Piezocomposite actuators

Piezos for high forces!

Faster than resonant frequencies!

- *high forces up to 70 kN*
- *resonant frequencies up to 60 kHz*
- *variable lengths from millimeters to meter*

piezosystemjena
incredibly precise

1 Piezocomposite actuators

Piezocomposites are linear high load actuators designed in a discrete joining technology. Their advantages lay in high force generation and high stiffness. Another key advantage is the ability to use a variable selection of piezo-ceramics. With these varieties in design and material, piezocomposite actuators can be used in many applications.

Applications of piezocomposite actuators

Piezocomposite actuators are used for:

- shakers
- active vibration damping
- shock wave generation
- material testing
- short impulse excitation

Features

Features of piezocomposites (compared to conventional high load actuators)

- construction of metal-ceramic-compound through discrete joining technology
- adaptation for special applications through choice of piezoceramic (d_{33}; Curie Temp.; loss factor)
- integrated temperature management for high temperature (HT) applications (thermostable)
- high shock resistance and high vibrational excitation through optimized construction
- adjustment of the internal preload

2 Piezoelectrical PIA impulse generators

- adjustable impulse parameters: energy <4 J; acceleration >10'000 g; amplitude >100 µm
- precise time behavior: triggering in the microsecond range
- variable repetition rates: up to kHz (burst)
- fast rise time: down to µ sec's
- adjustable pulse width: down to 10 µ sec's
- High repeatability of the pulse parameters.
- Synchronization of several pulse generators is possible!

PIA impulse generators provide fast accelerations to test objects, structures and materials. A special dielectrical piezoceramic is used for highly-effective piezo impulse generators with a high power density.
The impulse energy density is twice as high as the comparable impulse energy density of ceramics for actuators.

Physical explanation

When the piezo actuator is charged quickly (short pulse), then the axial compression stress in the piezo ceramic jumps to a large value.
This increase takes place instantaneously, and results in high acceleration with high strain rates. The blocking pressure is generated. As a result the piezo-rod expands in an accelerated manner. The piezo stack can build up a propagating pressure front, in a coupled body.
Therefore the piezo stack-type actuator is an "active rod" which generates mechanical shocks when driven by electrical power pulses.

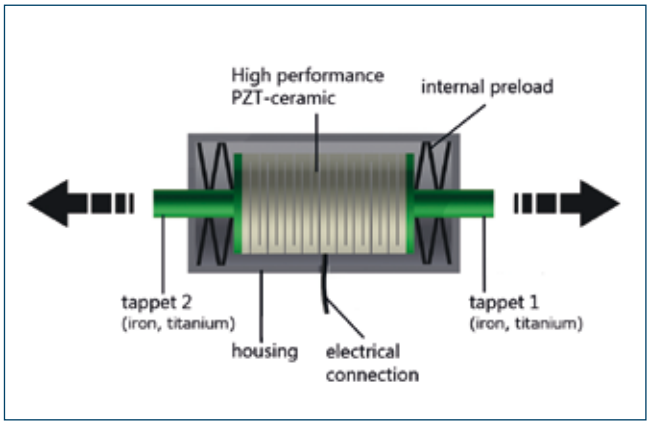


Image 1: *Scheme of a symmetrically acting shock generator working in axial direction.*

