Piezocomposite actuators

Piezos for high forces!
Faster than resonant frequencies!

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

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. This variety of thermal behavior, dynamics, voltage stress and Curie temperature allow piezocomposite actuators to be used in countless applications.

Applications of piezocomposite actuators

Piezocomposite actuators are used for:

- shaker
- 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 HT applications (thermostable)
- high shock resistance and high vibrational excitation through optimized construction
- adjustment of the internal preload

2. Piezoelectrical PIA impulse generators

- adjustable impact parameters like energy/ acceleration/ deflection/ E < 4 Joule; a > 10.000g, ΔL up to > 100µm
- high repeatability of the impact parameters, precise time behavior
- pulse energies in the Joule range
- variable collision- and repetition rate
- lowest rising times in the µs's
- pulse width at about 10 µs
- precise triggering in the µs-range
- contact between actuator and specimen before impulse

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 much as the comparable ceramics for actuators.

physical explanation

When the piezo actuator is charged quickly (square 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. A locking pressure emerges. 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 electrical power pulses when driven by mechanical shocks.

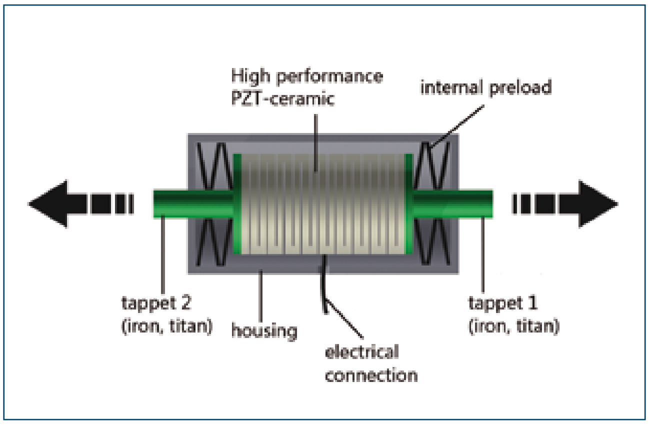


Image 1: Scheme of a symmetric acting shock generator working in axial direction

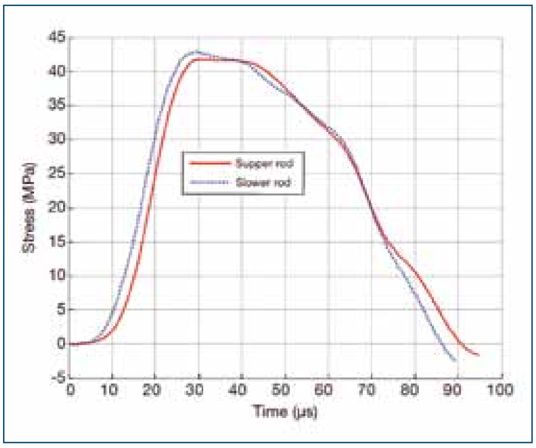


Image 2: Pulse shape of an impulse generator with a symmetrical arrangement

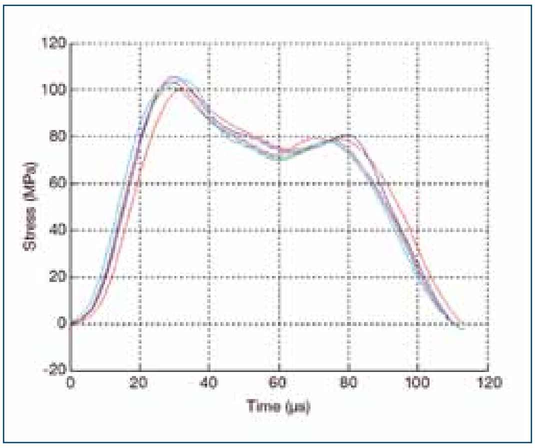


Image 3: typical double-pulse shape with the seismic mass

PIA-electronics - requirements of the electronic

High Voltage Pulser HVP controller

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

The basic principle of the HVP amplifier is the following: A capacitor (multiple 100µF) 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 1000V within a few µs.

