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THORLABS

PA3JE-1K - February 26, 2018

Item # PA3JE-1K was discontinued on February 26, 2018. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

LOW-VOLTAGE PIEZOELECTRIC CHIPS, 0.7 MM - 3.6 MM TRAVEL

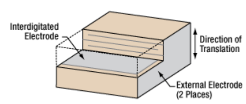
- Low-Voltage Piezo Chips with 75 V, 100 V, or 150 V Max Voltage
- Sub-Millisecond Response Time with No Load
- Available Unwired, Wired, and in Packs of 16, 25, or 1000

Application Idea
Piezo Chips Tune the Position of a Ø1" Mirror in a Laser Cavity

OVERVIEW

Features

- Sub-Micron Resolution
- Mounting Face Dimensions from 0.9 mm x 0.9 mm to 10.0 mm x 10.0 mm
  - Custom Options Available by Contacting Tech Support
- Drive Voltage Range of 0 - 75 V, 0 - 100 V, or 0 - 150 V
- Recommended Loads from 13 N (3 lbs) to 1600 N (360 lbs)
- For Use in Open-Loop Setups
- Many Chips Available with Pre-Attached Wires
- Ideal for Vacuum and OEM Applications
- End Hemispheres and Flat End Plates also Available Separately



Click to Enlarge
Three-Dimensional Cross Section of Multilayer Piezo with Interdigitated Electrodes (Item # TA0505D024 Shown); Dashed Lines Indicate Cutaway

Webpage Features	
(i)	Clicking this icon below will open a window that contains item specific specifications and mechanical drawings.

Piezo Selection Guide[a]
Piezo Chips
Square
Square with Through Hole
Round
Ring
Shear
Benders
Piezo Stacks
Discrete, Square
Discrete, Square with Through Hole
Discrete, Round
Discrete, Ring
Discrete, Shear (1D to 3D Positioners)
Co-Fired, Square
Co-Fired or Discrete, Square with Strain Gauges
Piezo Actuators
Mounted

- For more information about the design and function of piezoelectric chips, please see our piezoelectric tutorial.

Thorlabs' piezoelectric actuators are fabricated from layered sheets of piezoelectric ceramic as is shown in the diagram at upper right and described in the *Manufacturing Our Piezoelectric Chips and Stacks* box below. Electrodes are printed on each sheet before they are layered, and a precision lapping process ensures the height tolerance of each chip is better than ±5 µm. The compact multilayer design results in chips with high resonant frequencies and sub-millisecond response times.

These actuators are characterized by precision movement and produce free stroke (unloaded conditions) displacements from 0.7 µm to 3.6 µm. The maximum displacement of these actuators is achieved when they are preloaded with the maximum displacement load, which is specified for each product. The actual value of the maximum displacement varies for each item and must be experimentally determined; however, the maximum displacement will always be larger than the free stroke displacement. Please see the *Operation* tab for additional information.

Electrodes are included on each layer of the chip, as this minimizes the voltage required to drive them. Our piezoelectric chips are available with one of three drive voltage ranges: 0 - 75 V, 0 - 100 V, or 0 - 150 V. When your application is highly sensitive to voltage, consider our chips with maximum drive voltages of 75 V. For applications that are less sensitive, the 100 V and 150 V options have longer lifetimes. For a complete list of specifications, see the tables below.

Four sides of the chip are coated with a ceramic layer that acts as a barrier against moisture. The ceramic layer offers better protection against moisture than an epoxy coating. Screen-printed silver electrodes are printed on the other two sides of the chip, to which the drive voltage is applied. The positive side will be denoted with either a silver "+" or by a black dot. For convenience, many of our products ship with 75 mm wires soldered to these two sides.

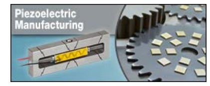
To accommodate a variety of loading conditions, flat ceramic or hemispherical ceramic endplates may be purchased as accessories for these chips. In addition, Thorlabs offers conical end cups, which are compatible with ball contacts possessing diameters between 1.5 to 7.0 mm. Please see the *Operation* tab for information on interfacing piezoelectric actuators with loads, special operational considerations, and data that will allow the lifetimes of these actuators to be estimated when their operational conditions are known.

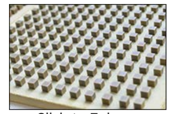
Piezoelectric chips with custom dimensions, voltage ranges, and coatings are available. Additionally, we support high-volume orders. Please contact Tech

Support for more information.

Thorlabs' In-House Piezoelectric Manufacturing

Our piezoelectric chips are fabricated in our production facility in China, giving us full control over each step of the manufacturing process. This allows us to economically produce high-quality products, including custom and OEM devices. A glimpse into the fabrication of our piezoelectric chips follows. For more information about our manufacturing process and capabilities, please see our Piezoelectric Capabilities page.