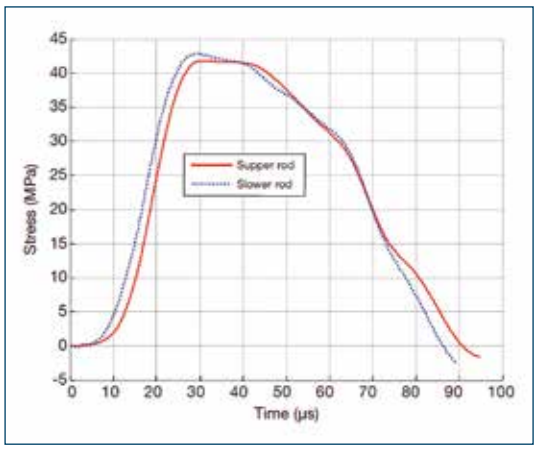


Image 2: *Pulse shape of an impulse generator with a symmetrical arrangement.*

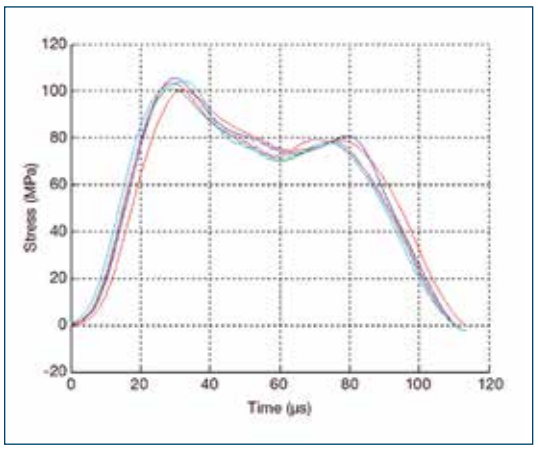


Image 3: *Typical double-pulse shape with a seismic mass.*

PIA-electronics - requirements of the electronic

High Voltage Pulser HVP Controller

- high pulse currents up to 400 A
- µs accurate triggering
- peak power up to 400 kW
- rise times in the µs-range

The basic principle of the HVP amplifier is the following: A capacitor (multiple 100 µF) is charged with a desired voltage. The capacitor will be disconnected from its power supply and suddenly discharged through the piezo-shock generator.
Currents reach several hundred Amperes for a short-term period. The voltage which is applied to the piezo thus increases to 1000 V within a few µs.

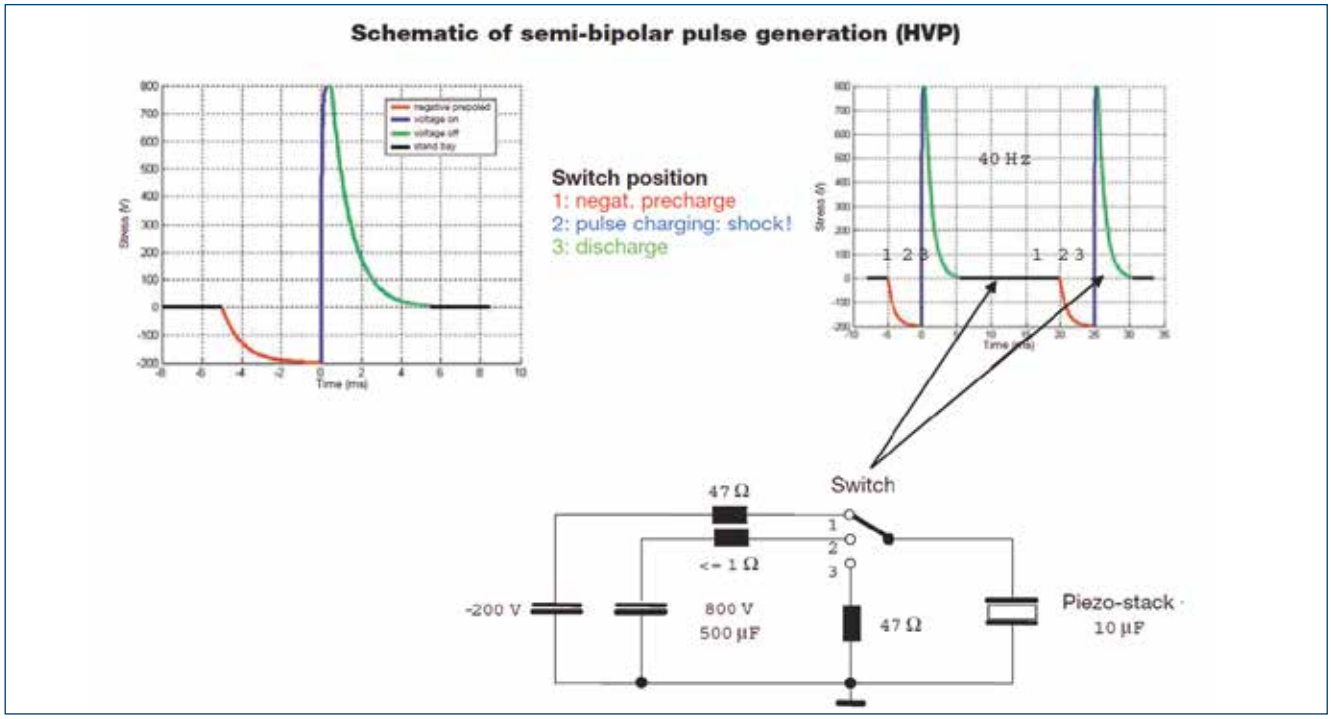


Image 4: *Schematic bipolar control of a power piezo actuator by a High-Voltage-Pulser (HVP).*

Please note:
The design and operation of PIA impulse generators require a very special expertise for impulse generation and pulse propagation to generate high acceleration and impact forces.
Without this knowledge and experience in operating shock generators, there is a high risk of not reaching the needed results and also damaging the actuator.