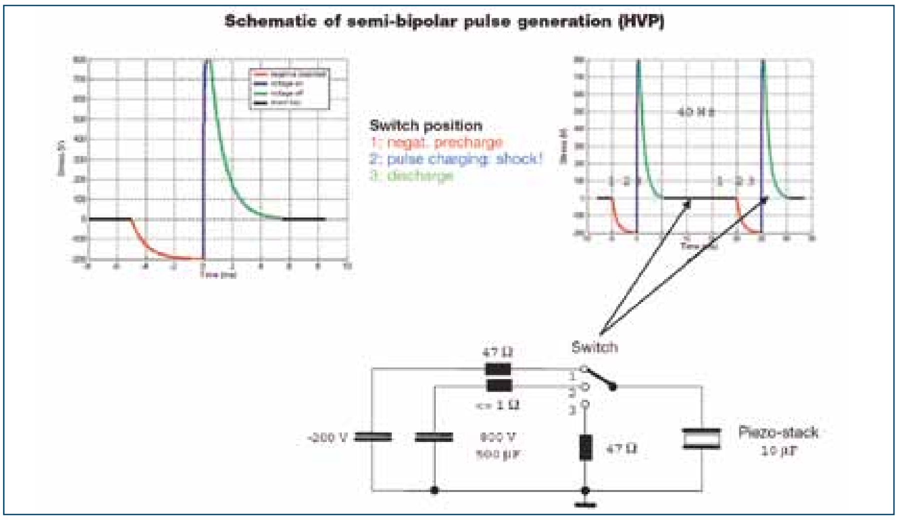


Image 4: schematic bipolar control of a power piezo actuator by a high-voltage-pulser (HVP)

Examples PIA

actuator type	operating voltage [V]	amplitude at max. current [µm]	capacity	max. acceleration [m/s²]
PIA 300/10/3	0 ... 300	7	140 nF	> 100’000
PIA 1000/10/7	0 ... 1000	7	20 nF	> 100’000
PIA 800/35/80	-200 ... 800	80	6,6µF	> 100’000

3. Piezoelectrical PiSha Shaker

- frequency range up to over 100 kHz, depending on the configuration of the shaker
- high accelerations up to 10’000 g
- amplitudes from microns to several hundred microns (depending on operating frequency)
- power modulation of several tens of kN
  (measured under blocking conditions – depending on shaker dimensioning, frequency of operation and installation conditions)
- compact dimensions of the piezoelectric structures down to the millimeter range
- high forces
- thermal management

Operating principle of piezoeletric shakers

Piezo shaker put the electrical excitation signal directly into a motion. Due to the operating voltage of the shaker, the amplitude of the deflection is determined by the charging current and the speed of the shaker movement (in the sub-resonant mode). 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.

Comparisson piezo-shaker / electromagnetic shaker

Compared to their size, piezo shakers have a higher stiffness and force potential at shorter travels than that of electromagnetic shakers.
Further applications are miniaturized components, where piezo technology offers higher power densities and smaller sizes.
Standard-piezo actuators are normally adapted on 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.

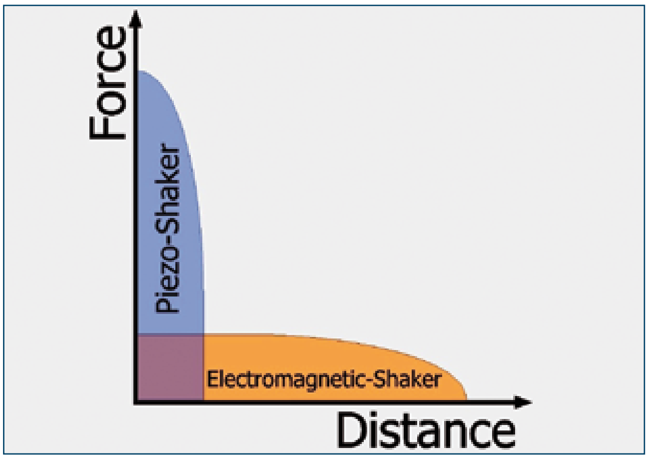


Image 5: Workspaces of piezoelectric and electromagnetic shakers in comparison.

Geo-Shaker:
for vibration - or pulse 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 RCV1000/7 (peak power 7 kW) voltages up to 1000 V
- seismic mass up to 200 kg (depending on the frequency tuning)
- max. vibration 80 microns
- max. force modulation ca. +/-15 kN
- basic response: typically at 200 Hz (depending on the seismic mass)

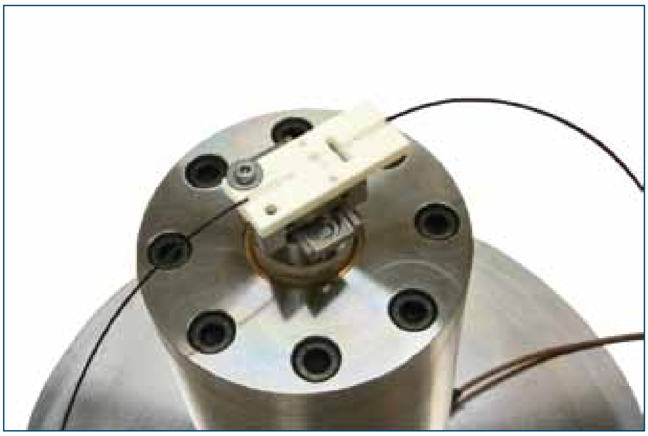


Image 6: Geoshaker with seismic mass

Micro-Shaker: Ring type

- mounting arrangement by clamps or as seismic response type
- 1st resonance up to 100 kHz
- max. amplitude: ±5 µm (frequency dependant)
- max. force modulation up to 1000 Newton (when fixed with clamps)
- max. operating voltage: 150 V
- electrical supply: broadband amplifier LE150/100 EBW

