PIEZO SYSTEMS, INC.

186 Massachusetts Avenue Cambridge, MA 02139 • Tel: (617) 547-1777 • Fax: (617) 354-2200 • Web: www.piezo.com • E-mail: sales@piezo.com

TABLE OF CONTENTS

SERVICE AND WARRANTY: All Piezo Systems, Inc. products are warranted against defective materials and workmanship. This warranty applies for a period of time of one year from the date of delivery to the original purchaser. Any instrument or part that is found within the one year period not to meet these standards, will be repaired or replaced. No other warranty is expressed or implied.

NOTE: Prices and specifications subject to change without notice.

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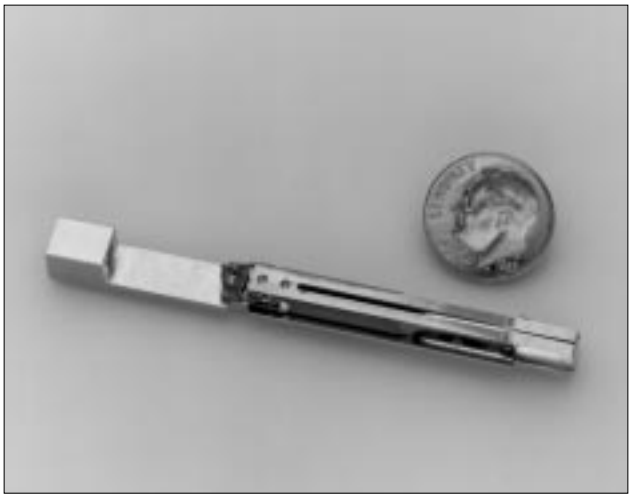
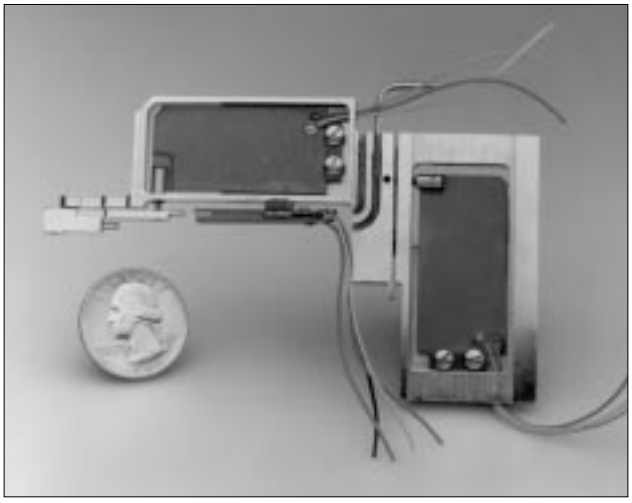
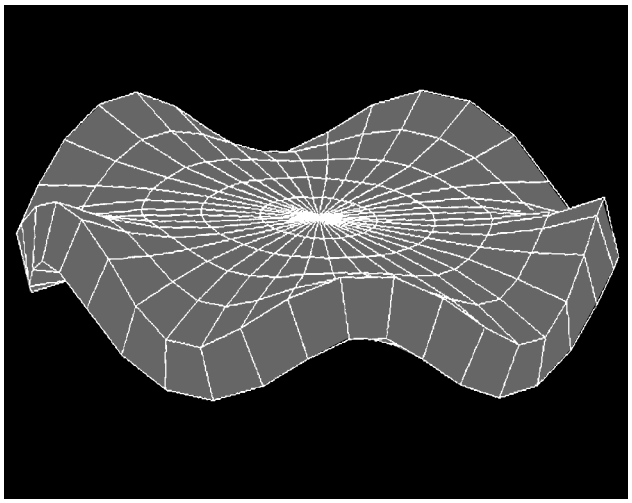
PRODUCT DEVELOPMENT



HIGH FREQUENCY TUNING FORK



2 - AXIS ROTATIONAL POSITIONER



FEA MODELING

CUSTOMER SPECIFICATIONS

Piezoceramic actuator design is based on customer specifications which include as a minimum:

- Motion and force requirements
- Space available
- Voltage available
- Stability
- Thermal operating range
- Frequency operating range
- Response time

ACTUATOR & SYSTEM DESIGN

Using extensive computer software and experience, Piezo Systems Inc. can move directly from your specifications to a complete optimized design. The actuator geometry, electroactive material, internal lamination, polarization, electrode configuration, mount, power take-off, and production process is designed to ensure repeatable and reliable performance.

Piezo Systems Inc. can also design and build the electronic system which drives the actuator and fabricate (or mold) the structure to which the piezo actuator is mounted.

PHASED DEVELOPMENT PROGRAM

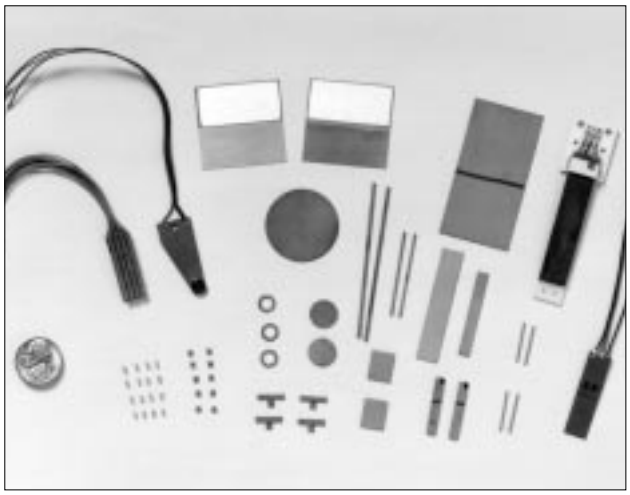
Piezo Systems Inc. offers a phased development program for custom device and product development. Our experience allows the elimination of potential design flaws which plague those unfamiliar with piezoceramic technology, especially in the areas of lamination bonding, flexure design, ceramic stress and fatigue criteria, thermal stability, mounting, power take-off attachments, electronic drive, testing, and evaluation. This service reduces the customer's need to dedicate highly qualified personnel during the development period, and development time is typically reduced from years to months. Financial and technical risks are minimized. The following phases are quoted on a fixed price basis:

- Analysis and Design Phase: Communication of specifications, analysis, and optimized design of actuator.
- Prototype Phase: Samples built to specification.
- Pre-production Phase: Pre-production samples for exhaustive testing.
- Production Phase: Production pieces at desired volume.

AREAS OF EXPERTISE

BENDING ACTUATORS & SENSORS

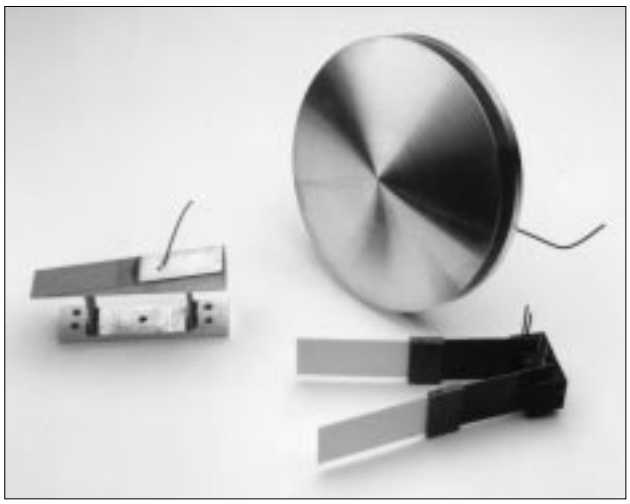
Piezo Systems' proprietary bonding process and ceramic quality testing program leads to consistent performance, high-strength, thermally stable, void free laminations. Our advanced cutting techniques produce actuators with dimensional tolerances within ±.001 inch if necessary; widths as narrow as .020 inch; chip free edges; non-linear shapes; and contamination free surfaces. Piezo Systems ships parts to performance specifications, not merely to dimensional tolerance. Our bending actuators are employed in piezo valves, choppers, modulators, fans, tunneling microscopes, and soil testers. Our bending sensors are used in implantable pacemakers and industrial equipment.



BENDING ELEMENTS

RESONANT DEVICES

Resonant devices are an effective way of achieving high periodic motion at low voltage and power. Products designed to operate at a single frequency require special attention be paid to shape uniformity, material consistency, and process control. A careful balance is sought between minimizing strain on the piezoceramic and maximizing the dynamic amplitude. Energy losses due to internal dissipation, external attachments, and output loading are addressed.

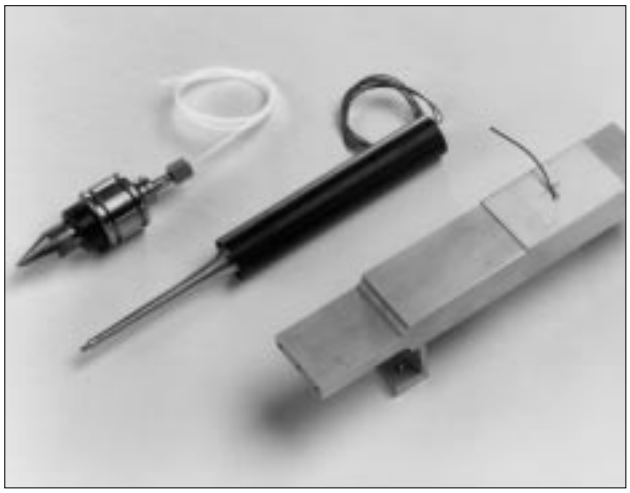


RESONATORS

ULTRASONIC DEVICES

Ultrasonics, a special portion of the resonant spectrum, find extensive use over a wide range of application areas. These devices are designed according to the same principles guiding resonant devices. However, additional consideration is given to amplitude stability, power consumption, over-heating, resonance tracking, and electronic drive.

Piezo Systems has developed a monolithic construction which eliminates many of the problems associated with precompressed bolt together systems.



ULTRASONICS

CONSULTING & ANALYSIS

Piezo Systems offers consultation on an hourly, daily, weekly, and monthly basis.

PRODUCTION

Combined with proprietary processing techniques, Piezo Systems works closely with a network of highly specialized vendors. As a result Piezo Systems is capable of supplying highly sophisticated single parts or hundreds of thousands of parts per year.

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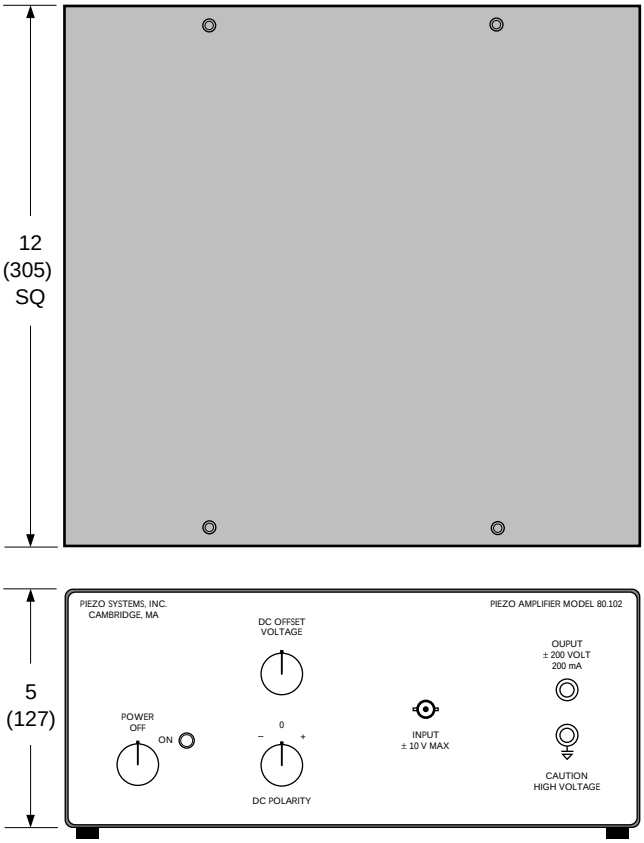
PIEZO LINEAR AMPLIFIER



DESCRIPTION

Piezo Systems offers a single channel high frequency amplifier for driving a variety of piezo actuators, including stacks, bimorphs, and single sheets.

The ability of an amplifier to drive a piezo device statically is determined primarily by the voltage level and stability. Its ability to drive a piezo device dynamically is determined by the capacitance of the actuator, the voltage to which it must be charged, and the number of times it must be charged and discharged per second. These establish the current, voltage, and frequency requirements of the amplifier.

The EPA-102 is a high voltage (± 200 Vp), high current (± 200 mA), and high frequency (DC to 300 KHz) amplifier designed to drive higher capacitive (low impedance) loads, such as low voltage stacks, at moderate frequencies or lower capacitive loads, such as ultrasonic devices, at high frequencies.

Low Electrical Noise, Low Distortion: The amplifier is made with a high quality Apex® High Voltage Hybrid Operational Amplifier, and utilizes high regulation linear power supplies. They are housed in a heavy high conductivity aluminum case which provides an excellent shield from external electromagnetic interference.

Input and Output Protection: Piezo loads present special problems to electronic drivers. The EPA-102 provides heavy input and output protection to take care of all shorting, turn-on, turn-off, and load generated voltage occurrences which can damage either the amp or your actuator.

Manual Bias Controls (Polarity and DC offset): Useful for making manual adjustments of drive voltage to verify piezo actuator static motion, for static setting, or for applying DC bias to dynamically driven piezo actuators such as piezo stacks.

External Control (via analog signal to the BNC input connector): Accepts up to ± 10 Vp signal waveforms from external signal generators, computer controllers, or feedback networks from DC to rated frequency. The combined AC plus DC offset voltage is adjustable from zero to the maximum rated voltage.

ORDERING INFORMATION	PART NO.	PRICE
Piezo Linear Amplifier, ± 200 Vp/200mA (115 VAC, 60 Hz)	EPA-102-115	$2,399
Piezo Linear Amplifier, ± 200 Vp/200mA (230 VAC, 50 Hz)	EPA-102-230	$2,399

SPECIFICATIONS

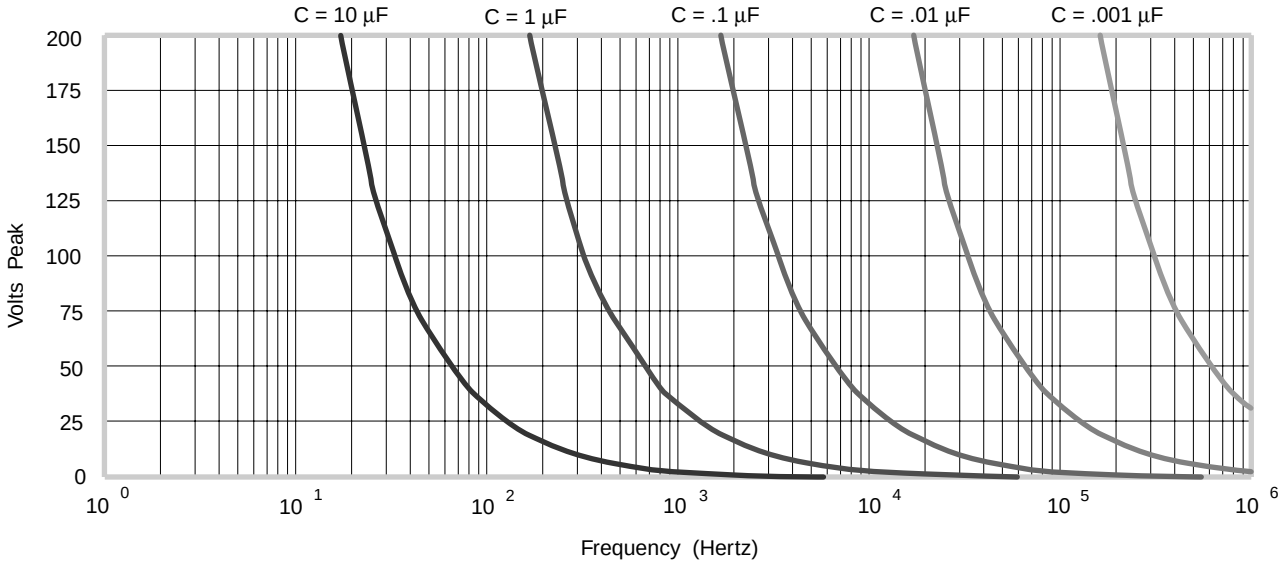
EPA-102 PIEZO LINEAR AMPLIFIER

ELECTRICAL

Maximum Voltage	±200 volts peak	
Maximum Current	±200 mA peak	
Output Power	40.0 watts peak	
Frequency Range	DC to 300 KHz	
Bandwidth	Into 1 KΩ resistive load	Flat: DC to 275 KHz 3db roll-off: 350 KHz
	Into capacitive load	See chart below
Voltage Gain	Fixed at X20	
Slew Rate (No Load)	180 volts / µsec	
Maximum Input Voltage	±10 volts peak	
Maximum DC Component	±10 volts DC	
Input Coupling	Direct DC coupling only	
Input Impedance	10K ohm	
Output Coupling	DC coupling	
Variable DC Offset	Normally zero volts. Adjustable to ± volts peak	
Load Impedance	Capable of driving any load within the voltage and current limitations of the amplifier.	
Load Power Factor	1 to 0, leading or lagging	
AC Power Source	115/120VAC, 50/60 Hz or 230/240VAC, 50/60 Hz	
Circuit Protection	Overload Short Circuit	

MECHANICAL

Controls	Power Switch; DC Polarity (+,0,-); DC Offset Level
Terminals	BNC for Input; Binding posts for Output
Weight	16 lbs.
Dimensions	12" L x 12" D x 5" H



Peak Voltage Delivered to Capacitive Load at Peak Current Rating as a Function of Operating Frequency
(Steady State Sinusoidal Waveforms; Temperature = 25 °C)

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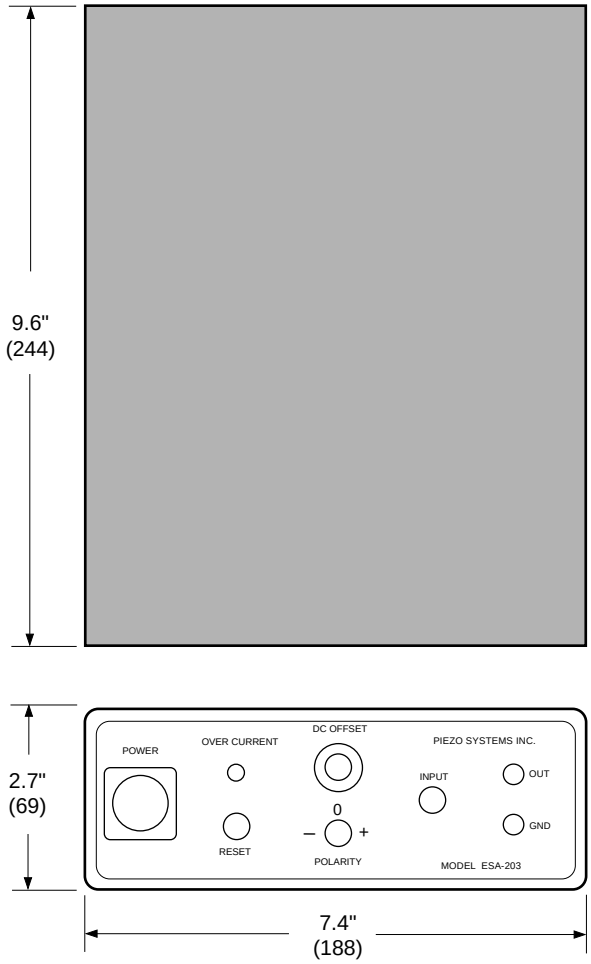
PIEZO SWITCHING AMPLIFIER

LIGHTWEIGHT - ENERGY EFFICIENT - COMPACT



Piezo Systems offers a single channel audio frequency switching amplifier for driving a variety of piezo actuators, including stacks, bimorphs, and single sheets.

DESCRIPTION

The ESA-208 achieves its flat response and wide bandwidth by employing a unique technology which is patent pending. It is the first of its kind to be offered for sale, and demonstrates concretely a future trend in miniaturization for high voltage power circuitry that will open up new practical applications for piezo actuators.

The ESA-208 is a lightweight (3 lbs.), compact (7.4"W x 2.7"H x 9.6"D), high voltage (± 180 Vp), high current (± 500 mA), and audio frequency (DC to 5 KHz) amplifier designed to drive high capacitive loads, such as low voltage stacks, at moderate frequencies or low capacitive loads, such as acoustic sources, at high frequencies.

Principle of Operation: The input signal to the amplifier is converted into a train of width modulated pulses. The polarity and duration of these pulses alternately control the turn on and turn off of two (high and low) high voltage power switches operating at 200 KHz. The high frequency carrier is filtered out to pass the audio signal.

High Current Capability: A typical linear amplifier achieves voltage control by intelligently adjusting the resistance value of the output stage which is in series with the load. If the load draws .5 amps, all that current must flow through the output stage resistance and be turned into heat. By contrast, the switching amplifier has an output stage which is either fully on of fully off (never in between), and so is capable of metering out far higher currents for the same size circuit with a minimum of heat loss.

Input and Output Protection: Piezo loads present special problems to electronic drivers. The ESA-208 provides input and output protection to take care of turn-on, turn-off, and load generated voltage occurrences which can damage either the amp or your actuator.

Manual Bias Controls (Polarity and DC offset): Useful for making manual adjustments of drive voltage to verify piezo actuator static motion, for static setting, or for applying DC bias to dynamically driven piezo actuators such as piezo stacks.

External Control (via analog signal to the BNC input connector): Accepts up to ± 10 Vp signal waveforms from external signal generators, computer controllers, or feedback networks from DC to rated frequency. The combined AC plus DC offset voltage is adjustable from zero to the maximum rated voltage.

ORDERING INFORMATION	PART NO.	PRICE
Piezo Switching Amplifier, ± 180 Vp/±500mA (115 VAC, 60 Hz)	ESA-208-115	$1,799

SPECIFICATIONS

ESA-208 PIEZO SWITCHING AMPLIFIER

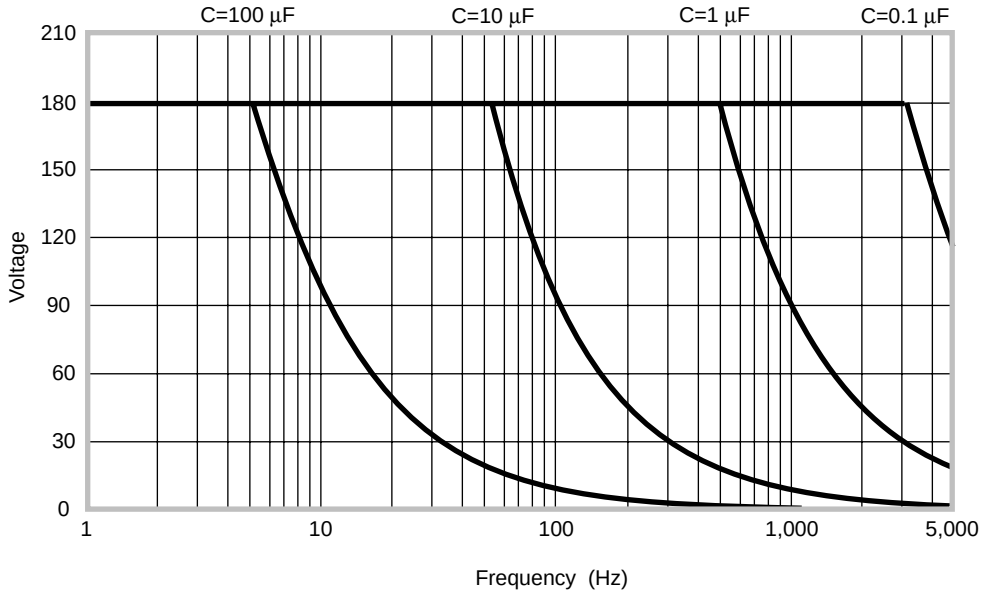
MECHANICAL

Dimensions	7.4" W x 9.6" D x 2.7" H (188 x 244 x 69)
Weight	3 lbs. (1.6 Kg)
Controls	Power Switch; DC Polarity (+, zero, -); DC Offset
Terminals	BNC for Input; Binding posts for Output

ELECTRICAL

Maximum Output Voltage	± 180 volts peak
Maximum Output Current	± 500 mA peak (see graph below)
Variable DC Offset	± 180 volts peak, Adjustable
Frequency Range	DC to 5 KHz
Voltage Gain	x 20, +10% / -5%
Maximum Input Voltage	±10 volts peak
Maximum Input, DC Component	±10 volts DC
Input Coupling	DC coupled
Input Impedance	47K ohm
Output Coupling	DC coupled
Load Impedance	Any capacitive loads and resistive loads above 500 Ω
AC Power Source	115-125VAC, 50-60 Hz
Circuit Protection	Current limit, short circuit, and thermal protection with manual reset.