3 Piezoelectrical PiSha Shakers

- frequency range: up to 100 kHz (depending on the shakers configuration)
- amplitudes: up to several 100 µm
- accelerations: up to 10'000 g
- force generation: up to several 10 kN
- dimensions: compact dimensions down to mm range are available
- Thermal management for high dynamics.

Operating principle of piezoeletric shakers

Piezo shakers convert the electrical excitation signal directly into a motion. The amplitude is set by the operating voltage, velocity and maximum frequency are depending on the current. The internal structure of the shaker is adapted to the occurring high forces, pressures and accelerations. So the shaker achieves a reliable operation under oscillation at a continuous load.

Please note:

PiSha piezocomposite actuators can work very fast. They have the capability to generate high force modulations and can move high masses.
To achieve the best results and best technical parameters PiSha shakers have to be optimized for every application. There are no off the shelf/standard actuators for high end technical solutions.
Please ask our experts for consultation and help with your application.

Power supplies for piezocomposite actuators

Power amplifier for PIA and PiSha piezocomposite actuators operate with up to 1000 V and provide high peak currents up to 400 A. With values this high there is a high risk of damaging the standard piezo actuators (even preloaded). Please ask our experts for advice in handling these systems!

Comparison piezo-shaker/ electromagnetic shaker

Compared to their size, piezo shakers have a higher stiffness and force potential at shorter travels than electromagnetic shakers.

Further applications are miniaturized components, where piezo technology offers higher power densities and smaller sizes.

Standard-piezo actuators are normally adapted to smaller dynamics like positioning tasks. To some extent, they can also be used with low modulation for vibrational excitation.

However dynamic excitation with high power densities and high frequencies/accelerations require special adaptations in order to achieve reliable operation.

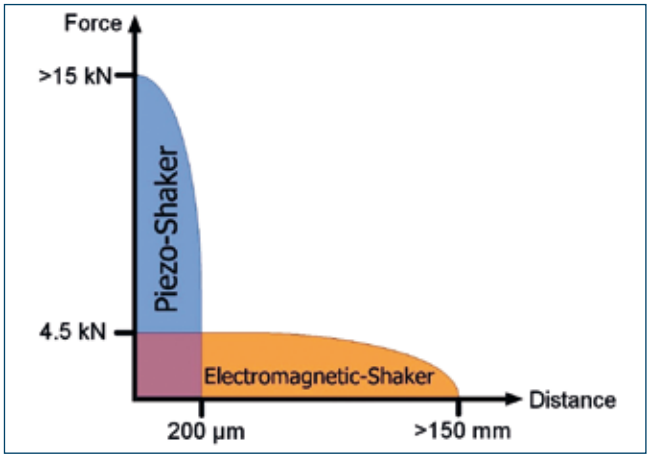


Image 5: *Workspaces of piezoelectric and electromagnetic shakers in comparison.*

Geo-Shaker: for vibration excitation of the ground and of buildings

- coupling to the ground via base plate
- force-generation: reaction/acceleration forces in conjunction with seismic masses
- power electronics: amplifier RCV 1000/7 (peak power 7 kW) voltages up to 1000 V
- seismic mass up to 200 kg (depending on the frequency tuning)
- max. amplitude vibration 80 microns
- max. force modulation ca. +/-15 kN
- basic response: typically at 200 Hz (depending on the seismic mass)

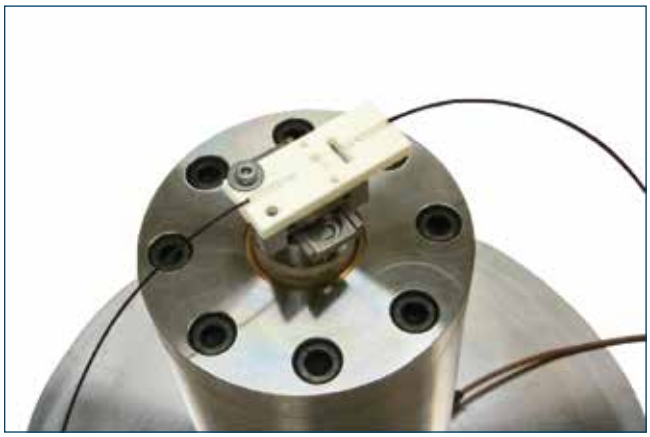


Image 6: *Geo-Shaker with test object.*

Micro-Shaker: Ring type

- mounting arrangement by clamps or as seismic response type
- working area up to 100 kHz
- max. amplitude: ±5 µm (frequency dependant)
- max. force modulation up to 1000 Newton (under blocking conditions)
- max. operating voltage: 150 V
- electrical supply: broadband amplifier LE150/100 EBW

