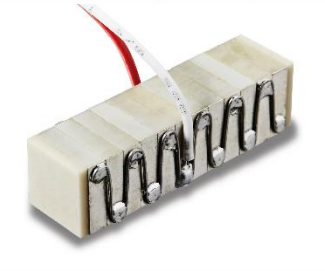
Linear Actuators

Plate Stacks

Features



- Free displacement up to 128.7 µm
- Very low operating voltages (down to 60V)
- Very high force in the kN range
- High stiffness for short response times (<1ms)
- Height up to 80 mm
- Wide range of add-ons

Applications

- Micro- and nanopositioning
- Industrial equipment
- Active vibration control
- Valves
- Laser tuning
- Shaker

Description

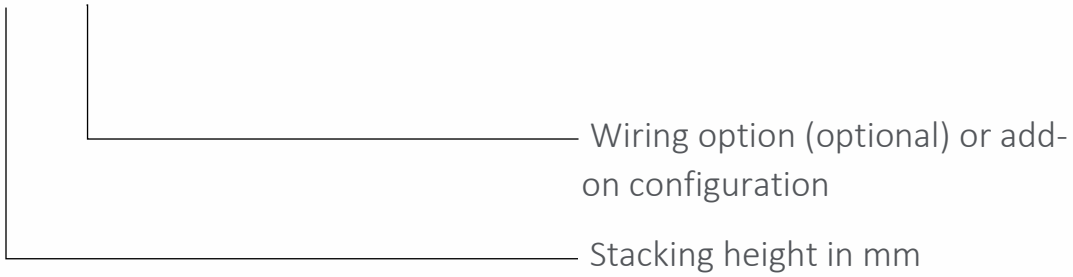
CTS tape cast multilayer piezoelectric linear actuators are ideal for a wide range of electronic designs requiring precise and fast movement. CTS multilayer piezoelectric plate actuator stacks can be stacked to fit the needed height or stroke. Maximum height and stroke are 80 mm and 128.7 µm for our standard products and with a capacitance up to 34050 nF depending of the height of the plate stack. The specific stroke and capacitance of each product can be found below.

Standard Product, add-ons or Custom Solution

This document contains information about the CTS standard multilayer plate stacks and available add-ons. All the CTS multilayer products can be custom designed to match specific requirements – find more information on www.ctscorp.com or contact your local sales representative.

Product Designation

NAC2013-H20-A01



Specifications

Common parameters for the product series:

Product series	NAC2001-HXX	NAC2011-HXX	NAC2002-HXX	NAC2012-HXX	Unit
Length (L)	2 +0.30/-0.10		3 +0.30/-0.10		mm
Width (W)	2 +0.30/-0.10		3 +0.30/-0.10		mm
Max width (W_M)	3.8 Max		4.8 Max		mm
Height (H)	4 to20* +/-0.2 or 1% (whichever is largest)		4 to 30* +/-0.2 or 1% (whichever is largest)		mm
Operating voltage, V_{max}	60	150	60	150	V
Blocking force, 0 to V_{max}	168 +/-20%		378 +/-20%		N
Max. operating temp.	150				°C
Material	NCE51	NCE51F	NCE51	NCE51F	-
External electrodes	Screen-printed silver, tinned copper bus-wire				-