• *This is a new technology and specifications are subject to change.*



ESA-208 Peak Output Voltage versus Frequency for various capacitive loads (sinusoidal waveform).

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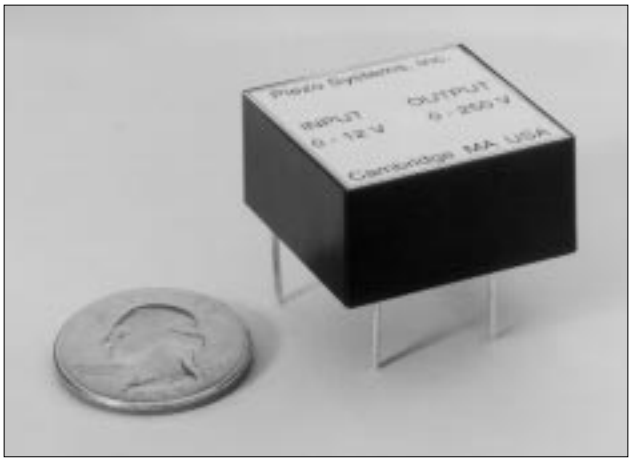
PROPORTIONAL VOLTAGE BOOSTER



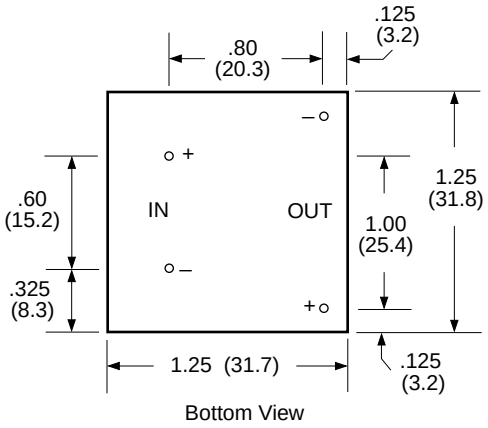
DESCRIPTION

The Proportional Voltage Booster is a simple means for obtaining the higher voltage used for driving piezo devices, such as sheets, benders and stacks, at static or quasi static frequency. It requires only a low voltage DC supply (such as the output of an op-amp), commonly available in the laboratory.

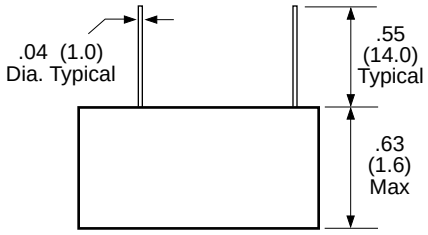
The booster is small in size, PC board mountable, and suited for low current / high voltage applications. Output voltage is proportional to the input voltage and is linear from ~ 10% to the maximum output voltage. Output ripple is low. Floating output enables the user to choose either positive or negative drive. And, it is short circuit and reverse polarity protected.

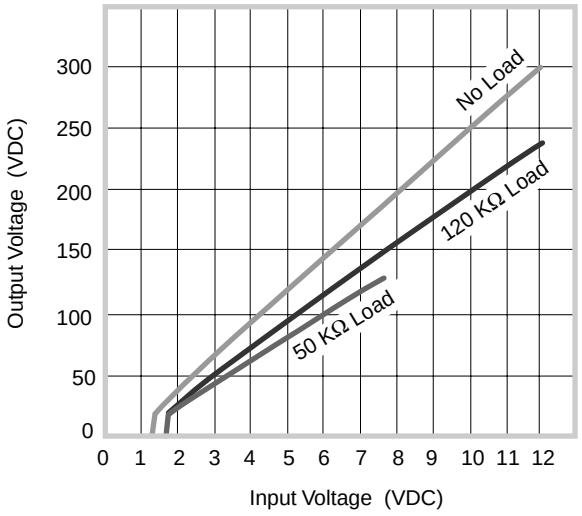
BOOSTER SPECIFICATIONS

Input Voltage:	0 - 12 VDC
Input Current:	85 mA Nominal
Output Voltage:	0 - 250 VDC Nominal
Output Current:	2 mA
Load Regulation:	5% (1/2 to full load)
Ripple:	< 0.5% p-p
Insulation Resistance:	3500 VDC
Weight:	~1.5 oz
Temperature Range:	-20°C to +70°C



Bottom View





ORDERING INFORMATION	PART NO.	PRICE
Proportional Voltage Booster	EVB-304	$299

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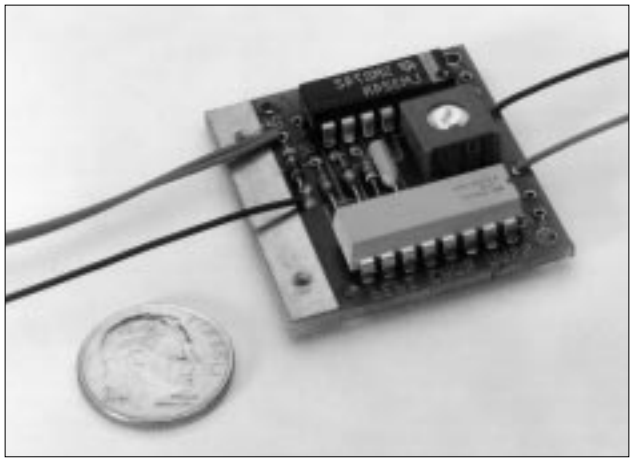
DC TO AC INVERTER DRIVE CIRCUIT

DESCRIPTION

The inverter drive circuit converts a DC voltage input into an oscillating AC output. The inverter circuit is provided for driving low voltage (up to 56 Vp-p), low frequency (75 Hz - 400 Hz) resonant piezo devices such as fans, choppers, and vibrators. The output frequency is adjusted manually by turning the trimmer pot on the PCB. Optimum tuning is accomplished by visual observation of the device motion or inspection of the output waveform on an oscilloscope during operation.



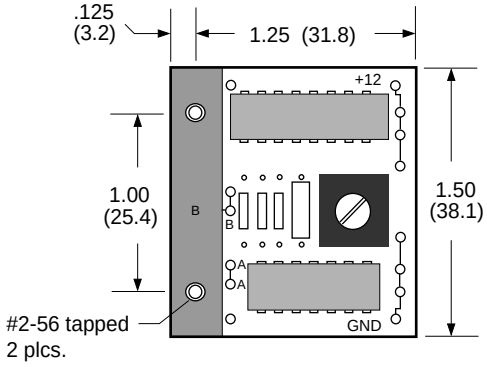
DRIVING PIEZO RESONATORS

12VDC Piezo Fan: The 12 VDC fan (see page 24) can be bolted directly to the EIN-406. Two wires from terminal "A" connect to the two solder dots on the piezo fan, and the metal spacer bolts directly to terminal "B".

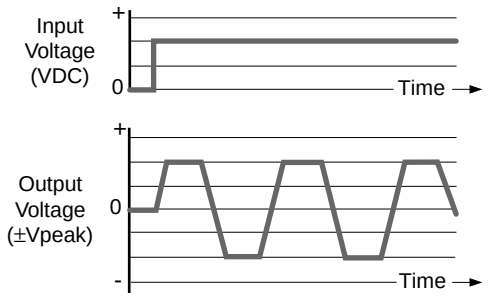
Piezo Resonant Element: The resonant blade element (see page 25) may be driven using the EIN-406.

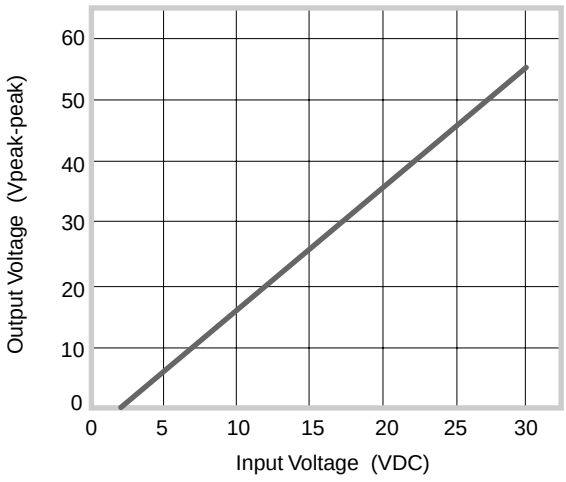
Piezo Chopper. The piezo chopper (see page 26) may be driven using the EIN-405.

Piezo Benders: Bending elements (see pages 32 - 37) may be driven at resonance using the appropriate inverter Circuit.



INPUT / OUTPUT WAVEFORM





INVERTER SPECIFICATIONS

		EIN-405	EIN-406
Input Voltage Range	VDC	3 - 30	3 - 30
Output Voltage Range	Vp-p	0 - 56	0 - 56
Frequency Range	Hz	50 - 200	150 - 400
Temperature Range	°C	0 -60	0 - 60

ORDERING INFORMATION	PART NO.	PRICE
Inverter Drive Circuit (75 Hz - 200 Hz)	EIN-405	$129
Inverter Drive Circuit (150 Hz - 400 Hz)	EIN-406	$129

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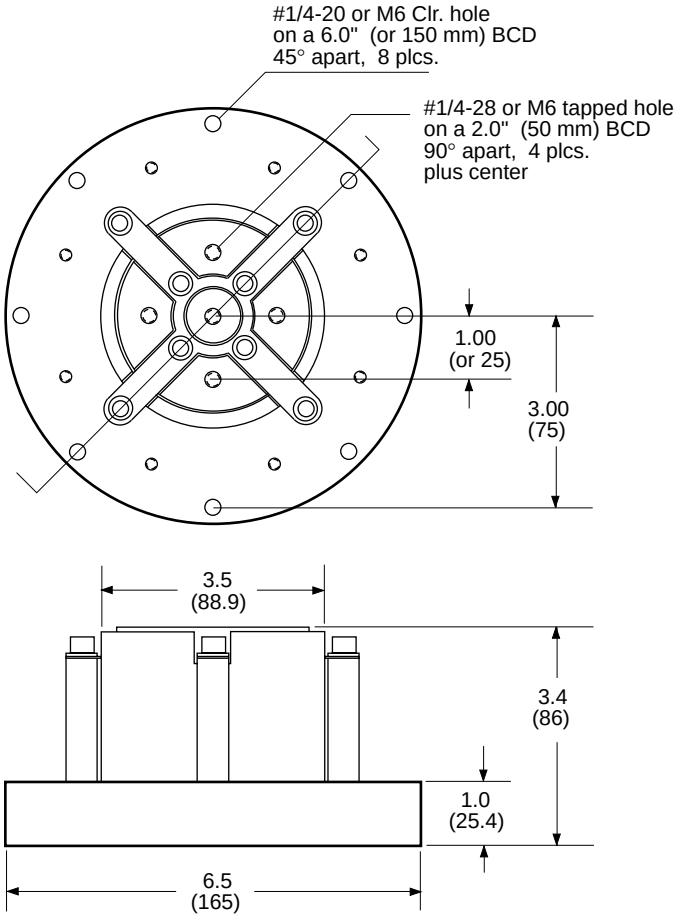
HEAVY DUTY PIEZO VIBRATION TABLE

LOW VOLTAGE, LARGE LOAD CAPACITY & NON-MAGNETIC



DESCRIPTION

The heavy duty piezoelectric Vibration Table requires only 15 Vrms to deliver a peak to peak amplitude of 9 µM from DC to 200 Hertz. The system consists of a low frequency vibration table and electronic driver.

The Vibration Table is driven by piezoelectric stacks located symmetrically about the outer diameter of the table top. Piezoelectric stacks provide a means of generating oscillations electrostatically rather than magnetically. A spring-plate assembly provides stack compression, torsional resistance, and moment compensation.

Both english and metric bolt patterns are available. The base plate bolts to ground using 1/4" (or M6) hardware on 6" (or 150 mm) centers. A load up to 150 lbs. may be bolted to the table top using the 1/4-28 UNF (or M6) tapped holes located on the 1.0" (or 25 mm) centers.

NOTE: The shake table can be driven statically from 0 to +100 VDC and achieve a motion range of 0 to + 30µm.

DRIVER

The Vibration Table Driver accepts 0 to ±10 Vp input signals from a frequency generator, computer, or feedback network and delivers 0 to 15 Vrms to the Vibration Table, allowing the operator to scan through an operating frequency range from 0 to 200 Hz.

Since the stack motors cannot tolerate appreciable voltage in the antipoling direction, the electronic package provides both an AC drive voltage and a DC bias voltage. The bias voltage superimposes a positive DC voltage greater than the peak negative swing introduced during maximum AC operation.

The driver protects the table from excessive voltage, current, and frequency.

FEATURES

- No magnetic field generation.
- All non-magnetic materials
- Safe operating voltage, 15 Vrms
- High load capacity

ORDERING INFORMATION	PART NO.	PRICE
Piezo Vibration Table (English version)	IVB1-003-E	$4,500
Piezo Vibration Table (Metric version)	IVB1-003-M	$4,500
Vibration Table Electronic Driver	IVB1-003-C01	$3,250

SPECIFICATIONS

PIEZO VIBRATION TABLE

DIMENSIONS		
Dimensions (H x OD)	inches	3.43 x Ø 6.50
	mm	87 x Ø 165
Table Top Diameter	inches	Ø 3.00
	mm	Ø 76
Weight	N	22
Mounting, Base Plate	English	1/4 clearance holes on 6.0" BCD
	Metric	M6 clearance holes on 150mm BCD
Mounting, Table Top	English	1/4-28 tapped holes, 1.0" centers, 9 places
	Metric	M6 tapped holes, 50mm centers, 9 places
ELECTRICAL		
Rated Input Voltage (at 200 Hz with 30 VDC bias voltage applied)		
	Vrms	15
Input Capacitance	Farad	45 x 10-6
Bleed Resistance	Ω	10K
Power Cable		RG 174/U, 10 Feet (3 m), 4 pin connector
THERMAL		
Operating Temperature Range	°C	10 to 40
Storage Temperature Range	°C	0 to 50
PERFORMANCE		
Dynamic Deflection		
(150 lb. load, 200 Hz, 15Vrms)	µm peak	±4.5
Static Deflection		
(150 lb. load, 0 Hz, 0 - 100VDC)	µm peak	0 - 28
Frequency Range	Hz	0 - 200
Rated Load	N	660
Maximum Compressive Load	N	4,400

VIBRATION TABLE ELECTRONIC DRIVER

INPUT POWER SOURCE		115VAC, 60 Hz or 230VAC, 50/60Hz
DIMENSIONS	Inches	12 x 12 x 5
	mm	305 x 305 x 127
INPUT SIGNAL		
Maximum Input Voltage	Vp	± 10
OUTPUT SIGNAL		
DC Offset Voltage	VDC	30
AC Drive Voltage	Vrms	0-15
Output Current	Arms	1.25
Frequency Range	Hz	DC - 200
PROTECTION		Output terminal protected from back EMF. Power amplifier thermally protected. Input voltage and current protection Frequency protection.

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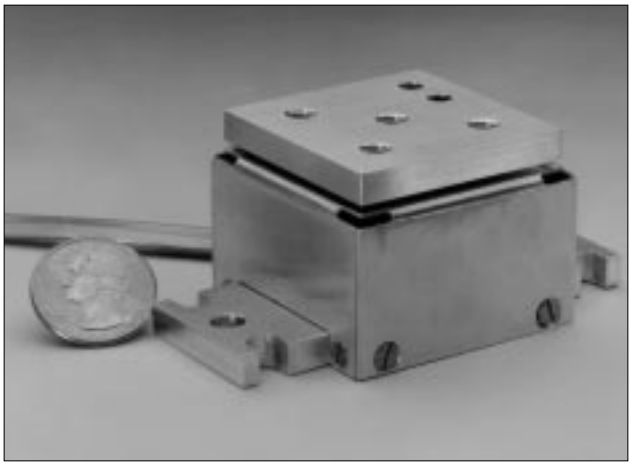
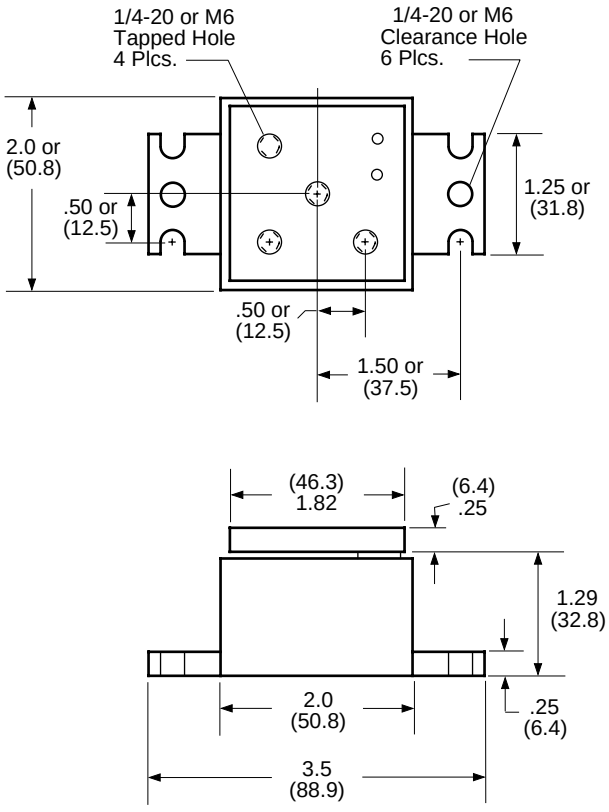
2-AXIS LINEAR POSITIONER, ± 200 µm





Scale: x1/2

DESCRIPTION

The piezoelectric 2-axis linear positioner is a low frequency device designed for delicate manipulations of relatively light loads. The piezoelectric motors are configured to provide linear motion along the x and y axis without rotation and shortening commonly associated with standard cantilever devices. The design leads to higher displacements than normally associated with piezoelectric devices, while delivering the fine resolution generally sought. The positioner produces displacements of ± 200 µm with no time lag, vibration, or backlash. When used under a microscope, voltage may be reversed to compensate for inverted optics. The motors produce no magnetic fields and are clean room compatible.

The positioner may be electronically driven with the EPA-102 Piezo Amplifier . Two hole patterns are available for mounting: 1/4-20 on 1 inch centers or M6-1.0 on 25 mm centers.

Custom Configurations: Other piezo linear positioner features are available in custom configurations, including: single axis, higher and lower motions, totally non-magnetic constructions, and custom sizes.

APPLICATIONS

- Scientific Research: Invitro fertilization
- Biology: Micro dissection, Gene splicing
- Precision Engineering: Robotics
- Electronics: Microchip circuitry testing
- Microscopy: Slide manipulation

ORDERING INFORMATION	PART NO.	PRICE
2-Axis Linear Positioner (1/4-20 on 1 inch centers)	ILN2-001-E	$2,499
2-Axis Linear Positioner (M6-1.0 on 25mm centers)	ILN2-001-M	$2,499

SPECIFICATIONS

2 - AXIS LINEAR POSITIONER, ±200 µm

MECHANICAL			
	Dimensions (L x W x H)	Inches	3.5 x 2.0 x 1.5
		mm	89 x 51 x 46
	Weight (without platform)	grams	140
	(with platform)	grams	175
	Mounting	English	1/4-20 clr. holes on 3" centers, 6 plcs.
		Metric	M6 clr. holes on 75mm centers, 6 plcs.
ELECTRICAL			
	Rated Input Voltage	Vp	± 180
	Capacitance / Channel	nF	35
	Input Cable		2.1 meters (7 feet)
	Input Connector		6 Pin, RJ12 Modular Plug
THERMAL			
	Operating Temperature Range	°C	10 - 60
	Storage Temperature Range	°C	0 - 70
PERFORMANCE			
	Free Deflection @ ± 180 Vp	µm	± 200
	Resolution	nm	25
	Load Capacity	grams	50
	Frequency Range (No load)	Hz	DC - 10

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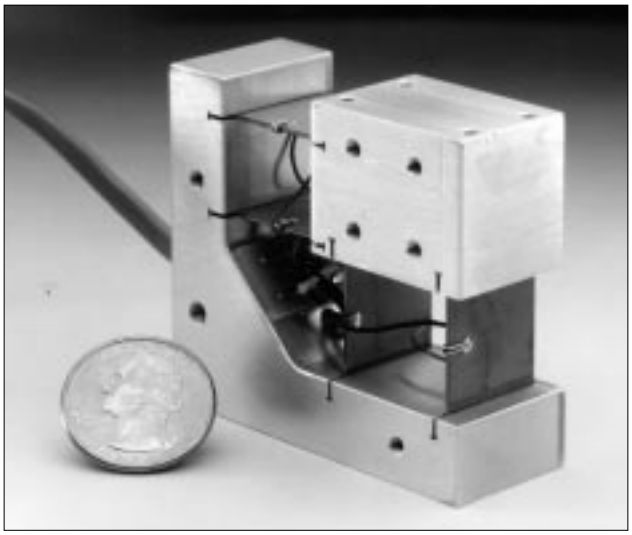
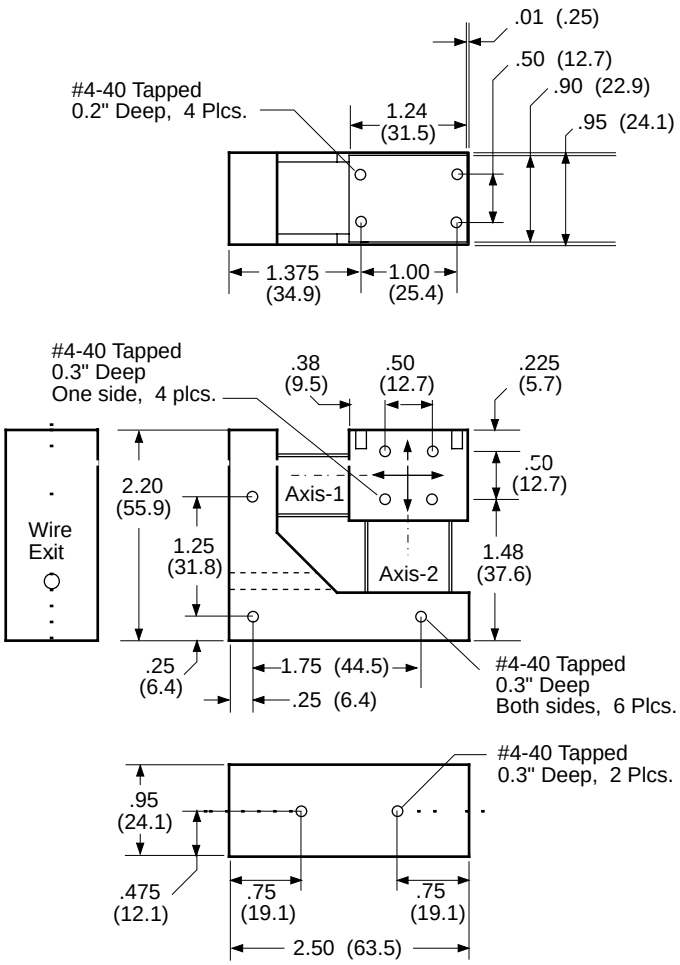
2-AXIS LINEAR POSITIONER, ± 1µm





DESCRIPTION

The 2-Axis Linear Positioner is a solid state high frequency device designed for optical fiber alignment or general micropositioning. The power take-off block is driven by piezoelectric motors configured to provide linear motion along the x and y axes. The positioner delivers extremely fine displacements (in the nm range) by adjusting the applied voltage. The piezoelectric motors produce no contamination or magnetic fields and show no wear over time.

The positioner can be mounted to ground using mounting holes on the bottom or sides. Power take-off can be accessed from the top or side. A power cable exits from the rear edge.

The positioner may be electronically driven with the EPA-102 Piezo Amplifier.

Custom Configurations: Other piezo linear positioner features are available in custom configurations, including: single axis, higher and lower motions, totally non-magnetic constructions, custom sizes and hole patterns.

