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THORLABS

AE0203D08F - June 18, 2019

Item # AE0203D08F was discontinued on June 18, 2019. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

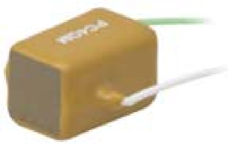
CO-FIRED PIEZOELECTRIC ACTUATORS, 4.6 MM TO 20.0 MM TRAVEL

- ▶ Free-Stroke Displacement Options from 4.6 µm to 20.0 µm
- ▶ On-Stack Insulation with Full-Width Internal Electrodes
- ▶ Sub-Millisecond Response Times with No Load
- ▶ Low 150 V Maximum Drive Voltage

PC4WL
4.6 µm Stroke
3.5 mm x 4.5 mm x 5.0 mm

PC4FL
4.6 µm Stroke,
5.0 mm x 5.0 mm x 5.0 mm

AE0203D08F
9.1 µm Stroke,
3.5 mm x 4.5 mm x 10.0



PC4QM
9.1 µm Stroke
6.5 mm x 6.5 mm x 10.0 mm

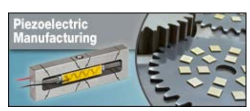
PC4QR
20.0 µm Stroke
6.5 mm x 6.5 mm x 20.0 mm

Hide Overview

OVERVIEW

Features

- Epoxy-Coated for Protection Against Rough Handling and Mechanical/Chemical Contamination
- Co-Fired Design Sinters the Stack as a Single Monolithic Unit
- Maximum Displacements from 4.6 µm to 20.0 µm
- 150 V Max Drive Voltage
- Fast Response Time: 1 / (3 * Resonant Frequency)
- Internal Electrodes Span Entire Active Cross Section with On-Stack Insulation



Thorlabs' Co-Fired Piezoelectric Actuators are composed of stacked PZT layers separated by electrodes that span the entire surface area of the layer. The entire stack, with its interdigitated electrodes, is sintered together into one monolithic structure. These piezoelectric actuators transform electrical energy into precisely controlled mechanical displacements and are ideal for applications requiring rapid, precise positional changes on the nanometer or micrometer scale. They are able to achieve a free stroke displacement that is significantly larger than their single chip counterparts while maintaining sub-millisecond response times and low drive voltage ranges. Co-Fired Piezo Stacks differ from Discrete Piezo Stacks in the insulation and conductor design. For more details, please refer to the *Operation* tab.

These multilayer devices are ideal for nano- and micro-positioning. As the voltage applied to the actuator goes from 0 V to the maximum drive voltage, the piezo expands longitudinally. These open-loop piezoelectric actuators offer maximum displacements from 4.6 µm to 20.0 µm. Piezoelectric devices, such as these actuators, exhibit hysteresis, thus the displacement of the actuator is not solely based on applied voltage. When it is necessary to precisely track the displacement of the actuator, Thorlabs recommends our piezo stack actuators with attached strain gauges.

Integration
Our PC4 Series Piezo Stacks are compatible with hemispheres and end cups to minimize internal stress when mounting. Please refer to the *Specs* tab for item-specific compatibility. To connect a load to our AE series piezo stacks, we recommend using a room-temperature epoxy, such as Thorlabs' F120. To mount the PC4 series piezo stacks and attach hemispheres and end cups, we recommend using an epoxy that cures at 80 °C (176

Piezo Selection Guide[a]
Piezo Chips
Square
Square with Through Hole
Round
Ring
Tube
Shear
Benders
Piezo Stacks
Discrete, Square
Discrete, Square with Through Hole
Discrete, Round
Discrete, Ring
Co-Fired, Square
Co-Fired or Discrete, Square with Strain Gauges
Piezo Actuators
Mounted

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

Webpage Features

°F) or below, such as our 353NDPK or TS10 epoxies or Loctite® Hysol® 9340. When interfacing a mechanical load with the piezoelectric actuator, it is important to center the mechanical load on the actuator's end face to avoid applying a torque that could damage the actuator. Additionally, the piezoelectric actuator should be interfaced with an external load such that the induced force is directed along the actuator's axis of displacement. If the actuator is incorporated into a design that calls for a preload, it is recommended that the preload does not exceed 50% of the specified clamping force. Please refer to the *Operation* tab above for more information.