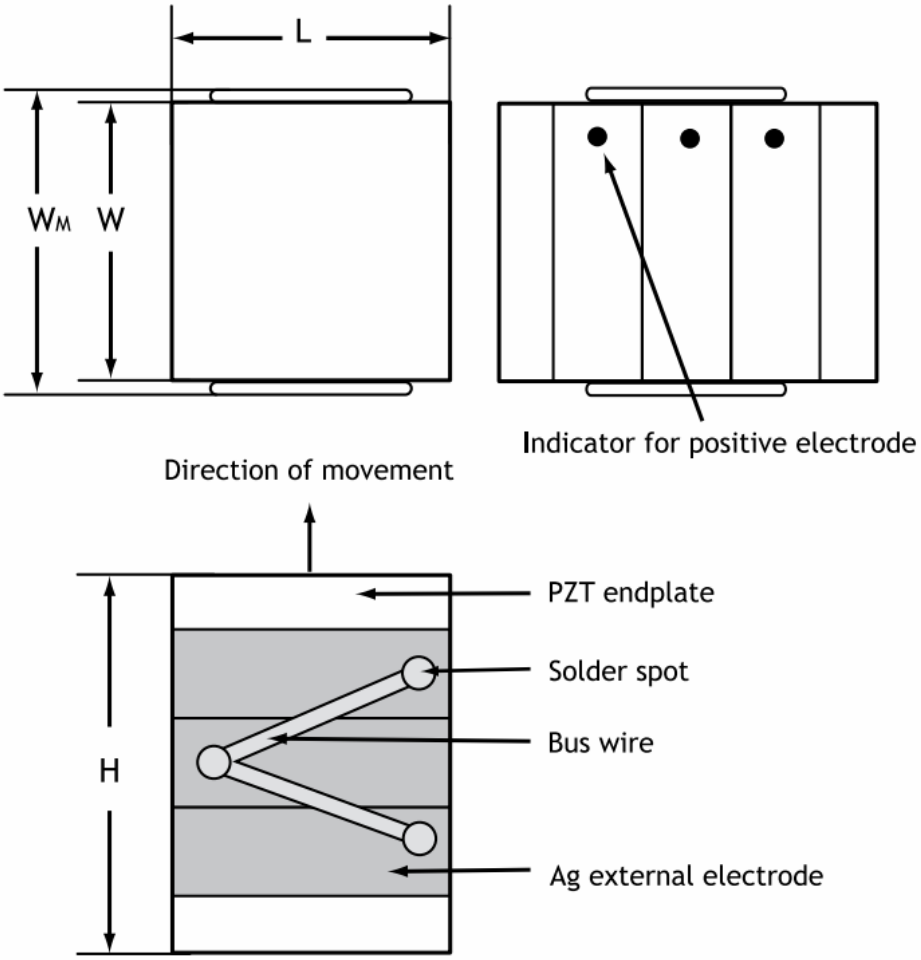
Product series	NAC2003-HXX	NAC2013-HXX	NAC2014-HXX	NAC2021-HXX	Unit
Length (L)	5 +0.30/-0.10		7 +0.30/-0.10		mm
Width (W)	5 +0.30/-0.10		7 +0.30/-0.10		mm
Max width (W_M)	6.8 Max		8.8 Max		mm

Height (H)	4 to 50* +/-0.2 or 1% (whichever is largest)		4 to 70* +/-0.2 or 1% (whichever is largest)		mm
Operating voltage, V_{max}	60	150	150	200	V
Blocking force, 0 to V_{max}	1050 +/-20%		2060 +/- 15%		N
Max. operating temp.	150				°C
Material	NCE51	NCE51F	NCE51F	NCE51F	-
External electrodes	Screen-printed silver, tinned copper bus-wire				-

Product series	NAC2015-HXX	NAC2022-HXX	NAC2023-HXX	Unit
Length (L)	10 +0.30/-0.10		15 +0.30/-0.10	mm
Width (W)	10 +0.30/-0.10		15 +0.30/-0.10	mm
Max width (W_M)	11.8 Max		16.8 Max	mm
Height (H)	4 to 80* +/-0.2 or 1% (whichever is largest)		4 to 80* +/-0.2 or 1% (whichever is largest)	mm
Operating voltage, V_{max}	150	200	200	V
Blocking force, 0 to V_{max}	4200 +/- 20%		9450 +/- 20%	N
Max. operating temp.	150			°C
Material	NCE51F			-
External electrodes	Screen-printed silver, tinned copper bus-wire			-

* See the different height options and corresponding free displacement and capacitance data in the tables below.

