

**Position  
Feedback control electronics  
PosiCon.an  
for piezoactuators  
(low voltage and high voltage actuators)**



Above:  
PosiCon 150/3 with actuator PSt 150/14/20 VS 20, option: position detection.  
Sensor: white cable and actuator: brown cable are connected to channel I.

**株式会社キーストンインターナショナル**

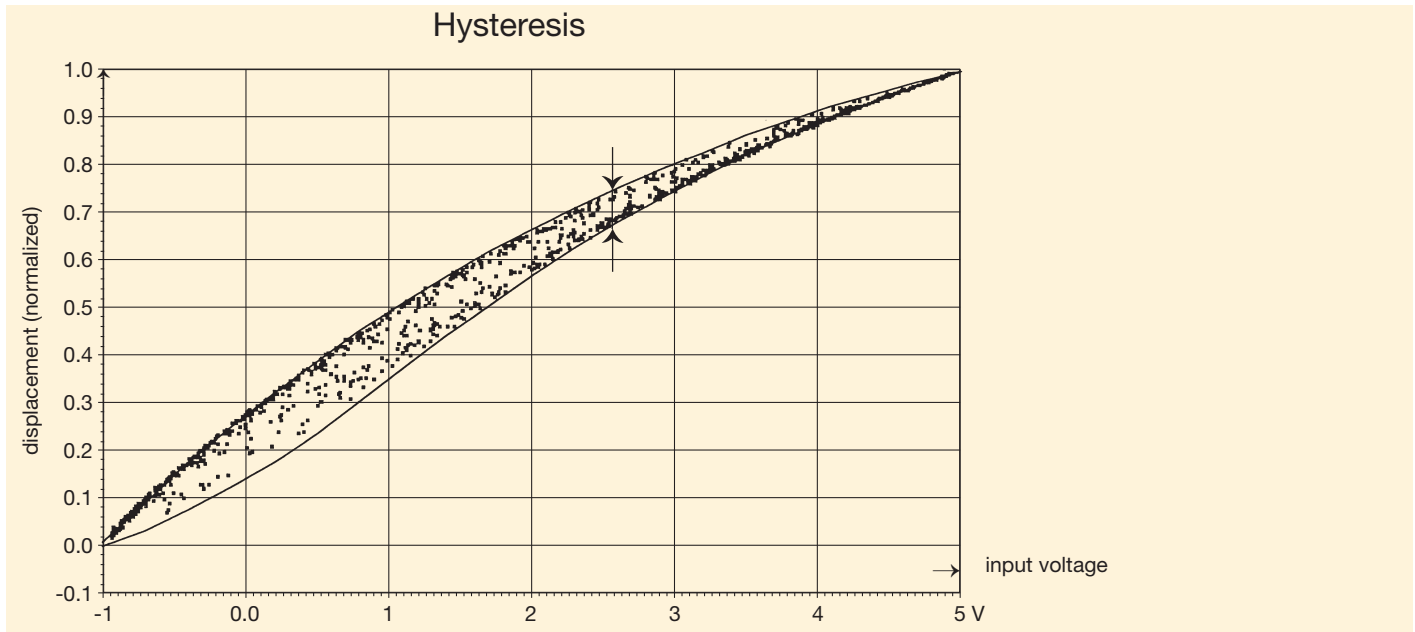
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# Precision positioning by piezoactuators:

## open and closed loop operation

One **essential feature of a piezoceramic actuator** is its ability to make **infinitely small movements**, when a correspondingly small voltage signal is applied. This enables piezoactuators for ultraprecise positioning tasks (unlimited relative positioning sensitivity).

On the other hand, when a large change in the voltage signal is applied to a piezoactuator, the actual position stepwidth can be influenced by a lot of internal and external parameters acting onto the actuator, so that in the first instant, the relationship between voltage and the induced motion can only roughly be predicted. This can be easily demonstrated by applying a series of random voltage steps to a piezoactuator (Fig. 1) or by running a cycle over a distinct voltage range producing the wellknown hysteresis loop.



*Fig.1*  
Open loop correlation of piezo actuator's position and driving voltage for a sequence of random voltage steps. Additionally the usual hysteresis cycle for a continuous full scale voltage variation is shown. The randomly generated sequence of points is filling up the area envelopped by the hysteresis cycle.

When a distinct piezo voltage level is accessed from randomly distributed starting points of the actuator, the uncertainty in the final position is roughly equivalent to the intersect of the hysteresis field with the voltage level. So the uncertainty in open loop piezo positioning in random access operation can be up to 10% to 15% of the actually applied total piezo actuator range.

(In fig.1 the characteristic of a low voltage actuator PSt 150 is shown equivalent a full output voltage range -30 V thru +150 V. The hysteresis intersect (position uncertainty) for 2.5 V input signal at open loop operation is indicated.