(info icon)	Clicking this icon opens a window containing item-specific specifications.

The red or green lead on the piezoelectric actuator must be connected to the high side of the voltage source used to drive the actuator. Do not drive the piezoelectric actuator with a reverse bias voltage, as this could destroy the device. Piezoelectric actuators should not be used in liquid, in the presence of combustible gases or liquids, or cleaned with organic solvents.

Thorlabs also offers an expanding line of 75 V, 100 V, and 150 V piezoelectric stacks and chips, including discrete piezo stacks with 5.2 µm - 100.0 µm travel and piezo chips with 0.7 - 3.6 µm travel, which are ideally suited for OEM applications. For applications requiring larger displacements, we offer amplified piezo actuators with 220 µm - 1500 µm travel.

Item #[a]	Info	Max Drive Voltage	Displacement (Free Stroke)[b]	Stack Dimensions	Resonant Frequency (No Load)[b,c]	Recommended Preload[d]	Capacitance[e]	Blocking Force	Length Tolerance	Operating Temperature
PC4WL	(i)	150 V	4.6 µm ± 15%	3.5 mm x 4.5 mm x 5.0 mm	235 kHz ± 10%	<125 N (<27.5 lbs)	60 nF ± 15%	250 N (55 lbs)	±5 µm	-25 to 110 °C
PC4FL	(i)	150 V	4.6 µm ± 15%	5.0 mm x 5.0 mm x 5.0 mm	240 kHz ± 10%	<250 N (<55 lbs)	125 nF ± 15%	500 N (110 lbs)	±5 µm	-25 to 110 °C
AE0203D08F[f]	(i)	150 V[g]	9.1 µm ± 16%	3.5 mm x 4.5 mm x 10.0 mm	138 kHz	<100 N (<22.5 lbs)	180 nF ± 20%	200 N (45 lbs)	±100 µm	-25 to 85 °C
PC4QM	(i)	150 V	9.1 µm ± 15%	6.5 mm x 6.5 mm x 10.0 mm	115 kHz ± 10%	<500 N (<110 lbs)	650 nF ± 15%	1000 N (220 lbs)	±5 µm	-25 to 110 °C
PC4WM	(i)	150 V	9.5 µm ± 15%	3.5 mm x 4.5 mm x 10.0 mm	115 kHz ± 10%	<125 N (27.5 lbs)	180 nF ± 15%	250 N (55 lbs)	±5 µm	-25 to 110 °C
PC4QQ	(i)	150 V	18.0 µm ± 12%	6.5 mm x 6.5 mm x 18.0 mm	65 kHz ± 10%	<500 N (<110 lbs)	1350 nF ± 15%	1000 N (220 lbs)	±5 µm	-25 to 110 °C
PC4QR	(i)	150 V	20.0 µm ± 11%	6.5 mm x 6.5 mm x 20.0 mm	59 kHz ± 10%	<500 N (<110 lbs)	1400 nF ± 15%	1000 N (220 lbs)	±5 µm	-25 to 110 °C

a. To more easily compare full specifications of all co-fired piezo stacks, please see the *Specs* tab.
b. Specified at No Load
c. The maximum frequency will be close to the resonant frequency, which changes when a mechanical load is applied to the piezo stack. For more information on estimating the resonant frequency for different applied loads, see the *Operation* tab. When operating the piezo stack at high frequencies, sufficient cooling should be supplied to avoid overheating.
d. Preloading is used to protect the piezo from experiencing tensile force, which can cause structural failure. In some cases, preloading can also be used to compensate for dynamic forces generated by inertia. Displacement varies with loading, and displacement decreases above the recommended preload range. In general, the preload should be chosen to be as low as possible. As a service to the user, the load for maximum displacement has been determined and is specified for the PC4 series piezo stacks on the *Specs* tab.
e. Specified at 1 kHz, 1 V_{RMS}.
f. Discrete stacks can be used as drop-in replacements.
g. These items are not recommended for continuous operation at the maximum drive voltage. The recommended drive voltage limit for continuous operation is 100 V.