ORDERING INFORMATION	PART NO.	PRICE
2-Axis Linear Positioner, ±1µm (English Version)	ILN2-002-E	$2,999

SPECIFICATIONS

2 - AXIS LINEAR POSITIONER, ± 1µm

MECHANICAL			
Dimensions (L x W x H)	Inches (mm)	2.5 x 1.0 x 2.2	(63.5 x 24.1 x 55.9)
Weight	grams	153	
ELECTRICAL			
Rated Input Voltage	Vp	± 70	
Input Capacitance (per axis)	nF	82	
Input Resistance (per axis)	MΩ	10	
ENVIRONMENTAL			
Operating Temperature	°C	10-40 °C	
Storage Temperature Range	°C	0 - 50 °C	
PERFORMANCE			
Motion (X Direction)	µm	±1	
Motion (Z Direction)	µm	±1	
Resolution	nm	±1	
Frequency Limit (no load)	Hz	5,000	
Load Capacity	grams	200	

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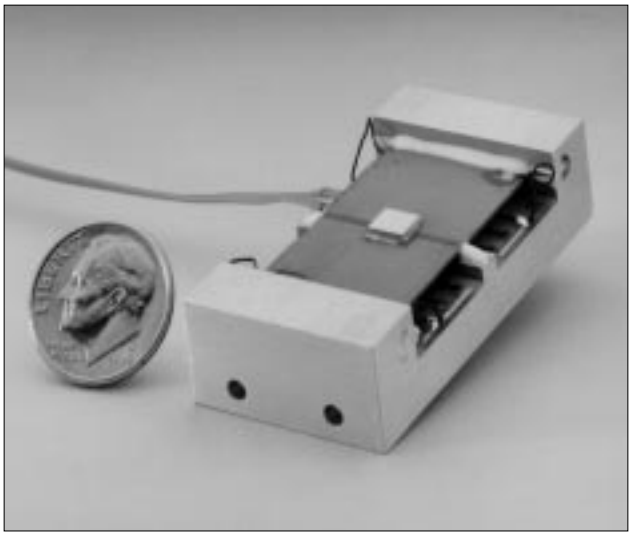
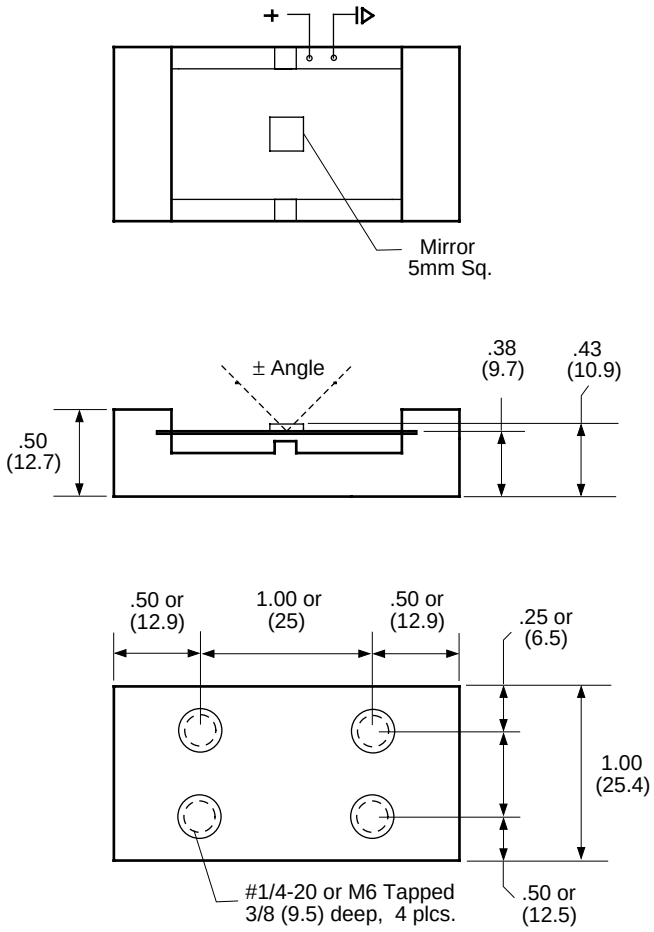
1-AXIS MIRROR TILTER, ± 0.75°





DESCRIPTION

The piezoelectric 1-Axis Mirror Tilter is a high frequency device designed to produce angular motion at high speed and low power. Because of its small size, this device is capable of being directly bolted to a gimbal mount and replaces bulky galvanometer systems. The piezoelectric motors provide reasonable displacement while delivering the fine resolution associated with piezoelectric devices. The motors produce no magnetic fields and are clean room compatible.

A 5mm x 5mm x 1mm crown glass mirror with a protective gold coating is directly attached to the motor assembly. The tilter may be electronically driven using the EPA-102 Piezo Linear Amplifier .Two hole patterns are available for mounting: 1/4-20 on 1 inch centers, or M6-1.0 on 25 mm centers.

Custom Tilter Configurations: Other piezo single axis tilter features are available in custom configurations, including: different angles and frequencies, custom mirror attachment, high temperature operation (up to 150°C), low temperature / low vacuum operation, totally non-magnetic constructions, and custom sizes.

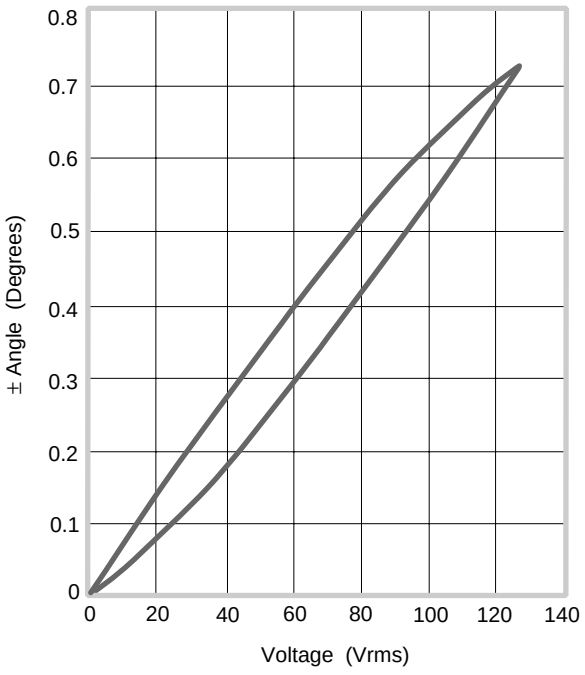
ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
1 - Axis Mirror Tilter (English version)	IAG1-004-E	$2,000	$1,250	$750	$400
1 - Axis Mirror Tilter (Metric version)	IAG1-004-M	$2,000	$1,250	$750	$400

SPECIFICATIONS

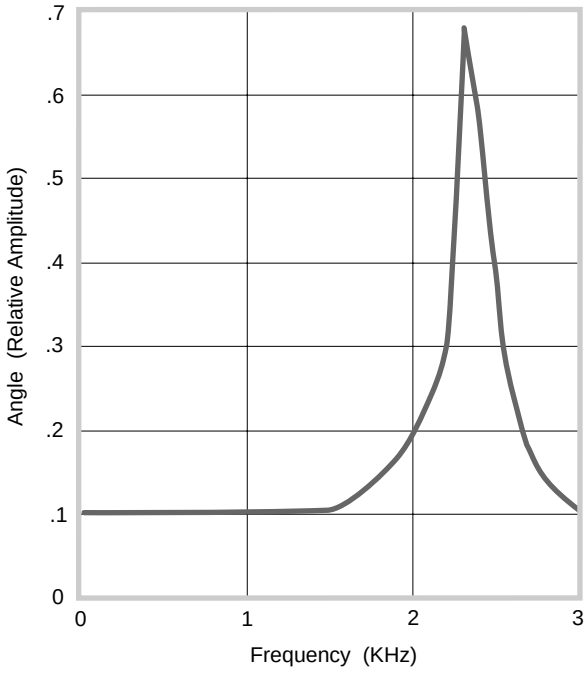
1- AXIS PIEZOELECTRIC MIRROR TILTER, ±0.75°

MECHANICAL			
	Dimensions (L x W x H)	Inches	2.0 x 1.0 x 0.5
		mm	50 x 25 x 12.5
	Mirror		
	Material		Crown Glass, Protective Gold Coating
	Dimensions (L x W x T)	mm	5 x 5 x 1
	Flatness		3 l per 25 mm
	Weight	Grams	30
	Mounting	English	#1/4-20 tapped holes, 4 places, .5" x 1.0"
		Metric	M6 tapped holes, 4 places, 12.5mm x 25mm
ELECTRICAL			
	Maximum Input Voltage (Vp)	V peak	±180
	Capacitance	nF	22
PERFORMANCE			
	Angular Range (@ ± 180 Vp)	Degrees	± .72
	Broadband Operating Range	Hz	0 - 1,500
	Resonant Frequency	Hz	2,200
	Thermal Operating Range	° C	-20 to 60
	Thermal Storage Range	° C	-30 to 70

Angle versus Voltage



Amplitude versus Frequency



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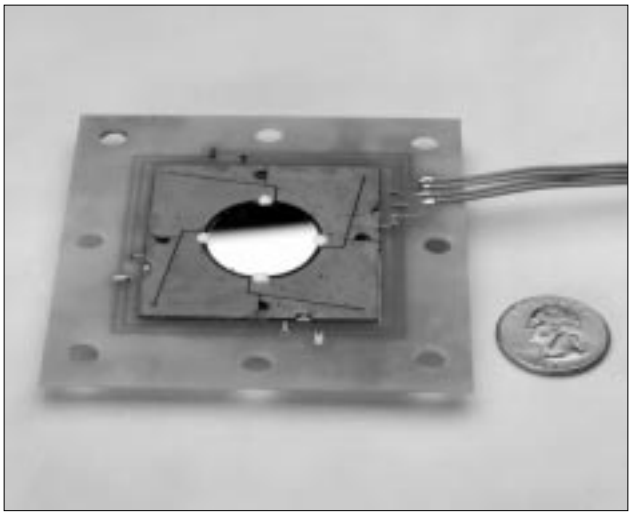
2-AXIS MIRROR TILTER, ± 1.5°

ULTRA THIN PROFILE

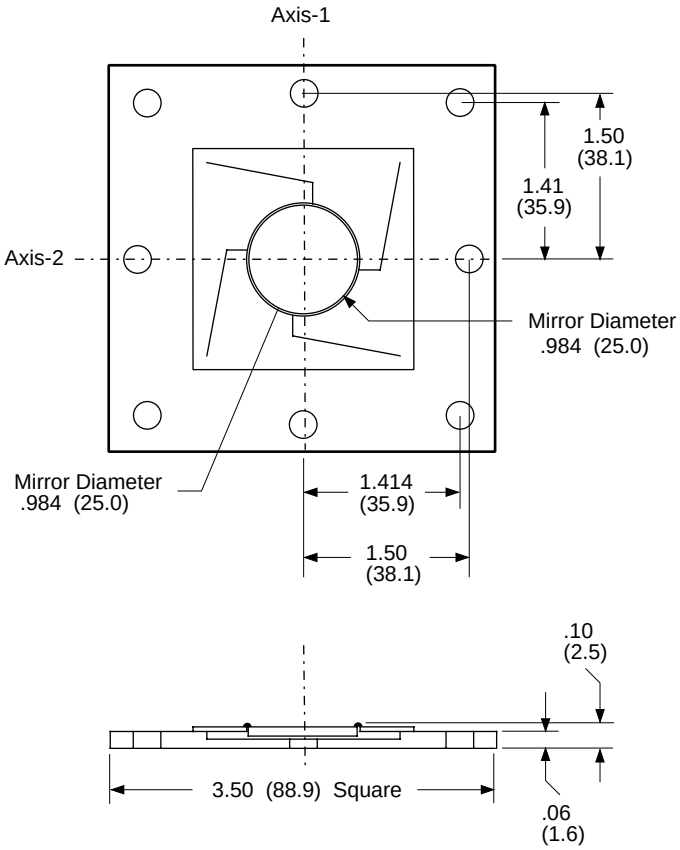


DESCRIPTION

The piezoelectric 2-axis mirror tilter is a low profile device designed for insertion between closely spaced components in an optical path. It may be used for either reflective or refractive optical elements. The tilter delivers precise angular motions for dynamic beam steering, adjustment, or stabilization. Large angular deflections ≥ ±25 milliradians and resolution better than 5 µradians are obtained. Mirror elements may be provided separately for individual application needs.

Drive Electronics: Each axis my be driven using the EPA-102 linear amplifier described on page 4 and 5.

Custom Tilter Configurations: Other piezo double axis tilter features are available in custom configurations, including: different angles and frequencies, mirror attachments, high temperature operation (up to 150°C), low temperature / low vacuum operation, non-magnetic, and custom sizes.



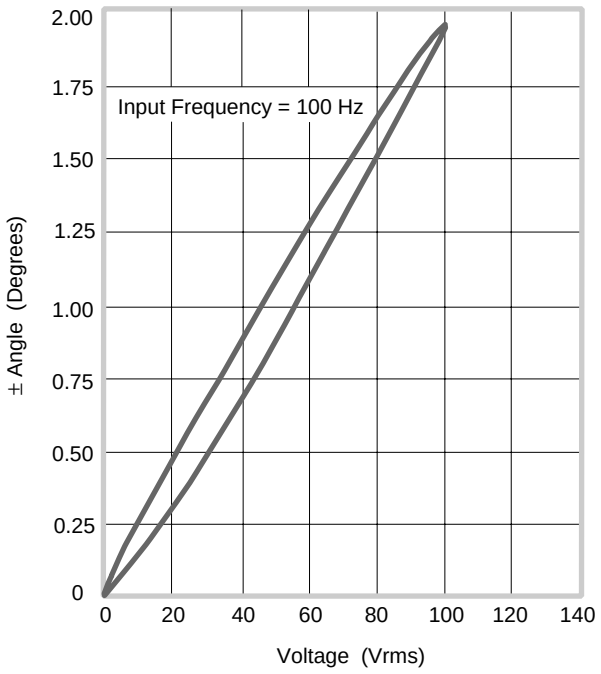
ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
2 - Axis Mirror Tilter (English version)	IAG2-005-E	$2,999	$1,999	$999	$599
2 - Axis Mirror Tilter (Metric version)	IAG2-005-M	$2,999	$1,999	$999	$599

SPECIFICATIONS

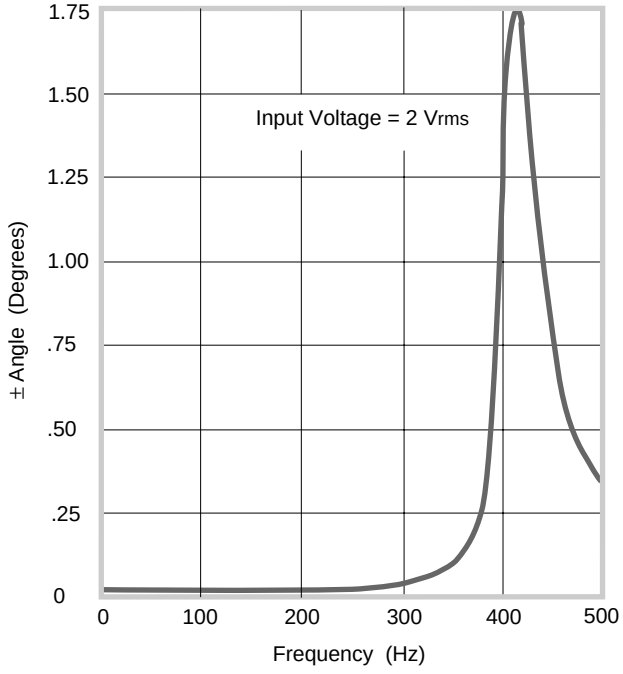
2 - AXIS PIEZOELECTRIC MIRROR TILTER, ±1.5°

MECHANICAL			
	Dimensions (L x W x H)	inches	3.5 x 3.5 x .090 (89 x 89 x 2.3)
	Round Flat Mirror		
	Material		Crown Glass, Aluminum Coating
	Dimensions (Dia. x T)	inches	Ø.984 x .039 (Ø25.0 x 1.0)
	Flatness		3 λ per 25 mm
	Weight	grams	28
	Mounting	English	#1/4-20 Clr holes on 3" centers (and 4")
		Metric	M6 Clr holes on 75mm centers (and 100mm)
ELECTRICAL			
	Rated Input Voltage (Vp)	Vp	± 180
	Capacitance (per axis)	nF	35
ENVIRONMENTAL			
	Thermal Operating Range	° C	-20 to +60
	Thermal Storage Range	° C	-30 to +70
PERFORMANCE			
	Angular Range (@ ± 180 Vp)	degrees	± 1.5
		radians	± .026
	Resolution	µradians	± 25
	Broadband Operating Range	Hz	0 - 200
	Resonant Frequency	Hz	~400

±Angle versus Voltage



Amplitude versus Frequency



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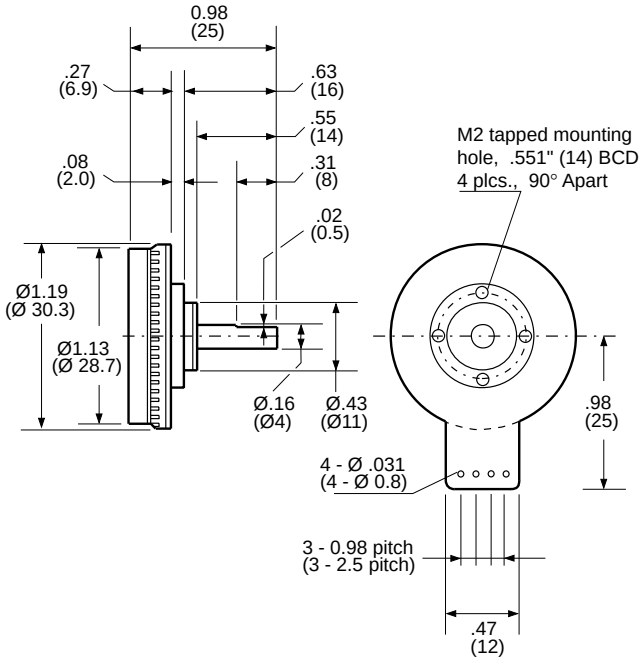
ULTRASONIC ROTARY MOTOR



DESCRIPTION

Phased excitation of a piezoelectric ring produces progressive elastic oscillations (travelling waves) along its surface. This wave induces rotational motion to the rotor pressed against it. When excitation is stopped, the shaft is held in place by friction force. By reversing electrical excitation, the rotor turns in the opposite direction.

Unique features of the ultrasonic motor are: compact size, low rpm without the need for gear reduction, quick response, quiet operation, holding torque greater than driving torque, and lack of magnetic field generation.

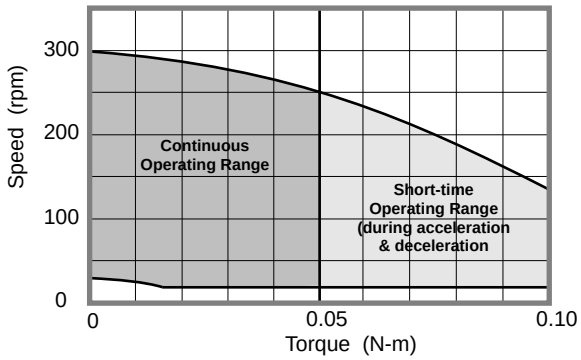
The ultrasonic motor / electronic driver require a ±24 VDC power supply, switches and wiring.

ULTRASONIC MOTOR KIT

The ultrasonic motor kit is intended primarily as a convenient demonstration device. It consists of an ultrasonic motor mounted to a stand, an electronic driver, and a controller. The controller houses the electronic driver, power supply, on-off switching, direction switch, and speed control.

MOTOR PERFORMANCE

Motor Speed versus Output Torque



ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Ultrasonic Motor	RU30-001	$499	$399	$329	$249
Electronic Driver Circuit	RU30-001-C01	$349	$249	$179	$99
Ultrasonic Motor Kit	RU30K-001	$1,499			

SPECIFICATIONS

ULTRASONIC MOTOR & DRIVER

MOTOR

Motor Size	30.3 mm Dia., 11 mm Thick,
Shaft Size	4 mm Dia., 14 mm Long
Mounting Holes	M2-3 on a 14 mm BCD, 90° Apart
Rated Torque	0.05 Nm
Holding Torque	0.1 Nm
Response (no load)	
Starting Response Ttime	~ 50 ms
Stopping Response Time	~ 1 ms
Direction Reversl Response Time	~ 10 ms
Direction of Rotation	CW, CCW
Continuous Operation	2,000 Hrs.
Steady State Operating Range	
No Load	30 - 300 rpm
0.05 Nm	30 - 250 rpm
Transient Operating Range	
0.1 Nm	30 - 150 rpm
Operating Temperature Range	-10 to 55 °C
Allowable Temperature Rise	65° C at stator surface
Storage Temperature Range	-20 - 80°C
Humidity	≤ 75%
Weight	20 grams

DRIVER

Required Input Power	24 VDC, 0.7 Amps
Driver Output	110 VAC, 2 Phase, ~50 Khz
Operating Temperature Range	-10 - 55 °C
Storage Temperature Range	-20 - 80°C
Size	71mm x 56mm x 22mm
Weight	240 gram

CONTROLLER (Kit only)

Required Input Power	115 VAC, 60 Hz
Driver Output	24 VDC, 0.7 Amps
Power Switch	On / Off
Start / Stop Control	CW, OFF, CCW
Speed control	Variable, B10KΩ , 0.1W potentiometer
Operating Temperature Range	-10 - 55 °C
Storage Temperature Range	-20 - 80°C

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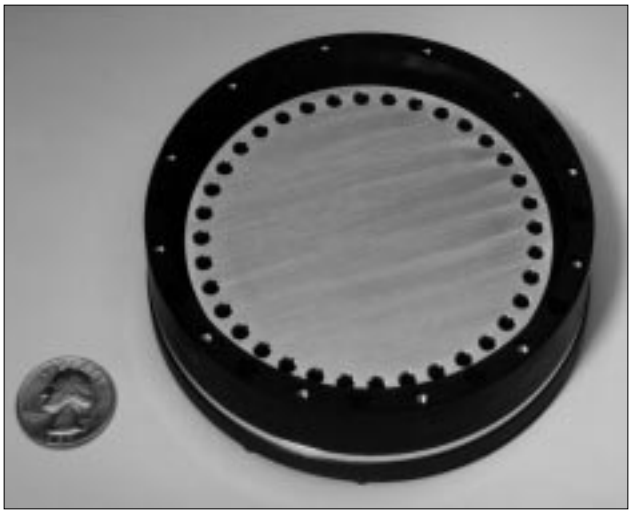
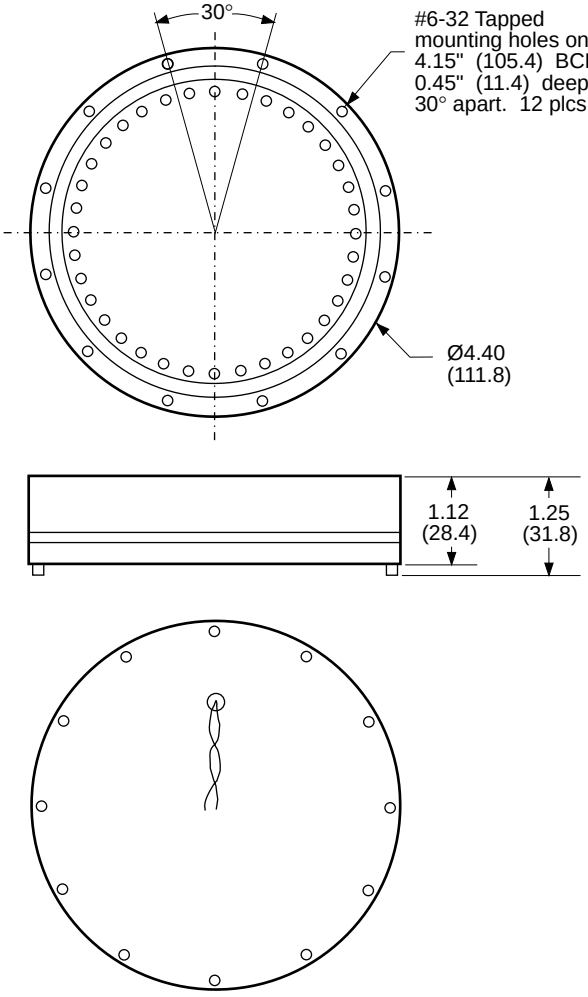
LIGHTWEIGHT ACOUSTIC SOURCE





DESCRIPTION

The Lightweight Acoustic Source is a rugged, high output, low mass acoustic source. It is a ceramic-metal composite structure. Unlike conventional speakers, it has no fragile cone or moving coils.