**How can this seemingly contradiction to “ultraprecise positioning” be overcome:  
By feedback controlled closed loop positioning:**

**The PosiCon System**

# Basics of closed loop operation:

The actuator produces only a motion, but does obviously not contain inherently a precise information about the exact position.

To get this information about the actual position, the actuator must be combined with a suitable kind of position sensitive effect or sensor. "Suitable" means: sufficiently high in accuracy, repeatability, linearity.

By a feedback control logic, the real position of the actuator is permanently compared with the wanted position, defined by the magnitude of the input signal. When there is a difference between wanted (reference) and real position, the feedback control cancels it immediately out (**closed actuator-sensor loop operation**) and the systems settles at the perfect position.

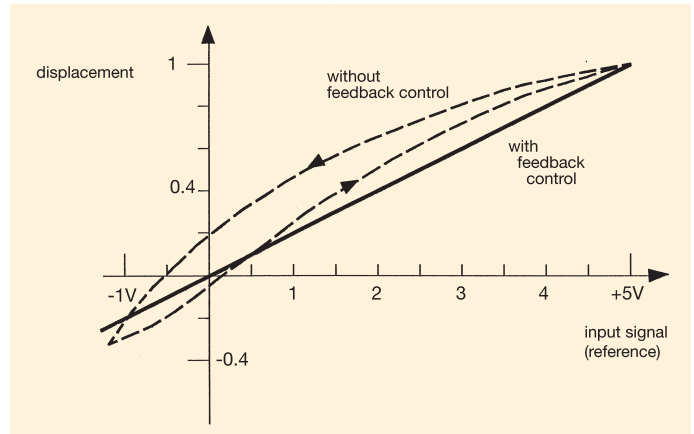


Fig. 2

Relation stroke – reference input voltage to a piezomechanical system in

A open loop operation (by standard amplifier or PosiCon in "feedback off" mode)

Result: typical piezoactuator nonlinear hysteresis characteristic.

Hysteresis about 15 %

B closed loop operation of a PosiCon system together with an actuator with position sensor

Result: linear characteristic with a residual hysteresis: order of magnitude 0.1 % of actuators maximum stroke

## What are the advantages of the feedback controlled PosiCon system

Piezoactuators stroke is measured by a position sensor (strain gage) applied directly onto the piezostack inside the casing:

Hereby the sensor detects all internal and external effects influencing the strain status of the stack:

The result is a

- highly linear and reproducible motion of the actuator according the input reference signal (elimination of piezomaterials creep, hysteresis, nonlinearity).
- automatic selfcompensation for varying load forces, potentially changing the strain of a piezo stack: the PosiCon system shows virtually infinite stiffness (no change of strain under varying forces).
- Special thermally compensated strain gages are used which compensate even for a potential thermal expansion of the actuator.

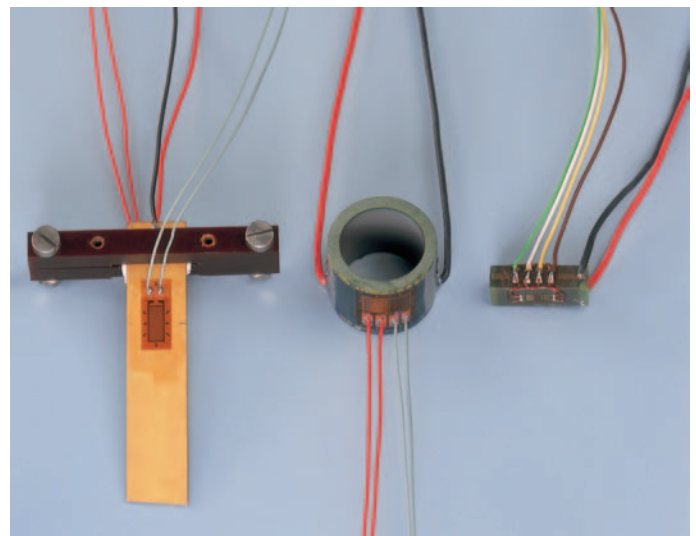


Fig. 3: Variety of piezoactuating components with surface mounted strain gauges

## The PosiCon Philosophy

The “PosiCon.an” piezo positioning system is a complete system comprising all necessary electronic subsystems for closed loop piezo actuator control (Fig. 4):

- position sensor signal amplifier stage
- feedback control logic
- piezo voltage amplifier (SVR type standard)

“Plug and play”:

Connect your piezo actuator and its position sensor to the PosiCon.an unit and put in your position control signal: that's all