Hide Specs

SPECS

Item #	PC4WL	PC4FL	AE0203D08F	PC4QM	PC4WM	PC4QQ	PC4QR
Maximum Drive Voltage	150 V	150 V	150 V[a]	150 V	150 V	150 V	150 V
Displacement at Maximum Drive Voltage (No Load)	4.6 µm ± 15%	4.6 µm ± 15%	9.1 µm ± 16%	9.1 µm ± 15%	9.5 µm ± 15%	18.0 µm ± 12%	20.0 µm ± 11%
Actuator End Face Area	3.5 mm x 4.5 mm	5.0 mm x 5.0 mm	3.5 mm x 4.5 mm	6.5 mm x 6.5 mm	3.5 mm x 4.5 mm	6.5 mm x 6.5 mm	6.5 mm x 6.5 mm
Length Along Actuating Axis	5.0 mm	5.0 mm	10.0 mm	10.0 mm	10.0 mm	18.0 mm	20.0 mm
Length Tolerance	±5 µm	±5 µm	±100 µm	±5 µm	±5 µm	±5 µm	±5 µm
Recommended Drive Voltage Limit for Continuous Operation	150 V	150 V	100 V	150 V	150 V	150 V	150 V
Displacement at Recommended Drive	4.6 µm ± 15%	4.6 µm ± 15%	6.1 µm ± 25%	9.1 µm ± 15%	9.5 µm ± 15%	18.0 µm ± 12%	20.0 µm ± 11%

Voltage Limit for Continuous Operation							
Hysteresis	≤15%	≤15%	-	≤15%	≤15%	≤15%	≤15%
Resonant Frequency (No Mechanical Load)[b]	235 kHz ± 10%	240 kHz ± 10%	138 kHz	115 kHz ± 10%	115 kHz ± 10%	65 kHz ± 10%	59 kHz ± 10%
Anti-Resonant Frequency[c]	335 kHz ± 10%	335 kHz	-	170 kHz	165 kHz ± 10%	95 kHz ± 10%	85 kHz ± 10%
Dissipation Factor[d]	<2.0%	<2.0%	-	<2.0%	<2.0%	<2.0%	<2.0%
Capacitance[d]	60 nF ± 15%	125 nF ± 15%	0.18 µF ± 20%	650 nF ± 15%	180 nF ± 15%	1.35 µF ± 15%	1.4 µF ± 15%
Impedance at Resonant Frequency	2.3 Ω	900 mΩ	-	300 mΩ	700 mΩ	200 mΩ	200 mΩ
Clamping Force (Blocking Force)	250 N (55 lbs)	500 N (110 lbs)	200 N (45 lbs)	1000 N (220 lbs)	250 N (55 lbs)	1000 N (220 lbs)	1000 N (220 lbs)
Recommended Preload[d]	<125 N (<27.5 lbs)	<250 N (<55 lbs)	<100 N (<22.5 lbs)	<500 N (<110 lbs)	<125 N (27.5 lbs)	<500 N (<110 lbs)	<500 N (<110 lbs)
Load for Maximum Displacement[e]	100 N (22.5 lbs)	200 N (45 lbs)	-	400 N (90 lbs)	100 N (22.5 lbs)	400 N (90 lbs)	400 N (90 lbs)
Operating Temperature	-25 to 110 °C	-25 to 110 °C	-25 to 85 °C	-25 to 110 °C	-25 to 110 °C	-25 to 110 °C	-25 to 110 °C
Max Storage Temperature	110 °C	110 °C	100 °C	110 °C	110 °C	110 °C	110 °C
Curie Temperature	230 °C	230 °C	-	230 °C	230 °C	230 °C	230 °C
Performance Graphs (Click Icon to View Graphs)			-				
Recommended Accessories	PKJESP Hemisphere; PKJCUP Cup	PKFESP Hemisphere; PKFCUP Cup	-	PKFESP Hemisphere; PKFCUP Cup	PKJESP Hemisphere; PKJCUP Cup	PKFESP Hemisphere; PKFCUP Cup	PKFESP Hemisphere; PKFCUP Cup

a. The AE0203D08F is not recommended for continuous operation at the maximum drive voltage. A recommended drive voltage limit for continuous operation is given separately.
b. The maximum frequency will be close to the resonant frequency, which changes when a mechanical load is applied to the piezo stack. For more information on estimating the resonant frequency for different applied loads, see the *Operation* tab. When operating the piezo stack at high frequencies, sufficient cooling should be supplied to avoid overheating.
c. Anti-Resonant Frequency is the frequency at which the piezo displacement is minimized.
d. Specified at 1 kHz, 1 V_{RMS}.
e. Preloading is used to protect the piezo from experiencing tensile force, which can cause structural failure. In some cases, preloading can also be used to compensate for dynamic forces generated by inertia. Displacement varies with loading, and displacement decreases above the recommended preload range. In general, the preload should be chosen to be as low as possible. As a service to the user, the load for maximum displacement has been determined and is specified for the PC4 series piezo stacks.