Drawing



Stacking Options

	NAC2001-Hxx		NAC2011-Hxx	
Height (H)	Free Stroke	Capacitance	Free Stroke	Capacitance
+/-0,2 mm or 1%*	+/-15%	+/-15%	+/-15%	+/-15%
mm	µm	nF	µm	nF
4	2.6	130	2.8	20
6	5.1	260	5.6	40
8	7.7	380	8.4	60
10	10.2	510	11.2	90
12	12.8	640	14.0	110
14	15.3	770	16.8	130
16	17.9	890	19.6	150
18	20.4	1020	22.4	170
20	23.0	1150	25.2	190

* whichever is largest

	NAC2002-Hxx		NAC2012-Hxx	
Height (H)	Free Stroke	Capacitance	Free Stroke	Capacitance
+/-0,2 mm or 1%*	+/-15%	+/-15%	+/-15%	+/-15%
mm	µm	nF	µm	nF
4	2.9	360	3.1	60
6	5.7	720	6.3	120
8	8.6	1080	9.4	190
10	11.4	1440	12.5	250
12	14.3	1800	15.7	310
14	17.1	2160	18.8	370
16	20.0	2520	21.9	430
18	22.8	2880	25.1	490
20	25.7	3240	28.2	560
22	28.5	3600	31.4	620
24	31.4	3960	34.5	680
26	34.2	4320	37.6	740
28	37.1	4680	40.8	800
30	39.9	5040	43.9	860

* whichever is largest

	NAC2003-Hxx		NAC2013-Hxx	
Height	Free Stroke	Capacitance	Free Stroke	Capacitance
+/-0,2 mm or 1%*	+/-15%	+/-15%	+/-15%	+/-15%
mm	µm	nF	µm	nF
4	3	1030	3.3	180
6	6	2050	6.6	360
8	9	3080	9.9	540
10	12	4100	13.2	720
12	15	5130	16.5	900
14	18	6160	19.8	1080
16	21	7180	23.1	1260
18	24	8210	26.4	1440
20	27	9230	29.7	1620
22	30	10260	33.0	1810
24	33	11290	36.3	1990
26	36	12310	39.6	2170
28	39	13340	42.9	2350
30	42	14360	46.2	2530
32	45	15390	49.5	2710
34	48	16420	52.8	2890
36	51	17440	56.1	3070
38	54	18470	59.4	3250
40	57	19490	62.7	3430
42	60	20520	66.0	3610
44	63	21550	69.3	3790
46	66	22570	72.6	3970
48	69	23600	75.9	4150
50	72	24620	79.2	4330

* whichever is largest

	NAC2014-Hxx		NAC2021-Hxx	
Height	Free Stroke	Capacitance	Free Stroke	Capacitance
+/-0,2 mm or 1%*	+/-15%	+/-15%	+/-15%	+/-15%
mm	µm	nF	µm	nF
4	3.3	340	3.3	200
6	6.6	680	6.6	400
8	9.9	1030	9.9	590
10	13.2	1370	13.2	790
12	16.5	1710	16.5	990
14	19.8	2050	19.8	1190
16	23.1	2390	23.1	1390
18	26.4	2740	26.4	1580
20	29.7	3080	29.7	1780
22	33.0	3420	33.0	1980

24	36.3	3760	36.3	2180
26	39.6	4100	39.6	2380
28	42.9	4450	42.9	2570
30	46.2	4790	46.2	2770
32	49.5	5130	49.5	2970
34	52.8	5470	52.8	3170
36	56.1	5810	56.1	3370
38	59.4	6160	59.4	3560
40	62.7	6500	62.7	3760
42	66.0	6840	66.0	3960
44	69.3	7180	69.3	4160
46	72.6	7520	72.6	4360
48	75.9	7870	75.9	4550
50	79.2	8210	79.2	4750
52	82.5	8550	82.5	4950
54	85.8	8890	85.8	5150
56	89.1	9230	89.1	5350
58	92.4	9580	92.4	5540
60	95.7	9920	95.7	5740
62	99.0	10260	99.0	5940
64	102.3	10600	102.3	6140
66	105.6	10940	105.6	6340
68	108.9	11290	108.9	6530
70	112.2	11630	112.2	6730

