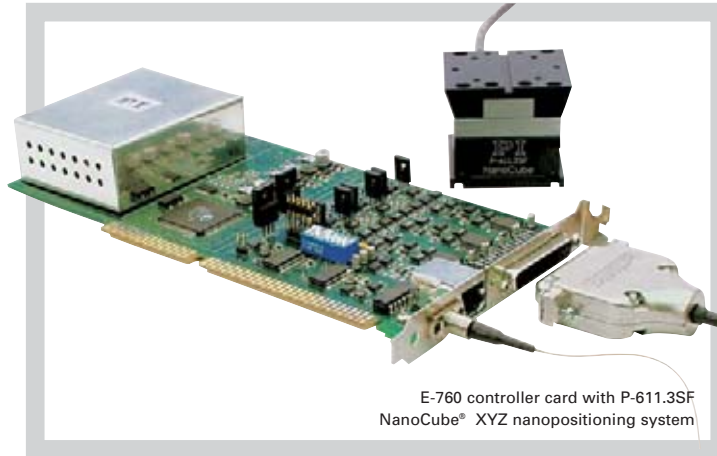
possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

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-760 NanoCube® Piezo Controller Card

For C-880 Automation Controller and F-206 Hexapod Precision Alignment System



E-760 controller card with P-611.3SF NanoCube® XYZ nanopositioning system

Ordering Information

E-760.3SV
NanoCube® Piezo Controller, Board for C-880 and F-206 Controller Systems, Photodetector (Visual Range)

E-760.3Si
NanoCube® Piezo Controller, Board for C-880 and F-206 Controller Systems, Photodetector (Infrared Range)

- 3 x 9 W Peak Power
- Position Servo-Control
- For P-611 NanoCube® and F-206 HexAlign™ 6-DOF Alignment Systems
- Built-in Optical Metrology for Automated Alignment

The E-760 is a piezo amplifier and position servo-controller card that was especially designed for the P-611 NanoCube® (see p. 2-50) XYZ nanopositioning system oper-

ated together with the F-206, M-824, M-840 or M-850 (see p. 4-6 ff). In addition to three low-noise amplifiers and position servo-controller circuits, it is equipped with optical metrolo-

gy and I/O for automatic alignment of photonics components. All functions are accessible via the computer-bus interface. In addition, there is an analog input for position control and an FC connector for the optical metrology. Thus, positioning accuracy and repeatability down to the sub-nanometer range is possible.

Technical Data

Models	E-760.3SV	E-760.3Si	Units
Function	Piezo controller card for P-611 NanoCube® systems	Piezo controller card for P-611 NanoCube® systems	
Axes	3	3	
Sensor			
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter	
Sensor type	SGS	SGS	
Sensor channels	3	3	
Amplifier			
Input voltage	-2 to +12 V	-2 to +12 V	
Output voltage	-20 to 120 V	-20 to 120 V	
Amplifier channels	3	3	
Peak output power per channel	9	9	W
Average output power per channel	1	1	W
Peak current per channel, <5 ms	90	90	mA
Average current per channel, >5 ms	8	8	mA
Current limitation	Short-circuit-proof	Short-circuit-proof	
Voltage gain	10 ±0.1	10 ±0.1	
Interfaces and operation			
Communication interfaces	Standard computer bus (ISA); FC-connector	Standard computer bus (ISA); FC-connector	
Piezo / sensor connector	25-pin sub-D connector	25-pin sub-D connector	
Analog input	8-pin connector (piezo); FC connector (optical metrology)	8-pin connector (piezo); FC connector (optical metrology)	
Supported functionality	Visible-range detector	Infrared-range detector	

E-464 PICA™ Piezo Driver / Amplifier

For Piezo Systems and Actuators, for up to 3 Axes



E-464.00 3-channel HVPZT amplifier

- 3 Powerful Channels
- Peak Power 3 x 25 W
- Output Voltage Range 0 to 1100 V
- 3 LED Voltage Displays
- Precision DC-Offset Potentiometers for Input-Signal Bias & Manual Control

The E-464 is a bench-top piezo driver/amplifier for PICA™ high-voltage PZTs. Its three low-noise, 4-quadrant amplifiers provide a gain of 100 and can output and sink a peak current of 25 mA and an average current of >3 mA each. If only 1 channel is operated, an average output power of 12 W can be achieved.

Three 3½-digit LED displays show the output voltage of each individual channel.

Analog Control

E-464 amplifiers are designed to provide precise control of open-loop piezo positioning systems. The amplifier output voltage is determined by the analog signal at the Control Input combined with the

DC-offset potentiometer setting.

Computer Control

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-464.00
HVPZT Piezo Amplifier,
3 Channels, 1100 V, Bench-Top

E-500.ACD
CD with Driver Set for Analog
Controllers

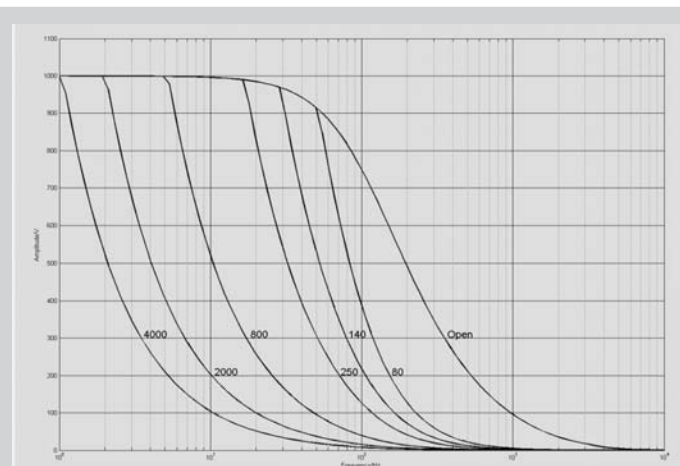
E-500.HCD
HyperBit™ Functionality for
Enhanced System Resolution
Supports certain D/A boards

Extension cables, adapters &
connectors: see in "Accessories"
(p. 2-168 ff)

Ask about custom designs!

Technical Data

Model	E-464.00
Function	Power amplifier for PICA™ high-voltage PZTs
Amplifier	
Output voltage	0 to +1100 V
Amplifier channels	3
Average output power per channel	>3.5 W (up to 12 W if 1 channel is operated)
Peak output power per channel, <5 ms	25 W
Average current per channel	>3.5 mA (up to 12 mA if 1 channel is operated)
Peak current per channel, <5 ms	25 mA
Amplifier bandwidth, small signal	1 kHz
Amplifier bandwidth, large signal	3.5 Hz (660 nF); 35 Hz (70 nF)
Ripple, noise 0 to 100 kHz	5 mV _{RMS} 50 mV _{P-P} (100 nF)
Current limitation	Short-circuit-proof
Voltage gain	+100 ±1
Control input voltage	0 to 11 V
Input impedance	100 kΩ
Interface and operation	
PZT voltage output socket	3 x LEMO EGG.0B.701.CJL1173
Control input socket	3 x BNC
DC Offset	3 x 10-turn pot, adds 0 to +10 V to Control IN
Display	3 x 3½-digit LED display for output voltages
Miscellaneous	
Operating voltage	100 to 120 or 220 to 240 VAC, selectable (fuse change required)
Operating temperature range	+5 to +50 °C (over 40 °C, max. av. power derated 10%)
Mass	4.3 kg
Dimensions	236 x 88 x 273 mm + handles



E-464: operating limits with various PZT loads, capacitance is measured in nanofarads

E-712 Digital Piezo Controller Modular System for up to 6 Axes with Highest Precision



E-712 digital controller for nanopositioning systems with up to 6 axes

- **Digital Controller of the Newest Generation: 600 MHz Tact Rate; up to 50 kHz Servo Update Rate; Highly Stable 20-bit D/A Converter**
- **Real-Time Operating System for Excellent Trajectory Control**
- **Modular Design for Greatest Flexibility in Meeting Custom Requirements**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Versatile Interfaces: Ethernet, USB, RS-232**
- **Optional High-Bandwidth Analog Inputs and Outputs**
- **Extensive Software Support**

The E-712 digital piezo controller is ideal when it comes to meeting the most demanding accuracy and dynamic-performance requirements of multi-axis nanopositioning systems. The high-performance, real-time operating system makes possible coordinated servo-control of multiple axes (also in parallel-kinematics systems) and thus ensures excellent trajectory control even during complex motion. The modular design allows flexible confection of systems supporting the number of axes and channels required for the application. Flexibility in meeting customers' needs is also behind the interface design: The optional analog inputs and outputs support processing external sensor or control signals as well as driving external amplifiers.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.01% of the travel range. The high-speed processor with a sensor sampling rate of 50 kHz, assures settling times in the millisecond range and below. The controller is perfectly suited for high-dynamic operation, thanks to its high-resolution DA-converters and high-performance voltage amplifiers.