The front face of the ABS mounting ring allows attachment and electrical isolation from the structure to which it is mounted. Twelve #6-32 tapped metal inserts located 30° apart on a 4.15" bolt circle are provided for this purpose.

FEATURES

- Useful output band of one octave starting at 1 KHz.
- Precision manufacturing method ensures close phase response matching from one unit to the next for large array noise cancellation experiments.
- Shallow mechanical envelope for tight spaces.
- Light weight and rigid metal diaphragm makes the acoustic source impervious to air buffeting and frame vibrations that compromise plastic and paper cone speaker outputs.
- Exposure to repetitive high "G" forces will not change speaker properties or shorten life.
- Plastic ring mount electrically isolates piezo actuator from mechanical ground, giving flexibility and safety to electronic drive schemes.
- Can be driven with Piezo Systems' small light weight switching amplifier (2 lbs).

Custom Acoustic Source Configurations: Other Acoustic Source features are available in custom configurations, including: different sound levels and frequencies, high temperature operation (up to 150°C), low temperature / low vacuum operation, non-magnetic, and custom sizes.

APPLICATIONS

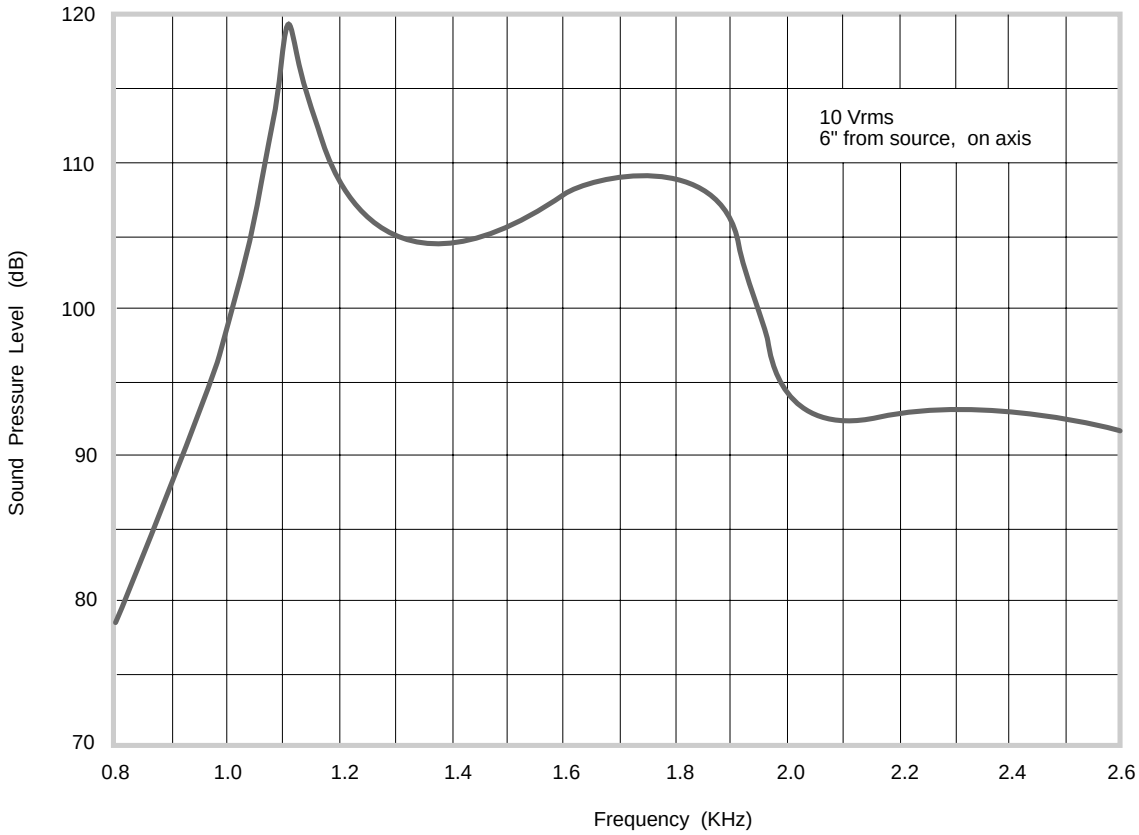
- Noise Cancellation
- High Intensity Sound Experimentation
- High "G" Environment Acoustic Experimentation
- Warning Speaker

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Piezoelectric Lightweight Acoustic Source	DAS-001	$799	$499	$299	$199

SPECIFICATIONS

LIGHTWEIGHT ACOUSTIC SOURCE

MECHANICAL		
Dimensions		
Dia. x Thickness	inches (mm)	4.50 x 1.25 (114 x 32)
Weight	grams	241
Mounting		#4-40 screws, front mounted 12 places, 30° apart
ELECTRICAL		
Rated Input Voltage	Vp	±100
Capacitance	nF	132
ENVIRONMENTAL		
Thermal Operating Range	°C	0 to +70
Thermal Storage Range	°C	-10 to +70
PERFORMANCE		
Operating Frequency Range		See graph below
Nominal Output, SPL	dB	125 (70 Vrms, 6 inches from source)



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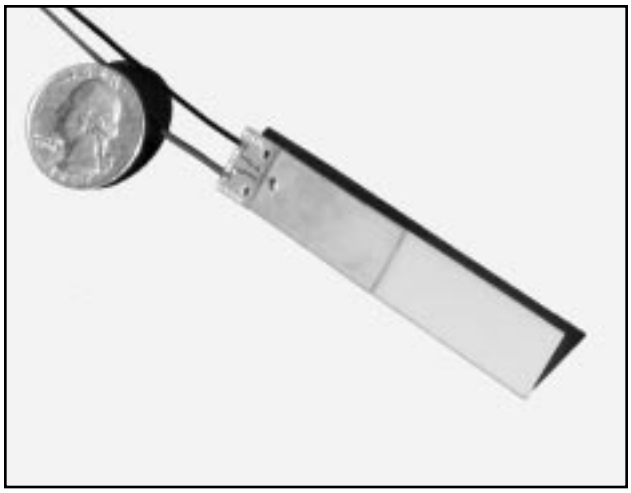
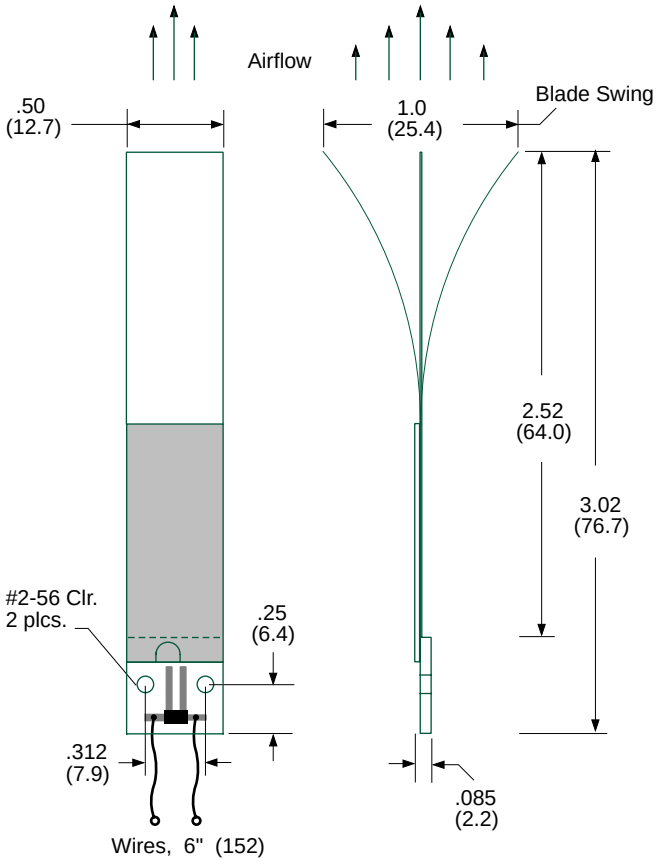
PIEZO FAN BLADE, 115 V / 60 HZ VERSION





DESCRIPTION OF PIEZO FAN

Piezo fans are solid state devices without wearing parts. Their oscillating mylar blade is driven at resonance by a piezo bending element. In free air, high amplitude resonant vibration of the plastic blade causes formation of high velocity unidirectional flow stream. Maximum airflow occurs on axes of the fan's centerline, relative to both width and height dimensions. Air intake is above and below the swept out plane of the blade. Its' simple design lends itself to low cost in high volume production.

Piezo fans offer advantages over conventional fan technology. These include: instant starting with no power surge, making them especially desirable for spot cooling; ultra-light weight; thin profile; and extremely low magnetic permeability. They produce almost no heat dissipation making them ideal for sealed enclosures. The 115 V / 60 Hz version piezo fan requires no drive circuit and can be driven directly off the power bus.

Custom Piezo Fan Configurations: Other piezo fan features are available in custom configurations, including: different flow rates and sizes, high temperature operation (up to 150°C), low temperature / low vacuum operation, totally non-magnetic versions, DC operation, flow-through, and water-proof configurations.

FAN SPECIFICATIONS

Input Voltage:	115 VAC, 60 Hz
Capacitance:	15 nF
Power Consumption	30 mW
Volume Flow Rate:	2 CFM, (0.9 l/s)
Peak Air Velocity:	400 FPM, (2.0 m/s)
Weight:	2.8 grams
Mounting :	#2-56 clr. holes, 2 places
Temperature Range:	-20° C to 70° C
EMI / RFI:	None

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Piezo Fan Blade, 115 V / 60 Hz	RFN1-005	$149	$79	$49	$34

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PIEZOELECTRIC RESONANT BLADE ELEMENT

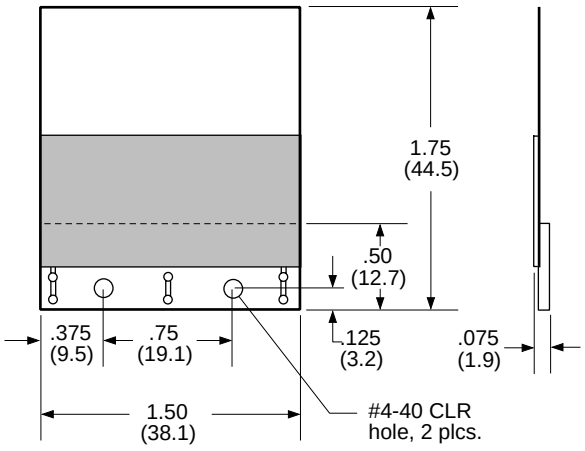
DESCRIPTION OF RESONATOR

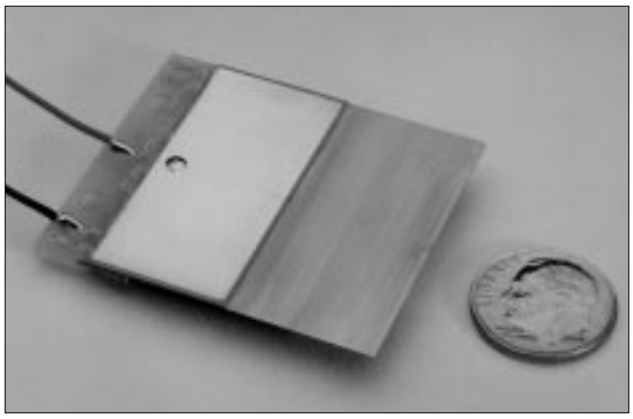
The piezoelectric resonant blade element can be used as a single fan blade, a vibration source, a chopper, or modulator.

The resonant element is easy to use and install. Its low profile, small size, low power consumption, low EMI, and thermal operating range make it possible to install in places forbidden to electro-magnetic devices.

The element resonates at approximately 185 Hz. Mass may be added to the tip of the element. to increase amplitude and decrease resonant frequency, or, metal may be trimmed from the tip to decrease amplitude and increase resonant frequency. The elements are particularly useful for establishing feasibility of a piezoelectric device for a resonant application, such as a chopper.

Custom Configurations: Other piezo resonator features are available in custom configurations, including: different amplitudes, frequencies, sizes , thermal operating ranges (up to 150°C), low temperature / low vacuum operation, and non-magnetic constructions.





PRINCIPLE OF OPERATION

The piezoelectric resonant element is powered electrostatically rather than magnetically. The metal portion of the blade is driven at resonance by a piezoelectric bender section at the base of the blade.

SPECIFICATIONS

Performance measured while driving the resonant blade element with Inverter Drive Circuit (PN: EIN-406).

Input Voltage (to Inverter):	30 V
Current:	5.1 mA
Power Consumption:	153 mW
Nominal Resonant Frequency:	185 Hz
Tip Amplitude (p-p):	.2 inches
Weight:	3.8 grams
Mounting :	#2-56 clr. holes
Temperature Range:	-40° C to 70° C

INVERTER DRIVE CIRCUIT

The resonant blade element requires an oscillating drive signal matched to the resonant frequency of the blade. This may be provided by a frequency generator / amplifier or inverter circuit. Piezo Systems provides a simple inverter circuit (PN: EIN-406 described on page 9). Output frequency of the inverter is adjusted manually by turning a trim pot on the PCB.

RESONATOR EVALUATION KIT

The resonator evaluation kit includes one piezoelectric resonant element and one inverter drive circuit.

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Piezoelectric Resonant Blade Element	RBL1-006	$149	$99	$60	$35
Piezoelectric Resonant Blade Evaluation Kit	RBL1K-006	$250			

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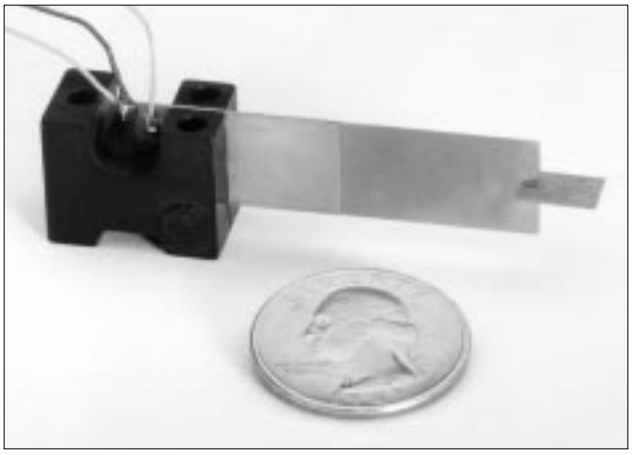
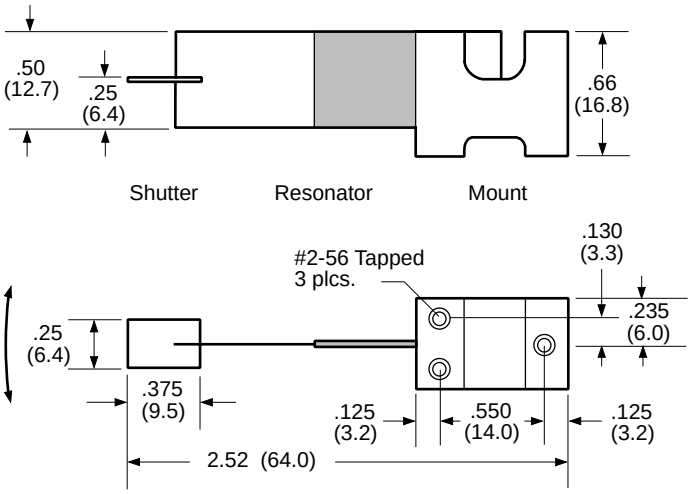
PIEZOELECTRIC CHOPPER



PRINCIPLE OF OPERATION

Piezoelectric choppers are powered electrostatically rather than magnetically. The oscillating blade and shutter is driven by a piezoelectric bending element operating at resonance.



INVERTER DRIVE CIRCUIT

When being driven sinusoidally, the 100 Hz piezo chopper requires an oscillating drive signal matched to the resonant frequency of the blade. This may be provided by a frequency generator/amplifier or inverter circuit. Piezo Systems provides a simple inverter circuit (PN: EIN-405 described on page 9). Output frequency is adjusted manually by turning a trim pot on the PCB.

CHOPPER DESCRIPTION

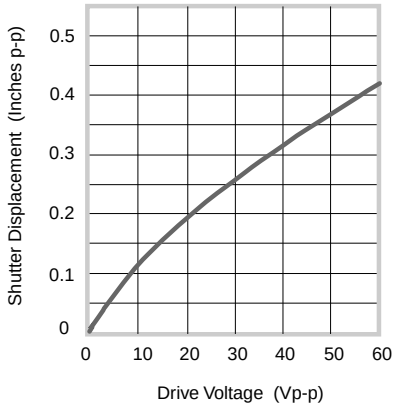
The piezoelectric chopper is a resonant device which moves a shutter attached to the front tip of its blade. Piezoceramic on one side of the blade can be used for excitation while the piezoceramic on the other side can be used for drive circuit feedback.

Compared to electro-magnetically driven wheels and tuning forks, the piezo chopper is lightweight, small, produces no EMI, operates over a wide temperature range, low power, reliable, and cost effective.

Custom Configurations: Other piezo chopper features are available in custom configurations, including: different amplitudes and frequencies, high temperature operation (up to 150°C), low temperature / low vacuum operation, and non-magnetic constructions, and two bladed (tuning fork configurations.

SPECIFICATIONS

Drive Voltage:	60 Vp-p
Nominal Resonant Frequency:	100 Hz
Shutter Amplitude:	.42 Inches p-p
Feedback Voltage:	20 Vp-p
Weight:	4.8 grams
Mounting Holes:	#2-56 tapped holes, 3 plcs.
Temperature Range:	0° to 60° C



CHOPPER EVALUATION KIT

The evaluation kit includes a 100 Hz piezo chopper and an inverter drive circuit.

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Piezo Chopper	RCH1-005	$249	$199	$59	$39
Piezo Chopper Evaluation Kit	RCH1K-005	$350			

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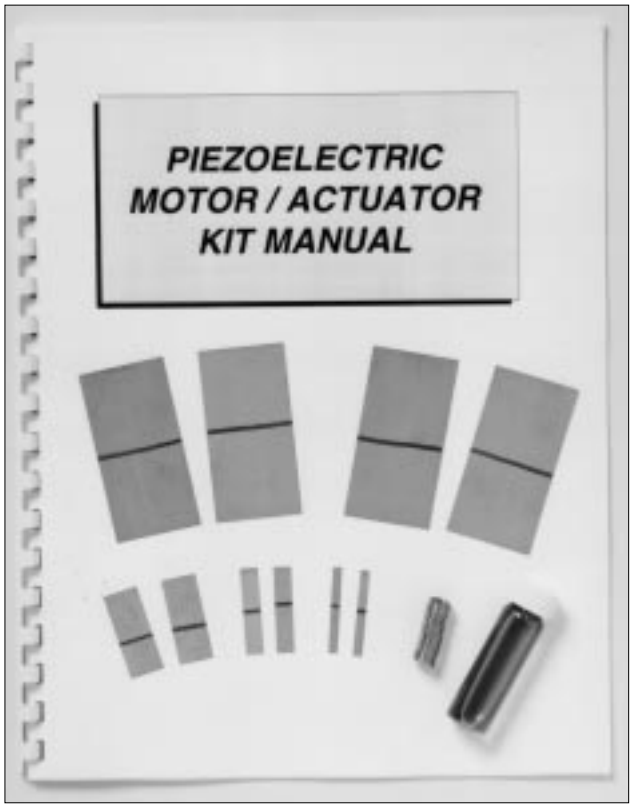
PIEZOELECTRIC MOTOR/ACTUATOR KIT

DESCRIPTION

The motor actuator kit is designed as a development tool for those who wish to quickly verify the feasibility of a piezoelectric approach to an idea or application. The piezoelectric materials provided in this kit represent some of the basic building blocks employed in constructing bending motors, extension motors, and stack motors. Emphasis is placed on designing and building bending actuators. Because the piezoelectric effect is reversible, the same elements are used as sensors and generators. PSI-5A-S4-ENH piezoceramic was chosen for the kit because it offers the fewest voltage, temperature, and stress restrictions. It is, by far, the most commonly used piezoceramic in the industry.

The manual is intended to help the user model, fabricate, and test a prototype actuator as rapidly as possible. Quick and simple techniques for cutting piezoceramic elements to desired size are described, as well as, attaching leads to the electrodes. Equations for free deflection, block force , resonant frequency, maximum stress, and capacitance allow the user to scale experimental results to many actuator designs.



PIEZO MOTOR APPLICATIONS

- Micro actuators and manipulators for optical, robotic, fluidic, biomedical, electronic, and process engineering.
- Vibrating shutters and dithering devices.
- Acoustics and ultrasonics.
- Micro-pumps for process control and medical instrumentation.
- Small size, light weight, low power, solid state, actuators of all types for aerospace and battery powered devices.

THE KIT INCLUDES

- Piezoceramic Single Sheets; PSI-5A-S4-ENH
  2 pieces: 1.25" x 2.5" x .0075"
- 2– Layer Standard Brass Piezo Motor Elements
  Poled for series operation
  1 piece: 2.50" x 1.250" x .020"
  1 piece: 1.25" x 0.500" x .020"
  1 piece: 1.25" x 0.250" x .020"
  1 piece: 1.25" x 0.125" x .020"
  Poled for parallel operation
  1 piece: 2.50" x 1.250" x .020"
  1 piece: 1.25" x 0.500" x .020"
  1 piece: 1.25" x 0.250" x .020"
  1 piece: 1.25" x 0.125" x .020"
- Piezoelectric Motor/Actuator Manual
  Introduction to Piezoelectricity
  Designing Piezoelectric Actuators
  Building Piezoelectric Actuators
- Wires, Solder and Flux

ORDERING INFORMATION	PART NO.	PRICE
Piezoelectric Motor/Actuator Kit	KMA--005	$499

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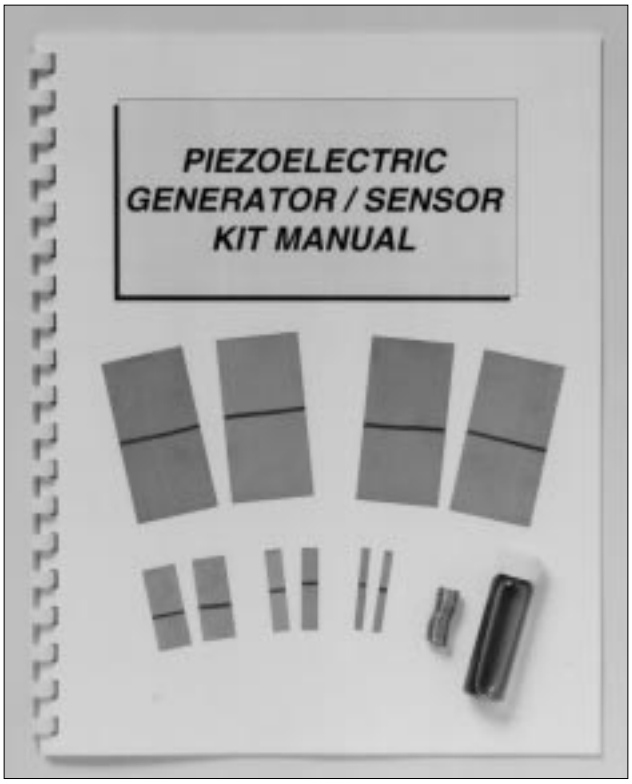
PIEZOELECTRIC GENERATOR/SENSOR KIT



DESCRIPTION

The generator / sensor kit is designed as a development tool for those who wish to quickly verify the feasibility of a piezoelectric approach to an idea or application. The piezoelectric materials provided in this kit represent some of the basic building blocks employed in constructing bending generators, extension generators, and stack generators. Because the piezoelectric effect is reversible, the same elements are used as motors and actuators. PSI-5A-S4-ENH piezoceramic was chosen for the kit because it offers the fewest voltage, temperature, and stress restrictions. It is, by far, the most commonly used piezoceramic in the industry.