* whichever is largest

	NAC2015-Hxx		NAC2022-Hxx	
Height	Free Stroke	Capacitance	Free Stroke	Capacitance
+/-0,2 mm or 1%*	+/-15%	+/-15%	+/-15%	+/-15%
mm	µm	nF	µm	nF
4	3.3	680	3.3	400
6	6.6	1370	6.6	790
8	9.9	2050	9.9	1190
10	13.2	2740	13.2	1580
12	16.5	3420	16.5	1980
14	19.8	4100	19.8	2380
16	23.1	4790	23.1	2770
18	26.4	5470	26.4	3170
20	29.7	6160	29.7	3560
22	33.0	6840	33.0	3960

24	36.3	7520	36.3	4360
26	39.6	8210	39.6	4750
28	42.9	8890	42.9	5150
30	46.2	9580	46.2	5540
32	49.5	10260	49.5	5940
34	52.8	10940	52.8	6340
36	56.1	11630	56.1	6730
38	59.4	12310	59.4	7130
40	62.7	13000	62.7	7520
42	66.0	13680	66.0	7920
44	69.3	14360	69.3	8320
46	72.6	15050	72.6	8710
48	75.9	15730	75.9	9110
50	79.2	16420	79.2	9500
52	82.5	17100	82.5	9900
54	85.8	17780	85.8	10300
56	89.1	18470	89.1	10690
58	92.4	19150	92.4	11090
60	95.7	19840	95.7	11480
62	99.0	20520	99.0	11880
64	102.3	21200	102.3	12280
66	105.6	21890	105.6	12670
68	108.9	22570	108.9	13070
70	112.2	23260	112.2	13460
72	115.5	23940	115.5	13860
74	118.8	24620	118.8	14260
76	122.1	25310	122.1	14650
78	125.4	25990	125.4	15050
80	128.7	26680	128.7	15440

* whichever is largest

NAC2023-Hxx		
Height	**Free Stroke**	**Capacitance**
+/-0,2 mm or 1%*	+/-15%	+/-15%
mm	µm	nF
4	3.3	870
6	6.6	1750
8	9.9	2620
10	13.2	3490
12	16.5	4370

14	19.8	5240
16	23.1	6110
18	26.4	6980
20	29.7	7860
22	33.0	8730
24	36.3	9600
26	39.6	10480
28	42.9	11350
30	46.2	12220
32	49.5	13100
34	52.8	13970
36	56.1	14840
38	59.4	15710
40	62.7	16590
42	66.0	17460
44	69.3	18330
46	72.6	19210
48	75.9	20080
50	79.2	20950
52	82.5	21830
54	85.8	22700
56	89.1	23570
58	92.4	24440
60	95.7	25320
62	99.0	26190
64	102.3	27060
66	105.6	27940
68	108.9	28810
70	112.2	29680
72	115.5	30560
74	118.8	31430
76	122.1	32300
78	125.4	33170
80	128.7	34050

* whichever is largest

Stack heights exceeding listed values on request.

Add-ons

Wire Options

When you order actuators from CTS, you can have wires fitted to save time and money. However, you should consider these parameters, when you select a wire for connection:

- Operation voltage
- Intensity of current
- Operating temperature
- Environment for example vacuum

We recommend wires with PTFE insulation

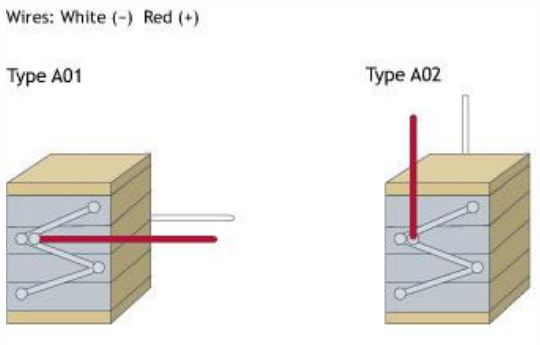
PTFE wires can stand temperatures above 200 °C, whereas PVC wires only resist temperatures up to 80 °C. We recommend PTFE for the thermal and chemical resistance of the insulation.