More than just a Controller—Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with

Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

This control algorithm enables the spatial and temporal tracking during a dynamic scan. The integrated wave generator can save and output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Flexible Analog Inputs

Four analog inputs allow different configurations. As Control In, the applied voltage is correlated to one of the motion axis e.g. to give a target value. Configured as the input line for an external sensor signal the inputs may be used for autofocusing instead of an integrated sensor.

Simple System Integration

All parameters can be checked and reset via software. System setup and configuration is done with the included Nano-

Ordering Information

E-712.3CD
Modular Digital Multi-Channel Piezo Controller, 3 Channels, Capacitive Sensors

E-712.3CDA
Modular Digital Multi-Channel Piezo Controller, 3 Channels, Capacitive Sensors, Analog INs and OUTs

E-712.6CD
Modular Digital Multi-Channel Piezo Controller, 6 Channels, Capacitive Sensors

E-712.6CDA
Modular Digital Multi-Channel Piezo Controller, 6 Channels, Capacitive Sensors, Analog INs and OUTs

Ask about custom designs!

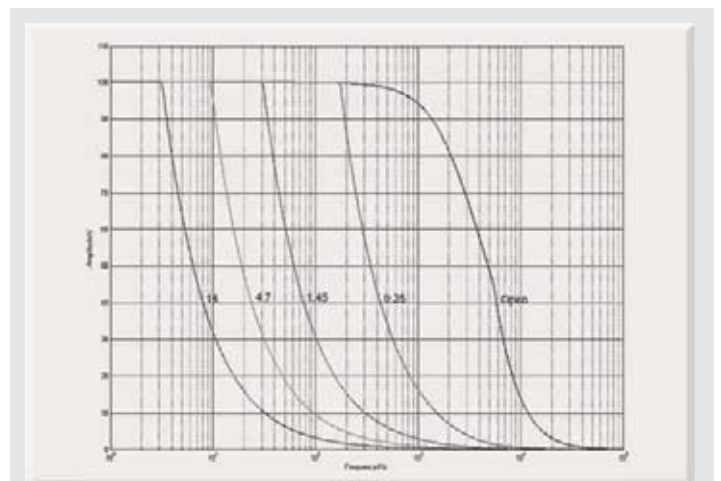
Options and Accessories

E-710.SCN
DDL (Dynamic Digital Linearization) Firmware Upgrade

E-711.i1B
Analog Cable for Analog I/O, BNC Connector, 1.5 m

E-711.i10
Analog Cable for Analog I/O, Solderable End, 1.5 m

Capture™ and PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs.



E-712 operating limits with various PZT loads, capacitance is measured in μF

System programming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.

Technical Data

Model	E 712.3CD/E 712.3CDA	E 712.6CD/E 712.6CDA
Function	Modular digital controller for multi-axis piezo nanopositioning systems with capacitive sensors	Modular digital controller for multi-axis piezo nanopositioning systems with capacitive sensors
Axes	3	6
Processor	PC-based, 600 MHz, real-time operating system	PC-based, 600 MHz, real-time operating system
Sampling rate, servo-control	50 kHz	20 kHz
Sampling rate, sensor	50 kHz	20 kHz
Sensor		
Servo characteristics	P-I, two notch filters	P-I, two notch filters
Sensor type	Capacitive	Capacitive
Sensor channels	3	6
Sensor bandwidth (-3 dB)	5.6 kHz	5.6 kHz
Sensor resolution	16-bit	16-bit
Ext. synchronization	Yes	Yes
Amplifier		
Output voltage	-30 to +135 V	-30 to +135 V
Amplifier channels	4	8
Peak output power per channel	6 W	6 W
Average output power per channel	3.5 W	3.5 W
Peak current	140 mA	140 mA
Average current per channel	60 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Resolution DAC	20-bit	20-bit
Interfaces and operation		
Communication interfaces	Ethernet, USB, RS-232	Ethernet, USB, RS-232
Piezo / sensor connector	Sub-D special	Sub-D special
Analog in/out	E-712.3CD: none E-712.3CDA: 4 x in, 4 x out (LEMO), ±10 V	E-712.6CD: none E-712.6CDA: 4 x in, 4 x out (LEMO), ±10 V
Digital in/out	MDR20; 2 x IN, 8 x OUT; TTL	MDR20; 2 x IN, 8 x OUT; TTL
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)
User software	NanoCapture™, PIMikroMove®	NanoCapture™, PIMikroMove®
Software drivers	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs
Supported functionality	Wave gen, trigger I/O	Wave gen, trigger I/O
Display	LEDs for OnTarget, Err, Power	LEDs for OnTarget, Err, Power
Linearization	4 th order polynomials, DDL option (Dynamic Digital Linearization)	4 th order polynomials, DDL option (Dynamic Digital Linearization)
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overtemp protection	Max. 75 °C, deactivation of the piezo voltage output	Max. 75 °C, deactivation of the piezo voltage output
Mass	5.35 kg/5.53 kg	5.78 kg/5.96 kg
Dimensions	9,5" chassis, 236 x 132 x 296 mm + handles (47 mm length)	9,5" chassis, 236 x 132 x 296 mm + handles (47 mm length)
Power consumption	100 W max.	100 W max.
Operating voltage	90 to 240 VAC, 50-60 Hz	90 to 240 VAC, 50-60 Hz

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages /
High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors /
Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

Piezoelectrics in Positioning

Nanometrology

Micropositioning

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E-500 · E-501 Modular Piezo Controller

Flexible System for Piezo Actuators and Nanopositioners



Configuration example: E-500 Chassis with optional modules: E-505 piezo amplifier (3 x), E-509.S servo-controller for SGS sensors, 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

E-500 • E-501 Modular Piezo Controller

Module Survey & Ordering Information

A more compact 9½-inch version of the system is available as the E-501.00. It can hold one amplifier module (1- or 3-channel units available), one servo-control module (1- or 3-channel) and one display / interface module (1- or 3-channel).

A modified E-500 chassis for more channels is available on request. For systems with up to 12 channels, the E-500.621 chassis with E-621 amplifier / controller modules can be used (see p. 2-160).

The following modules can be installed in an E-500 / E-501 chassis:

■ Amplifier modules

E-503.00

Piezo Amplifier Module, -20 to 120 V, 3 Channels

E-504.00F

High-Power-Piezo Amplifier Module, 1 Channel, 280 W Peak Power, 100 W Average Power, -30 to 135 V

E-505.00

Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

E-508.00

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

■ Sensor and Servo-Control Modules

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

E-509.E3 (see p. 2-152)

PISeCa™ Sensor / Piezo Servo-Control Module for Single-Electrode Capacitive Sensor Probes, 3 Channels

E-509.E03 (see p. 2-152)

PISeCa™ Modular Signal Conditioner Electronics for Single Electrode Capacitive Sensors, 3 Channels

■ Module for Servo-Control for External Piezo Amplifier

E-515.E3

In- / Output Module for Servo Control with External Piezo Amplifier, 3 Channels

Note: this module can only be used together with an E-509 servo controller module and is installed in the amplifier slot

■ Interface / Display Modules

E-517.i1

Interface / Display Module, 24-Bit D/A, TCP / IP, USB, RS-232, 1 Channel

E-517.i3

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

E-515.01

Display Module for Piezo Voltage and Displacement, 1 Channel

E-515.03

Display Module for Piezo Voltage and Displacement, 3 Channels

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

Piezoelectrics in Positioning

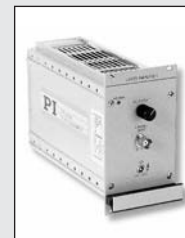
Nanometrology

Micropositioning

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E-503, p. 2-146



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E-517, p. 2-156



E-509, p. 2-152

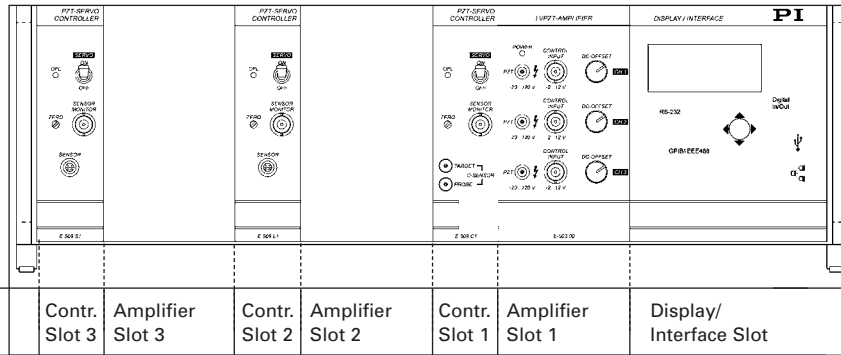
E-500 • E-501 Modular Piezo Controller

System Configuration

E-500, 19" Chassis Models

E-501, 9.5" Chassis

E-500 chassis with the following optional modules: E-503 LVPZT amplifier, three E-509 piezo servo-controllers (E-509.S1: strain gauge; E-509.C1A: capacitive sensor) and DAC interface/display.