Hide Piezo Bandwidth

PIEZO BANDWIDTH

Piezo Driver Bandwidth Tutorial

Knowing the rate at which a piezo is capable of changing lengths is essential in many high-speed applications. The bandwidth of a piezo controller and stack can be estimated if the following is known:

1. The maximum amount of current the controllers can produce. This is 0.5 A for our BPC Series Piezo Controllers, which is the driver used in the examples below.
2. The load capacitance of the piezo. The higher the capacitance, the slower the system.
3. The desired signal amplitude (V), which determines the length that the piezo extends.
4. The absolute maximum bandwidth of the driver, which is independent of the load being driven.

To drive the output capacitor, current is needed to charge it and to discharge it. The change in charge, *dV/dt*, is called the slew rate. The larger the capacitance, the more current needed:

$$slew\ rate = \frac{dV}{dt} = \frac{I_{max}}{C}$$

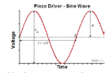
For example, if a 100 µm stack with a capacitance of 20 µF is being driven by a BPC Series piezo controller with a maximum current of 0.5 A, the slew rate is given by

$$slew\ rate = \frac{0.5\,A}{20\,\mu F} = 25\,V/ms$$

Hence, for an instantaneous voltage change from 0 V to 75 V, it would take 3 ms for the output voltage to reach 75 V.

Note: For these calculations, it is assumed that the absolute maximum bandwidth of the driver is much higher than the bandwidths calculated, and thus, driver bandwidth is not a limiting factor. Also please note that these calculations only apply for open-loop systems. In closed-loop mode, the slow response of the feedback loop puts another limit on the bandwidth.

Sinusoidal Signal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The bandwidth of the system usually refers to the system's response to a sinusoidal signal of a given amplitude. For a piezo element driven by a sinusoidal signal of peak amplitude *A*, peak-to-peak voltage V_{pp}, and frequency *f*, we have:

$$V(t) = Asin(2\pi ft) + A$$

A diagram of voltage as a function of time is shown to the right. The maximum slew rate, or voltage change, is reached at *t = 2nπ, (n=0, 1, 2,...)* at point *a* in the diagram to the right:

$$\left.\frac{dV}{dt}\right|_{t\,=\,2n\pi} = 2\pi A f_{max}$$

From the first equation, above:

$$\frac{dV}{dt} = \frac{I_{max}}{C}$$

Thus,

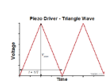
$$f_{max} = \frac{I_{max}}{2\pi AC} = \frac{I_{max}}{\pi V_{pp} C}$$

For the example above, the maximum full-range (75 V) bandwidth would be

$$f_{max} = \frac{I_{max}}{\pi V_{pp} C} = \frac{0.5\,A}{\pi(20\,\mu F)(75\,V)} \approx 106\,Hz$$.

For a smaller piezo stack with 10 times lower capacitance, the results would be 10 times better, or about 1060 Hz. Or, if the peak-to-peak signal is reduced to 7.5 V (10% max amplitude) with the 100 µm stack, again, the result would be 10 times better at about 1060 Hz.

Triangle Wave Signal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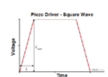
For a piezo actuator driven by a triangle wave of max voltage V_{peak} and minimum voltage of 0, the slew rate is equal to the slope:

$$\frac{I_{max}}{C} = \frac{2V_{peak}}{T}$$.

Or, since *f = 1/T*:

$$f_{max} = \frac{I_{max}}{2V_{peak}C} = \frac{0.5\,A}{2(20\,\mu F)(75\,V)} \approx 167\,Hz$$

Square Wave Signal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For a piezo actuator driven by a square wave of maximum voltage V_{peak} and minimum voltage 0, the slew rate limits the minimum rise and fall times. In this case, the slew rate is equal to the slope while the signal is rising or falling. If t_r is the minimum rise time, then

$$\frac{I_{max}}{C} = \frac{V_{peak}}{t_r}$$

or

$$t_r = \frac{CV_{peak}}{I_{max}}$$.