For vacuum and cryogenic applications, we recommend Kapton wires, which offer superior outgassing and flexibility.

Standard wire options for Plate Stacks

Two standard wire options are available:

		Option A01	Option A02
Wire type	NAC2001, NAC2011, NAC2002, NAC2012	MIL-W-16878/6, 32 AWG, 7 strands	
	NAC2003, NAC2013, NAC2014, NAC2021, NAC2015, NAC2022, NAC2023	MIL-W-16878/4, 28 AWG, 7 strands	
Length		200mm +/-10mm	
Position		Middle of the actuator	
Direction		Perpendicular to the height	Toward the top



Wire gauge (AWG)

The wire gauge (AWG) and insulation type should be determined according to the voltage, current and operating environment. Should the standard –A01 or –A02 configuration not suit your application, we offer several alternative wire types:

Wire type	Voltage rating [V]	Approx. outer diameter [mm]	Rec. max. current [A]	Min. operating temperature [°C]
32AWG, MIL-W-16878/6, 7 strands	250	0.6	0.53	-60
30AWG, MIL-W-16878/4, 7 strands	600	0.8	0.86	-60
28AWG, MIL-W-16878/4, 7 strands	600	0.9	1.4	-60
28AWG, Allectra 311-KAPM-035 (Kapton insulation, UHV)	1000*	0.5	1.0	-269
22AWG, BS3G210 Type A, 19 strands	300	1.1	8	-75

* In vacuum conditions

As part of our custom program, we can also stock specific wire.

UHV preparation

Ultra high vacuum (UHV) is the vacuum regime characterized by pressures lower than about 10^{-7} pascal or 100 nanopascals (~10^{-9} torr). Extreme cleanliness and low outgassing are essential parameters in sustaining the vacuum level in such systems. Elevated temperature compatibility is often needed since water vapor and other trace gasses are removed from the system during a "bake-out".

CTS piezoceramic components are designed to support system development and integration of piezo technology in UHV applications. Among many technical capabilities, CTS is competent in producing piezoelectric actuators meeting the demands on temperature compatibility and out gassing levels set by UHV operation.

For low outgassing, Kapton-insulated wires are recommended. In addition, with the UHV preparation the products will undergo a specific cleaning process and be packaged in sealed pouches.

Reduced tolerances

For demanding applications, piezoelectric actuators can be re-worked after stacking in order to achieve better geometrical and dimensional properties. CTS offer this customization possibility for stacks with cross sections of 5x5 mm, 7x7 mm and 10x10 mm.

Product series	Standard heigh tolerance	Reduced height tolerance
NAC2003 NAC2013	+/-0.2mm or +/-1%*	+/-0.025mm
NAC2014 NAC2021	+/-0.2mm or +/-1%*	+/-0.040mm
NAC2015 NAC2022	+/-0.2mm or +/-1%*	+/-0.050mm

* whichever is largest

In addition, it is possible to re-work the length or specify a smaller maximum width. These possibilities are available through our custom program.

Strain-gauge

A strain gauge is a simple way of obtaining feedback on the deformation of a piezoelectric actuator, typically to achieve closed-loop control. Strain gauges are recommended for experimental setups and small series. CTS offer a standard version for piezo plate actuators (single and stacked) which is designed as a half bridge with two grids at 90°. The strain gauge is a very compact solution and can therefore be fitted to actuators with a free surface of 5x5 mm or bigger, i.e. series NAC2003/NAC2013 and above.

The characteristics of the strain gauge are:

Strain gauge parameters	
Nominal resistance	350 Ω
Nominal sensitivity	1 mV/V
Maximal range of deformation	2%
Deformation range of the actuator	0.1 – 0.2 % Depending on the actuator type
Temperature range	-40 – +150 °C
Recommended supply voltage	5 V AC or DC Depending on temperature range and heating of the gauge

The bandwidth of the measurement system will depend on the signal conditioner that is used. A conditioner with a carrier frequency will typically have a cutoff frequency below 200Hz. “DC” type conditioners have a wider bandwidth but are more sensitive to noise.