Click to Enlarge
Chips After Binder Burnout and Sintering


Click to Enlarge
Dicing the PZT Block into Individual Elements

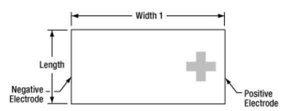
- Build Blocks from Flexible Sheets of Lead Zirconate Titanate (PZT) Powder
  - Screen Print Electrodes on Each Individual Sheet
  - Layer the Printed Sheets One Top of Another
  - Consolidate the Layered Sheets in an Isostatic Press
- Dice the Block into Individual Elements
- Purge Solvent and Binder Material Residues by Heat Treating the Elements
- Sinter the Elements to Fuse the Piezoelectric Pressed Powder and Grow PZT Crystals
- Lap the Elements to Achieve Tight Dimensional Tolerances: ±5 µm for Each Element
- Screen Print the Outer Electrodes on the Elements
- Align the Individual PZT Crystals Along the Same Axis by Poling the Elements

OPERATION

Operation Notes

Power Connections

A positive bias should be applied across the device. The positive electrode should receive positive bias, and the other electrode should be connected to ground. Applying a negative bias across the device may cause mechanical failure. For products that ship with wires attached, the positive wire may be identified in two ways: it is red, as can be seen in the product images, and it is attached to the electrode on the side of the chip indicated by a + mark, as is depicted in the image at right. (On some devices, the + mark is replaced by a dot.) The wire that should be grounded is black, and it is attached to the electrode on the side of the chip opposite the side with the positive electrode.



Click to Enlarge
Schematic of TA0505D024W Piezo Chip

Preloading

The maximum displacement of these actuators is achieved when they are preloaded with the maximum displacement load, which is specified for each product. The actual value of the maximum displacement varies for each item and must be experimentally determined; however, the maximum displacement will always be larger than the free stroke displacement. Preloading increases the length of the actuator's stroke because the poling process performed during fabrication does not align all ferroelectric grains in the piezoelectric material in the same direction. Preloading the actuator mechanically forces many of the mis-aligned grains into a more ideal alignment. Applying a driving voltage across the piezo material causes the orientations of the ferroelectric grains to rotate so they become aligned with the applied field, and this results in a dimensional change of the piezo material. When more ferroelectric grains are initially aligned in the same direction, the dimensional change of the piezo material in response to the applied driving voltage is greater. Preloads greater than the optimal maximum displacement load result in displacements less than the maximum displacement, as higher loads oppose the switching of the grain orientations in response to the applied driving voltage.

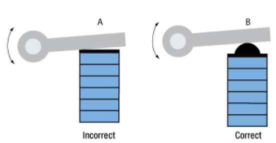
Soldering Wire Leads to the Electrodes

If wire leads must be attached or reattached to the electrodes, a soldering temperature no higher than 370 °C (700 °F) should be used, and heat should be applied to each electrode for a maximum of 2 seconds. Solder the lead to the middle of the electrode and keep the region over which heat is applied as small as possible.

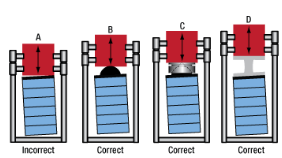
Interfacing a Piezoelectric Element with a Load

Piezoceramics are brittle and have low tensile strength. Avoid loading conditions that subject the actuator to lateral, transverse, or bending forces. When applied incorrectly, an external load that may appear to be compressive can, through bending moments, cause high tensile stresses within the piezoelectric device. Improperly mounting a load to the piezoelectric actuator can easily result in internal stresses that will damage the actuator. To avoid this, the piezoelectric actuator should be interfaced with an external load such that the induced force is directed along the actuator's axis of displacement. The load should be centered on and applied uniformly over as much of the actuator's mounting surface as possible. When interfacing the flat surface of a load with an actuator capped with a flat mounting surface, ensure the two surfaces are highly flat and smooth and that there is good parallelism between the two when they are mated. If the external load is directed at an angle to the actuator's axis of displacement, use an actuator fitted with a hemispherical end plate or a flexure joint to achieve safe loading of the piezoelectric element.

To accommodate a variety of loading conditions, flat ceramic or hemispherical ceramic end plates may be purchased as accessories for these chips. In addition, Thorlabs offers Conical End Cups which feature concave surfaces that can interface with Ø1.5 mm to Ø7.0 mm hemispherical or curved contacts. To attach a load to the piezo chip, we recommend using an epoxy that cures at a temperature lower than 80 °C (176 °F), such as our 353NDPK or TS10 epoxies or Loctite® Hysol® 9340. Loads should be mounted only to the faces of the piezoelectric chip that translate. Mounting a load to a non-translating face may lead to the mechanical failure of the actuator. Some correct and incorrect approaches to interfacing loads with piezoelectric actuators capped with both kinds of end plates are discussed in the following.



The image at left presents incorrect (A, far-left) and correct (B, near-left) methods for using a piezoelectric element to actuate a lever arm. The correct method uses a hemispherical end plate so that, regardless of the angle of the lever arm, the force exerted is



Click to Enlarge
Actuation of a lever arm using a piezo element fitted with a flat plate (A, Incorrect), and a hemispherical plate (B, Correct).

always directed along the translational axis of the actuator. The incorrect interfacing of the element and the lever arm, shown at far-left, endangers the piezo element by applying the full force of the load to one edge of the element. This uneven loading causes dangerous stresses in the actuator, including a bending moment around the base.