For additional information about piezo theory and operation, see the Piezoelectric Tutorials page.

Hide Operation

OPERATION

Operation Notes

Co-Fired Piezo Chips, Co-Fired Piezo Stacks, and Discrete Piezo Stacks

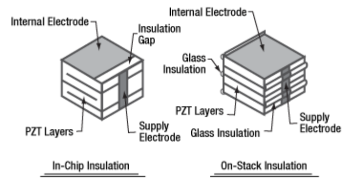

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Figure 1: Diagram of Piezo Stack Insulation Methods:
(a) In-Chip Insulation Used in Standard Chips and Discrete Stacks,
(b) On-Stack Insulation Used in Co-Fired Stacks

Generally speaking, Thorlabs' co-fired piezo chips and stacks are constructed similarly. In both cases, a structure is built up from alternating electrode layers and green-state lead zirconate titanate (PZT) piezoelectric layers. The assembled structure is then sintered into a single monolithic unit. Supply electrodes of opposite polarity are attached to opposite sides of the structure. Each internal electrode is electrically coupled to one or the other supply electrode, such that no two adjacent internal electrodes have the same polarity. The most significant differences between the co-fired chips and stacks arise from the way each internal electrode is electrically isolated from the supply electrodes of opposite polarity. The different electrical insulation approaches influence the mechanical properties of the actuators. Actuators fabricated using the two different approaches are diagrammed in Figure 1.

In the case of the chips (In-Chip Insulation), the internal electrodes of opposite polarities alternate. Each internal electrode layer is shorter than the full width of the piezo layer. All electrodes of one polarity have edges that are flush with one side of the chip, and all electrodes with the opposite polarity are flush with the opposite side of the chip. Because the electrode does not extend all the way to the opposite edge, the far end of the electrode is completely surrounded by PZT material. The PZT material enclosing the end of the electrode is insulating, which electrically isolates this electrode from the supply electrode of opposite polarity. This approach to electrically insulating the electrodes creates a region of stress at the edge of the electrode. The stress arises both due the abrupt change in thickness on either side of the electrode edge, as well as the tensile stress created when the PZT material sandwiched between electrodes responds to an applied voltage drive signal, but the insulating PZT material beyond the edge of the electrodes does not. This stress limits the maximum height of chips manufactured using this approach. The height of chips are limited to ensure internal stresses are low and do not affect lifetime or performance. Chips are sealed in a ceramic layer that offers superior resistance to humidity and heat than epoxy resin coatings.

One way of increasing the height, and therefore the maximum stroke, of piezo actuators based on these chips is to fabricate discrete piezo stacks. These are manufactured by bonding multiple chips together in series using a glass-bead epoxy. Discrete stacks can be fabricated to substantially longer lengths than co-fired chips or stacks, and this allows them to achieve higher maximum displacements while maintaining sub-millisecond response times and a low drive voltage range. As the constituent chips are sealed within a ceramic barrier layer, discrete stacks have superior resistance to humidity and heat than co-fired stacks, which are sealed in an epoxy resin coating.

In the case of co-fired stacks (On-Stack Insulation), the electrodes extend across the full width of the PZT layers. The edges of the electrodes are flush with all four sides of the stack, including the side with the supply electrode of opposite polarity. The edge of the internal electrode is insulated from that supply electrode by a layer of glass filament applied to the side of the stack. Precision localized application of the glass filament ensures that the electrode edge is electrically isolated from the supply electrode, and that the filament is applied over minimal surface area; the ability of the supply electrode to make electrical connections to the desired internal electrodes is not affected, and the small amount of applied glass filament does not affect the operation of the actuator. With their full-width electrodes, piezo actuators made using this insulating approach are characterized by homogeneous internal stress. Co-fired stacks can therefore be fabricated with greater heights than chips fabricated using the in-chip insulation approach. Co-fired stacks also have a higher percentage of active PZT material than the discrete stacks, which include inactive bonding layers of glass-bead epoxy. They are coated in an epoxy resin.