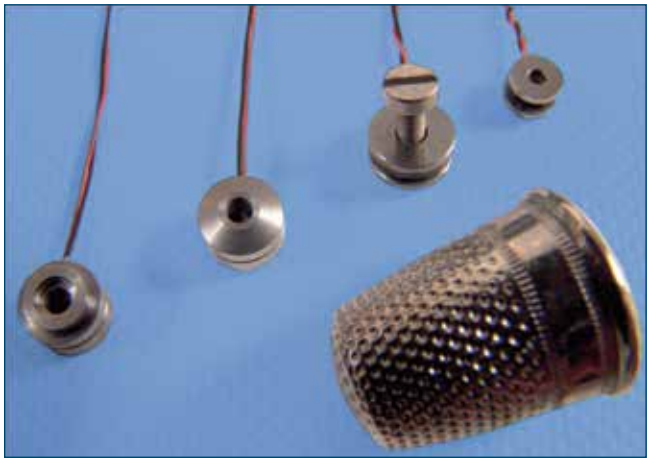


Image 7: *Different micro-shakers. Size comparison with thimble.*

Examples for PIA and PiSha piezocomposite actuators

PIA pulse generator for micro adjustment

- Type of actuator: PIA 80 µm motion, diameter: 80 mm
- Force generation: up to 4 KN
- Pulse rise time: < 50 µsec

Piezocomposites for material research

- Properties: piezocomposite actuator
- Length: 750 mm
- Diameter: 65 mm
- Motion: up to 1 mm
- Force generation: 35 kN

Ultrasonic shaker for detection of defects in carbon fiber composites

- Type of actuator: shaker, piezocomposite actuator
- Technical properties: motion: up to 12 µm; resonant frequency: 45 kHz

Tests of acceleration sensors under strong environmental conditions

- Type of actuator: PIA 35/150 with acoustical matching
- Parameter: pulse generation with up to 2000 g (acceleration)
- Repetition rate: 200 Hz
- Operating voltage: 1000 V
- Blocking force: 20 kN
- Pulse duration: several 10 µsec

4 Product range

4.1 Stack type actuators

PSt series - stack type actuators without casing and without preload

- maximum force generation up to 50'000 N
- temperature range from -60 °C up to +200 °C

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [kHz]
PSt 1000/10/7	12/7	9	20	300	60
PSt 1000/10/20	24/18	18	45	150	40
further versions at www.piezosystem.com/piezocomposite					
PSt 1000/35/60	80/60	54	2500	600	20
PSt 1000/35/80	105/80	72	3300	450	15

* *stroke at a voltage of -200 V to 1000 V/0 to 1000 V*

PSt VS series - stack type actuators with casing and with preload

- maximum force generation up to 50'000 N
- ideally suited for dynamic application due to high preload
- temperature range from -60 °C up to +200 °C

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [kHz]
PSt 1000/10/7 VS18	12/7	24	20	300	40
PSt 1000/10/20 VS18	27/20	33	45	150	35
further versions at www.piezosystem.com/piezocomposite					
PSt 1000/35/150 VS45	200/150	154	5700	220	7
PSt 1000/35/200 VS45	260/200	194	6500	150	4

* *stroke at a voltage of -200 V to 1000 V/0 to 1000 V*

4.2 Ring type actuators

HPSt series - ring type actuators without casing and without preload

- inside aperture for optical positioning and laser applications
- improved cooling
- also available as 500 V version with diameters 10-5 and 15-8

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [kHz]
HPSt 1000/10-5/7	12/7	9	15	210	50
HPSt 1000/10-5/20	25/17	18	40	110	35
further versions at www.piezosystem.com/piezocomposite					
HPSt 1000/35-25/80	105/80	72	1300	250	12
HPSt 1000/35-25/100	130/100	90	1800	160	10

* *stroke at a voltage of -200 V to 1000 V/0 to 1000 V*

HPSt VS series - ring type actuators with casing and with preload

- free inside aperture
- with internal preload: ideally suited for optical applications with high dynamics
- also available as 500 V version with diameters 10-5 and 15-8

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [kHz]
HPSt 1000/10-5/7 VS18	12/7	24	15	210	35
HPSt 1000/10-5/20 VS18	27/20	33	40	110	27
further versions at www.piezosystem.com/piezocomposite					
HPSt 1000/35-25/80 VS45	105/80	89	1300	250	12
HPSt 1000/35-25/100 VS45	130/100	107	1800	160	10

* *stroke at a voltage of -200 V to 1000 V/0 to 1000 V*

4.3 Piezo amplifiers

1 and 3-channel-amplifier SVR 1000 - up to 1000 V

- for static and quasi-static applications
- max. current 8 mA
- low noise (~1 mV at 0.47 µF load)
- manual control of DC-offsets
- also available as ±350 V bipolar and 500 V version

The SVR 1000 is available as a multi-channel and single channel amplifier. Due to its low voltage noise, it is excellent for positioning applications, especially for the positioning of optics.