Click to Enlarge
Loads properly and improperly mounted to piezo actuators using a variety of interfacing methods.

The image at right shows one incorrect (near-right, A) and three correct approaches for interfacing a flat-bottomed, off-axis load with a piezoelectric actuator. Approaches A and B are similar to the incorrect and correct approaches, respectively, shown in the image at left. Correct approach C shows a conical end cup, such as the PKFCUP, acting as an interface. The flat surface is affixed to the mating surface of the load, and the concave surface fits over the hemispherical dome of the end plate. In the case of correct approach D, a flexure mount acts as an interface between the off-axis flat mounting surface of the load and the flat mounting plate of the actuator. The flexure mount ensures that the load is both uniformly distributed over the surface plate of the actuator and that the loading force is directed along the translational axis of the actuator.

Operating Under High-Frequency Dynamic Conditions
It may be necessary to implement an external temperature-control system to cool the device when it is operated at high frequencies. The maximum operating temperature of these devices is 130 °C (266 °F), and high-frequency operation causes the internal temperature of the piezoelectric device to rise. The dependence of the device temperature on the drive voltage frequency for each product can be accessed by clicking the Info icons, , below. The temperature of the device should not be allowed to exceed its specified maximum operating temperature.

Estimating the Resonant Frequency for a Given Applied Load
A parameter of significance to many applications is the rate at which the piezoelectric actuator changes its length. This dimensional rate of change depends on a number of factors, including the actuator's resonant frequency, the absolute maximum bandwidth of the driver, the maximum current the piezoelectric device can produce, the capacitance of the piezoelectric actuator, and the amplitude of the driving signal. The length of the voltage-induced extension is a function of the amplitude of the applied voltage driving the actuator and the length of the piezoelectric device. The higher the capacitance, the slower the dimensional change of the actuator.

Quick changes in the applied voltage result in fast dimensional changes to the piezoelectric chip. The magnitude of the applied voltage determines the nominal extension of the chip. Assuming the driving voltage signal resembles a step function, the minimum time, T_{min}, required for the length of the actuator to transition between its initial and final values is approximately 1/3 the period of resonant frequency. If there is no load applied to the piezoelectric actuator, its resonant frequency is f_o and its minimum response time is:

$$T_{min} \cong \frac{1}{3f_o}$$

After reaching this nominal extension, there will follow a damped oscillation in the length of the actuator around this position. Controls can be implemented to mitigate this oscillation, but doing so may slow the response of the actuator.

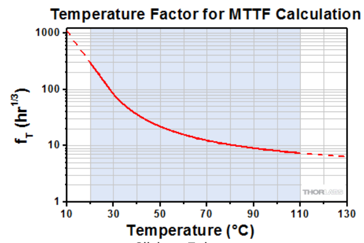
Applying a load to the actuator will reduce the resonant frequency of the piezoelectric chip. Given the unloaded resonant frequency of the actuator, the mass of the chip, m, and the mass of the load, M, the loaded resonant frequency (f_o') may be estimated:

$$f_o' \cong f_o \sqrt{\frac{m/3}{m/3 + M}}$$

Estimating Device Lifetime for DC Drive Voltage Conditions
The lifetime of a piezoelectric device is a function of the operating temperature, applied voltage, and relative humidity conditions. Lifetimes are reduced as a consequence of humidity-driven electrolytic reactions, which occur at the electrodes of the piezoelectric devices when a DC voltage is applied. These reactions both generate hydrogen and result in metal dendrites growing from the cathode towards the anode. The hydrogen liberated by the electrolytic reaction chemically reacts with and degrades the piezoelectric material. Dendrites that grow to electrically connect the cathode and anode result in increasing levels of leakage current. Failed piezoelectric devices are defined as those that exhibit leakage current levels above an established threshold.

A ceramic moisture-barrier layer that insulates Thorlabs' piezoelectric devices on four sides is effective in minimizing the effects of humidity on device lifetime. As there is interest in estimating the lifetime of piezoelectric devices, Thorlabs conducted environmental testing on our ceramic-insulated, low-voltage, piezoelectric actuators. The resulting data were used to create a simple model that estimates the mean time to failure (MTTF), in hours, when the operating conditions of humidity, temperature, and applied voltage are known. The estimated MTTF is calculated by multiplying together three factors that correspond, respectively, to the operational temperature, relative humidity, and fractional voltage of the device. The fractional voltage is calculated by dividing the operational voltage by the maximum specified drive voltage for the device. The factors for each parameter can be read from the following plots, or they may be calculated by downloading the plotted data values and interpolating as appropriate.

In the following trio of plots, the solid-line segment of each curve represents the range of conditions over which Thorlabs performed testing. These are the conditions observed to be of most relevance to our customers. The dotted-line extensions to the solid-line segments represent extrapolated data and represent a wider range of conditions that may be encountered while operating the devices.