Power Connections

A positive bias should be applied across the device using the wires connected to the electrodes. The positive wire should receive positive bias, and the other wire should be connected to ground. Applying a negative bias across the device may cause mechanical failure. The positive wire is either red or green, while the ground wire is white.

Interfacing a Piezoelectric Stack 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 stack.

To attach a load to one of our AE series piezo stacks, we recommend using a room-temperature epoxy, such as Thorlabs' F120. For connecting loads to our PC4WL, PC4FL, and PC4QM piezo stacks, 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 translating, uncoated faces of the piezoelectric stack; the coated sides of our co-fired piezo stacks do not translate, and mounting a load to a non-translating face may lead to the mechanical failure of the actuator. Our PC4 Series Piezo Stacks are compatible with hemispheres and end cups to minimize internal stress when mounting. Please refer to the *Specs* tab for item-specific compatibility. Some correct and incorrect approaches to interfacing loads with piezoelectric stacks fitted with end plates are discussed in the following.

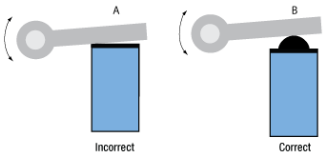

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Figure 2: Actuation of a lever arm using stack fitted with a flat plate (A, Incorrect), and a hemispherical plate (B, Correct).

Figure 2 presents incorrect (A, far-left) and correct (B, near-left) methods for using a piezoelectric stack 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 always directed along the translational axis of the actuator. The incorrect interfacing of the stack and the lever arm, shown at far-left, endangers the stack by applying the full force of the load to one edge of the stack. This uneven loading causes dangerous stresses in the actuator, including a bending moment around the base.

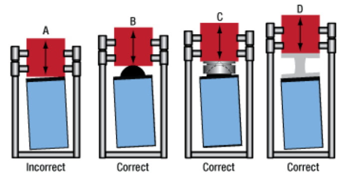

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Figure 3: Loads properly and improperly mounted to PZT actuators using a variety of interfacing methods.

Figure 3 shows one incorrect (near-right, A) and three correct approaches for interfacing a flat-bottomed, off-axis load with a piezoelectric stack. 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. 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 select products can be found in the Spec Sheet accessed by clicking the red Docs icon ( ) 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 bandwidth of the piezoelectric actuator (its resonant frequency), the absolute maximum bandwidth of the driver (its slew rate), the maximum current the piezoelectric device can produce, the capacitance of the piezoelectric stack, 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 stack. 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 stack. The magnitude of the applied voltage determines the nominal extension of the stack. 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 stack, 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 stack. Given the unloaded resonant frequency of the actuator, the mass of the stack, m, and the mass of the load, M, the loaded resonant frequency (f_o') may be estimated:

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

Hide 150 V Piezoelectric Actuators

150 V Piezoelectric Actuators

Part Number	Description	Price	Availability
PC4WL	**Piezoelectric Actuator, 4.6 µm Max Displacement, 3.5 mm x 4.5 mm x 5.0 mm**	**$70.45** **Volume Pricing Available**	**Today**
PC4FL	**Piezoelectric Actuator, 4.6 µm Max Displacement, 5.0 mm x 5.0 mm x 5.0 mm**	**$78.28** **Volume Pricing Available**	**Today**

AE0203D08F	Piezoelectric Actuator, 9.1 µm Max Displacement, 3.5 mm x 4.5 mm x 10.0 mm	$85.62	Lead Time
PC4QM	Piezoelectric Actuator, 9.1 µm Max Displacement, 6.5 mm x 6.5 mm x 10.0 mm	$140.78 Volume Pricing Available	5-8 Days
PC4WM	NEW! Piezoelectric Actuator, 9.5 µm Max Displacement, 3.5 mm x 4.5 mm x 10.0 mm	$85.62 Volume Pricing Available	Today
PC4QQ	NEW! Piezoelectric Actuator, 18.0 µm Max Displacement, 6.5 mm x 6.5 mm x 18.0 mm	$160.00 Volume Pricing Available	Today
PC4QR	NEW! Piezoelectric Actuator, 20.0 µm Max Displacement, 6.5 mm x 6.5 mm x 20.0 mm	$164.94 Volume Pricing Available	5-8 Days