Installable Amplifier Modules

E-503.00 (-20 to 120 V, 3 ch) / E-503.00S*						
E-504.00 (-30 to 135 V, 1 ch) / E-504.00S*						
E-505.00 (-20 to 120 V, 1 ch) / E-505.00S*						
E-508.XX (+3 to 1100 V, 1 ch)						

Installable Sensor & Position Servo-Control Modules

E-509.C1A (Capacitive, 1 ch)						
E-509.S1 (SGS, 1 ch)						
E-509.C2A (Capacitive, 2 ch)						
E-509.C3A (Capacitive, 3 ch)						
E-509.S3 (SGS, 3 ch)						

Installable Display/Interface Modules

E-515 (1 / 3 ch)						
E-517 (1 / 3 ch)						

Minimal Configuration, Piezo Amplifier Function only

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Extended Configuration, Piezo Amplifier with additional Position Servo-Controller

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Extended Configuration, Piezo Amplifier with additional Display/Interface, no Servo-Controller

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Extended Configuration, Piezo Amplifier with additional Servo-Controller and Display/Interface

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Can be installed in E-500
 Can be installed in E-501 or E-500

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* For differential tip/tilt systems with one fixed voltage of +100 V.

Configuration Examples

■ Low-Voltage Piezo Amplifiers, 3 Channels (14 W), Medium Dynamics, No Display:

1 x E-501.00

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

1 x E-503.00

Piezo Amplifier Module, -20 to 120 V, 3 Channels

■ High-Voltage Piezo Amplifier for PICA™, 3 Channels, with PC Interface and Display:

1 x E-500.00

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

3 x E-508.00

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

1 x E-517.i3

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

■ High-Voltage Piezo Amplifier / Servo-Controller (Strain Gauge Sensors), 3 Channels, with PC Interface and Display:

1 x E-500.00

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

3 x E-508.00

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

1 x E-509.S3

Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

1 x E-517.i3

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

■ Position Feedback Control of a P-734.2CL XY Nanopositioning Stage (Capacitive Position Sensors), Minimum Response Time, Analog Control:

1 x E-500.00

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

2 x E-505.00

Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

1 x E-509.C2A

Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

■ Position Feedback Control of a P-733.2CL XY Nanopositioning Stage (Capacitive Position Sensors) and P-721.CLQ PIFOC® Objective Positioner (Capacitive Position Sensor), Medium Dynamics, PC Control, Compact Design:

1 x E-501.00

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

1 x E-503.00

Piezo Amplifier Module, -20 to 120 V, 3 Channels

1 x E-509.C3A

Sensor / Piezo Servo-Control Module, Capacitive Sensors, 3 Channels

1 x E-517.i3

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

■ Position Feedback Control of a S-325 Tip/Tilt Platform (Strain Gauge Sensors), Minimum Response Time, Analog Control:

1 x E-500.00

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

2 x E-505.00

Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

1 x E-505.00S

Offset Voltage Supply for Tip/Tilt Systems, One Fixed Voltage of +100 V

1 x E-509.S3

Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

■ Position Feedback Control of a P-733.2CL XY Nanopositioning Stage (Capacitive Position Sensors) and a P-721.SL2 PIFOC® Objective Positioner (Strain Gauge Position Sensor), Minimum Response Time, Analog Control:

1 x E-500.00

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

3 x E-505.00

Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

1 x E-509.C2A

Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

1 x E-509 .S1

Sensor / Piezo Servo-Control Module, SGS Sensor, 1 Channel

■ Position Feedback Control of 3 P-841.10 Piezo Translators (Strain Gauge Position Sensors), Medium Dynamics, Analog Control, with Future Upgrade Option for High-Power, High-Dynamics Amplifiers E-505 (Large Chassis):

1 x E-500.00

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

1 x E-503.00

Piezo Amplifier Module, -20 to 120 V, 3 Channels

1 x E-509.S3

Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

Option:

1 x E-515.03

Display Module for Piezo Voltage and Displacement, 3 Channels

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Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

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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 14 W Peak Power
- Output Voltage Range -20 to 120 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 -20 to 120 V voltage range. For frequency response with selected capacitive loads, see graph below. The piezo amplifier 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 servocontroller 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 high resolution with maximum bandwidth are essential. Here, commanding and reading the

Bestellinformation

E-503.00
Piezo Amplifier Module,
-20 to 120 V, 3 Channels

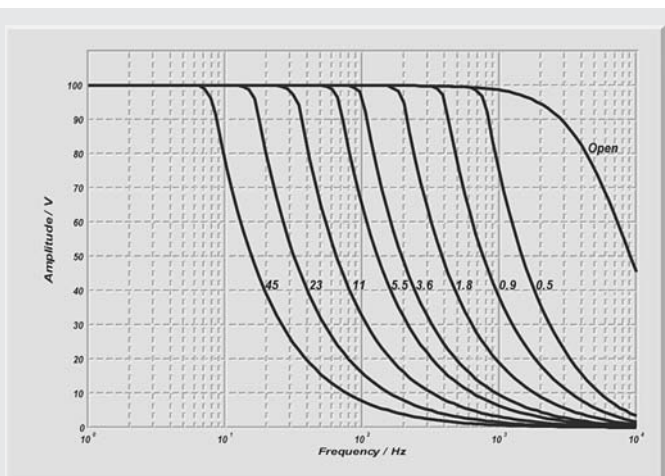
E-503.00S
Piezo Amplifier Module,
-20 to 120 V, 3 Channels,
Modified E-503.00 for S-330, S-334,
S-340 Tip/Tilt Systems, with
One Fixed Voltage of +100 V,
Two Variable Voltages

Ask about custom designs

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
Amplifier		
Control input voltage range	-2 to +12 V	-2 to +12 V
Output voltage	-20 bis 120 V	-20 bis 120 V; one additional fixed voltage of +100 V
Peak output power per channel	14 W	14 W
Average output power per channel	6 W	6 W
Peak current per channel, <5 ms	140 mA	140 mA
Average current per channel, >5 ms	60 mA	60 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
Interfaces and operation		
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
Miscellaneous		
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	30 W	30 W



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

E-505 Piezo Amplifier Module

High Power, E-500 Piezo Controller System



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

- 200 W Peak Power
- Output Voltage Range -20 to 120 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 positioners, that can output and sink a peak current of up to 2000 mA in the -20 to 120 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.

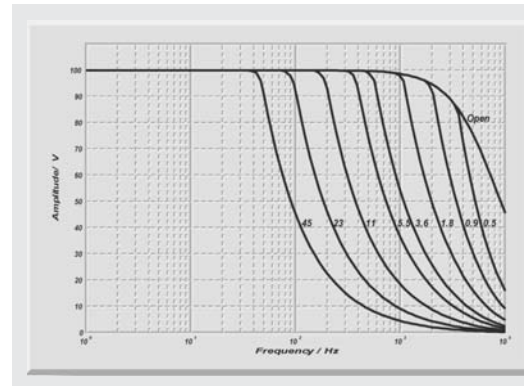
For frequency response with selected capacitive loads, see graph below.

Ordering Information

E-505.00
Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

E-505.10
Piezo Amplifier Module for Switching Applications, 1000 W, -20 to 120 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 μF

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
Amplifier			
Control input voltage range	-2 to +12 V	-2 to +12 V	–
Output voltage	-20 to +120 V	-20 to +120 V	100 V
Peak output power	200 W (<5 ms)	1000 W (<200 μs)	200 W (<5 ms)
Average output power	30 W	30 W	30 W
Peak current	2 A (<5 ms)	10 A (<200 μs)	2 A (<5 ms)
Average current	300 mA	300 mA	300 mA
Current limitation	Short-circuit-proof	Short-circuit-proof	Short-circuit-proof
Noise, 0 to 100 kHz	<0.7 mVrms	1.0 mVrms	<0.7 mVrms
Voltage gain	12 \pm 0.1	12 \pm 0.1	–
Input impedance	1 M Ω / 1 nF	1 M Ω / 1 nF	–
Interfaces and operation			
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	–
Miscellaneous			
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	45 W	45 W	45 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-504 Piezo Amplifier Module

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 135 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.

