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PA4GEH5-16 - March 8, 2018

Item # PA4GEH5-16 was discontinued on March 8, 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 WITH THROUGH HOLES, 1.8 MM TO 3.0 MM TRAVEL

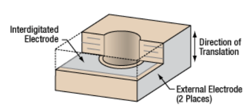
- 150 V Max Voltage and Sub-Millisecond Response Time
- Available with Ø2.0 mm, Ø3.0 mm, or Ø3.1 mm Central Through Holes
- Provided with and without Pre-Attached Wires
- Packs of 16 or 25 Unwired Chips Available from Stock

Hide Overview

OVERVIEW

Features

- Sub-Micron Resolution
- Four Sizes Available
  - 5.0 mm × 5.0 mm x 2.0 mm with Ø2.0 mm Through Hole
  - 5.0 mm × 5.0 mm x 3.0 mm with Ø2.0 mm Through Hole
  - 7.0 mm × 7.0 mm x 2.0 mm with Ø3.1 mm Through Hole
  - 7.0 mm × 7.0 mm x 3.0 mm with Ø3.0 mm Through Hole
  - Custom Size Options Available by Contacting Tech Support
- Drive Voltage Range of 0 - 150 V
- For Use in Open-Loop Setups
- Available from Stock with Pre-Attached Wires and in Packs of 16 or 25
- Ideal for Vacuum and OEM Applications



Click to Enlarge
Three-Dimensional Cross Section of Multilayer Piezo with Interdigitated Electrodes (Item # PA4FEH3 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 with a central through hole consist of stacked piezoelectric ceramic layers with interdigitated electrodes, as pictured in the diagram to the right. The multilayer design enables high resonant frequencies and sub-millisecond response times, while the use of interdigitated electrodes minimizes the drive voltage range. The central through hole is ideal for laser tuning and micro-dispensing applications. They are available with a drive voltage range of 0 - 150 V; for a complete list of specifications, see the table below.

These compact piezoelectric chips can be easily integrated into systems for precision movement and provide maximum free stroke displacements from 1.8 µm to 3.0 µm. Through a precision grinding process, the accuracy of the design height is ensured to better than ±5 µm. This high accuracy makes it significantly easier to design devices around our piezoelectric chips.

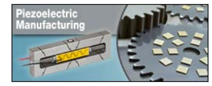
The maximum displacement of these actuators is achieved when they are preloaded with the maximum displacement load, which is specified for each product. The actual value of the maximum displacement varies for each item and must be experimentally determined; however, the maximum displacement will always be larger than the free stroke displacement. Please note that when mounting a load onto the piezoelectric chip, the force should be directed along the actuator's axis of displacement. For more details see the *Operation* tab.

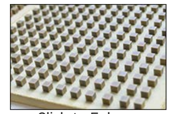
Each chip has an insulating ceramic layer on four exterior sides and along the interior through hole, which offers better protection against moisture than common epoxy-coated designs. The remaining two sides have screen-printed silver electrodes, to which the drive voltage is applied. For convenience, they are available with pre-attached 75 mm wires.

Piezo chips with custom dimensions, voltage ranges, and coatings are available. Additionally, customers can order these piezo chips in high-volume quantities. 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

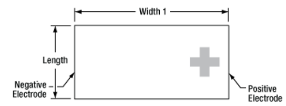
Hide Operation

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. 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 PA4FEH3 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. 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.

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:

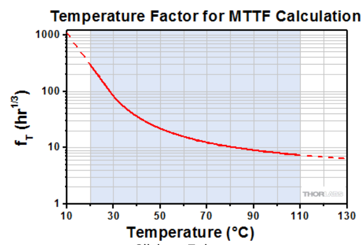
$$f_o' \cong f_o \sqrt{\frac{m/3}{m/3 + M}}$$

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

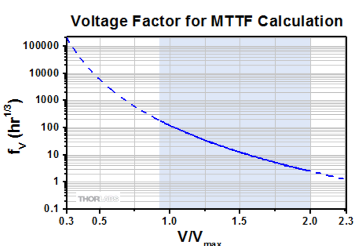
Given the relative humidity conditions, device temperature, and DC operational voltage, the device lifetime can be estimated. It is the product of voltage, temperature, and humidity factors, which can be determined using relationships plotted at right, lower-right, and below.

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_{max} = 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.



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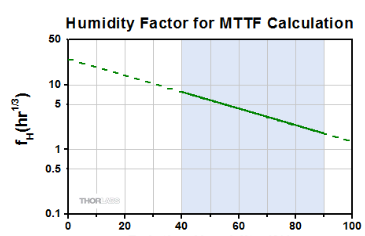
For an Excel file containing these f_V vs. V/V_{max} data, please click here.



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: $f_H(T) = A_2 e^{cH}$
- An Arrhenius relationship for the temperature: $f_T(H) = A_3 e^{b2/T}$

where A_1, A_2, A_3, b_1, b_2, 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.