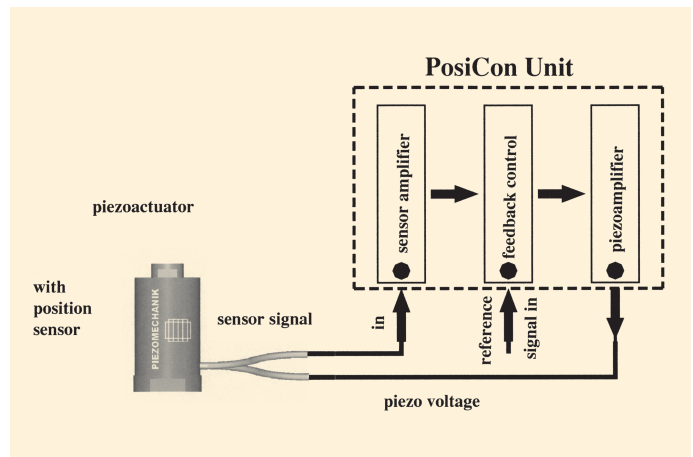


Fig. 4  
Modul Structure of the PosiCon feedback control unit

## Technical details:

### General:

For feedback/closed loop operation, the piezo actuator must accept the voltage range of the PosiCon.an device and show option “position sensor” (see actuator’s data sheet)

The PosiCon.an feedback controllers use analog feedback strategy.

The standard versions use SVR high voltage output stages to supply the piezo actuators (see general catalog “electronic supplies”)

A wide range of positioning applications using even mid-sized actuators are covered with respect to precision and response time.

The SVR amplifier stages provide semi-bipolar operation for largest stroke and feature lowest noise for highly stable positions together with a smooth reaction characteristic of the positioning system.

### Dual use:

The PosiCon.an devices can be used in “closed loop” or “open loop” mode.

The mode selection is done simply by a switch on the front panel.

For multichannel devices, each channel can be set individually. In the “open loop” mode the PosiCon.an acts as simple piezo amplifier as described in catalog “Electronic supplies for Piezomechanics”.

Position information is provided even in the “open loop” mode (see “Display” and “Monitor”)

### Repeatability, Sensitivity

Precision means the tolerance range for hitting a wanted position upon application of the equivalent input signal.

A, for random access addressing of a position, the PosiCon-system can show a repetition tolerance of about  $\pm 1\%$ . A 50  $\mu\text{m}$  actuator can be operated within a  $\pm 50$  nanometer tolerance field (residual hysteresis)

B, the repeatability is still better for cyclic motion profiles

C, the minimum resolvable relative shift in position is about 5 nm in the closed loop mode.

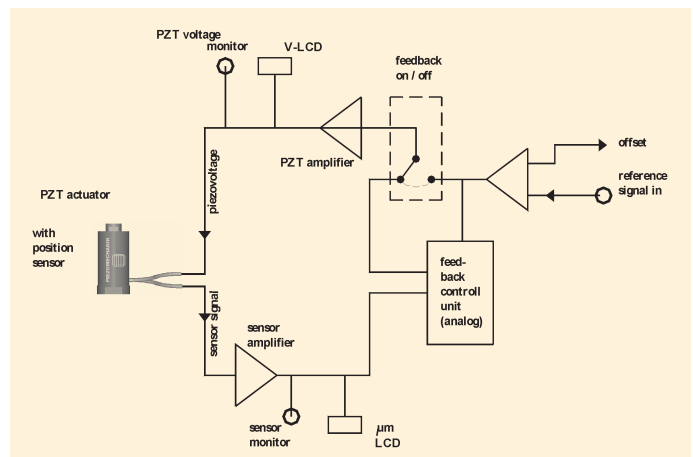


Fig. 5:  
Functional block diagram of a PosiCon system

## Response time

The closed loop response time of a feedback system is defined as the settling time when a new position is addressed. With a well adjusted control loop and sufficient high output power, the settling time can be shorter than 10 msec.

The response time depends to some extent on the capacitance of the actuator and can further be affected by external influences too e.g. by changing the mass load of an actuator or

## Stroke, forces and stiffness

A closed loop systems shows virtually infinitely high stiffness: a change of force load does not change actuator’s position.

**On the other hand:** As shown in the brochure “Piezomechanics: An Introduction” chapter 1.3 piezo actuators show full stroke only, when there is no or neglectable change of the axial force balance acting on the piezo actuator. When axial forces are varying during piezo actuator’s action, then the stroke is reduced.

The fundamental limit of PosiCon.an is reached when the blocking force is applied:

In the closed loop mode the PosiCon.an is encountering for the potential compression by applying the maximum voltage. No further change of stroke is possible.

## Functional elements (see front-page)

### “Offset”

PosiCon.an unit show an “offset” potentiometer per channel for manual setting of a DC-input signal level.