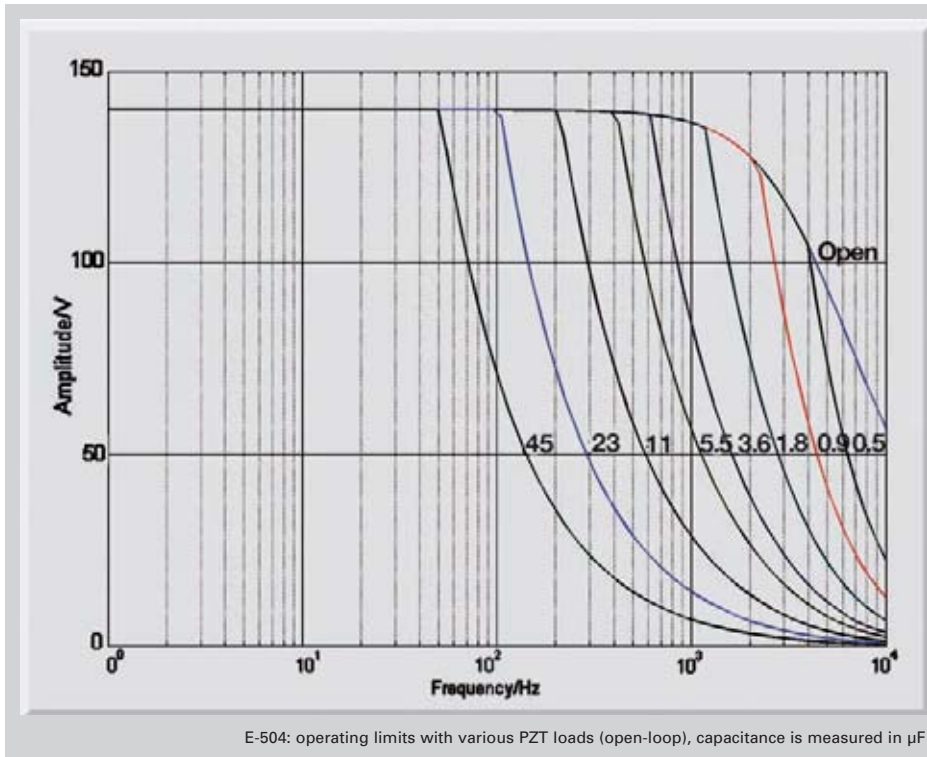
Open-Loop Operation

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 135 V



Technical Data

Model	E-504.00F
Function	Power amplifier with energy recovery, 1 channel
Amplifier	
Control input voltage range	-2.5 to +12 V
Output voltage	-30 V to 135 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	12 \pm 0.1
Ripple, noise, 0 to 10 kHz	5 mV _{RMS} 20 mV _{P-P}
Output impedance	0,5 Ω / 2,5 μF
Interfaces and operation	
Piezo connector	LEMO ERA.00.250.CTL
Analog input	SMB
DC-Offset	10-turn pot., adds 0 to +10 V to Control In
Miscellaneous	
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

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E-508 PICA™ Piezo Amplifier Module

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



- 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-

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

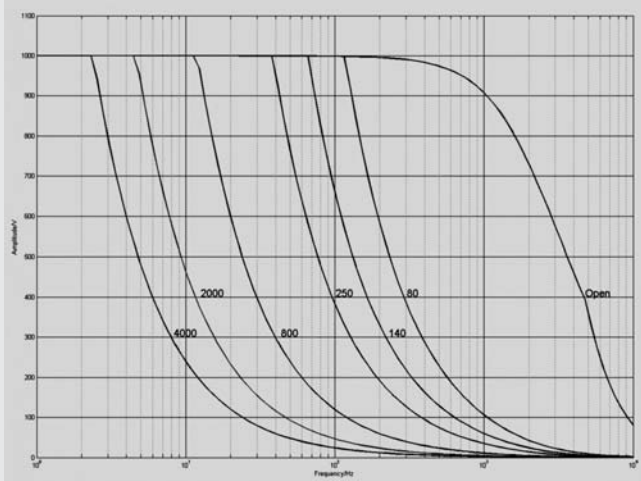
E-508.00
HVPZT Piezo Amplifier Module, +3 to +1100 V, 1 Channel

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

Ask about custom designs!



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



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	
Amplifier			
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 _{RMS} mV _{P-P}
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
Interfaces and operation			
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	-	
Miscellaneous			
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	

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E-509 Signal Conditioner / Piezo Servo Module 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

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!

- **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)**

tance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications.

For PISeCa™ single-plate high-resolution capacitive sensors (see p. 3-8), the E-509.E3 or E-509.E03 versions are available (see p. 2-152).

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 resolution and stability in the nanometer range and below. For high-end applications, capaci-



The E-509 controller module installed in an E-501 9½-inch chassis together with E-516 digital interface and E-503 three-channel amplifier modules

Technical Data

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
Sensor		
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 ^{1/2}	
Thermal drift	<0.3 mV / C°	<3 mV / C°
Linearity	<0.05%	<0.2%
Interfaces and operation		
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
Miscellaneous		
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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Single-Channel

Multi-Channel

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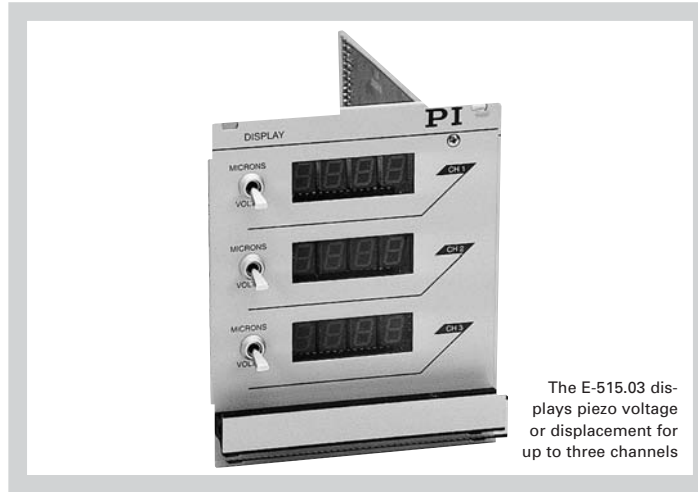
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E-515 Display Module for Piezo Controllers

Voltage and Displacement Display for E-500 Piezo Controller System



The E-515.03 displays piezo voltage or displacement for up to three channels

Ordering Information

E-515.01
Display Module for Piezo Voltage and Displacement, 1 Channel

E-515.03
Display Module for Piezo Voltage and Displacement, 3 Channels

- 3½-digit Display for Voltage and Position
- 1- & 3-Channel Versions
- Plug-In Module for E-500 System

The E-515.01 and E-515.03 are one and three channel display modules for piezo voltage and displacement data. Toggle switches for each channel select voltage or displacement mode. The voltage/displacement range for each channel is internally set by jumpers and trimmers.

The display module is designed to work in the E-500 piezo controller system (see p. 2-142).

Technical Data

Model	E-515.01	E-515.03
Function	Display Module for Piezo Voltage and Position	Display Module for Piezo Voltage and Position
Channels	1	3
Display linearity	0.1 %	0.1 %
Display	1 x 3½ digits	3 x 3½ digits
Dimensions	21HP/3U	21HP/3U
Mass	0.3 kg	0.3 kg
Operating voltage	E-500 System	E-500 System

E-515.E3 Servo In-/Output Module

Servo Control with External Piezo Amplifier, E-500 Piezocontroller System



The E-515.E3 plug-in module makes analog in- and output lines available on the front panel

- **Servo Control Connection for up to 3 External Piezo Amplifiers**
- **For Use with E-509 Servo-Controller in E-500 or E-501 Rack**
- **Easy-To-Use BNC Connectors**
- **High-Resolution, 10-Turn, DC-Offset Potentiometers**

The E-515.E3 servo in/out module allows easy connection of up to 3 external piezo amplifiers to an E-509 position servo-controller module, when installed in the modular E-500 or E-501 piezo controller rack.

BNC connections for control input and servo output (to the amplifier) are available on the front panel.

The analog control input signals can be shifted manually by 0 to 10 V with a high-resolution 10-turn, DC-offset potentiometers.

Together with the E-509 sensor & servo controller module positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and amplifier used.

Interface for Computer Control

Installing the E-517, computer interface/display module with

24-bit resolution makes possible control from a host PC.

Optionally, digital control via a D/A converter is possible. For several D/A boards from National Instruments, PI offers

Technical Data

Models	E-515.E3
Function	In- / Output Module for Servo Control with External Piezo Amplifier, 3 Channels
Control input voltage range	0 to 10 V in closed-loop operation with E-509
Servo Output Voltage Range	-2 to 12 V
Bandwidth	10 kHz
Current limitation	Short-circuit-proof
Input impedance	10 k Ω /1 nF
Interfaces and operation	
Control input sockets	3 x BNC
Servo-control output socket	3 x BNC
DC offset	3 x 10-turn pot., adds 0 to +10 V to Control In
Miscellaneous	
Operating voltage	E-500 system
Operating temperature range	+5 to +50 °C
Mass	280 g
Dimensions	One 7T slot wide, 3H high

Ordering Information

E-515.E3
In- / Output Module for Servo Control with External Piezo Amplifier, 3 Channels

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.