Click to Enlarge
For an Excel file containing these f_T vs. temperature data, please click here.

Calculation of MTTF to Estimate Lifetimes: MTTF = f_V * f_T * f_H

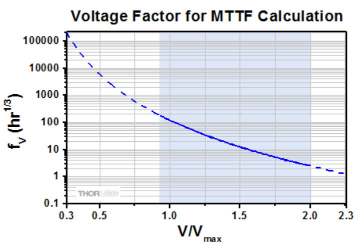
Given the relative humidity conditions, device temperature, and DC operational voltage, the device lifetime can be estimated. It is the product of voltage, temperature, and humidity factors, which can be determined using relationships plotted at right, lower-right, and below.

As an example, when a device of type PK2FSF1 is operated with a voltage of 60 V, at a temperature of 30 °C, and in an environment with 75% relative humidity:

- From the graph below, the voltage factor is 427 (The maximum rated voltage, V_{max}, of the PK2FSF1 is 75 V, giving $V/V_{ma}x$ = 60 V / 75 V = 0.80)
- From the graph at right, the temperature factor is 83
- From the graph at lower-right, the humidity factor is 2.8

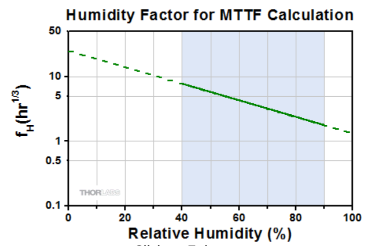
Then MTTF = 472 * 83 * 2.8 = 99234.8 hours, which is greater than 11 years.

Note that relationships graphed on this page apply only to Thorlabs' ceramic-insulated, low-voltage, chip-based piezoelectric actuators.



Click to Enlarge

For an Excel file containing these f_V vs. V/V_{max} data, please click here.



Click to Enlarge

For an Excel file containing these f_H vs. relative humidity data, please click here.

The data used to generate these temperature, voltage, and humidity factor plots resulted from the analysis of measurements obtained from testing devices under six different operational conditions. Different dedicated sets of ten devices were tested under each condition, with each condition representing a different combination of operational voltage, device temperature, and relative humidity. After devices exhibit leakage current levels above a threshold of 100 nA, they are registered as having failed. The individual contributions of temperature, humidity, and voltage to the lifetime are determined by assuming:

- MTTF = $f_V(V) * f_T(T) * f_H(H)$
- A power law dependence for the voltage: $f_V(V) = A_1 V^{b1}$
- An exponential relationship for the relative humidity: $f_H(T) = A_2 e^{c^H}$
- An Arrhenius relationship for the temperature: $f_T(H) = A_3 e^{b2/T}$

where A1, A2, A3, b1, b2, and c are constants determined through analysis of the measurement data, V is the DC operational voltage, T is the device temperature, and H is the relative humidity. Because the MTTF has a different mathematical relationship with each factor, the dependence of the MTTF on each factor alone may be determined. These are the data plotted above. The regions of the above curves marked by the blue shading are derived from experimental data. The dotted regions of the curves are extrapolated.

Lifetime testing of these devices continues, and additional data will be published here as they become available.

75 V Piezoelectric Chips

Key Specifications[a]							
Item #	Info	Pre-Attached Wires	Displacement (Free Stroke)[b]	Dimensions	Resonant Frequency[b]	Load for Maximum Displacement[c]	Blocking Force[d]
PA2AB		No	0.7 µm ± 15%	0.9 mm x 0.9 mm x 0.8 mm	1350 kHz	13 N (3 lbs)	32 N (7.2 lbs)
PA2AD		No	1.1 µm ± 15%	0.9 mm x 0.9 mm x 1.5 mm	850 kHz	13 N (3 lbs)	32 N (7.2 lbs)
PA2JE		No	2.0 µm ± 15%	3.0 mm x 3.0 mm x 2.0 mm	450 kHz	144 N (32 lbs)	360 N (81 lbs)
PA2JEW		Yes					
TA0505D024		No	2.8 µm ± 15%	5.0 mm x 5.0 mm x 2.4 mm	315 kHz	400 N (90 lbs)	1000 N (225 lbs)
TA0505D024W		Yes					

- a. For complete specifications, please see the Info Icons( ) above.
- b. Without Load
- c. Displacement varies with loading. When used with this load, these chips achieve the maximum displacement, which is larger than the free stroke displacement.
- d. At Max Voltage

Part Number	Description	Price	Availability
PA2AB	**Piezo Chip, 75 V, 0.7 µm Displacement, 0.9 × 0.9 × 0.8 mm, Bare Electrodes**	**$27.29** **Volume Pricing Available**	**Today**
PA2AB-25	**Piezo Chip, 75 V, 0.7 µm Displacement, 0.9 x 0.9 x 0.8 mm, Bare Electrodes, 25 Pieces**	**$603.42**	**Lead Time**