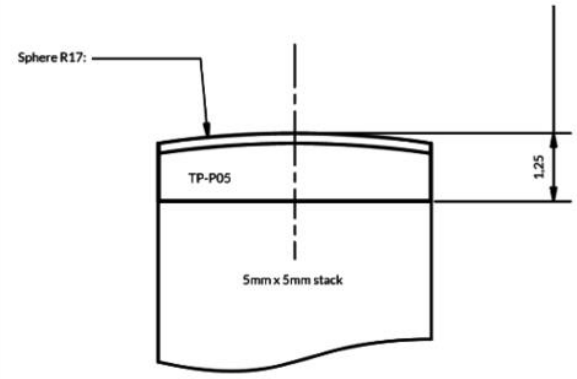
The strain gauge has a range of 2% strain while the stack typically generates 0.18% strain (at room temperature). Therefore the output range will be about 9% of the full range. The nominal gauge factor specified by the manufacturer is 1,99+/-2%. However if quantitative measurements are required, it is recommended to perform an initial characterization of the strain-gauge directly in the application using an external sensor.

End-pieces

Metallic end-pieces can be useful in terms of:

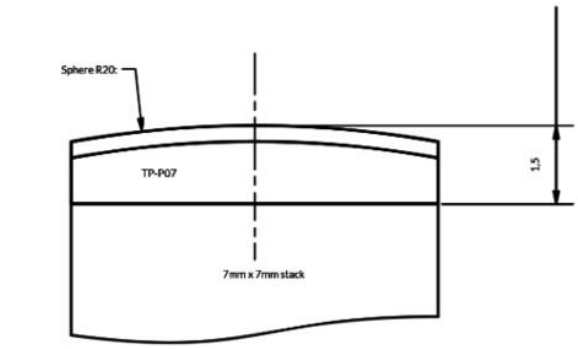
- Spreading a high mechanical load on the whole surface of an actuator
- Providing some de-coupling, i.e. allowing a stack to tilt
- Centering an actuator in an assembly

CTS stock end-pieces for our most popular cross-sections (5x5, 7x7 and 10x10 mm). The material is stainless steel (AISI 316). These products are compatible with:



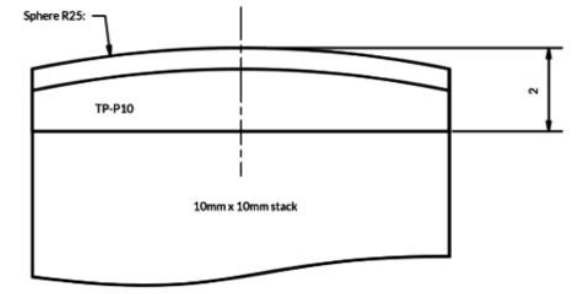
End-piece TP-P05: 5x5 mm

NAC2003-Hxx, NAC2013-Hxx



End-piece TP-P07: 7x7 mm

NAC2014-Hxx, NAC2021-Hxx



End-piece TP-P10: 10x10 mm

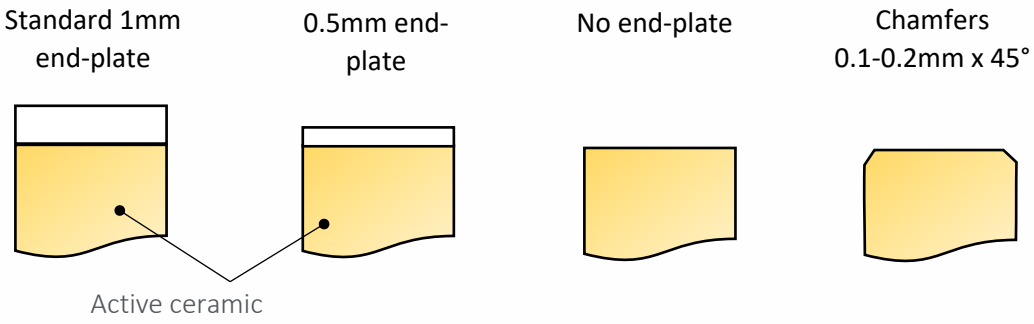
NAC2015-Hxx, NAC2022-Hxx

The design is compact, with spherical caps providing some de-coupling, thereby releasing the requirements on alignment. The parts are low-magnetic and compatible with our other add-ons (UHV, wires etc.). End-pieces can be attached at one or both ends of a stack. They can be supplied with a short lead-time and are more cost-effective for small series.

End-plates

As a standard, piezoelectric stacks are supplied with 1mm thick ceramic end-plates. All our standard end-plates and end rings are produced with our piezoceramic material NCE51. Ceramic provides ideal electrical insulation properties, low thermal expansion mismatch as well as good mechanical properties to spread the load over the surface of the active piezoceramic. We recommend a thickness of 1mm for a good spread of the load.

It is nevertheless possible to use different configurations as illustrated below:



Note that stacks without end-plates or chamfers must not be mounted against a conductive surface, to avoid the risk of short-circuits between the surface electrodes.

Storage

We recommend storing piezoelectric ceramic components in a cool and dry environment to avoid tarnishing of the silver electrodes. The ceramic material itself is not affected by humidity, as long as no voltage is applied. If components have been stored in uncontrolled environment, we recommend drying them thoroughly before use. Heat drying is well adapted, for example 24h at 110°C, if possible in low-pressure environment.

Piezoelectric components can be stored for many years without problem. Piezoelectric ceramic is subject to aging from the date of poling, meaning that performance (capacitance, stroke) will decrease according to a logarithmic trend, typically 2-5% per decade (after 1 day, 10 days, 100 days…).

Handling

Piezoelectric ceramic components are fragile and must be handled with care. We recommend to:

- Prevent the components from hitting each other or hard surfaces, keep components separate
- Particularly for tall, narrow stacks, make sure that no bending is induced
- Use plastic tweezers and tools rather than metallic ones
- Use gloves to avoid contamination
- Do not apply excessive force on the pre-attached wires

When submitted to a force or to temperature changes, be aware that piezoelectric components will generate charge (i.e. voltage when in open circuit), so they must be properly discharged before use. Always discharge through a resistor rather than shorting the wires, as it would create high dynamic forces that can damage the component. It is recommended to keep larger components short-circuited during shipment and storage to avoid charge build-up.

Cleaning

For the cleaning of ceramic components, we recommend isopropyl-alcohol (propanol) or ethanol. The components have to be thoroughly dried before use. If needed, linear stacks can be fully submerged in solvent, however we recommend to limit the exposure to a few seconds to avoid weakening of the epoxy.

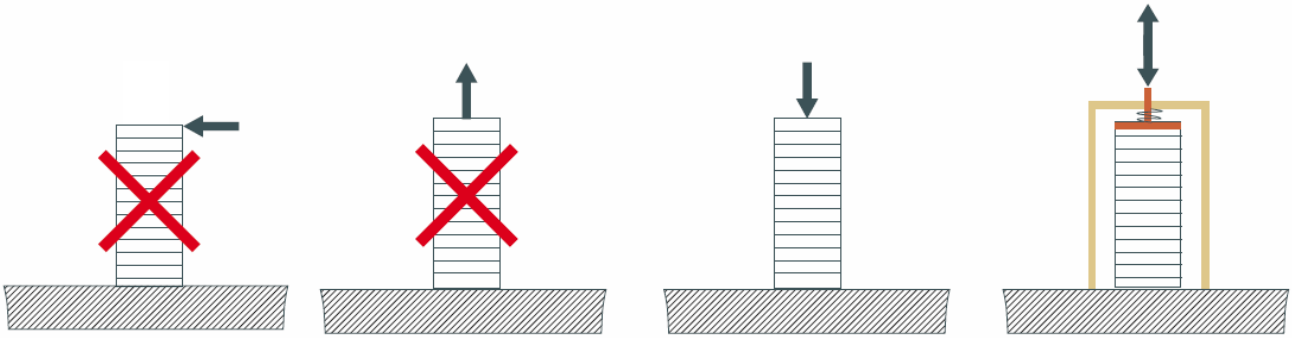
Mounting

Linear stacks offer flat and parallel surfaces for mounting. The actuators may be mounted either by mechanical clamping or using adhesive.