Hide 150 V Piezo Chips with Through Holes

150 V Piezo Chips with Through Holes

Item #[a]	Info	Pre-Attached Wires	Displacement (Free Stroke)[b]	Dimensions[c]	Through Hole Diameter	Resonant Frequency	Load for Maximum Displacement[d]	Blocking Force[e]
PA4FEH3		No	1.8 µm ± 15%	5.0 mm x 5.0 mm x 2.0 mm	2.0 mm	610 kHz	300 N (68 lbs)	800 N (180 lbs)
PA4FEH3W		Yes						
PA4FKH3		No	3.0 µm ± 15%	5.0 mm x 5.0 mm x 3.0 mm	2.0 mm	500 kHz	300 N (68 lbs)	800 N (180 lbs)
PA4FKH3W		Yes						
PA4GEH5		No	2.0 µm ± 15%	7.0 mm x 7.0 mm x 2.0 mm	3.1 mm	530 kHz	700 N (155 lbs)	1600 N (360 lbs)
PA4GEH5W		Yes						
PA4GKH5		No	3.0 µm ± 15%	7.0 mm x 7.0 mm x 3.0 mm	3.0 mm	430 kHz	700 N (155 lbs)	1600 N (360 lbs)
PA4GKH5W		Yes						

- All specifications are quoted at 25 °C, unless otherwise stated. We recommend using the MDT69xB or KPZ101 Open-Loop Controllers with these piezos. Our MPZ601 (≤75 V) or BPC30x Closed-Loop Controllers are also compatible. However, the actuators sold on this page do not contain a strain gauge and therefore will not provide positional feedback. If closed-loop feedback is needed, please consider our PK4FYC2 or PZS001 actuators.
- The "free stroke" displacement corresponds to no load.
- Dimensions are quoted for the chip. In the case of our wired products, the dimensions exclude the wire connection area.
- Displacement varies with loading. When used with this load, these chips achieve the maximum displacement, which is larger than the free stroke displacement.
- At Max Voltage

Part Number	Description	Price	Availability
PA4FEH3	Piezo Chip with Ø2.0 mm Through Hole, 150 V, 1.8 µm Displacement, 5.0 mm × 5.0 mm × 2.0 mm, Bare Electrodes	$37.49 Volume Pricing Available	Today
PA4FEH3-25	Piezo Chip with Ø2.0 mm Through Hole, 150 V, 1.8 µm Displacement, 5.0 mm × 5.0 mm × 2.0 mm, Bare Electrodes, 25 Pieces	$843.42	Lead Time
PA4FEH3W	Piezo Chip with Ø2.0 mm Through Hole, 150 V, 1.8 µm Displacement, 5.0 mm × 5.0 mm x 2.0 mm, Pre-Attached Wires	$39.78 Volume Pricing Available	Today
PA4FKH3	Piezo Chip with Ø2.0 mm Through Hole, 150 V, 3.0 µm Displacement, 5.0 mm × 5.0 mm × 3.0 mm, Bare Electrodes	$41.82 Volume Pricing Available	Today
PA4FKH3-25	Piezo Chip with Ø2.0 mm Through Hole, 150 V, 3.0 µm Displacement, 5.0 mm × 5.0 mm × 3.0 mm, Bare Electrodes, 25 Pieces	$872.10	Lead Time
PA4FKH3W	Piezo Chip with Ø2.0 mm Through Hole, 150 V, 3.0 µm Displacement, 5.0 mm × 5.0 mm x 3.0 mm, Pre-Attached Wires	$43.86 Volume Pricing Available	Today
PA4GEH5	Piezo Chip with Ø3.1 mm Through Hole, 150 V, 2.0 µm Displacement, 7.0 mm × 7.0 mm × 2.0 mm, Bare Electrodes	$52.02 Volume Pricing Available	Today
PA4GEH5-16	Piezo Chip with Ø3.1 mm Through Hole, 150 V, 2.0 µm Displacement, 7.0 mm × 7.0 mm × 2.0 mm, Bare Electrodes, 16 Pieces	$735.42	Lead Time
PA4GEH5W	Piezo Chip with Ø3.1 mm Through Hole, 150 V, 2.0 µm Displacement, 7.0 mm × 7.0 mm × 2.0 mm, Pre-Attached Wires	$54.32 Volume Pricing Available	Today
PA4GKH5	Piezo Chip with Ø3.0 mm Through Hole, 150 V, 3.0 µm Displacement, 7.0 mm × 7.0 mm × 3.0 mm, Bare Electrodes	$62.48 Volume Pricing Available	Today
PA4GKH5-16	Piezo Chip with Ø3.0 mm Through Hole, 150 V, 3.0 µm Displacement, 7.0 mm × 7.0 mm × 3.0 mm, Bare Electrodes, 16 Pieces	$888.42	Lead Time
PA4GKH5W	Piezo Chip with Ø3.0 mm Through Hole, 150 V, 3.0 µm Displacement, 7.0 mm × 7.0 mm × 3.0 mm, Pre-Attached Wires	$64.52 Volume Pricing Available	Today