PA2AD	Customer Inspired!Piezo Chip, 75 V, 1.1 µm Displacement, 0.9 x 0.9 x 1.5 mm, Bare Electrodes	$28.31 Volume Pricing Available	Today
PA2AD-25	Piezo Chip, 75 V, 1.1 µm Displacement, 0.9 x 0.9 x 1.5 mm, Bare Electrodes, 25 Pieces	$625.86	Lead Time
PA2JE	Piezo Chip, 75 V, 2.0 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes	$26.01 Volume Pricing Available	Today
PA2JEW	Piezo Chip, 75 V, 2.0 µm Displacement, 3.0 x 3.0 x 2.0 mm, Pre-Attached Wires	$28.31 Volume Pricing Available	3-5 Days
PA2JE-25	Piezo Chip, 75 V, 2.0 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes, 25 Pieces	$584.70	Lead Time
TA0505D024	Piezo Chip, 75 V, 2.8 µm Displacement, 5.0 x 5.0 x 2.4 mm, Bare Electrodes	$31.37 Volume Pricing Available	Today
TA0505D024W	Piezo Chip, 75 V, 2.8 µm Displacement, 5.0 x 5.0 x 2.4 mm, Pre-Attached Wires	$33.41 Volume Pricing Available	Today
TA0505D024-25	Piezo Chip, 75 V, 2.8 µm Displacement, 5.0 x 5.0 x 2.4 mm, Bare Electrodes, 25 Pieces	$705.72	Lead Time
TA0505D024-1K	Piezo Chip, 75 V, 2.8 µm Displacement, 5.0 x 5.0 x 2.4 mm, Bare Electrodes, 1000 Pieces	$0.00	Lead Time

100 V Piezoelectric Chips

Key Specifications[a]							
Item #	Info	Pre-Attached Wires	Displacement (Free Stroke)[b]	Dimensions	Resonant Frequency[b]	Load for Maximum Displacement[c]	Blocking Force[d]
PA3BC		No	1.0 µm ± 15%	1.5 mm x 1.5 mm x 1.0 mm	920 kHz	36 N (8 lbs)	90 N (20 lbs)
PA3BCW		Yes					
PA3JE		No	1.8 µm ± 15%	3.0 mm × 3.0 mm × 2.0 mm	450 kHz	144 N (32 lbs)	360 N (81 lbs)
PA3JEW		Yes					
PA3CE		No	2.0 µm ± 15%	2.0 mm × 2.0 mm × 2.0 mm	560 kHz	65 N (15 lbs)	160 N (36 lbs)
PA3CEW		Yes					
PA3JEA		No	2.2 µm ± 15%	3.0 mm × 3.0 mm × 2.0 mm	450 kHz	144 N (32 lbs)	360 N (81 lbs)
PA3JEAW		Yes					

- a. For complete specifications, please see the Info Icons ( ) above.
- b. Without Load
- c. Displacement varies with loading. When used with this load, these chips achieve the maximum displacement, which is larger than the free stroke displacement.
- d. At Max Voltage

Part Number	Description	Price	Availability
PA3BC	Customer Inspired!Piezo Chip, 100 V, 1.0 µm Displacement, 1.5 x 1.5 x 1.0 mm, Bare Electrodes	$23.97 Volume Pricing Available	Today
PA3BCW	Piezo Chip, 100 V, 1.0 µm Displacement, 1.5 x 1.5 x 1.0 mm, Pre-Attached Wires	$26.01 Volume Pricing Available	Today
PA3BC-25	Piezo Chip, 100 V, 1.0 µm Displacement, 1.5 x 1.5 x 1.0 mm, Bare Electrodes, 25 Pieces	$539.58	Lead Time
PA3JE	Piezo Chip, 100 V, 1.8 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes	$28.31 Volume Pricing Available	Today
PA3JEW	Piezo Chip, 100 V, 1.8 µm Displacement, 3.0 x 3.0 x 2.0 mm, Pre-Attached Wires	$30.35 Volume Pricing Available	Today
PA3JE-25	Piezo Chip, 100 V, 1.8 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes,25 Pieces	$518.93	Lead Time
PA3JE-1K	Piezo Chip, 100 V, 1.8 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes, 1000 Pieces	$0.00	Lead Time
PA3CE	Piezo Chip, 100 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Bare Electrodes	$22.95 Volume Pricing Available	Today
PA3CEW	Piezo Chip, 100 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Pre-Attached Wires	$24.99 Volume Pricing Available	Today
PA3CE-25	Piezo Chip, 100 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Bare Electrodes,25 Pieces	$516.38	Lead Time
PA3CE-1K	Piezo Chip, 100 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Bare Electrodes,1000 Pieces	$0.00	Lead Time
PA3JEA	Customer Inspired!Piezo Chip, 100 V, 2.2 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes	$28.31 Volume Pricing Available	Today
PA3JEAW	Customer Inspired!Piezo Chip, 100 V, 2.2 µm Displacement, 3.0 x 3.0 x 2.0 mm, Pre-Attached Wires	$30.35 Volume Pricing Available	Today
PA3JEA-25	Customer Inspired!Piezo Chip, 100 V, 2.2 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes, 25 Pieces	$636.87	Lead Time