Switching amplifier RCV 1000/3 - up to 1000 V

- high load switching amplifier system
- max. current 3 A
- also available as 7 A version
- manual control of the DC offset

The RCV 1000/3 is a switching amplifier with a peak power of 3 kW. It is ideally suited for dynamic control of high volume piezo-actuators with capacitances in the µF-range.

High voltage pulse generator HVP series - up to 1000 V

- peak current up to 400 A
- adjustable rise time via additional ohmic load
- external or manual setup of charging voltage

The high voltage pulser HVP series has been designed to drive special piezo electric shock generators from piezosystem jena or other suitable loads with high charging currents for pulse-wise operation in a kind of "on-off" square-wave mode.

5 Theory

Force

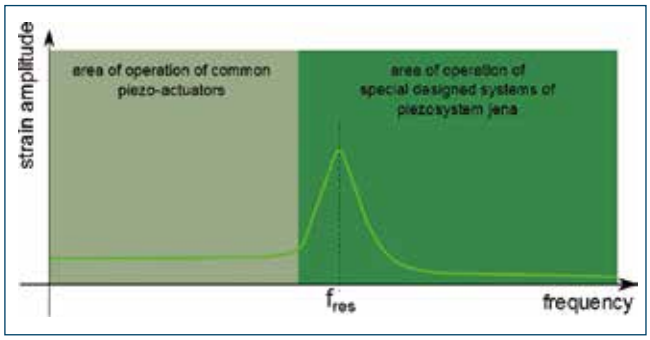
In dynamic applications the generation of tensile and pressure forces depends on the acceleration. For a sinusoidal input signal the following formula applies:

$$F = m \cdot a = m \cdot \frac{\mathrm{d}^2 s}{\mathrm{d}t^2} = m \cdot \hat{s} \cdot 4\pi^2 f^2 \cdot sin(2\pi f t)$$

F = force
m = moved mass
a = acceleration
ŝ = amplitude
f = working frequency

Frequencies

With specially designed piezo shakers from piezosystem jena it is possible to work above the resonant frequency.



Actuators that work near or above the resonant frequency need to be prestressed. Please consider resonance magnification near the resonant frequency and decrease in amplitude for higher frequencies.

Collision excitation

For highly effective piezo pulse generators with a high power density a special piezo ceramic material is used. The mechanical impact energy density of the used ceramic material is twice as high compared to the energy density of the stadard ceramic material used for actuators. The mechanical energy content of the shock can be calculated by:

$$W = \frac{1}{2} \cdot V \cdot Y_{ceramic} \cdot d_{33} \cdot E^2$$

The generated energy can reach several joules.

W: energy content (up to several Joule)
V: volume (up to 100 cm^3)
$Y_{ceramic}$: Young's modulus of the ceramic material ($4 \ldots 5 \cdot 10^{10}$ N/mm^2)
d_{33}: piezo electric charge constant (approx. 700 C/N)
E: electric field strength (up to 2 kV/mm)

Shock momentum

The momentum of the shock can be calculated in the following way:

$$p = A \cdot \int_0^T \sigma(t)\ \mathrm{d}t$$

p: momentum (up to 1 Ns)
A: cross section
T: pulse duration
σ: mechanical stress (up to 200 MPa for a steel bar with 18 mm diameter)

Particle velocity inside the piezo ceramic

The particle velocity matches the maximum displacement velocity of the elementary cell of the piezo ceramic. The particle velocity can reach several m/s.

Force generation at the beginning of the pulse

The generated force at the beginning of the expansion depends on the actuators cross section, the applied electrical field strength and the type of piezo ceramic. According to the actuators configuration the generated force can reach several 10's kN.

Pulse width

The pulse width depends on the runtime of the mechanical pulse in the actuator, the length of the actuator and sonic velocity. According to the actuators configuration the pulse width reaches from a few µs to over 100 µs.

Achievable displacement

The displacement depends on the type of piezo ceramic, the length of the piezo stack and the electric field strength. According to the actuators configuration a displacement over 100 µm is possible.

For more information please visit: ***www.piezosystem.com***

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