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

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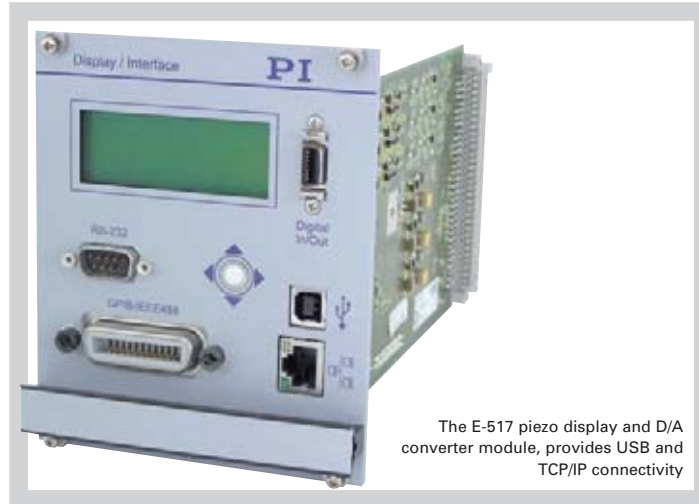
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E-517 Digital Piezo Controller Operation Module

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



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

- 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

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

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!

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, ± 12 V ADC: 18 bit, sampling	DAC: 24 bit, ± 12 V ADC: 18 bit, sampling
Interfaces and operation		
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
Miscellaneous		
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

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E-470 – E-472 / E-421 PICA™ Piezo Controller Modular High-Power Amplifier/Controller



E-471 Configuration example: E-471.20 HVPZT amplifier, with optional E-509 PZT servo-controller and E-516 20-bit DAC interface/display

- Peak Power 550 W
- Output Voltage 3 to 1100 V or Bipolar
- Optional Position Servo-Control Modules
- Optional 20-Bit Computer Interface Module & Display
- Precision DC-Offset Potentiometer for Input-Signal Bias & Manual Control

The E-470 series high-power piezo amplifiers/controllers are specifically designed to drive high-capacitance PICA™ PZT actuators. They are based on the E-421 four-quadrant amplifier module, which can output

and sink a peak current of 500 mA and an average current of 100 mA in a voltage range of 3 to 1100 V (jumper selectable bipolar range also provided). 3 standard configurations are available:

- E-470.20 is a bench-top amplifier in a 9.5" chassis for open-loop operation (1 channel)
- E-471.20 is the amplifier module in a 19" rackmount chassis that can hold additional servo-control, interface and display modules
- E-472.20 is a 2-channel version in a 19" rackmount chassis for dynamic open-loop operation

These amplifiers can be used to drive open and closed-loop piezo positioning systems.

Open Loop Piezo Operation

For open-loop piezo operation the amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting. Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop.

Optional Servo Controller Upgrade

The E-471.20 version allows easy installation of an optional E-509 sensor- / servo-controller module for closed-loop piezo position control. In this mode the amplifier is slaved to the E-509 servo controller. Depending on the attached piezo mechanics and feedback sensor, positioning accuracy and repeatability in the nanometer range and below are feasible.

Computer Control

The E-517 computer interface/display module can also be installed in the E-471 / E-472.

Ordering Information

- E-470.20**
HVPZT Piezo Amplifier, 550 W, 1100 V, Bench-Top
- E-471.20**
HVPZT Piezo Amplifier, Controller & Interface / Display Upgrade possible, 550 W, 1100 V, Bench-Top, 19"
- E-472.20**
HVPZT Piezo Amplifier, 2 Channels, 550 W, 1100 V, Bench-Top, 19"
- E-421.00**
HVPZT Piezo Amplifier Module, 550 W, 1100 V, Integrated P / S

Upgrades for E-471.20

Sensor / Position Servo-Control Modules

E-509.C1A
Sensor / Servo-Controller Module, Capacitive Sensor

E-509.S1
Sensor / Servo-Controller Module, SGS - Sensor

Computer Interface & Display Modules

E-517.i1
Interface- / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 1 Channel

E-515.01
Display Module for PZT Voltage and Position

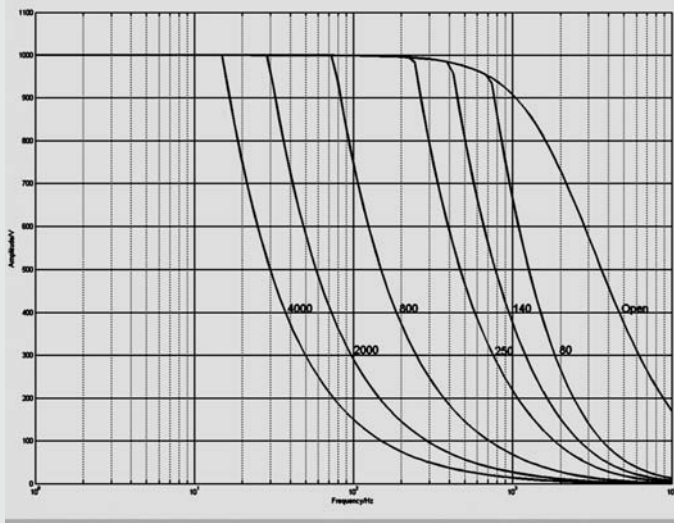
E-500.ACD
CD with Driver Set for Analog Controllers

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

Supports certain D/A boards.

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" (page 2-168 ff).

Ask about custom designs!



E-421, E-470, E-471, E-472: operating limits with various PZT loads, capacitance is measured in nanofarads

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 patent-

ed HyperBit™ technology providing enhanced system resolution.

Please read details on Calibration Information (see p. 2-103).



E-421.00 HVPZT piezo amplifier module

Technical Data

Model	E-470.20, E-471.20, E-472.20, E-421.00
Function	Power amplifier for PICA™ high-voltage PZTs (servo-controller option for E-471)
Amplifier	
Output voltage	3 to +1100 V (default) (Selectable -260 to +780 V -550 to +550 V +260 to -780 V -3 to -1100 V)
Amplifier channels	1 (E-472: 2)
Average output power	110 W
Peak output power, <5 ms	550 W
Average current	100 mA
Peak current, <5 ms	500 mA
Amplifier bandwidth, small signal	DC to 3 kHz, related to load capacitance, see operating limits graph
Amplifier bandwidth, large signal	DC to 3 kHz, related to load capacitance, see operating limits graph
Ripple, noise 0 to 100 kHz	<25 mV _{RMS} 100 mV _{P-P} (200 nF)
Current limitation	Short-circuit-proof
Voltage gain	+100 ±1, -100 ±1 (selectable)
Control input voltage	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V
Input impedance	100 kΩ
Interfaces and operation	
PZT voltage output	LEMO EGG.0B.701.CJL1173
Control input	BNC
DC Offset	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous	
Operating voltage	100-120 or 220-240 VAC, selectable (fuse change required)
Operating temperature range	+5 to +50 °C (over 40 °C, max. av.) power derated 10 %
Mass	5.2 kg (E-470); 7.6 kg (E-471); 10.1 kg (E-472); 2.5 kg (E-420)
Dimensions	236 x 132 x 296 mm + handles (E-470) 450 x 132 x 296 mm + handles (E-471, E-472) 215 x 123 x 185 mm (E-420)

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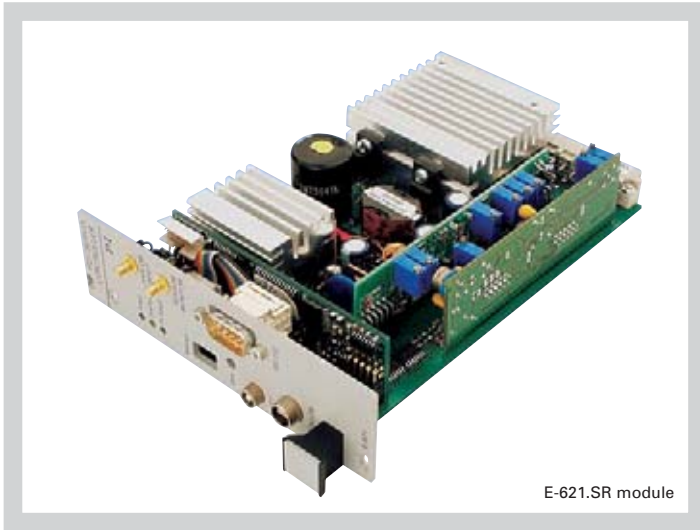
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E-621 Piezo Servo-Controller & Driver

Modules with Fast 20-Bit Interface



E-621.SR module

- Integrated 20-Bit High-Speed RS-232 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 interface and precision 20-bit D/A and A/D 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 RS-232 digital interface includes high-precision 20-bit D/A and A/D converters for optimum position stability and resolution and supports fast communication with the host computer, with up to 300 bidirectional read/write operations per second.