150 V Piezoelectric Chips

Key Specifications[a]							
Item #	Info	Pre-Attached Wires	Displacement (Free Stroke)[b]	Dimensions	Resonant Frequency[b]	Load for Maximum Displacement[c]	Blocking Force[d]
PA4CE		No	2.0 µm ± 15%	2.0 mm × 2.0 mm × 2.0 mm	560 kHz	65 N (15 lbs)	160 N (36 lbs)
PA4CEW		Yes					
PA4HE		No	2.1 µm ± 15%	10.0 mm × 10.0 mm × 2.0 mm	165 kHz	1600 N (360 lbs)	4000 N (900 lbs)
PA4HEW		Yes					
PA4JE		No	2.2 µm ± 15%	3.0 mm × 3.0 mm × 2.0 mm	450 kHz	144 N (32 lbs)	360 N (81 lbs)
PA4JEW		Yes					
PA4GE		No	2.2 µm ± 15%	7.0 mm × 7.0 mm × 2.0 mm	225 kHz	785 N (177 lbs)	1960 N (441 lbs)
PA4GEW		Yes					
PA4DG		No	2.3 µm ± 15%	2.5 mm × 2.5 mm × 2.3 mm	470 kHz	100 N (22 lbs)	250 N (56 lbs)
PA4DGW		Yes					
PA4FE		No	2.5 µm ± 15%	5.0 mm × 5.0 mm × 2.0 mm	310 kHz	400 N (90 lbs)	1000 N (225 lbs)
PA4FEW		Yes					
PA4GK		No	3.4 µm ± 15%	7.0 mm x 7.0 mm x 3.0 mm	220 kHz	785 N (177 lbs)	1960 N (441 lbs)
PA4GKW		Yes					
PA4JK		No	3.5 µm ± 15%	3.0 mm x 3.0 mm x 3.0 mm	355 kHz	144 N (32 lbs)	360 N (81 lbs)
PA4JKW		Yes					
PA4HK		No	3.5 µm ± 15%	10.0 mm × 10.0 mm × 3.0 mm	160 kHz	1600 N (360 lbs)	4000 N (900 lbs)
PA4HKW		Yes					
PA4FK		No	3.6 µm ± 15%	5.0 mm × 5.0 mm × 3.0 mm	270 kHz	400 N (90 lbs)	1000 N (225 lbs)
PA4FKW		Yes					

- a. For complete specifications, please see the Info Icon() above.
- b. Without Load
- c. Displacement varies with loading. When used with this load, these chips achieve the maximum displacement, which is larger than the free stroke displacement.
- d. At Max Voltage