The manual is intended to help the user model, fabricate, and test a prototype generator as rapidly as possible. For example, quick and simple techniques for cutting ceramic elements to desired size are described. Equations for open circuit voltage, closed circuit current , resonant frequency, maximum stress, and capacitance allow the user to scale experimental results to many actuator designs.

THE KIT INCLUDES

- Piezoceramic Single Sheets; PSI-5A-S4-ENH
  2 pieces: 1.25" x 2.5" x .0075"
- 2– Layer Standard Brass Piezo Motor Elements
  Poled for series operation
  1 piece: 2.50" x 1.250" x .020"
  1 piece: 1.25" x 0.500" x .020"
  1 piece: 1.25" x 0.250" x .020"
  1 piece: 1.25" x 0.125" x .020"
  Poled for parallel operation
  1 piece: 2.50" x 1.250" x .020"
  1 piece: 1.25" x 0.500" x .020"
  1 piece: 1.25" x 0.250" x .020"
  1 piece: 1.25" x 0.125" x .020"
- Piezoelectric Generator / Sensor Manual
  Introduction to Piezoelectricity
  Designing Piezoelectric Generators
  Building Piezoelectric Generators
- Wires, Solder and Flux

PIEZO GENERATOR APPLICATIONS

- Self energized accelerometers
- Activity & rate response sensors
- Vibration control & damping
- Dynamic strain instrumentation
- Small size, light weight, self-power, solid state sensors

ORDERING INFORMATION	PART NO.	PRICE
Piezoelectric Generator/Sensor Kit	KGS-006	$499

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PIEZO DESIGN AID SOFTWARE DISKETTE

DESCRIPTION

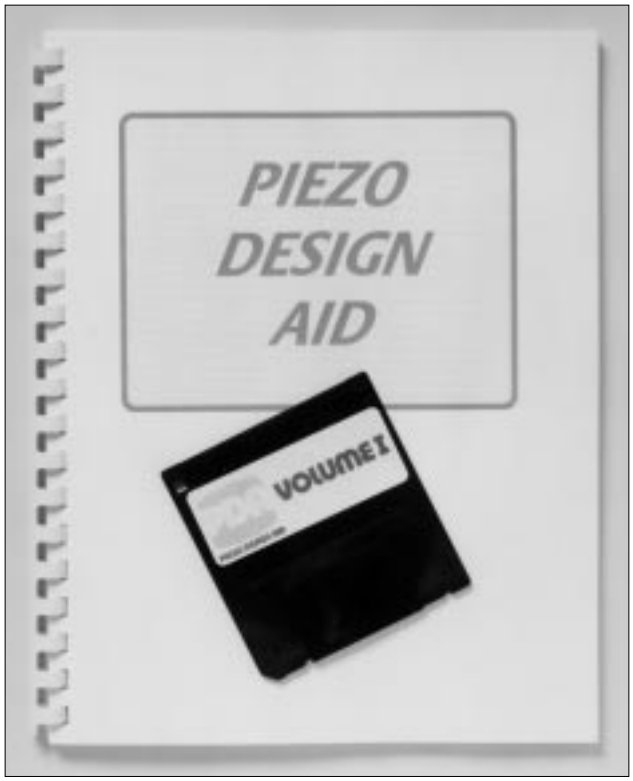
The Piezo Design Aid (PDA) is an iterative, text based, tutorial diskette for your IBM PC or any IBM compatible computer. It allows the user to rapidly complete numerous feasibility computations of basic piezoelectric actuator and generator applications.

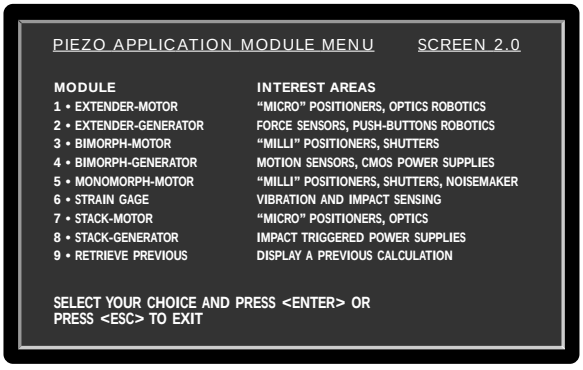
The PDA is a complete seminar that teaches piezoelectric theory and concepts. An expandable materials data base and application modules allow you to estimate performance for many variations on 8 basic "motor" and "generator" designs . Each application module is a full display calculator showing all formulae, inputs and outputs clearly:

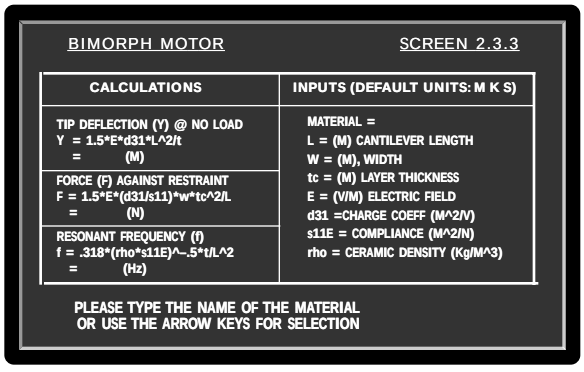
- Type in the piezo material of your choice. The program looks up all relevant material coefficients and displays them.
- Type in design parameters in any units.
- The program displays the results of the indicated formula acting on your inputs.
- Compare the computed performance with your design goals.
- Edit any inputs to achieve design goals or observe parameter trade-offs.
- Save calculations for later retrieval.

The menu driven piezo tutorial includes:

- Historical Perspective
- Evolution of Piezoelectric Applications
- Piezoceramic Materials
  - Properties
  - Fundamental Behavior
  - Manufacturing Processes
- Introduction to Piezoceramic Design
  - Design Fundamentals
- Thinking Piezo
  - Familiarity with Piezo Properties and Behavior
- Symbol Explanations
- Application Modules
  - Stacks: Motors and Generators
  - Benders: Motors and Generators
  - Extenders: Motors and Generators
  - Strain Gauges
- Glossary
- Bibliography







ORDERING INFORMATION	PART NO.	PRICE
Piezo Design Aid ($5^1/_4$" or $3^1/_2$" media)	KSF-002	$199

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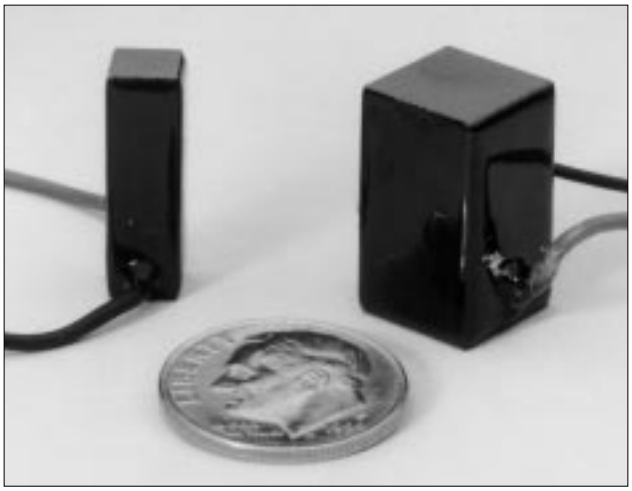
LOW VOLTAGE PIEZOELECTRIC STACKS



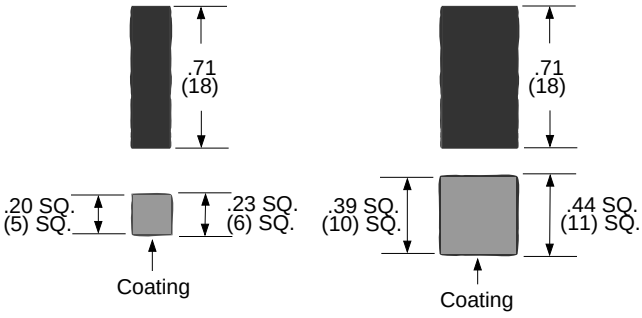
DESCRIPTION

A low voltage piezoelectric stack is a monolithic ceramic construction of many thin piezoceramic layers which are connected in parallel electrically. The principal characteristics of the stack are: a high energy conversion efficiency, low voltage operation, large force, low motion, fast response, and no EMI.

Motion may be increased, at the expense of force, by mechanical amplification. The stack offers a high energy density in a small package. Due to its superior compressive strength, it provides a high load bearing capability. However, it is relatively weak in tension.

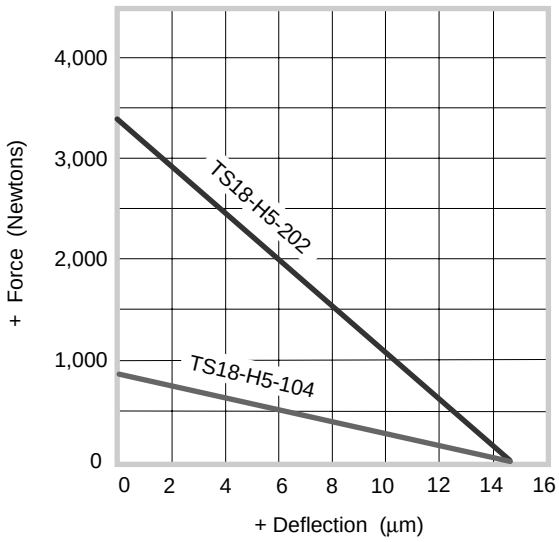
Generally, excitation should be applied only in the direction of polarization.

Hysteresis is typically about 15% in static applications.

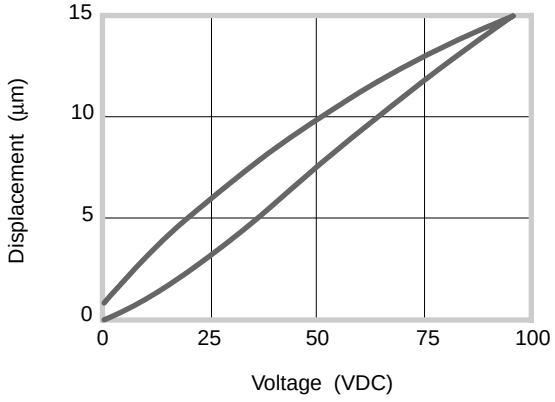


TS18-H5-104 TS18-H5-202

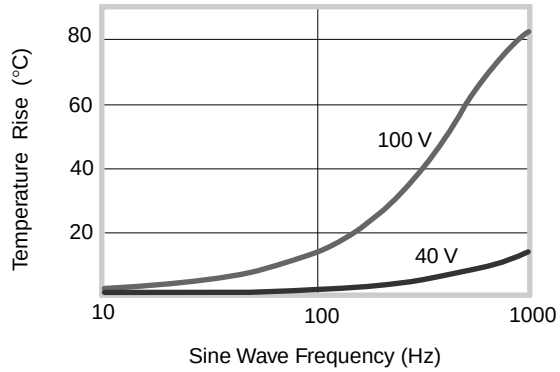
STACK PERFORMANCE



TSI8-H5-104 & TSI8-H5-202



TSI8-H5-104



ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Low Voltage Piezoelectric Stack (small)	TS18-H5-104	$350	$300	$250	$200
Low Voltage Piezoelectric Stack (large)	TS18-H5-202	$499	$425	$350	$275

SPECIFICATIONS

PIEZOELECTRIC STACKS

		TS18-H5-104	TS18-H5-202
MECHANICAL			
Dimensions (L x W x H)	Inches	0.2 x 0.2 x 0.72	0.4 x 0.4 x 0.72
	mm	5 x 5 x 18	10 x 10 x 18
Compressive Strength	N/m^2	8.8×10^8	8.8×10^8
Tensile Strength	N/m^2	4.9×10^6	4.9×10^6
Young's Modulus	N/m^2	4.4×10^{10}	4.4×10^{10}
Poisson Ratio		0.34	0.34
Density	Kg/M^3	7,900	7,900
Weight	Grams	4.5	16.
Wires		.002 x 50 Stranded, Red wire positive	
ELECTRICAL			
Rated Voltage (Positive Only)		+100 VDC	+100 VDC
Capacitance	nF	1600	6,500
PERFORMANCE (@ =100 VDC)			
Free Deflection	µm	+14.5	+14.5
Blocked Force	N	840	3,388
Response Time	µs	50	50
ENVIRONMENTAL			
Thermal Operating Range	° C	-20° to +80°	
Thermal Storage Range	° C	-30° to +85°	
Humidity	%	< 50%	

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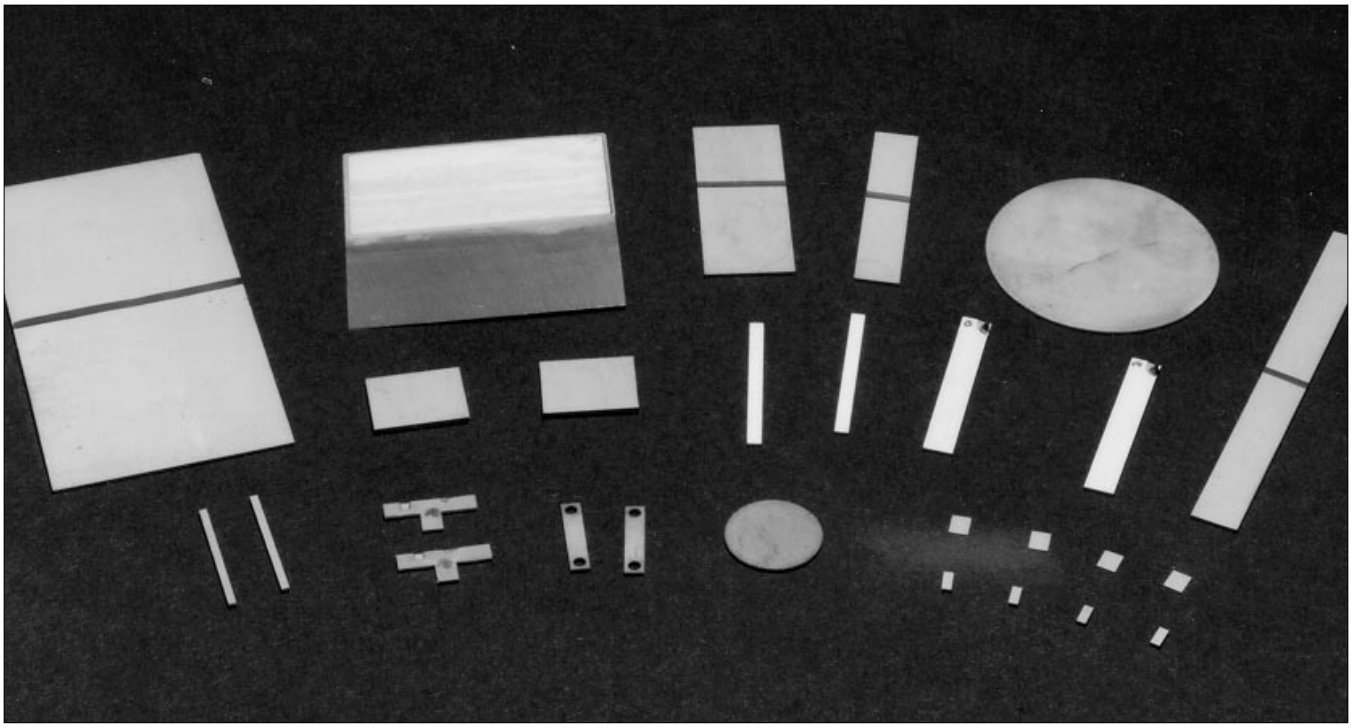
INTRODUCTION TO BENDING TRANSDUCERS



BENDING MOTORS

The piezoceramic bender is a versatile low power electromechanical transducer. As a motor, electrical excitation (voltage and current) leads to a mechanical response (motion and force).

The application of an electric field across the two layers of a bender causes one layer to expand while the other contracts. The net result is a curvature much greater than the length or thickness deformation of the individual layers.

A simple bender is actually a nine layer device consisting of four electrode layers, two piezoceramic layers, two adhesive layers, and a center shim. Crucial electromechanical properties of all individual sheets utilized for bending motors (or generators) are monitored. Piezo Systems proprietary bonding process leads to high-strength, uniform, void free laminations. Our advanced cutting techniques produce actuators with dimensional tolerances within ±.001 inch if necessary, widths as narrow as .020 inch, chip free edges, non-linear shapes, and contamination free surfaces.

Piezo Systems provides design, engineering, and production capabilities to develop custom bimorph actuators based on performance specifications rather than simple part geometry.

BENDING GENERATORS

As a generator (or sensor), mechanical excitation (motion and force) leads to an electrical response (voltage and current).

When a piezoceramic bender is forced to flex, one layer will be in tension while the other in compression. The stresses in each layer will produce electrical outputs which will simply be the summation of the outputs of each layer.

Benders may be used as strain gauges for easy and rapid determination of the characteristics of dynamic strains in structures. They exhibit extremely high sensitivities, in the order of 50 times that of wire strain gauges and are small enough that on most structures they will not materially affect the vibrational characteristics of the structure.

"SMART" DEVICES

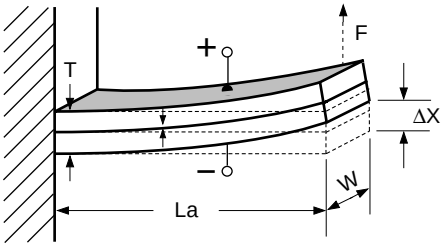
Piezo devices are ideal for use as "smart" devices. That is, part of the piezo volume is able to sense its surroundings while the other portion is able to respond as necessary. Each layer of a bender may be used for each purpose.

BENDING TRANSDUCER CHOICES

BENDING CONFIGURATIONS

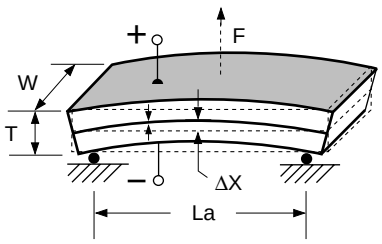
The common bending configurations, piezoceramic materials, bender thicknesses, and methods of mounting are shown below.

CANTILEVER CONFIGURATION



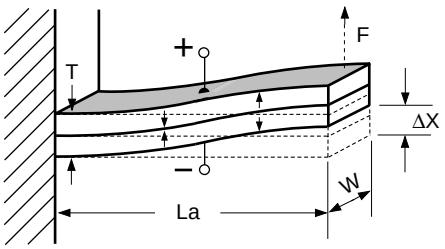
Standard Materials: PSI-5A type or PSI-5H type piezoceramic
Standard Thickness, T: .015" (.38 mm)
.020" (.50 mm),
.026" (.66 mm)
Characteristics: Right end moves along arc. Simplest to mount.

SIMPLE BEAM CONFIGURATION



To convert cantilever to simple beam performance:
Xf, Free Deflection = 1/4X cantilever motion
Fb, Blocked Force = 4X cantilever force
tr, Response Time ≈ 1/3X cantilever response
C, Capacitance = same as cantilever capacitance
Characteristics: Center moves up and down.

"S" BEAM CONFIGURATION



To convert cantilever to "S" beam performance:
Xf, Free Deflection = 1/2X cantilever motion
Fb, Blocked Force = 2X cantilever force
tr, Response Time ≈ 0.6X cantilever response
C, Capacitance = same as cantilever capacitance
Characteristics: Right end moves ~ linearly.

PIEZOCERAMIC MATERIAL

Typically PSI-5A piezoceramic is the first choice of most designers. 5A is the most temperature insensitive and offers the widest temperature range. PSI-5A achieves motion similar to PSI-5H if higher voltage is available. PSI-5H is recommended only when low voltage operation is essential.

CENTER SHIM MATERIALS

Center shim materials are available for enhancing strength (stainless steel), thermal range, non-magnetism (brass), and economy (brass). Specially designed center shims promote unique composite properties.

SERIES & PARALLEL OPERATION

Series operation refers to a bender with voltage applied across both piezoceramic layers. It is a two wire device, with one wire attached to each of the outside surfaces. Parallel operation refers to a bender with voltage applied across each piezoceramic layer individually. It is a three wire device, with one wire attached to each of the outside surfaces and a third wire attached to the center shim . For the same motion, a bender polarized for series operation requires twice as much voltage as a bender poled for parallel operation (see page 46). Polarization is depicted graphically as an arrow pointing from the positive electrode to the negative electrode.

NON-MAGNETIC

Totally non-magnetic piezo transducers are specially fabricated using non-magnetic electrode and center shim materials.

HIGH TEMPERATURE

High temperature piezo actuators are specially constructed to operate up to 150° C.

CRYOGENIC

Cryogenic piezo actuators are specially constructed to operate below 4.2° C. Motor performance is reduced by ~1/5 at 77° K and ~1/7 at 4.2° K. However, much higher voltages may be applied to the bender, thereby recovering lost performance.

VACUUM

Vacuum compatible piezo actuators are constructed to be baked-out up to 150°C and have a low cross-section for outgassing.

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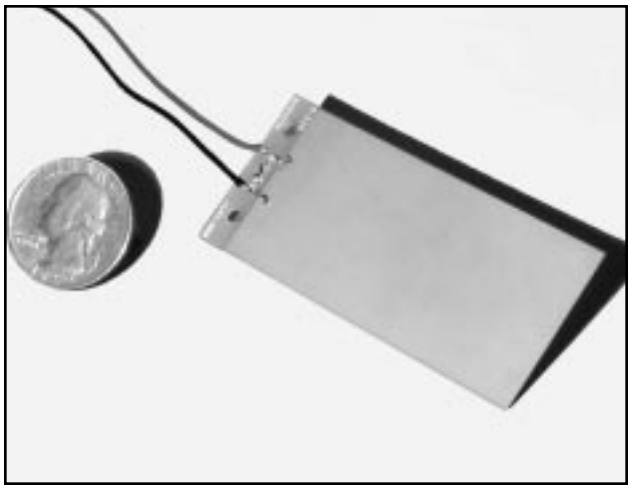
QUICK MOUNT BENDING ELEMENT, ±1300µM VERSION

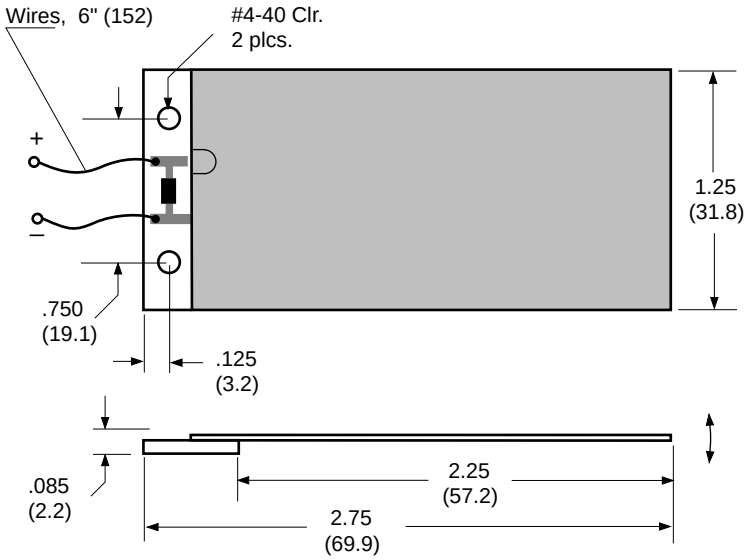


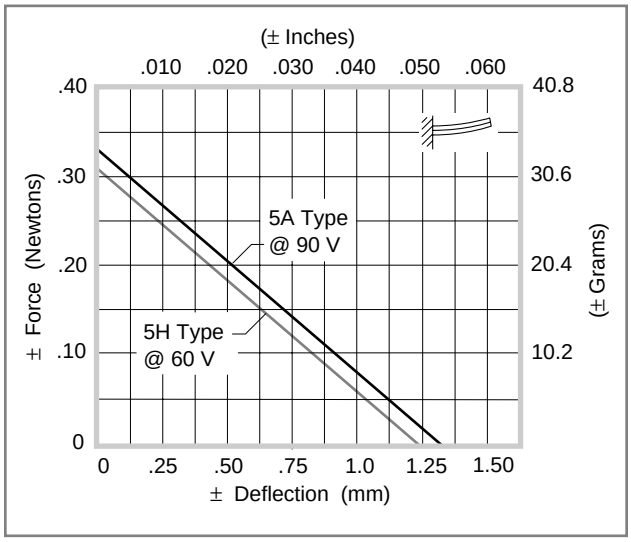
DESCRIPTION

The ±1300 µm version Quick Mount bending element may be used as an actuator and / or sensor. It is ready to be used immediately. The standard T220-A4-503 bending element is wired for low voltage operation and the PCB to which it has been mounted may be attached to mechanical ground using the two #4-40 mounting holes provided. A bleed resistor across the terminals protects the transducer from thermal transients. The user must provide the mechanical connection between the transducer tip and their load.