According the “dual use” philosophy of the PosiCon.an system, the function of “Offset” is twofold:

#### Closed loop operation:

A manual setting of the position can be done.

The position varies linearly with “Offset”, no hysteresis and creep.

Variations in position by varying load forces are compensated for automatically.

The “offset” setting is superimposed to external signals, applied to PosiCon.an’s inputs.

#### Open loop operation

A manual setting of the output piezo voltage can be done.

The position of the actuator varies with “Offset” resulting in the normal open loop behaviour with hysteresis and creep.

The “offset” setting is superimposed to external signals.

### LC-displays

for individual “ $\mu\text{m}$ ” and “Volt” reading per channel

Each channel of the PosiCon.an is provided with a double

#### **LCD read out** both for **stroke** and **piezo voltage**.

Even when the system is running open loop, you get information about position.

### Zero-setting:

The starting point of piezo actuator’s action can depend on various side conditions like mounting forces, preloading etc.

To get a reasonable position read-out, each channel for the PosiCon can be set to “zero” individually by a potentiometer in the front panel.

### Gain factor:

The amplifier gain factor of each channel of the PosiCon can be set individually by a switch to accept alternatively **5V or 10V input signal** for full stroke action.

### “Open/closed loop” selector switch “Feedback”

Each channel of the PosiCon can be selected by a switch for “open loop” or “closed loop” operation.

In the “open loop” mode, the PosiCon behaves like a normal piezo amplifier.

Position detection remains active, so position information is provided via “LC-Display” and “Monitor”.

### “Monitor”

Via BNC connectors on front and rear panel, analog signals are provided as real time information for position and piezo-voltage for each channel individually.

Piezovoltage is reduced by a factor 1:1000.

Position is represented as a 5V swing equivalent full stroke.

### Sensor input:

The PosiCon.an unit requires a signal from a 4-element Wheatstone bridge for input.

This sensing element is usually applied to the piezo actuator (Option: position detection).

But the sensor can be attached to an external mechanism too, where the piezo actuator’s motion leads to an equivalent deformation (e.g. hinges of flex stages).

The electrical connecting system is 4-pole LEMO 0S.304

### Piezovoltage output:

The connecting system is

BNC for 150V/500V devices

LEMO 0S.250 or 1000V devices

Optionally, other connecting systems like LEMO 00250 are available.

### Output voltage ranges for standard PosiCon.an devices.

The standard PosiCon.an incorporates SVR amplifier stages as described in catalog “Electronic supplies”. The unique feature is the semibipolar voltage range resulting in a 20 % to 30 % increase of piezo actuator stroke compared to unipolar devices.

PosiCon.an 150: – 30V thru +150V/max. current: 60 mA

PosiCon.an 500: –100 V thru +500V/max. current: 15 mA

PosiCon.an 1000: –200V thru +1000V/max. current: 8 mA

### Optional High Power PosiCons:

To drive large piezo actuators with high dynamics the power requirements may exceed the range of the standard PosiCons.

Optionally High Power PosiCons can be offered on the base of high power amplifier stages

LE150/025

LE430/015

LE150/100

LE150/200

LE1000

### Calibration:

Calibration is only necessary to set the position read outs of the PosiCon.an (“ $\mu\text{m}$ ”-LCD and “Monitor”) to the actuator performance.

Calibration is done at PIEZOMECHANIK factory and is valid for the distinct actuator-PosiCon combination.

Uncalibrated systems work in “closed loop” feedback mode too (compensation for hysteresis, creep etc.), only the position read outs are not valid.

### Available configurations, ordering information

The standard PosiCon.an systems are offered in single and triple channel arrangements.

e.g. PosiCon.an 150/1 or PosiCon.an 150/3.

High power PosiCons are usually delivered as single channel devices.

On request other configurations are offered.

# Piezomechanik's product range

## Piezo stack and ring actuators:

- low voltage and high voltage types
- high dynamic elements for adaptive structure control
- rapid valve switching
- cryo applications down to the sub-Kelvin level
- very long stroke high load elements
- high temperature applications (up to 200 °C)
- UHV application
- Space applications
- Special designed elements
- Bipolar actuators

## Analog / switching amplifiers

- Voltage controller type
  - +150 / +200 V: up to 50 Amperes peak
  - +500 V: up to 20 Amperes peak
  - +1000 V: up to 15 Amperes peak
  - semibipolar supplies for widest range piezo-deflection
- Current and charge controlling amplifiers:
  - for open loop linear and hysteresis free high dynamic operation of piezo actuators
  - low and high voltage / low and high power versions available
- High power, electronic pulsers:
  - pulse powers up to 500 KiloWatts
  - low and high voltage versions
- Constant current pulsers for charge control piezo-driving strategy e.g. in highest speed / high power valve and fuel injection control



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