Part Number	Description	Price	Availability
PA4CE	**Piezo Chip, 150 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Bare Electrodes**	**$22.95** **Volume Pricing Available**	**Today**
PA4CEW	**Piezo Chip, 150 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Pre-Attached Wires**	**$24.99** **Volume Pricing Available**	**Today**
PA4CE-25	**Piezo Chip, 150 V, 2.0 µm Displacement, 2.0 x 2.0 x 2.0 mm, Bare Electrodes, 25 Pieces**	**$516.38**	**Lead Time**
PA4HE	**Piezo Chip, 150 V, 2.1 µm Displacement, 10.0 x 10.0 x 2.0 mm, Bare Electrodes**	**$62.48** **Volume Pricing Available**	**Today**
PA4HEW	**Piezo Chip, 150 V, 2.1 µm Displacement, 10.0 x 10.0 x 2.0 mm, Pre-Attached Wires**	**$64.52** **Volume Pricing Available**	**Today**
PA4HE-16	**Piezo Chip, 150 V, 2.1 µm Displacement, 10.0 x 10.0 x 2.0 mm, Bare Electrodes, 16 Pieces**	**$899.64**	**Lead Time**
PA4JE	**Piezo Chip, 150 V, 2.2 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes**	**$26.01** **Volume Pricing Available**	**Today**
PA4JEW	**Piezo Chip, 150 V, 2.2 µm Displacement, 3.0 x 3.0 x 2.0 mm, Pre-Attached Wires**	**$28.31** **Volume Pricing Available**	**Today**
PA4JE-25	**Piezo Chip, 150 V, 2.2 µm Displacement, 3.0 x 3.0 x 2.0 mm, Bare Electrodes,25 Pieces**	**$584.70**	**Lead Time**
PA4GE	**Piezo Chip, 150 V, 2.2 µm Displacement, 7.0 x 7.0 x 2.0 mm, Bare Electrodes**	**$43.86** **Volume Pricing Available**	**Today**
PA4GEW	**Piezo Chip, 150 V, 2.2 µm Displacement, 7.0 x 7.0 x 2.0 mm, Pre-Attached Wires**	**$45.90** **Volume Pricing Available**	**Today**
PA4GE-16	**Piezo Chip, 150 V, 2.2 µm Displacement, 7.0 x 7.0 x 2.0 mm, Bare Electrodes, 16 Pieces**	**$631.80**	**Lead Time**
PA4DG	**Customer Inspired!Piezo Chip, 150 V, 2.3 µm Displacement, 2.5 x 2.5 x 2.3 mm, Bare Electrodes**	**$26.01** **Volume Pricing Available**	**Today**
PA4DGW	**Customer Inspired!Piezo Chip, 150 V, 2.3 µm Displacement, 2.5 x 2.5 x 2.3 mm, Pre-Attached Wires**	**$28.31** **Volume Pricing Available**	**Today**
PA4DG-25	**Piezo Chip, 150 V, 2.3 µm Displacement, 2.5 x 2.5 x 2.3 mm, Bare Electrodes,25 Pieces**	**$585.23**	**Lead Time**
PA4DG-1K	**Piezo Chip, 150 V, 2.3 µm Displacement, 2.5 x 2.5 x 2.3 mm, Bare Electrodes,1000 Pieces**	**$0.00**	**Lead Time**
PA4FE	**Piezo Chip, 150 V, 2.5 µm Displacement, 5.0 x 5.0 x 2.0 mm, Bare Electrodes**	**$29.33** **Volume Pricing Available**	**Today**
PA4FEW	**Piezo Chip, 150 V, 2.5 µm Displacement, 5.0 x 5.0 x 2.0 mm, Pre-Attached Wires**	**$31.37** **Volume Pricing Available**	**Today**
PA4FE-25	**Piezo Chip, 150 V, 2.5 µm Displacement, 5.0 x 5.0 x 2.0 mm, Bare Electrodes,25 Pieces**	**$659.82**	**Lead Time**
PA4GK	**Piezo Chip, 150 V, 3.4 µm Displacement, 7.0 x 7.0 x 3.0 mm, Bare Electrodes**	**$52.02** **Volume Pricing Available**	**Today**
PA4GKW	**Piezo Chip, 150 V, 3.4 µm Displacement, 7.0 x 7.0 x 3.0 mm, Pre-Attached Wires**	**$54.32** **Volume Pricing Available**	**Today**
PA4GK-16	**Piezo Chip, 150 V, 3.4 µm Displacement, 7.0 x 7.0 x 3.0 mm, Bare Electrodes, 16 Pieces**	**$755.33**	**Lead Time**
PA4JK	**Piezo Chip, 150 V, 3.5 µm Displacement, 3.0 x 3.0 x 3.0 mm, Bare Electrodes**	**$25.00** **Volume Pricing Available**	**Today**
PA4JKW	**Piezo Chip, 150 V, 3.5 µm Displacement, 3.0 x 3.0 x 3.0 mm, Pre-Attached Wires**	**$27.00** **Volume Pricing Available**	**Today**
PA4JK-25	**Piezo Chip, 150 V, 3.5 µm Displacement, 3.0 x 3.0 x 3.0 mm, Bare Electrodes, 25 Pieces**	**$560.00**	**Lead Time**
		$79.31	

PA4HK	**Piezo Chip, 150 V, 3.5 µm Displacement, 10.0 x 10.0 x 3.0 mm, Bare Electrodes**	**Volume Pricing Available**	**Today**
PA4HKW	**Piezo Chip, 150 V, 3.5 µm Displacement, 10.0 x 10.0 x 3.0 mm, Pre-Attached Wires**	**$81.35** **Volume Pricing Available**	**Today**
PA4HK-16	**Piezo Chip, 150 V, 3.5 µm Displacement, 10.0 x 10.0 x 3.0 mm, Bare Electrodes, 16 Pieces**	**$1,140.53**	**Lead Time**
PA4FK	**Piezo Chip, 150 V, 3.6 µm Displacement, 5.0 x 5.0 x 3.0 mm, Bare Electrodes**	**$32.39** **Volume Pricing Available**	**Today**
PA4FKW	**Piezo Chip, 150 V, 3.6 µm Displacement, 5.0 x 5.0 x 3.0 mm, Pre-Attached Wires**	**$34.43** **Volume Pricing Available**	**Today**
PA4FK-25	**Piezo Chip, 150 V, 3.6 µm Displacement, 5.0 x 5.0 x 3.0 mm, Bare Electrodes,25 Pieces**	**$729.19**	**Lead Time**

End Cups

- Compatible with Our Piezoelectric Chips (Sold Above)
- Use with End Hemispheres Available Below
- Conical End Cups Accept Ball Contacts:
  - From Ø1.5 mm to Ø3.0 mm (PKJCUP)
  - From Ø2.6 mm to Ø5.0 mm (PKFCUP)
  - From Ø3.6 mm to Ø7.0 mm (PKGCUP)
- Restricts Applied Stress to the Axial Direction
- Sold in Packs of 10

The PKJCUP, PKFCUP, and PKGCUP are 416 stainless steel conical end cups designed to be used with our piezoelectric chips when interfaced with the end hemispheres sold below. The conical cup can accept a ball contact, such as one of the end hemispheres available below, with a diameter from 1.5 to 3.0 mm (PKJCUP), 2.6 to 5.0 mm (PKFCUP), or 3.6 to 7.0 mm (PKGCUP). Using a ball contact with a piezo actuator ensures that the applied stress is restricted to the axial direction, limiting the probability of stress-induced failure. They can be affixed either to a flat face of a piezo chip or to the mechanical device that is being actuated. If affixing a cup to the chip itself, we recommend using an epoxy that cures at a temperature lower than 80 °C (176 °F), such as 353NDPK or TS10 epoxies or Loctite® Hysol® 9340.