As an actuator, the transducer provides large deflection and moderate force at low frequencies. It exhibits low magnetic permeability and generates no magnetic fields.

Positioners constructed of 5A or 5H type piezoceramic are stocked for "off-the-shelf" delivery. Custom sizes and configurations are available on request.





SPECIFICATIONS & BENDING MOTOR PERFORMANCE (In the cantilever configuration)

PART NUMBER	PIEZO MATERIAL	WEIGHT	CAPACITANCE	MAXIMUM VOLTAGE	RESONANT FREQUENCY	RESPONSE TIME	FREE DEFLECTION	BLOCKED FORCE
		grams	nF	±Vp	Hz	ms	±µm	±N
T220-A4-503-QM	5A-S4-ENH	9.4	290	±90	70	5.0	± 1325	± .33
T220-H4-503-QM	5H-S4-ENH	9.4	480	±60	70	5.0	± 1240	± .31

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Quick Mount Bending Element, ± 1325 µm, 5A type	T220-A4-503-QM	$199	$129	$79	$54
Quick Mount Bending Element, ± 1240 µm, 5H type	T220-H4-503-QM	$199	$129	$79	$54

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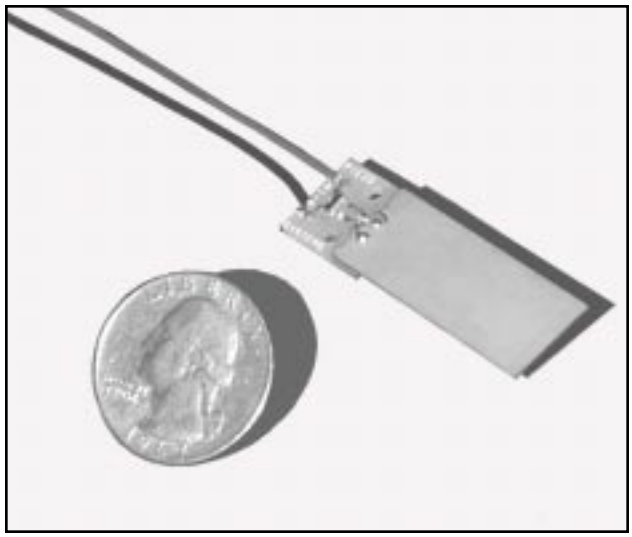
QUICK MOUNT BENDING ELEMENT ±300µM VERSION

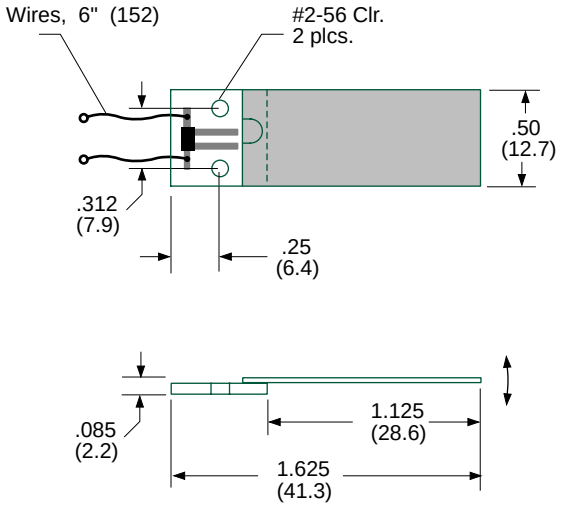


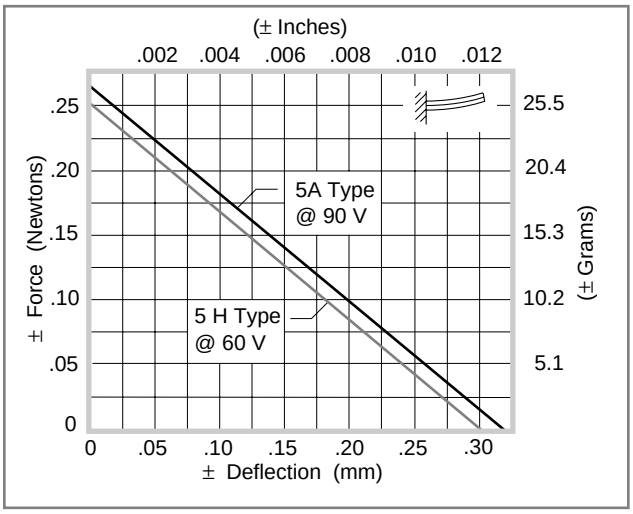
DESCRIPTION

The ±300 µm version Quick Mount bending element may be used as an actuator and / or sensor. It is ready to be used immediately. The standard T220-A4-303 bending element is wired for low voltage operation and the PCB to which it has been mounted may be attached to mechanical ground using the two #2-56 mounting holes provided. A bleed resistor across the terminals protects the transducer from thermal transients. The user must provide the mechanical connection between the transducer and their load.

As an actuator, the transducer provides medium range deflection and force. It exhibits low magnetic permeability and generates no magnetic fields.

Positioners constructed of 5A or 5H type piezoceramic are stocked for "off-the-shelf" delivery. Custom sizes and configurations are available upon request.





SPECIFICATIONS & BENDING MOTOR PERFORMANCE (In the cantilever configuration)

PART NUMBER	PIEZO MATERIAL	WEIGHT	CAPACITANCE	MAXIMUM VOLTAGE	RESONANT FREQUENCY	RESPONSE TIME	FREE DEFLECTION	BLOCKED FORCE
		grams	nF	±Vp	Hz	ms	±µm	±N
T220-A4-303-QM	5A-S4-ENH	2.5	58	±90	280	1.2	±320	± .27
T220-H4-303-QM	5H-S4-ENH	2.5	96	±60	280	1.2	±300	± .25

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Quick Mount Bending Element, ± 320 µm, 5A type	T220-A4-303-QM	$149	$79	$49	$34
Quick Mount Bending Element, ± 300 µm, 5H type	T220-H4-303-QM	$149	$79	$49	$34

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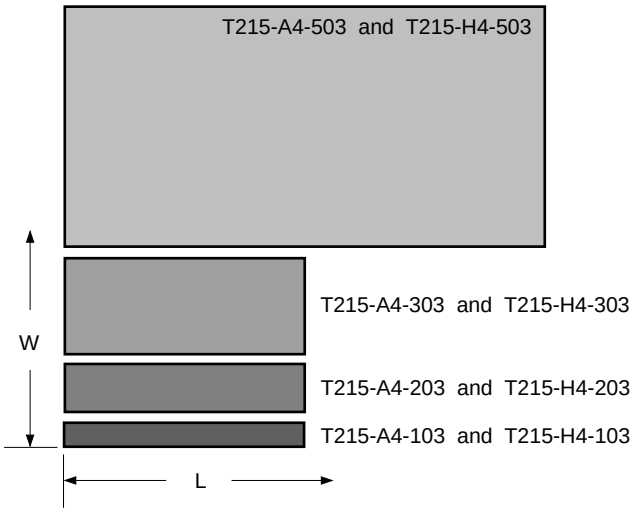
T215 BRASS SHIM BENDING ELEMENTS
STANDARD SIZES

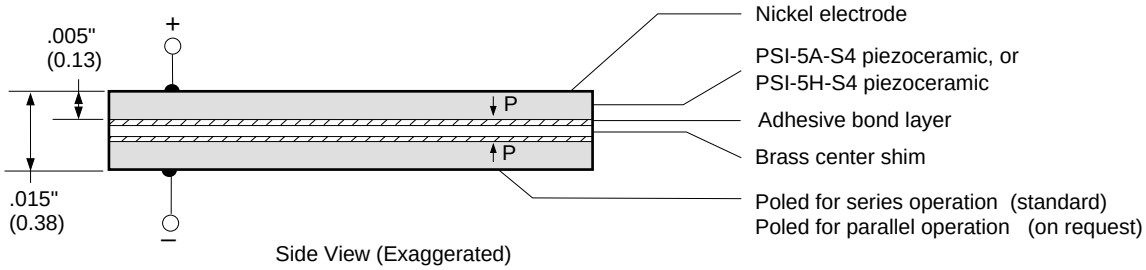
DESCRIPTION

The T215 Standard Brass Shim Bending Elements are .015" (0.38 mm) thick and sized to be produced economically. They are general purpose actuators designed to produce high deflections and moderate forces at low voltage, and exhibit low magnetic permeability. The parts are stocked for "off-the-shelf" delivery. Custom sizes are available on request.



Top View (Scale: x1)

PART NUMBER	WIDTH		LENGTH	
	Inches	(mm)	Inches	(mm)
Elements made with PSI-5A-S4 Piezoceramic				
T215-A4-103	.125	(3.2)	1.250	(31.8)
T215-A4-203	.250	(6.4)	1.250	(31.8)
T215-A4-303	.500	(12.7)	1.250	(31.8)
T215-A4-503	1.250	(31.8)	2.500	(63.5)
Elements made with PSI-5H-S4 Piezoceramic				
T215-H4-103	.125	(3.2)	1.250	(31.8)
T215-H4-203	.250	(6.4)	1.250	(31.8)
T215-H4-303	.500	(12.7)	1.250	(31.8)
T215-H4-503	1.250	(31.8)	2.500	(63.5)



Side View (Exaggerated)

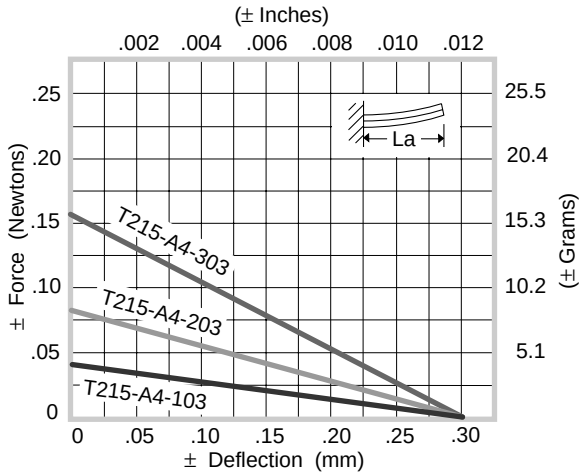
SPECIFICATIONS & BENDING MOTOR PERFORMANCE (In the cantilever configuration)

PART NUMBER	WEIGHT	CAPACITANCE		RATED VOLTAGE		RESPONSE TIME (FULL AMPLITUDE)		FREE DEFLECTION		BLOCKED FORCE	
		Series Operation	Parallel Operation	Series Operation	Parallel Operation	Active Cantilever Length, mm					
						25.4	50.8	25.4	50.8	25.4	50.8
	grams	nF	nF	±Vp	±Vp	ms	ms	±mm	±mm	±N	±N
T215-A4-103	.30	5.	20.	±120	±60	1.5	-	±0.3	-	±.04	-
T215-A4-203	.60	10.	40.	±120	±60	1.5	-	±0.3	-	±.08	-
T215-A4-303	1.2	20.	80.	±120	±60	1.5	-	±0.3	-	±.16	-
T215-A4-503	6.0	100.	400.	±120	±60	1.5	6.0	±0.3	±1.2	±.40	±.20
T215-H4-103	.30	8.	32.	±80	±40	1.5	-	±0.3	-	±.04	-
T215-H4-203	.60	16.	64.	±80	±40	1.5	-	±0.3	-	±.08	-
T215-H4-303	1.2	32.	128.	±80	±40	1.5	-	±0.3	-	±.16	-
T215-H4-503	6.0	160.	640.	±80	±40	1.5	6.0	±0.3	±1.2	±.40	±.20

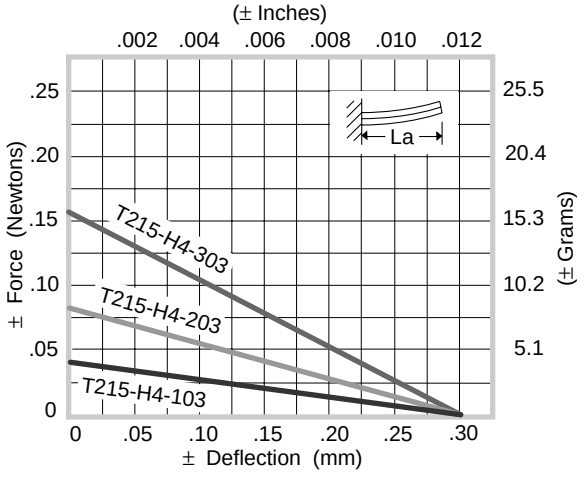
T215 BRASS SHIM BENDING ELEMENTS
STANDARD SIZES

BENDING MOTOR PERFORMANCE (In the cantilever configuration)

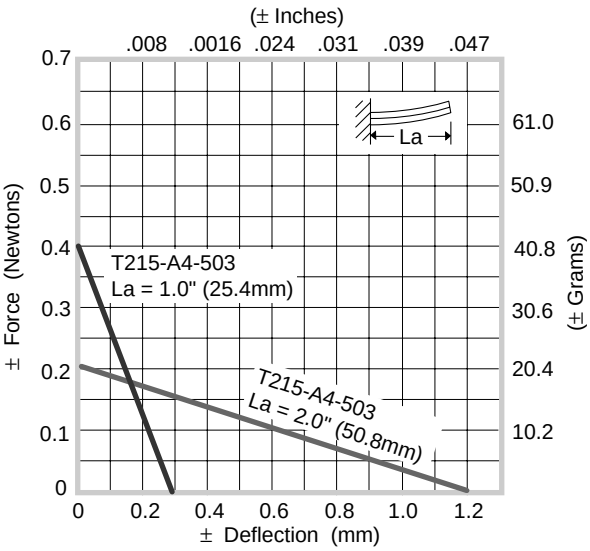
T215-A4-103, -203, -303 BENDING ELEMENTS
Voltage: ±120 Vp (Series) or ±60 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm)



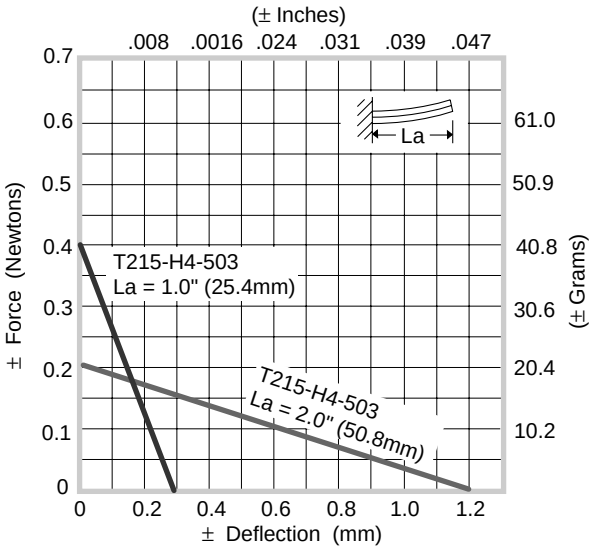
T215-H4-103, -203, -303 BENDING ELEMENTS
Voltage: ±80 Vp (Series) or ±40 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm)



T215-A4-503 BENDING ELEMENT
Voltage: ±120 Vp (Series) or ±60 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm) & 2.0" (50.8mm)



T215-H4-503 BENDING ELEMENT
Voltage: ±80 Vp (Series) or ±40 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm) & 2.0" (50.8mm)



ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
T215 Brass Shim Bending Element ("103" size)	T215-A4-103	$90	$40	$22	$12
T215 Brass Shim Bending Element ("203" size)	T215-A4-203	$90	$45	$25	$15
T215 Brass Shim Bending Element ("303" size)	T215-A4-303	$90	$50	$30	$20
T215 Brass Shim Bending Element ("503" size)	T215-A4-503	$125	$90	$60	$40
T215 Brass Shim Bending Element ("103" size)	T215-H4-103	$90	$40	$22	$12
T215 Brass Shim Bending Element ("203" size)	T215-H4-203	$90	$45	$25	$15
T215 Brass Shim Bending Element ("303" size)	T215-H4-303	$90	$50	$30	$20
T215 Brass Shim Bending Element ("503" size)	T215-H4-503	$125	$90	$60	$40

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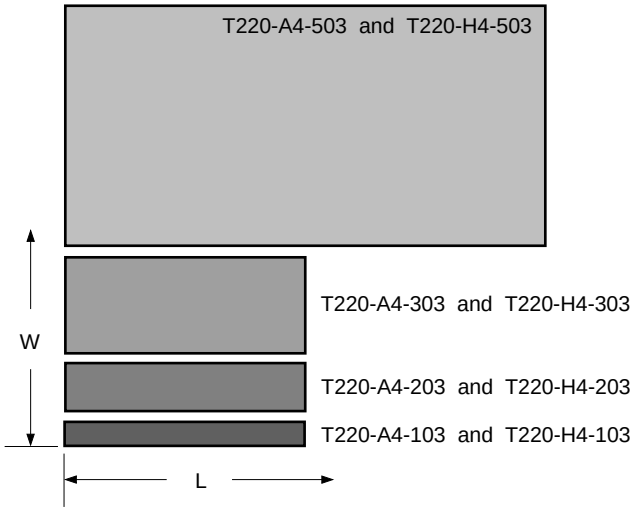
T220 BRASS SHIM BENDING ELEMENTS
STANDARD SIZES

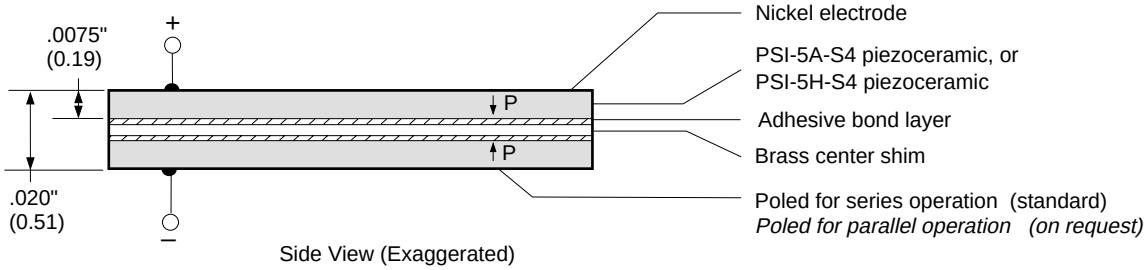
DESCRIPTION

The T220 Standard Brass Shim Bending Elements are .020" (0.5 mm) thick and sized to be produced economically. They are general purpose actuators designed to produce moderate deflections and forces, and exhibit low magnetic permeability. The parts are stocked for "off-the-shelf" delivery. Custom sizes are available on request.



Top View (Scale: x1)

PART NUMBER	WIDTH		LENGTH	
	Inches	(mm)	Inches	(mm)
Elements made with PSI-5A-S4 Piezoceramic				
T220-A4-103	.125	(3.2)	1.250	(31.8)
T220-A4-203	.250	(6.4)	1.250	(31.8)
T220-A4-303	.500	(12.7)	1.250	(31.8)
T220-A4-503	1.250	(31.8)	2.500	(63.5)
Elements made with PSI-5H-S4 Piezoceramic				
T220-H4-103	.125	(3.2)	1.250	(31.8)
T220-H4-203	.250	(6.4)	1.250	(31.8)
T220-H4-303	.500	(12.7)	1.250	(31.8)
T220-H4-503	1.250	(31.8)	2.500	(63.5)



Side View (Exaggerated)

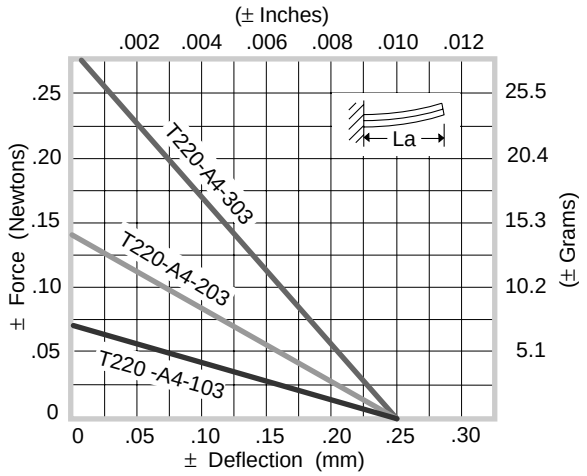
SPECIFICATIONS & BENDING MOTOR PERFORMANCE (In the cantilever configuration)

PART NUMBER	WEIGHT	CAPACITANCE		RATED VOLTAGE		RESPONSE TIME (FULL AMPLITUDE)		FREE DEFLECTION		BLOCKED FORCE	
		Series Operation	Parallel Operation	Series Operation	Parallel Operation	Active Cantilever Length, mm					
						25.4	50.8	25.4	50.8	25.4	50.8
	grams	nF	nF	±Vp	±Vp	ms	ms	±mm	±mm	±N	±N
T220-A4-103	.40	3.6	14.	±180	±90	1.2	-	±.25	-	±.07	-
T220-A4-203	.80	7.4	29.	±180	±90	1.2	-	±.25	-	±.14	-
T220-A4-303	1.6	14.5	58.	±180	±90	1.2	-	±.25	-	±.28	-
T220-A4-503	8.0	72.5	290.	±180	±90	1.2	4.8	±.25	±1.0	±.70	±.35
T220-H4-103	.40	6.0	24.	±120	±60	1.2	-	±.25	-	±07	-
T220-H4-203	.80	12.0	48.	±120	±60	1.2	-	±.25	-	±.14	-
T220-H4-303	1.6	24.	96.	±120	±60	1.2	-	±.25	-	±.28	-
T220-H4-503	8.0	120.	480.	±120	±60	1.2	4.8	±.25	±1.0	±.70	±.35

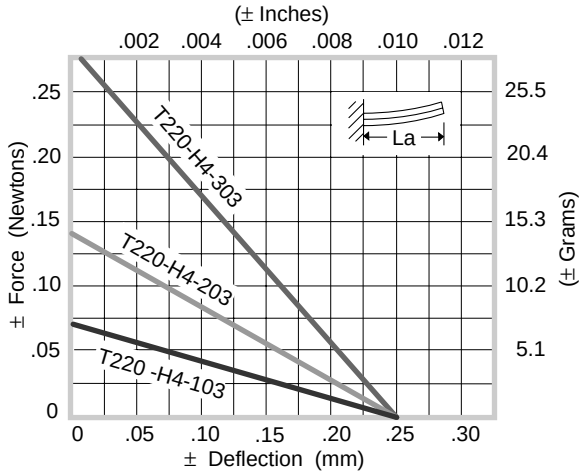
T220 BRASS SHIM BENDING ELEMENTS
STANDARD SIZES

BENDING MOTOR PERFORMANCE (In the cantilever configuration)

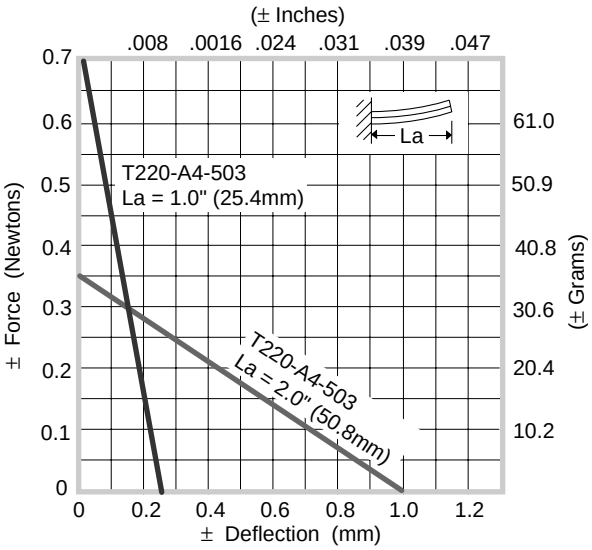
T220-A4-103, -203, -303 BENDING ELEMENTS
Voltage: ±180 Vp (Series) or ±90 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm)