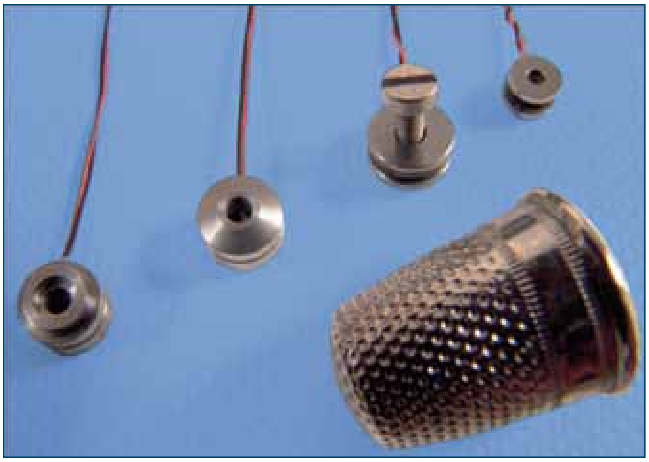


Image 7: different micro-shaker. size comparison with thimble

Examples PiSha

actuator type	operating voltage [V]	oscillation amplitude* [µm]	force modulation (blocking limit) [N]	1st resonant frequency
PiSha 300/10/3	0 ... 150	1,5	1800	30 kHz
PiSha 1000/35/150**	0 ... 1000	75	±15'000 with seismic mass	200 Hz
PiSha	0 ... 150	< 5	1000	100 kHz

* *frequency dependant*

** *with seismic mass of 80 kg (176 lbs)*

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 over +200°C

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [Hz]
PSt 1000/10/7	12/7	9	20	300	60
PSt 1000/10/20	24/18	18	45	150	40
further versions at www.piezo.eu					
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 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 over +200°C

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [Hz]
PSt 1000/10/7 VS18	12/7	24	20	300	40
PSt 1000/10/20 VS18	27/20	33	45	150	3 5
further versions at www.piezo.eu					
PSt 1000/35/150 VS45	200/150	154	570	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 with casing and without preload

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

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [Hz]
HPSt 1000/10-5/7	13/8	9	15	210	50
HPSt 1000/10-5/20	25/17	18	40	110	35
further versions at www.piezo.eu					
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 500V version with diameters 10-5 or 15-8

type	max. stroke* [µm]	length [mm]	electrical capacity [nF]	stiffness [N/µm]	resonant frequency [Hz]
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.piezo.eu					
HPSt 1000/35-25/80 VS45	105/80	89	1300	250	12
HPSt 1000/35-25/100 VS45	130/100	107	180	160	10

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

4.3. Piezo-amplifier

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

- for static and quasi-static applications
- max. current 8 mA
- low noise (~ 1mV at 0.47µF load)
- manual control of DC-offsets

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 3A
- optionally up to 7A on request
- 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 and with capacities in the µF-range.

5. Theory

Force

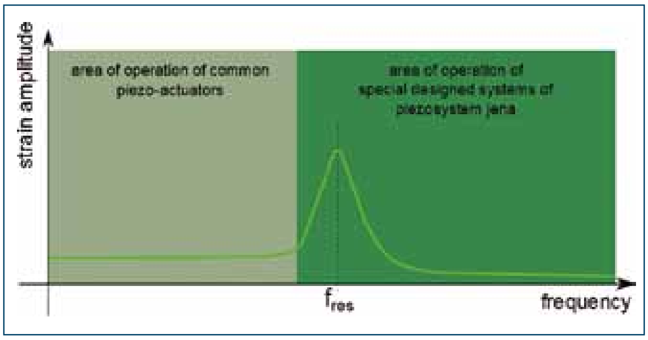
In dynamic applications the generation of tensile and pressure forces are bound to the acceleration. For a sinu-soidal input signal the following formula applies:

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

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 resonance 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 as the common ceramic material.

The mechanical energy content of the impact depends on the ceramic material (piezoelectric charge constant d_{33}, young modulus Y), the volume of the actuator (V) and the applied electric field (E).

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

The generated energy can reach several joules.

Shock pulse

The sock pulse (p) is the product of the mass which is moved into the shock front and the particle velocity. The shock pulse depends on the cross section of the actuator (A) and the used piezo ceramic (mechanical stress σ).

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

According to the actuators configuration the shock pulse can reach up to 1 Ns.

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 plunge 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 of the plunger

The displacement of the plunger 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.piezo.eu***

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