Part Number	Description	Price	Availability
PKJCUP	**Ø3.0 mm Conical End Cup for PZT Actuators, Pack of 10**	**$35.45**	**Today**
PKFCUP	**Customer Inspired!Ø5.0 mm Conical End Cup for PZT Actuators, Pack of 10**	**$24.99**	**Today**
PKGCUP	**Ø7.0 mm Conical End Cup for PZT Actuators, Pack of 10**	**$45.90**	**Today**

End Hemispheres and Flat End Plates

- End Hemispheres and Flat End Plates in Six Sizes
- Hemispheres Provide a Single Point of Contact for Actuation
- Flat Plates Spread Force Across Piezo Face at Contact Point
- Sold in Packs of 16 or 25

End Hemispheres		Flat End Plates		Compatible Piezo Chips
Item #	Diameter	Item #	Dimensions	
PKCESP	2.0 mm	PKCEP4	2.0 mm x 2.0 mm x 0.4 mm	PA3CE(W), PA4CE(W)
PKDESP	2.5 mm	PKDEP4	2.5 mm x 2.5 mm x 0.4 mm	PA4DG(W)
PKJESP	3.0 mm	PKJEP4	3.0 mm x 3.0 mm x 0.4 mm	PA2JE(W), PA3JE(W), PA3JEA(W), PA4JE(W), PA4JK(W)
PKFESP	5.0 mm	PKFEP4	5.0 mm x 5.0 mm x 0.4 mm	TA0505D024(W), PA4FE(W), PA4FK(W)
PKGESP	7.0 mm	PKGEP4	7.0 mm x 7.0 mm x 0.4 mm	PA4GE(W), PA4GK(W)
PKHESP	10.0 mm	PKGESP	10.0 mm x 10.0 mm x 0.4 mm	PA4HE(W), PA4HK(W)

The alumina end hemispheres and flat end plates used in our piezoelectric stacks are also available separately in six sizes (see the table to the right). The hemispheres can be used to create a single contact point between a PZT stack and a lever arm. Alternatively, a hemisphere can be used with a compatible conical end cup (sold above). End plates are used to spread the force at the contact point over the entire surface of the piezo stack. When selecting an end hemisphere or flat end plate to adhere to a piezo stack end face, it is important to match the bottom surface area of the hemisphere or plate to the cross section of the piezo stack in order to ensure that forces are spread evenly over the surface. The end hemispheres have a diameter tolerance of ±0.1 mm, and the end plates have a dimensional tolerance of ±0.04 mm. To secure the end hemisphere or the flat end plate to a piezo actuator, any epoxy that cures at a temperature lower than 80 °C is considered safe to use. We suggest using Thorlabs' 353NDPK High-Temperature Expoy or TS10 Vacuum Epoxy. Additionally, Loctite® Hysol® 9340 can also be used.

Part Number	Description	Price	Availability
PKCESP	**Customer Inspired!Ø2.0 mm End Hemisphere, Pack of 25**	**$32.39**	**Today**
PKDESP	**Customer Inspired!Ø2.5 mm End Hemisphere, Pack of 25**	**$32.39**	**Today**
PKJESP	**Customer Inspired!Ø3.0 mm End Hemisphere, Pack of 25**	**$32.39**	**Today**
PKFESP	**Customer Inspired!Ø5.0 mm End Hemisphere, Pack of 25**	**$32.39**	**Today**
PKGESP	**Customer Inspired!Ø7.0 mm End Hemisphere, Pack of 16**	**$28.31**	**Today**
PKHESP	**Customer Inspired!Ø10.0 mm End Hemisphere, Pack of 16**	**$45.14**	**Today**
PKCEP4	**Customer Inspired!2.0 mm x 2.0 mm x 0.4 mm Flat End Plate, Pack of 25**	**$9.38**	**Today**
PKDEP4	**Customer Inspired!2.5 mm x 2.5 mm x 0.4 mm Flat End Plate, Pack of 25**	**$9.38**	**Today**
PKJEP4	**Customer Inspired!3.0 mm x 3.0 mm x 0.4 mm Flat End Plate, Pack of 25**	**$9.38**	**Today**
PKFEP4	**Customer Inspired!5.0 mm x 5.0 mm x 0.4 mm Flat End Plate, Pack of 25**	**$11.53**	**Today**
PKGEP4	**Customer Inspired!7.0 mm x 7.0 mm x 0.4 mm Flat End Plate, Pack of 16**	**$10.40**	**Today**
PKHEP4	**Customer Inspired!10.0 mm x 10.0 mm x 0.4 mm Flat End Plate, Pack of 16**	**$16.73**	**Today**