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 RS-232 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 generator can store user-defined data points internally. These values can then be output automatically (or under the control of

Ordering Information

E-621.CR
Piezo Amplifier / Servo-Controller Module, 1 Channel, -20 to 120 V, Capacitive Sensor, RS-232

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

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

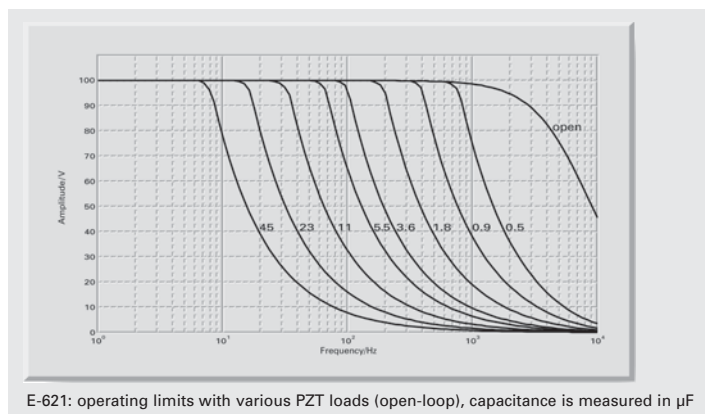
The E-621 controller comes with Windows™ installation software, DLLs and Lab View™ drivers. The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.



4 x E-621 in an E-501.621 chassis

Technical Data

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
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	RS-232 (9-pin Sub-D connector), 9.6 - 115.2 kBaud, 20-bit
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	PZTControl™, NanoCapture™
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave table, 64 data points, 100 Hz, external trigger
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



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E-621.CR module for
capacitive sensors

E-612 Piezo Controller Module / System

1- to 4-Channel System with High-Speed Parallel Port



Ordering Information

E-612.C0
Piezo Controller with High-Speed Parallel Interface, OEM Module, -20 to 120 V, Capacitive Sensor

E-501.10
9,5"-Chassis for up to 4 E-612.C0 Modules, incl Power Supply

- 10 μ s High-Speed Parallel Command Port
- Additional Analog Interface
- For Piezo Stages with Capacitive Sensors
- Notch Filter for Higher Bandwidth
- Integrated Piezo Power Amplifier
- Versatile Design: Module for Multi-Channel Chassis or Single-Channel Bench-Top Device (E-661)

The fast E-612 piezo controller module is designed for nanopositioning systems with integrated capacitive position feedback sensors. It possesses a low-noise integrated piezo amplifier providing -20 to 120 V with 80 mA sink and source capability.

High-Speed Interface

The controller features a high-speed parallel command port with optical coupled inputs and extra low-noise, linear, 16-bit D/A converters. Real-time position feedback is realized via a special trigger option. Additionally a broadband analog interface is installed (0 to 10 V).

Nanometer Resolution in Milliseconds

This high-performance controller is designed for nanopositioning tasks with highest precision and maximum turnover. Positioning with nanometer precisions and settling times of a few milliseconds are achieved in combination with

the P-726 objective positioners (see p. 2-32) or P-753 LISA™ actuators (see p. 2-16). More and more high-tech branches require "nanometer accuracy within milliseconds". This is the case in microscopy/pharmaceutical research or quality testing for read/write heads, where every millisecond saved raises the throughput and helps reduce costs.

Single and Multi-Channel Systems

Up to four E-612.C0 piezo controller modules can be installed in one E-501.10 chassis. An internal address bus allows control of all modules over a single parallel command port. The E-612 is also available in a compact, single-channel bench-top version (model E-661.CP). It comes with a metal case for EMI protection and an external power supply (see p. 2-116).

Technical Data (Controller)

Model	E-612.C0
Function	High-Speed Piezo Controller Module
Channels	1
Capacitive sensor circuit	
Clock frequency	1.6 MHz
Bandwidth	1.5 kHz
Amplifier	
Output voltage	-20 to +120 V
Average output power	8 W
Average current	80 mA
Current limitation	short-circuit proof (5 minutes to shutdown)
Bandwidth (no load)	>500 Hz
Digital circuit	
Data	16-bit
Input level	TTL
Timing	THmin 10 μ s; TLmin 10 μ s
Input current	10 mA
On-target indication	On: target position $\pm 0.025\%$ to 0.2%, jumper-selectable
Analog input / output	
Control input voltage	-2 to 12 V
Input impedance	27 k Ω , 1 nF
Sensor monitor output	
Voltage range	-12 to +12 V (jumper-selectable)
Output impedance	10 Ω (10 nF)
Bandwidth	1.5 kHz
Connectors	
Digital interface	25-pin sub-D
Piezo	LEMO ERA.00.250
Sensor	LEMO EPL.00.250
Sensor monitor output	SMB
Analog input	SMB
Power consumption	+5 V, 0.12 A, ± 15 V, 0.16 A, +130 V, 80 mA max.; -27 V, 80 mA max
Dimensions	Euroboard (64-pin rear connector. Mating extender card: Mod. P-896.00)

Technical Data (Chassis & Power Supply)

Model	E-501.10
Function	Chassis for 1–4 E-612.C0 piezo controller modules
Operating voltage	90–120 VAC, 50–60 Hz; 220–264 VAC, 50–60 Hz
Power Supply	linear regulated power supply, integrated
P/S Output voltages	+130 V, 0.2 A; -27 V, 0.2 A; +24 V, 1 A; ± 15 V, 0.5 A; +5 V, 1 A
Max. power consumption	50 W
Primary fuse	0.63 A slow
Dimensions	236 x 132 x 296 mm + handles

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E-831 Piezo Driver OEM Module, Power Supply for up to 3 Axes



E-831.03 amplifier module.

- Cost Effective Piezo Driver
- Small Size
- Low Noise, High Stability
- Easy-to-Use
- Full Overcurrent, Short-Circuit and Temperature Protection
- Power-up/down Without Voltage Spikes

The E-831.03 OEM piezo driver module is a very compact, cost-effective, single-channel, 4-quadrant power amplifier for low-voltage piezoelectric actuators.

It provides a peak output power of 12 W and average power of 2 W (expandable to 5 W with external heat sink). The E-831.03 is a high-precision amplifier with a fixed gain of 10.0 and outputs voltages in

the range of -20 to 120 V for control input signals ranging from of -2 to 12 V. The output is fully compensated for the capacitive loads of up to 10 μ F typical of PI's low-voltage PZTs such as PICMA[®] piezo actuators. For monitoring purposes, the output voltage is internally divided by 100 and provided at a special monitor pin.

Because piezo actuators require virtually no power in

steadystate operation and the power consumption depends on the operating frequency, high-powered amplifiers are not required for many applications. With a peak output current of 100 mA (sink/source) the E-831 is well-suited for switching applications and fast transitions where the capacitive load (the piezo actuator) needs to be charged as quickly as possible. The small-signal bandwidth is about 3 kHz.

Power Supplies for E-831.03

The E-841.05 (input voltage range 10 to 30V) and E-842.05 (input voltage range 30 V to 72 V) switched power supply modules provide all the operating voltages (± 15 V, -26 V and +127 V DC) required by the E-831.03 amplifier module. Both models supply enough power for up to three E-831.03 amplifiers with a total output power of 5 W.

A sync. input on the power supply allows synchronization of the internal switching frequency with an external clock (185 to 220 kHz) for elimination of interference in AC-driven position sensors or DACs.

Easy Implementation

E-831 and E-841/E-842 modules are enclosed in metal cases with solderable pins for PCB mounting. They are designed to work together without additional components.

Triple Safety

The E-831 amplifier is short-circuit proof with both a low-speed current limiter of 50 mA and a high-speed (8 msec) current limiter of 100 mA. When the case temperature rises above 70 °C (can be reached after a few minutes with maximum current) an internal temperature sensor shuts down

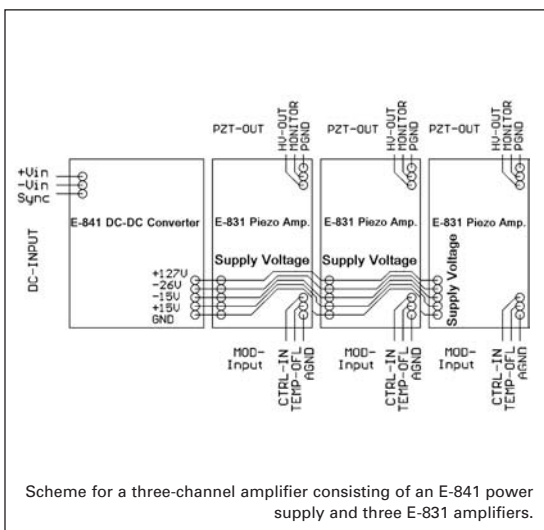
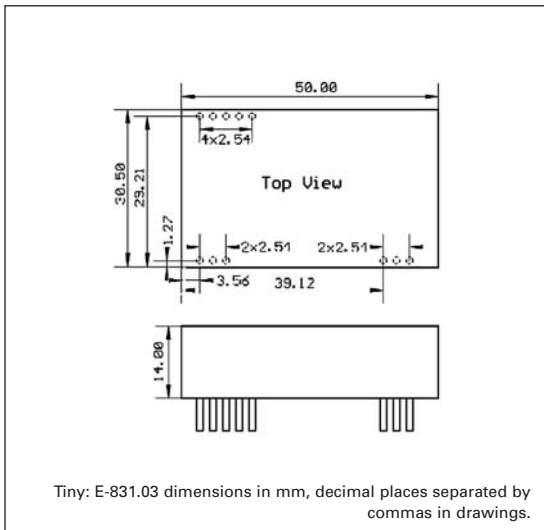
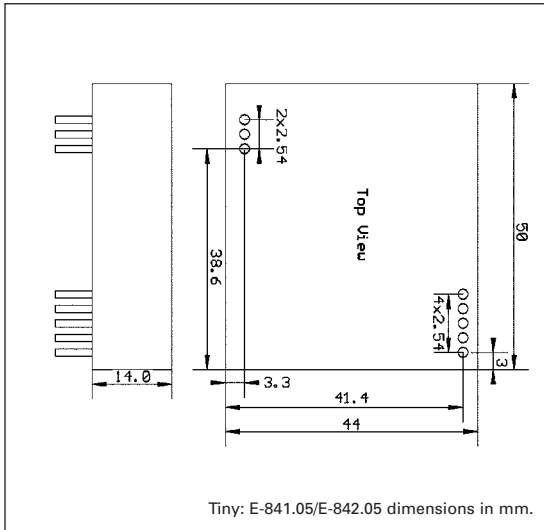
Ordering Information