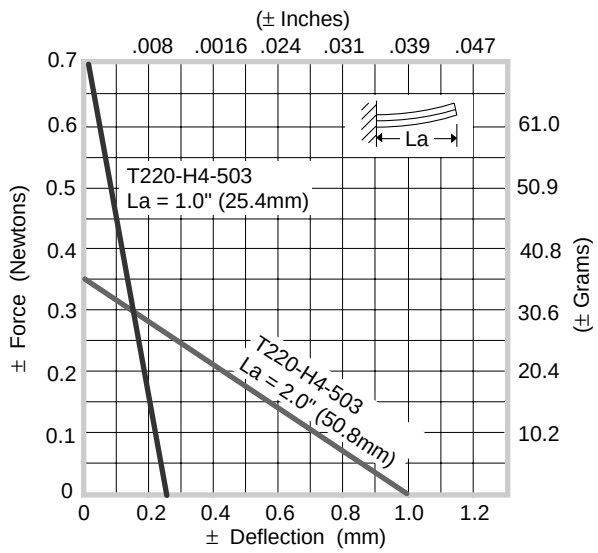
T220-H4-103, -203, -303 BENDING ELEMENTS
Voltage: ±120 Vp (Series) or ±60 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm)



T215-A4-503 BENDING ELEMENT
Voltage: ±180 Vp (Series) or ±90 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm) & 2.0" (50.8mm)



T220-H4-503 BENDING ELEMENT
Voltage: ±120 Vp (Series) or ±60 Vp (Parallel)
Active Cantilever Length: 1.0" (25.4mm) & 2.0" (50.8mm)



ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
T220 Brass Shim Bending Element ("103" size)	T220-A4-103	$75	$30	$18	$10
T220 Brass Shim Bending Element ("203" size)	T220-A4-203	$75	$35	$20	$12
T220 Brass Shim Bending Element ("303" size)	T220-A4-303	$75	$40	$25	$15
T220 Brass Shim Bending Element ("503" size)	T220-A4-503	$100	$75	$50	$35
T220 Brass Shim Bending Element ("103" size)	T220-H4-103	$75	$30	$18	$10
T220 Brass Shim Bending Element ("203" size)	T220-H4-203	$75	$35	$20	$12
T220 Brass Shim Bending Element ("303" size)	T220-H4-303	$75	$40	$25	$15
T220 Brass Shim Bending Element ("503" size)	T220-H4-503	$100	$75	$50	$35

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T220 BRASS SHIM BENDING ELEMENT

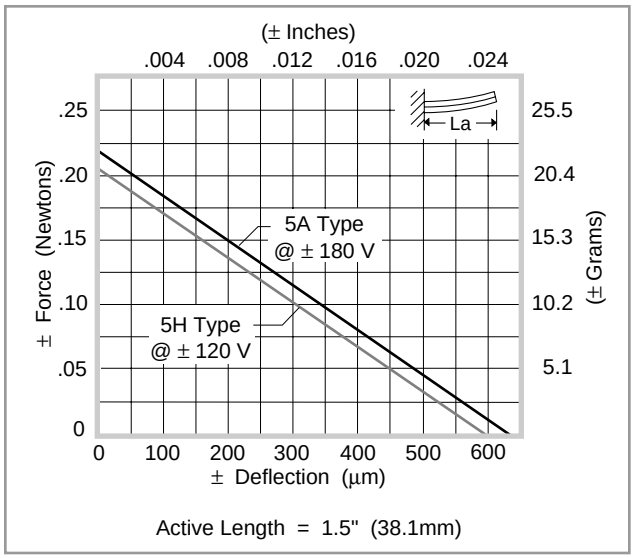
TOTALLY NON-MAGNETIC VERSION

DESCRIPTION

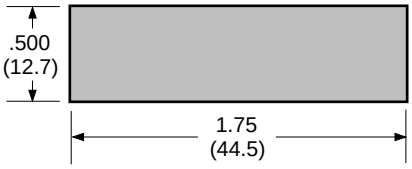
The non-magnetic bending element may be used as either an actuator or sensor.

As an actuator, the transducer provides medium range deflection, frequency, and force. It exhibits no magnetic permeability and generates no magnetic fields. It is well suited for use in high magnetic field environments such as NMR machinery and particle accelerators

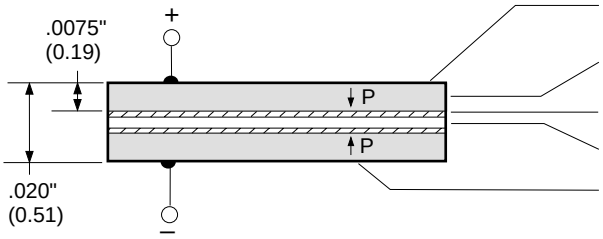
Positioners constructed of 5A or 5H type piezoceramic are stocked for "off-the-shelf" delivery. Custom sizes and configurations are available upon request. "Quick Mount" configurations are also available.



Active Length = 1.5" (38.1mm)



Top View (Scale: x1)



Silver electrode

PSI-5A-S3 piezoceramic, or
PSI-5H-S3 piezoceramic

Adhesive bond layer

Brass center shim

Poled for series operation (standard)
Poled for parallel operation (on request)

Side View (Exaggerated)

SPECIFICATIONS & BENDING MOTOR PERFORMANCE (cantilever configuration, la = 1.5")

PART NUMBER	PIEZO MATERIAL	WEIGHT	CAPACITANCE	MAXIMUM VOLTAGE	RESONANT FREQUENCY	RESPONSE TIME	FREE DEFLECTION	BLOCKED FORCE
		grams	nF	± Vp	Hz	ms	± µm	± N
T220-A3BS-304	5A-S3	2.3	17	± 180	150	2.5	± 635	± .22
T220-H3BS-304	5H-S3	2.3	30	± 120	150	2.5	± 595	± .21

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
Non-magnetic Bending Element, 5A type	T220-A3BS-304	$100	$75	$50	$35
Non-magnetic Bending Element, 5H type	T220-H3BS-304	$100	$75	$50	$35

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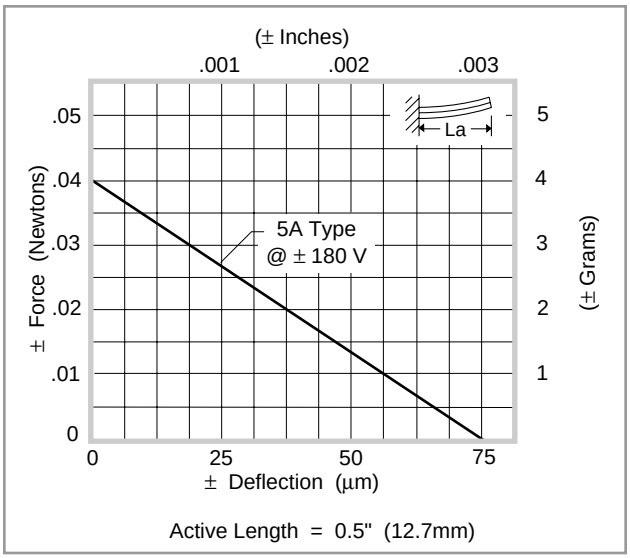
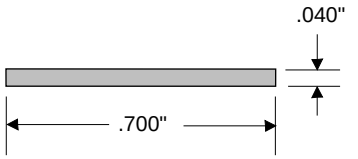
T220 STAINLESS STEEL SHIM BENDING ELEMENT
NARROW WIDTH

DESCRIPTION

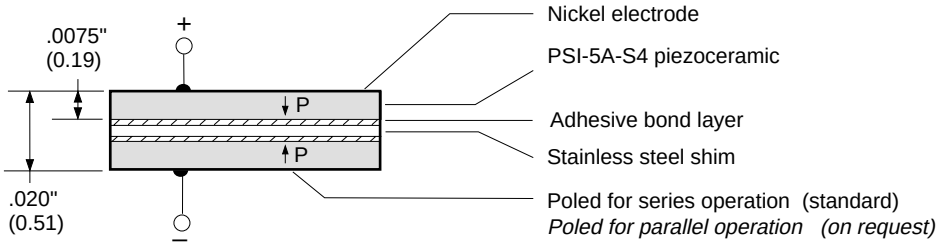
The superior construction of the narrow stainless steel shim bending element allows use as either a motor or sensor in applications requiring high strength and reliability at operating temperatures up to 100° C.

These elements are used in activity sensors and as rate response sensors in implantable pacemakers.





Top View (Scale: x2)



Side View (Exaggerated)

SPECIFICATIONS & BENDING MOTOR PERFORMANCE (cantilever configuration, la = 0.5")

PART NUMBER	PIEZO MATERIAL	WEIGHT	CAPACITANCE	MAXIMUM VOLTAGE	RESONANT FREQUENCY	RESPONSE TIME	FREE DEFLECTION	BLOCKED FORCE
		grams	nF	± Vp	Hz	ms	± μm	± N
T220-A4-105	PSI-5A-S4	.07	0.6	± 180	~1,250	0.3	± 75	± .04

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
T220 Stainless Steel Shim Bending Element Narrow Width (.040")	T220-A4-105	$99	$50	$30	$25

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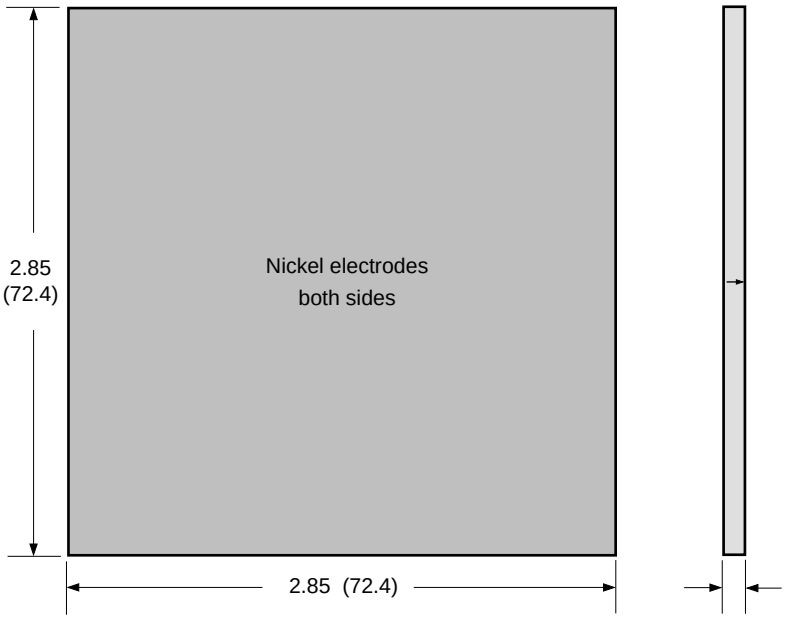
PSI-5A-S4-ENH PIEZOELECTRIC SINGLE SHEET



PART NUMBER	THICKNESS	CAPACITANCE
	mm	nF (±10%)
T105-A4E-602	.127	650
T107-A4E-602	.191	430
T110-A4E-602	.267	315
T120-A4E-602	.508	162
T140-A4E-602	1.02	80
T180-A4E-602	2.03	40

.005 ± .0005 (.127 ± .013)
.0075 ± .0005 (.191 ± .013)
.0105 ± .0005 (.267 ± .013)
.020 ± .0005 (.508 ± .013)
.040 ± .0005 (1.016 ± .013)
.080 ± .0005 (2.032 ± .013)

PIEZOELECTRIC AND MATERIAL PROPERTIES

PIEZOELECTRIC SINGLE SHEET

PIEZOELECTRIC			
Composition		Lead Zirconate Titanate	
Material Designation		PSI-5A-S4-ENH	
Relative Dielectric Constant (@1KHz)	K^T_{33}	1800	
Piezoelectric Strain Coefficient	d_{33}	390×10^{-12}	Meters/Volt
	d_{31}	-190×10^{-12}	Meters/Volt
Piezoelectric Voltage Coefficient	g_{33}	24.0×10^{-3}	Volt Meters/Newton
	g_{31}	-11.6×10^{-3}	Volt Meters/Newton
Coupling Coefficient	k_{33}	0.72	
	k_{31}	0.32	
Polarization Field	Ep	2×10^6	Volts/Meter
Initial Depolarization Field	Ec	5×10^5	Volts/Meter
MECHANICAL			
Density		7800	$Kg/Meter^3$
Mechanical Q		80	
Elastic Modulus	Y^E_3	5.2×10^{10}	$Newtons/Meter^2$
	Y^E_1	6.6×10^{10}	$Newtons/Meter^2$
THERMAL			
Thermal Expansion Coefficient		$\sim 4 \times 10^{-6}$	Meters/Meter °C
Curie Temperature		350	°C

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
PSI-5A-S4-ENH (2.85" Square x .005"T)	T105-A4E-602	$100	$70	$50	$35
PSI-5A-S4-ENH (2.85" Square x .0075"T)	T107-A4E-602	$100	$60	$40	$30
PSI-5A-S4-ENH (2.85" Square x .010"T)	T110-A4E-602	$100	$70	$50	$35
PSI-5A-S4-ENH (2.85" Square x .020"T)	T120-A4E-602	$125	$85	$60	$45
PSI-5A-S4-ENH (2.85" Square x .040"T)	T140-A4E-602	$150	$115	$80	$60
PSI-5A-S4-ENH (2.85" Square x .080"T)	T180-A4E-602	$200	$150	$100	$75

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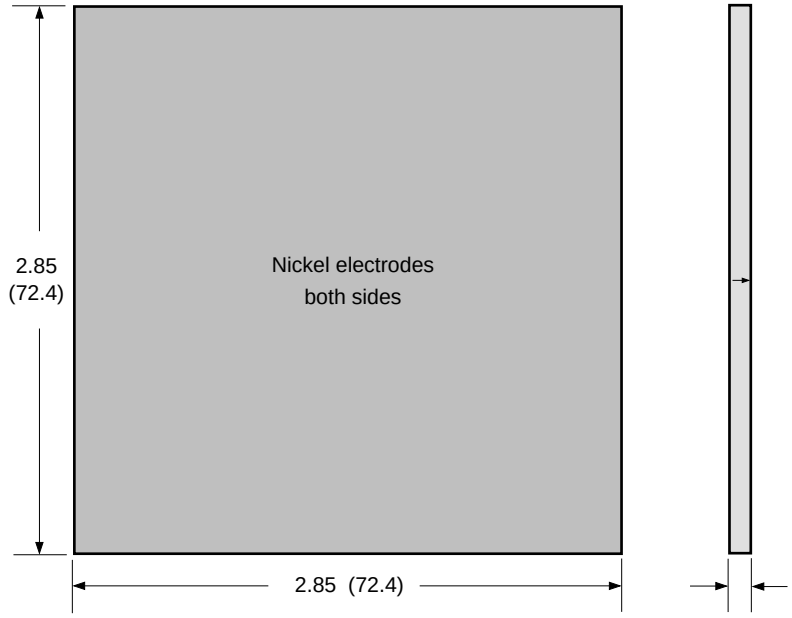
PSI-5H-S4-ENH PIEZOELECTRIC SINGLE SHEET



PART NUMBER	THICKNESS	CAPACITANCE
	mm	nF (±10%)
T105-H4E-602	.127	1250
T107-H4E-602	.191	850
T110-H4E-602	.267	610

.005 ± .0005 (.127 ± .013)
.0075 ± .0005 (.191 ± .013)
.0105 ± .0005 (.267 ± .013)

PIEZOELECTRIC AND MATERIAL PROPERTIES

PIEZOELECTRIC SINGLE SHEET

PIEZOELECTRIC			
Composition		Lead Zirconate Titanate	
Material Designation		PSI-5H-S4 ENH	
Relative Dielectric Constant (@1KHz)	K^T_{33}	3800	
Piezoelectric Strain Coefficient	d_{33}	650×10^{-12}	Meters/Volt
	d_{31}	-320×10^{-12}	Meters/Volt
Piezoelectric Voltage Coefficient	g_{33}	19.0×10^{-3}	Volt Meters/Newton
	g_{31}	-9.5×10^{-3}	Volt Meters/Newton
Coupling Coefficient	k_{33}	.75	
	k_{31}	.44	
Polarization Field	Ep	1.5×10^{6}	Volts/Meter
Initial Depolarization Field	Ec	3.0×10^{5}	Volts/Meter
MECHANICAL			
Density		7800	$Kg/Meter^3$
Mechanical Q		30	
Elastic Modulus	Y^E_3	5.0×10^{10}	$Newtons/Meter^2$
	Y^E_1	6.2×10^{10}	$Newtons/Meter^2$
THERMAL			
Thermal Expansion Coefficient		$\sim 3 \times 10^{-6}$	Meters/Meter °C
Curie Temperature		250	°C

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
PSI-5H-S4-ENH (2.85" Square x .005"T)	T105-H4E-602	$100	$70	$50	$35
PSI-5H-S4-ENH (2.85" Square x .0075"T)	T107-H4E-602	$100	$60	$40	$30
PSI-5H-S4-ENH (2.85" Square x .0105"T)	T110-H4E-602	$100	$70	$50	$35

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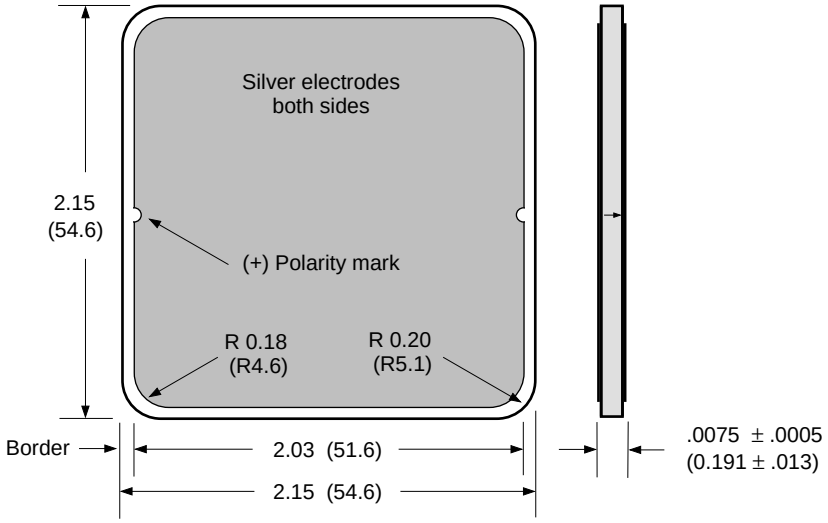
PSI-5A-S3 PIEZOELECTRIC SINGLE SHEET

PSI-5A-S3 piezoceramic sheet with silver electrodes is suitable for totally non-magnetic devices.

Note: Silver electrodes are not recommended for static high field DC applications.

CAPACITANCE (±10%)
190 nF



PIEZOELECTRIC AND MATERIAL PROPERTIES

PIEZOELECTRIC SINGLE SHEET

PIEZOELECTRIC			
Composition		Lead Zirconate Titanate	
Material Designation		PSI-5A-S3	
Relative Dielectric Constant	K^T_{33}	1800	
	K^T_{11}	1700	
Piezoelectric Strain Coefficient	d_{33}	450×10^{-12}	Meters/Volt
	d_{31}	-180×10^{-12}	Meters/Volt
Piezoelectric Voltage Coefficient	g_{33}	25.0×10^{-3}	Volt Meters/Newton
	g_{31}	-11.5×10^{-3}	Volt Meters/Newton
Coupling Coefficient	k_{33}	0.71	
	k_{31}	0.34	
Polarization Field	Ep	2×10^6	Volts/Meter
Initial Depolarization Field	Ec	5×10^5	Volts/Meter
MECHANICAL			
Density		7700	$Kg/Meter^3$
Mechanical Q		70	
Elastic Modulus	Y^E_3	5.0×10^{10}	$Newtons/Meter^2$
	Y^E_1	5.7×10^{10}	$Newtons/Meter^2$
Tensile Strength, Static		6.3×10^7	$Newtons/Meter^2$
Tensile Strength, Dynamic		2.1×10^7	$Newtons/Meter^2$
Compressive Strength		5.2×10^8	$Newtons/Meter^2$
THERMAL			
Thermal Expansion Coefficient		$\sim 4 \times 10^{-6}$	Meters/Meter °C
Curie Temperature		350	°C

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
PSI-5A-S3 Single Sheet (0.0075" thick)	T107-A3-502	$70	$40	$25	$20

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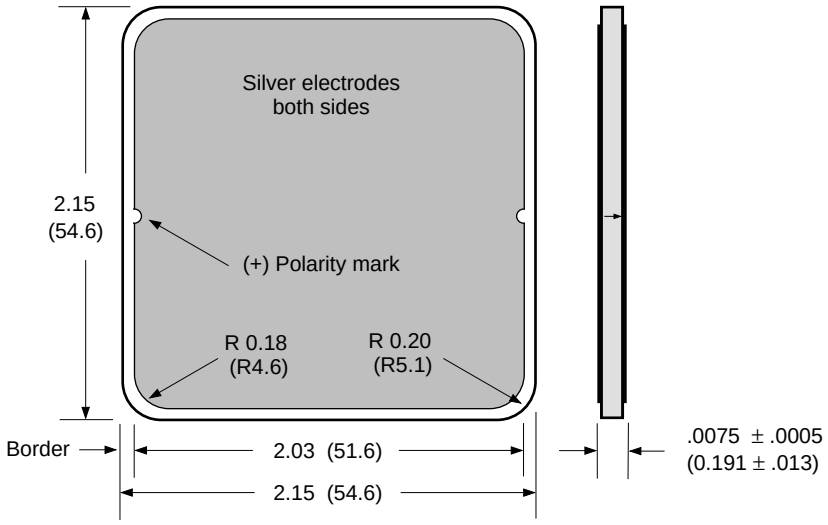
PSI-5H-S3 PIEZOELECTRIC SINGLE SHEET

PSI-5A-S3 piezoceramic sheet with silver electrodes is suitable for totally non-magnetic devices.

Note: Silver electrodes are not recommended for static high field DC applications.

CAPACITANCE (±10%)
470 nF



PIEZOELECTRIC AND MATERIAL PROPERTIES

PIEZOELECTRIC SINGLE SHEET

PIEZOELECTRIC			
Composition		Lead Zirconate Titanate	
Material Designation		PSI-5H-S3	
Relative Dielectric Constant	K^T_{33}	3800	
	K^T_{11}	2550	
Piezoelectric Strain Coefficient	d_{33}	380×10^{-12}	Meters/Volt
	d_{31}	-260×10^{-12}	Meters/Volt
Piezoelectric Voltage Coefficient	g_{33}	12.5×10^{-3}	Volt Meters/Newton
	g_{31}	-8.0×10^{-3}	Volt Meters/Newton
Coupling Coefficient	k_{33}	0.52	
	k_{31}	0.34	
Polarization Field	Ep	1.9×10^{6}	Volts/Meter
Initial Depolarization Field	Ec	3.0×10^{5}	Volts/Meter
MECHANICAL			
Density		7700	$Kg/Meter^3$
Mechanical Q		65	
Elastic Modulus	Y^E_3	4.8×10^{10}	$Newtons/Meter^2$
	Y^E_1	6.1×10^{10}	$Newtons/Meter^2$
Tensile Strength, Static		$\sim 4.8 \times 10^{7}$	$Newtons/Meter^2$
Tensile Strength, Dynamic		$\sim 1.6 \times 10^{7}$	$Newtons/Meter^2$
Compressive Strength		$\sim 3.9 \times 10^{8}$	$Newtons/Meter^2$
THERMAL			
Thermal Expansion Coefficient		$\sim 4 \times 10^{-6}$	Meters/Meter °C
Curie Temperature		220	°C

ORDERING INFORMATION	PART NO.	1 pc.	5 pc.	25 pc.	100 pc.
PSI-5A-S3 Single Sheet (0.0075" thick)	T107-H3-502	$70	$40	$25	$20

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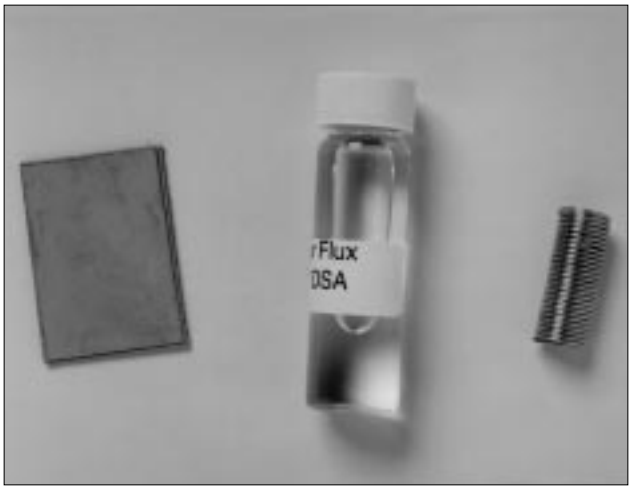
SOLDER & FLUX KIT



KIT INCLUDES:

Solder
- Tin/Lead solder for nickel electrodes, or Tin/Lead/Silver solder for silver electrodes, 12" length.