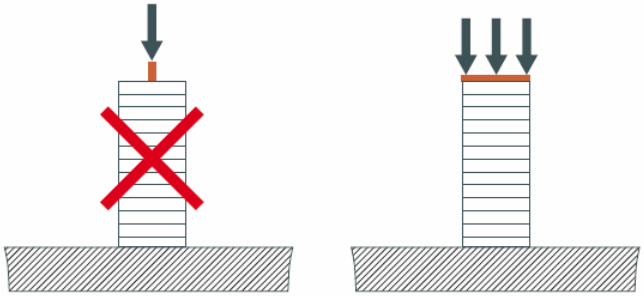
General recommendations

Piezoelectric ceramics can tolerate high compressive stress, but only limited tensile stress. CTS actuators can be safely operated without preload in quasi-static conditions, however preload is required to achieve the specified stiffness and dynamic performance. We recommend 5 MPa preload for quasi-static applications, 10 MPa for dynamic applications and up to 40 MPa in specific high loading conditions.

We recommend to avoid tensile stress, which could result from direct pulling, inertial forces or bending forces. If pull or bending forces cannot be avoided, the actuator must be properly pre-stressed to ensure tensile stress is eliminated. Refer to our online tutorial for additional information on the estimation of stack loads.

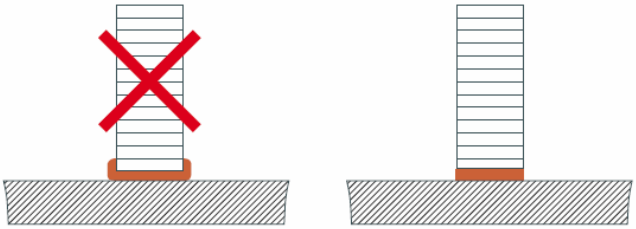


The mechanical load must be applied on the full surface of the actuator in order to avoid stress concentrations.



Mounting using adhesive

Epoxy adhesives are well suited for mounting piezoceramics. For linear actuators, we recommend using a semi-soft (Shore D hardness 50-70), non-conductive, unfilled epoxy. When bonding, it is important to ensure a very thin glue line between the actuator and the substrate. It is recommended to apply a pressure, e.g. 2-5 MPa, during the curing process. To avoid significant loss of performance, the mounting should avoid adhesive on the sides of the actuator.



Connecting and Driving

Linear actuators are easily connected using the optional wires. Alternatively, soldering, conductive epoxy, conductive film or mechanical contacting can be used. Refer to our website for soldering guidelines.

Ensure that the stacks are properly discharged and that there is no voltage on the output when connecting to a driver. Voltage differences will generate current peaks that can damage the actuator or the driver.

The current capability of the driver must be adapted to the driving signal. Due to the capacitive nature of the piezoelectric actuator, fast motion will often require very high currents. Please refer to our online tutorial for guidance about current calculation.

We recommend to add a resistance in series with the actuator to form a RC circuit to limit the peak current, bandwidth and eventual noise that may be generated by the driver.

Linear Actuators Product Families

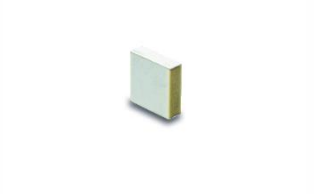


Plate and Ring Actuators

Stacked Actuators:

- Plate Stacks
- Plate Stacks, compact
- Ring Stacks
- High Temperature Stacks
- Damage Tolerant Stacks

Preloaded Actuators

Learn more about the different linear actuators product families on www.ctscorp.com.