- E-831.03**
Single-Channel Piezo Driver Module for LVPZTs
- E-841.05**
Power Supply Module for E-831, Input 10 to 30 V
- E-842.05**
Power Supply Module for E-831, Input 30 to 72 V

the output stage until the temperature drops below 60 °C. This operation mode is indicated by the active-high TEMP-OFL TTL status line.



E-841.05 power supply module



Technical Data E-831.03

Models	E-831.03
Function:	Single-channel piezo amplifier module
Output voltage range:	from [U+ - 6 V] (121 V for U+ = 127 V) to [U- + 8 V] (-20 V for U- = 28 V)
Gain	10 ±0.1
Max. output current:	100 mA for 8 ms (sink/source)
Max. average current:	50 mA for 2 min without heatsink
Output protection:	short-circuit protected, the module is overload protected to 70 °C case temperature
Max. output power:	2 W without ext. heatsink 5 W with ext. heatsink or forced airflow
Control input range:	-2 to +12 V
Input impedance:	100 kΩ
Dynamic current requirements:	depend on load, amplitude and slew rate
Cut off frequency:	3.5 kHz, no load
Operating temperature range:	+5° to +50° Celsius
Operating voltages:	+15 V / 20 mA (14 to 16 V) (all currents without dynamic load) -15 V / 7 mA (-14 th -16 V) +127 V / 1.8 mA +125 to 135 V) -26 V / 1.8 mA (-24 to -30 V)
Case	Metal shielded case, size: 50 x 30 x 14 mm
Soldering pins	1 mm diameter, 4 mm length

Technical Data E-84x.05

Models	E-841.05, E-842.05
Function:	Power Supply Module for E-831
Output voltages:	+127 V, 30 mA; -26 V, 30 mA; +15 V, 60 mA; -15 V, 20 mA
Max. output Power:	8 W
Max. average Power	8 W with forced air flow (5 W without)
Output protection:	short-circuit protected (1 min.)
Input voltage:	10 - 30 V (E-841.05); 30 - 72 V (E-842.05)
Quiescent current:	100 mA @15 V; 60 mA @30 V; 25 mA @72 V
Max. input current:	1000 mA (E-841.05 @ 10V); 200 mA (E-842.05 @ 72V)
Power-on, peak current:	1500 mA
Switching frequency	100 kHz typical
External clock frequency:	200 kHz (185 - 220 kHz possible)
Synchronization signal:	preferred TTL-level with duty cycle 50 %; operating from 1.8 V _{on} and offsets within ±7 V
Output ripple:	<100 mV _{pp}
Operating temperature range:	5° to +50° Celsius (with power derating above 40 °C)
Case	Metal shielded case, size: 50 x 44 x 14 mm
Soldering pins	1 mm diameter, 4 mm length

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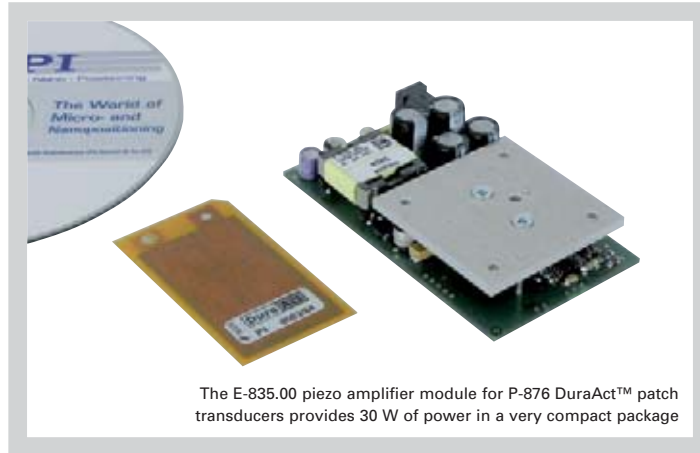
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E-835 DuraAct™ Piezo Driver Module

Bipolar Operation for Piezoelectric Patch Transducers



The E-835.00 piezo amplifier module for P-876 DuraAct™ patch transducers provides 30 W of power in a very compact package

- OEM Module for DuraAct™ Piezoelectric Patch Transducers
- Peak Power to 30 W
- Output Voltage Range -100 to +250 V
- High Bandwidth >4 kHz
- Compact: 87 x 50 x 21 mm
- Can be Used to Drive PicaShear™ Piezo Shear Actuators

The powerful, cost-effective E-835 OEM piezo amplifier module is designed for driving the P-876 DuraAct™ piezo patch transducers. It provides a peak output power of 30 W with a peak current of 120 mA in the semi-bipolar voltage range (-100 V/+250 V). The continuous output power is rated at 3 W.

This compact piezo amplifier module supplies adequate power for a broad range of DuraAct™ patch transducer applications, e.g. active vibration damping, structure monitoring and stabilization.

Voltage-Controlled Piezo Operation

The E-835 piezo driver module provides precision control for DuraAct™ Patch Transducers both in static and dynamic operation. Its output voltage is determined by an external analog signal in the -4 to +10 V-range applied to the respective input.

Operation / Contents of Delivery

The required electrical power can be supplied by a commercial 12 V-power supply (not included). An integrated DC/DC converter provides the piezo voltage and other voltages

Ordering Information

E-835.00
OEM Piezo Amplifier for DuraAct™ Patch Transducer

Ask about custom designs!

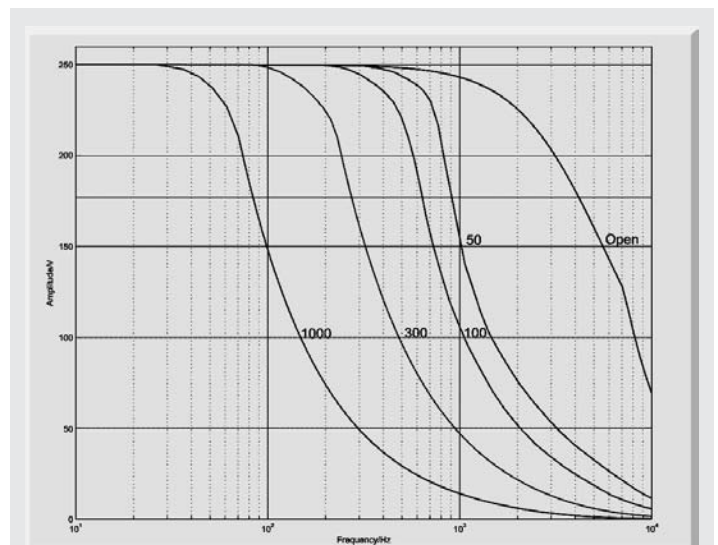
required internally. All inputs and outputs are on solder pads.

The E-835 piezo amplifier module is also suitable for operating PICA™ Shear piezo actuators at about 60% of the nominal maximum displacement.

Read the general considerations on piezo amplifiers.

Adaptive Structures with Piezo Patch Transducers

P-876 DuraAct™ patch transducers combine the actuator and sensor functionality of piezoceramic materials. Used as a bender or contraction actuators, they provide high deflection with high force and precision. Other possible DuraAct™ operation modes are as high-dynamics sensor (e.g. for structural health monitoring) or as energy harvesters.