Flux
- Liquid Flux for soldering to nickel or silver electrodes, 7 ml.
- Liquid Flux for soldering to stainless steel & brass center shims , 7 ml.

Wires
- Red wires, #30 Gauge, Stripped & tinned, 6" length, 5 pieces.
- Black wires, #30 Gauge, Stripped & tinned, 6" length, 5 pieces. Piezoceramic sheet

Small piezoceramic
- sheet with nickel or silver electrode to practice technique, 1 piece

PURPOSE OF THE KIT

Soldering wires to the electrodes of piezoceramic sheet and/or the center shim of a 2-layer bending element can be difficult if the proper materials are not used. There is a vast array materials to choose from. The solder & flux kit offers the right materials to get started at once and provides information to procure materials directly from the manufacturer later. Recommended procedure is described. Materials in the kit are for soldering to nickel electrodes unless specifically requested for silver.

DESCRIPTION OF ELECTRODES

Piezoceramic electrodes will be either fired silver or nickel. Silver electrodes are flat white in color while nickel electrodes are grey.

Silver electrodes are not recommended for high electric field DC applications where the silver is likely to migrate and bridge the two electrodes. It is often used in non-magnetic and AC applications. Silver used as an electrode is in the form of flakes suspended in a glass frit. It is generally screened onto the ceramic and fired. The glass makes the bond between the ceramic and the silver particles. Silver is soluble in tin and a silver loaded solder should be used to prevent scavenging of silver in the electrode.

Nickel has good corrosion resistance and is a good choice for both AC and DC applications. It can usually be soldered to easily with tin/lead solder. Electroless nickel, used for plating piezoceramic, contains phosphor. Sometimes the phosphor content in a plating run can make it hard to solder. Vacuum deposited nickel electrodes are usually very thin, making soldering tricky.

Choice of the correct flux (to remove surface oxidation) generally makes soldering to electrode surfaces easy even under adverse conditions.

DESCRIPTION OF CENTER SHIMS

Generally, the center shim layer of a 2-Layer piezoelectric bending element is either brass or stainless steel. A wire is attached to the center shim if the element is used in parallel operation. Shims are soldered in the same way as the nickel electrode. The proper liquid flux choice must be made depending on the shim material.

ORDERING INFORMATION	PART NO.	1 pc.
Solder & Flux Kit (For Nickel Electrodes)	MSF-003-NI	$49
Solder & Flux Kit (For Silver Electrodes)	MSF-003-AG	$59

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INTRODUCTION TO PIEZOELECTRICITY

When a piezoceramic element is stressed electrically by a voltage, its dimensions change. When it is stressed mechanically by a force, it generates an electric charge. If the electrodes are not short-circuited, a voltage associated with the charge appears.

A piezoceramic is therefore capable of acting as either a sensing or transmitting element, or both. Since piezoceramic elements are capable of generating very high voltages, they are compatible with today's generation of solid-state devices — rugged, compact, reliable, and efficient.

The following text describes the terminology of piezoceramics and the relationship among variables for functional applications.

RELATIONSHIPS

Relationships between applied forces and the resultant responses depend upon: the piezoelectric properties of the ceramic; the size and shape of the piece; and the direction of the electrical and mechanical excitation.

To identify directions in a piezoceramic element, three axes are used. These axes, termed 1, 2 and 3, are analogous to X,Y and Z of the classical three dimensional orthogonal set of axes (Figure 1a)

The polar or 3 axis is taken parallel to the direction of polarization within the ceramic. This direction is established during manufacturing by a high DC voltage that is applied between a pair of electroded faces to activate the material. The polarization vector "P" is represented by an arrow pointing from the positive to the negative poling electrode. In shear operations, these poling electrodes are later removed and replaced by electrodes deposited on a second pair of faces. In this event, the 3 axis is not altered, but is then parallel to the electroded faces found on the finished element (Figure 1b). When the mechanical stress or strain is shear, the subscript 5 is used in the second place.

Piezoelectric coefficients with double subscripts link electrical and mechanical quantities. The first subscript gives the direction of the electrical field associated with the voltage applied, or the charge produced. The second subscript gives the direction of the mechanical stress or strain.

Several piezoceramic material constants may be written with a "superscript" which specifies either a mechanical or electrical boundary condition. The superscripts are T, E, D and S, signifying:

T = constant stress
= mechanically free
E = constant field = short circuit
D = constant electrical displacement
= open circuit
S = constant strain
= mechanically clamped

As an example, K^T_3 expresses the relative dielectric constant (K), measured in the polar direction (3) with no mechanical clamping applied.

"D" CONSTANT

The piezoelectric constants relating the mechanical strain produced by an applied electric field are termed the strain constants, or the "d" coefficients. The units may then be expressed as meters per meter, per volts per meter (meters per volt).

$$d = \frac{\text{strain developed}}{\text{applied electric field}}$$

It is useful to remember that large d_{ij} constants relate to large mechanical displacements which are usually sought in motional transducer devices. Conversely, the coefficient may be viewed as relating the charge collected on the electrodes, to the applied mechanical stress. d_{33} applies

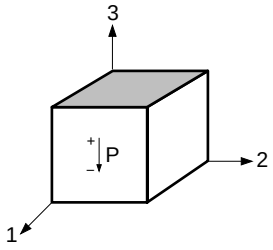

Figure - 1a

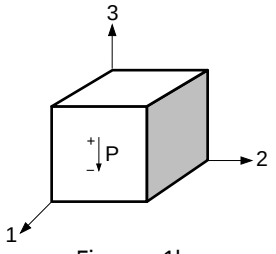

Figure - 1b

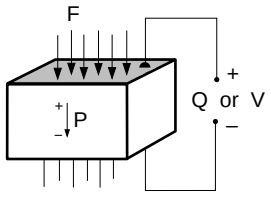

Figure - 2a

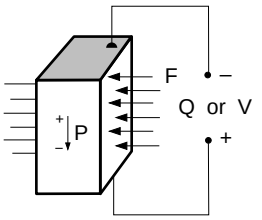

Figure - 2b

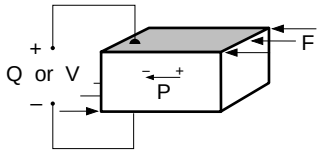

Figure - 2c

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when the force is in the 3 direction (along the polarization axis) and is impressed on the same surface on which the charge is collected (Figure 2a). d_{31} applies when the charge is collected on the same surface as before, but the force is applied at right angles to the polarization axis (Figure 2b).

The subscripts in d_{15} indicate that the charge is collected on electrodes which are at right angles to the original poling electrodes and that the applied mechanical stress is shear (Figure 2c.)

The units for the d_{ij} coefficients are commonly expressed as coulombs/square meter per newton/square meter.

$$d = \frac{\text{short circuit charge density}}{\text{applied mechanical stress}}$$

When the force that is applied is distributed over an area which is fully covered by electrodes (even if that is only a portion of the total electrode) the units of area cancel from the equation and the coefficient may be expressed in terms of change per unit force, coulombs per newton. To view the dij coefficients in this manner is useful when charge generators are contemplated, e.g., accelerometers.

"G" CONSTANT

The piezoelectric constants relating the electric field produced by a mechanical stress are termed the voltage constants, or the "g" coefficients. The units may then be expressed as volts/meter per newton/square meter.

$$g = \frac{\text{open circuit electric field}}{\text{applied mechanical stress}}$$

Output voltage is obtained by multiplying the calculated electric field by the thickness of ceramic between electrodes. A "33" subscript indicates that the electric field and the mechanical stress are both along the polarization axis. (Figure 2a.) A "31" subscript signifies that the pressure is applied at right angles to the polarization axis, but the voltage appears on the same electrodes as in the "33" case. (Figure 2b.)

A "15" subscript implies that the applied stress is shear and that the resulting electric field is perpendicular to the polarization axis. (Figure 2c.)

High g_{ij} constants favor large voltage output, and are sought after for sensors.

Although the g coefficient are called voltage coefficients, it is also correct to say the g_{ij} is the ratio of strain developed over the applied charge density with units of meters per meter over coulombs per square meter.

$$g = \frac{\text{strain developed}}{\text{applied charge density}}$$

DIELECTRIC CONSTANTS

The relative dielectric constant is the ratio of the permittivity of the material, ϵ, to the permittivity of free space, ϵ_0, in the unconstrained condition, i.e., well below the mechanical resonance of the part.

$$K = \frac{\text{permittivity of material}}{\text{permittivity of free space}} = \frac{\epsilon}{\epsilon_0}$$

CAPACITANCE

Whereas the relative dielectric constant is strictly a material property, the capacitance is a quantity dependent on the type of material and its dimensions. Capacitance is calculated by multiplying the relative dielectric constant by the permittivity of free space ($\epsilon_0 = 8.9 \times 10^{-12}$ farads/meter) and electrode surface area, and then dividing by the thickness separating the electrodes. Units are expressed in farads.

$$C = \frac{K \epsilon_0 A}{t}$$

K_3 is related to the capacitance between the original poling electrodes. K_1 is related to the capacitance between the second pair of electrodes applied after removal of the poling electrodes for the purposes of shear excitation.

At frequencies far below resonance, piezoelectric ceramic transducers are fundamentally capacitors. Consequently, the voltage coefficients g_{ij} are related to the charge coefficients d_{ij} by the dielectric constant Ki as, in a capacitor, the voltage V is related to the charge Q by the capacitance C.

The equations are:

$$Q = CV$$
$$d_{33} = K^T_{33} \epsilon_0 g_{33}$$
$$d_{31} = K^T_{33} \epsilon_0 g_{31}$$
$$d_{15} = K^T_{11} \epsilon_0 g_{15}$$

COUPLING COEFFICIENTS

Electromechanical coupling k_{33}, k_{31}, k_p, and k_{15} describe the conversion of energy by the ceramic element from electrical to mechanical form or vice versa. The ratio of the stored converted energy of one kind (mechanical or electrical) to the input energy of the second kind (electrical or mechanical) is defined as the square of the coupling coefficient.

$$k = \sqrt{\frac{\text{mechanical energy stored}}{\text{electrical energy applied}}}$$

or

$$k = \sqrt{\frac{\text{electrical energy stored}}{\text{mechanical energy applied}}}$$

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Subscripts denote the relative directions of electrical and mechanical quantities and the kind of motion involved. They can be associated with vibratory modes of certain simple transducer shapes; k_{33} is appropriate for a long thin bar, electroded on the ends, and polarized along the length, and vibrating in a simple length expansion and contraction. k_{31} relates to a long thin bar, electroded on a pair of long faces, polarized in thickness, and vibrating in simple length expansion and contraction. k_p signifies the coupling of electrical and mechanical energy in a thin round disc, polarized in thickness and vibrating in radial expansion and contraction. k_{15} describes the energy conversion in a thickness shear vibration. Since these coefficients are energy ratios, they are dimensionless.

YOUNG'S MODULUS

As with all solids, piezoelectric ceramics have mechanical stiffness properties described as Young's Modulus. Young's Modulus is the ratio of stress (force per unit area) to strain (change in length per unit length).

$$Y = \frac{\text{stress}}{\text{strain}}$$

Because mechanical stressing of the ceramic produces an electrical response which opposes the resultant strain, the effective Young's Modulus with electrodes short circuited is lower than with the electrodes open circuited. In addition, the stiffness is different in the 3 direction from that in the 1 or 2 direction. Therefore, in expressing such quantities both direction and electrical conditions must be specified. Y^E_{33} is the ratio of stress to strain in the 3 direction at constant field E (electrodes shorted). Y^D_{33} is the equivalent with the electrodes open circuited. Y^E_{11} and Y^D_{11} are the moduli in the 1 or 2 direction. Y^E_{55} and YD55 are the ratios of shear stress to shear strain. Units are usually newtons/square meter.

It should be clearly understood that the piezoceramic properties described above are defined for ideal shapes measured under ideal mechanical and electrical boundary conditions. When put to use under practical device operating conditions, the predicted performance is approached but seldom realized. Non-ideal shapes and non-ideal boundary conditions contribute to transduction losses due to such things as standing waves, interfering vibrational modes, pseudo-clamping, stray electric and dielectric resistances. Since the possibilities are infinite, the designer must evaluate each component under the use conditions for which it is intended.

DENSITY

The ratio of the mass to volume in the material, expressed in kg/m^3

$$r = \frac{\text{mass}}{\text{volume}}$$

DISSIPATION FACTOR

A measure of the dielectric losses in the material-defined as the tangent of the loss angle or the ratio of parallel resistance to the parallel reactance, expressed in percent.

MECHANICAL (QM)

The ratio of reactance to resistance in the equivalent series circuit representing the mechanical vibrating resonant system. The shape of the part affects the value.

CURIE TEMPERATURE

The temperature at which the crystal structure changes from a non-symmetrical (piezoelectric) to a symmetrical (non-piezoelectric) form, expressed in degrees Celsius.

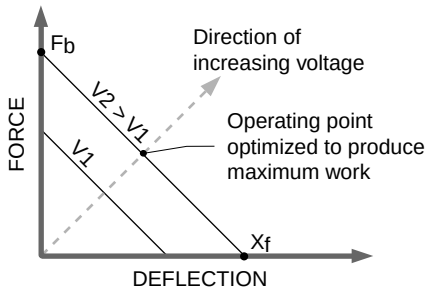
AGING RATE

Aging is the attempt of the ceramic to change back to its original state prior to polarization. Aging of piezoelectric ceramics is a logarithmic function with time. The aging rate defines change in the material parameters per decade of time, i.e., 1-10 days, 5-50 days, etc.

PERFORMANCE

Deflection and Force: Piezoelectric actuators are usually specified in terms of their free deflection and blocked force. Free deflection, X(f), refers to displacement at a given voltage level without the actuator working against any external load. Blocked force, F(b), refers to the force exerted at a given voltage level when the actuator is not allowed to move. Since the force at maximum deflection is zero, all other values of simultaneous displacement and force (for a given voltage level) are determined by a line drawn between these points on a force versus deflection diagram as shown below. In practice, a bending motor must move a specified amount and exert a specified force, which determines its operating point on the force versus deflection diagram. Work is maximized when the deflection performed permits one half the blocked force to be developed. This occurs when the deflection equals one half the free deflection.

For cantilevered bending motors, X(f) and F(b) are approximated by observing the tip deflection after energizing, and by holding a force gauge against the tip during energization.



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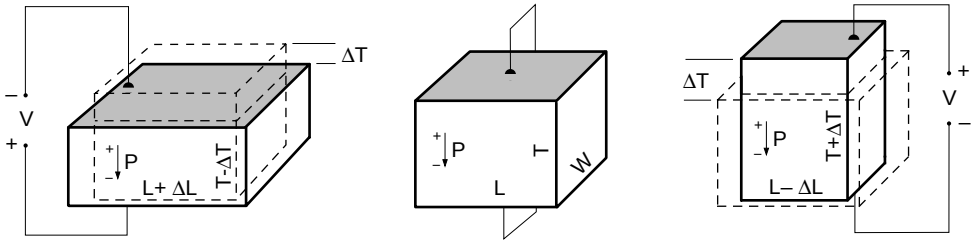
MOTOR TRANSDUCER RELATIONSHIPS

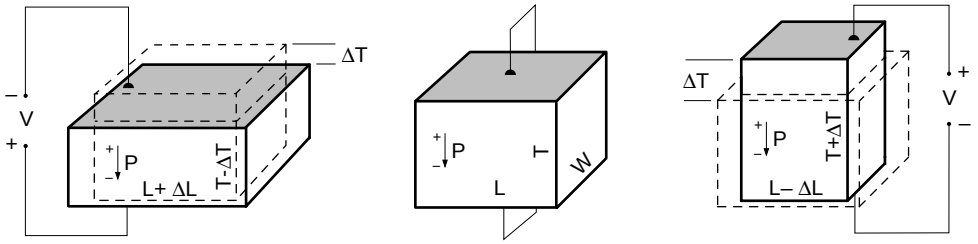
PARALLEL EXPANSION & CONTRACTION MOTOR



Parallel Expansion

$$\Delta T = Vd_{33}$$

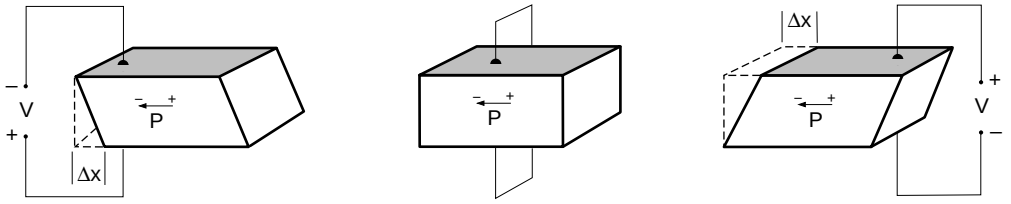
TRANSVERSE EXPANSION & CONTRACTION MOTOR



Transverse Expansion

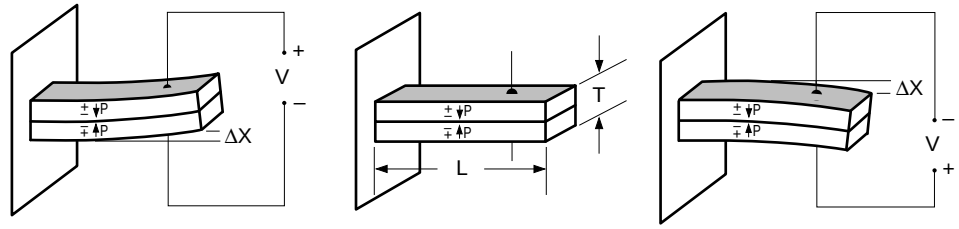
$$\frac{\Delta L}{L} = \frac{\Delta W}{W} = \frac{Vd_{31}}{T}$$

SHEAR MOTOR



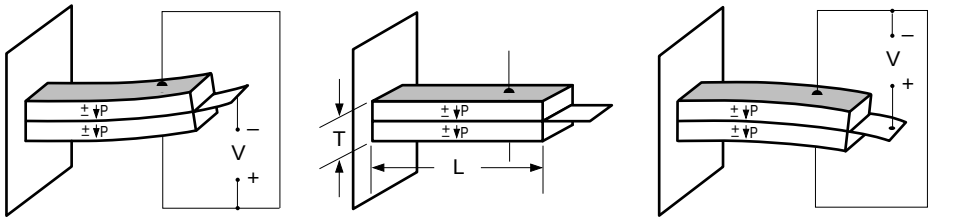
$$X = Vd_{15}$$

BENDING MOTOR



Series Connection

$$X = \frac{2L^2 V d_{31}}{T^2}$$



Parallel Connection

$$X = \frac{4L^2 V d_{31}}{T^2}$$

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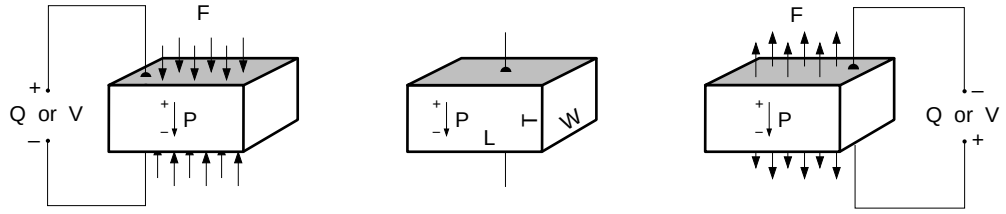
GENERATOR TRANSDUCER RELATIONSHIPS

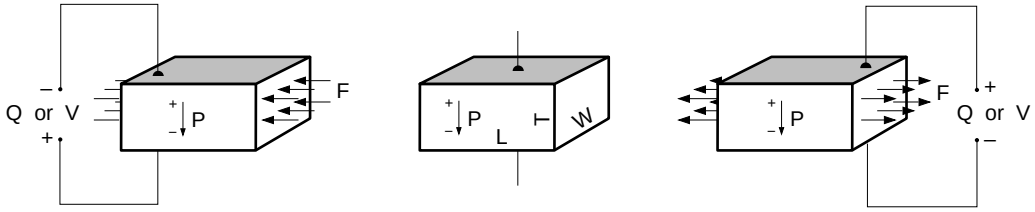
PARALLEL COMPRESSION OR TENSION GENERATOR



$$Q = Fd_{33}$$

$$\frac{V}{T} = \frac{Fg_{33}}{LW}$$

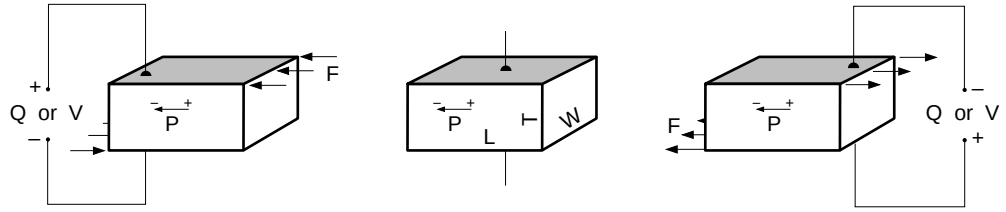
TRANSVERSE COMPRESSION OR TENSION GENERATOR



$$\frac{Q}{LW} = \frac{F\,d_{31}}{TW}$$

$$\frac{V}{T} = \frac{F\,g_{31}}{TW}$$

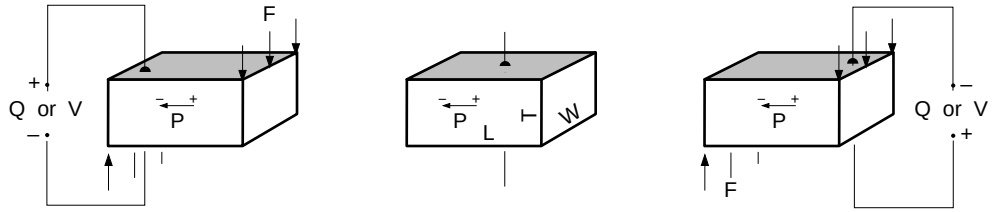
PARALLEL SHEAR GENERATOR



$$Q = Fd_{15}$$

$$\frac{V}{T} = \frac{F\,g_{15}}{LW}$$

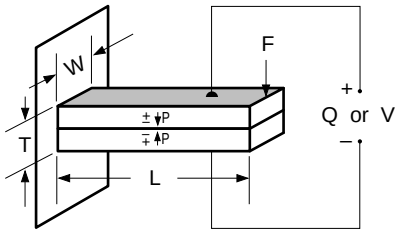
TRANSVERSE SHEAR GENERATOR



$$\frac{Q}{LW} = \frac{F\,d_{15}}{TW}$$

$$\frac{V}{T} = \frac{F\,g_{15}}{TW}$$

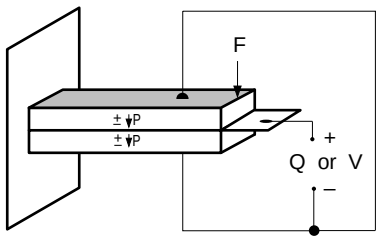
BENDING GENERATOR



Series Connection

$$Q = \frac{3FL^2\,d_{31}}{2T^2}$$

$$V = \frac{3FL\,g_{31}}{2WT}$$



Parallel Connection

$$Q = \frac{3FL^2\,d_{31}}{T^2}$$

$$V = \frac{3FL\,g_{31}}{4WT}$$

PIEZO SYSTEMS, INC.
186 Massachusetts Avenue Cambridge, MA 02139 • Tel: (617) 547-1777 • Fax: (617) 354-2200 • Web: www.piezo.com • E-mail: sales@piezo.com

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