E-835.00: frequency response with various PZT loads (250 V, open-loop), capacitance is measured in nF

Technical Data

Model	E-835.00
Function	Power amplifier for DuraAct™ piezo patch transducers
Channels	1
Amplifier	
Input voltage	-4 to 10 V
Output voltage	-100 to 250 V
Peak output power	30 W (<15 ms)
Average output power	3 W
Peak current	120 mA (<15 ms)
Average current	40 mA
Current limitation	Short-circuit-proof
Voltage gain	25
Amplifier bandwidth, small signal	4.2 kHz (60 nF)
Amplifier bandwidth, large signal	4.2 kHz (unloaded); 500 Hz (60 nF)
Ripple, noise, 20 MHz	2 mV _{pp}
Output impedance	33 Ω
Amplifier resolution	<10 mV
Input impedance	100 kΩ
Interfaces and operation	
Piezo voltage	Soldering pads
Control input	Soldering pads
Piezo voltage monitor	Soldering pad, 1:100
Miscellaneous	
Operating temperature range	+5 °C to +50 °C (10 % derated over 40 °C)
Overheat protection	Deactivation at 100 °C
Dimensions	87 x 50 x 21 mm
Mass	67 g
Operating voltage	12 V / 1.7 A; 5.5 mm – barrel connector
Max. power consumption	20 W

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Accessories

Cables, Connectors & Adapters for LVPZT Piezo Translators and Nanopositioning Systems

Notes

Unless stated otherwise, PI LVPZT translators and Nanopositioners are equipped with LEMO connectors and 1 m cables. The voltage connector is an FFS.00.250.CTCE24 as shown on the P-890 cable (Fig. 2). The sensor connector is an FFA.0S.304.CLAC32 as shown on the P-892 cable (p. 2-170, Fig. 9). Standard insulation materials are Teflon for the voltage cable and PUR for the sensor cable.

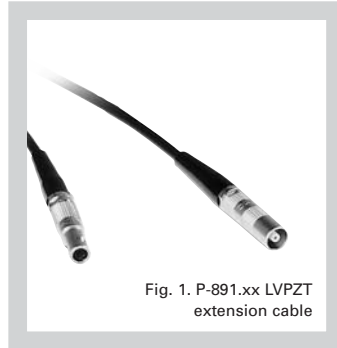


Fig. 1. P-891.xx LVPZT extension cable

P-891.xx LVPZT Extension Cable (Fig. 1)

Plug (left): LEMO FFS.00.250.CTCE31
Socket (right):

LEMO PCS.00.250.CTL.CTME31
Cable: RG 174 (PVC)
P-891.01 1 m
P-891.02 2 m
P-891.03 3 m
P-891.05 5 m
P-891.10 10 m



Fig. 2. P-890 LVPZT cable LEMO/ solderable end

P-890 LVPZT Cable LEMO/ Solderable End (Fig. 2)

Plug: FFS.00.250.CTCE24
(fits LVPZT amplifiers, e.g. E-505.00)
Cable: RG 178 (Teflon)
This cable can be soldered to PZTs with pigtails
P-890.10 1 m
P-890.20 5 m



Fig. 3. P-893.10 BNC adapter cable

P-893.10 LVPZT/BNC Adapter Cable (Fig. 3)

LEMO Plug / BNC female, adapter cable
Cable: RG 174 (PVC), 1 m
Plug: LEMO FFS.00.250.CTCE31 (male) and BNC.ST.250.NTAE31.
Allows LVPZT amplifier output voltage (e.g. E-505, etc.) to be connected to an oscilloscope, etc.



Fig. 4. P-210.20 BNC-cable

P-210.20 BNC Cable (Fig. 4)

BNC plug / solderable end.
Cable: RG 174 (PVC), 1 m. This cable can be soldered to PZTs with pigtails



Fig. 5. P-894.10 LVPZT adapter

P-894.10 LVPZT Adapter (Fig. 5)

LEMO plug / 2 x LEMO socket, adapter
Type: FTL.00.250.CTF with 1 x plug (right), 2 x socket (left, center). Allows two cables with LEMO FFS.00.250 male plugs to be connected to a device with LEMO 00.250 socket (e.g. E-505.00 amplifier module) or P-891 extension cable.



Fig. 6. P-894.30 BNC adapter

P-894.30 BNC/LVPZT Adapter (Fig. 6)

LEMO socket / BNC female, adapter
Type: ABA.00.250.NTL
Allows a cable with LEMO FFS.00.250 male plug to be attached to a device with BNC socket (e.g. direct operation of an LVPZT from a signal generator).

Accessories

Cables, Connectors & Adapters for PICA™ HVPZT Piezo Translators and Nanopositioning Systems

Notes

Unless stated otherwise, PI's preloaded PICA™ HVPZT piezo translators and nanopositioners are equipped with LEMO connectors and 1 m PVC cables. The voltage connector is an FGG.0B.701.CJL.1173. With integrated P-177.10 strain gauge, an additional sensor cable is installed. The length of the sensor cable is 1 m, the material PUR and the connector a LEMO FFA.0S.304.CLAC32 as shown on the P-892 cable (see page 2-170, Fig. 9).



Fig. 7. P-202 PICA™ HVPZT cable

P-202.xx PICA™ HVPZT Cable LEMO plug / solderable end

Plug: FGG.0B.701.CJL.1173 (fits PICA™ HVPZT amplifiers, e.g. E-508.00)

Cable with PUR insulation, 2-conductor, shielded

This cable can be soldered to PZTs with pigtails

P-202.06	0.6 m
P-202.10	1 m
P-202.12	2 m
P-202.13	3 m
P-202.15	5 m



Fig. 8. P-203 extension cable for PICA™ HVPZTs

P-203.xx PICA™ HVPZT Extension Cable

Plug: FGG.0B.701.CJL.1173

Socket: PHG.0B.701.CJL.1173

Cable: PUR-insulation, 2-conductor, shielded

P-203.01	1 m
P-203.02	2 m
P-203.03	3 m
P-203.05	5 m
P-203.10	10 m
P-203.15	15 m

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Accessories

Sensor Extension Cables



Fig. 09. P-892.xx Sensor extension cables for LVDTs and strain gauges

P-892.xx Sensor Extension Cable (Fig. 9)

For strain gauge sensors or LVDTs.

Plug (right):

FFA.0S.304.CLAC32

Socket (left):

PCA.0S.304.CLLC32

Cable: 4 wires; $\approx \varnothing 0.20$ mm;

#32 AWG (American)

\approx #35 SWG (British)

PVC-Isolation

P-892.01 1 m

P-892.02 2 m

P-892.03 3 m

P-892.05 5 m

P-892.10 10 m

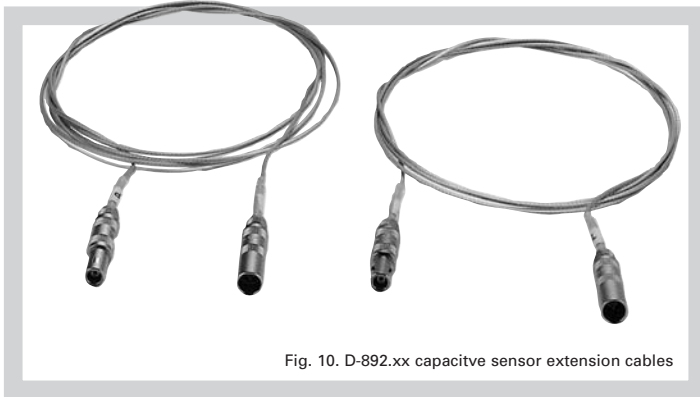


Fig. 10. D-892.xx capacitive sensor extension cables

D-892 Sensor Extension Cable Set (Fig. 10)

For capacitive sensors.

Set of two.

Plug (e.g., far left)

FFA.00.250.CTLC20

Socket (e.g., far right)

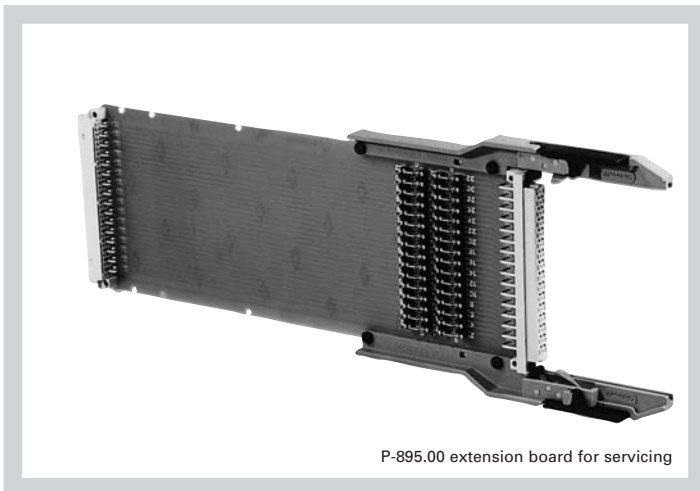
PCA.00.250.CTAC22

Cable: LSM 75 (Teflon)

D-892.01 1 m

D-892.02 2 m

D-892.03 3 m



P-895.00 extension board for servicing

P-895.00 Extension Board

The board is used for the extension of the 32-pin connector of all PI E-500 and E-501 electronics (except E-515 and E-516). It is required for calibration and maintenance work. To allow the measurements of electrical current, all traces on the board are jumpered.