Attracting Tomorrow

TDK Developer's Conference 2018

Piezoelectric Haptics Actuators for High Force and High Acceleration Applications (PowerHap™ and PiezoHapt™)

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EPCOS, Inc.
A TDK Group Company
PPD Business Group • Piezo Devices
Santa Clara, CA
September 17, 2018

We provide a comprehensive product portfolio

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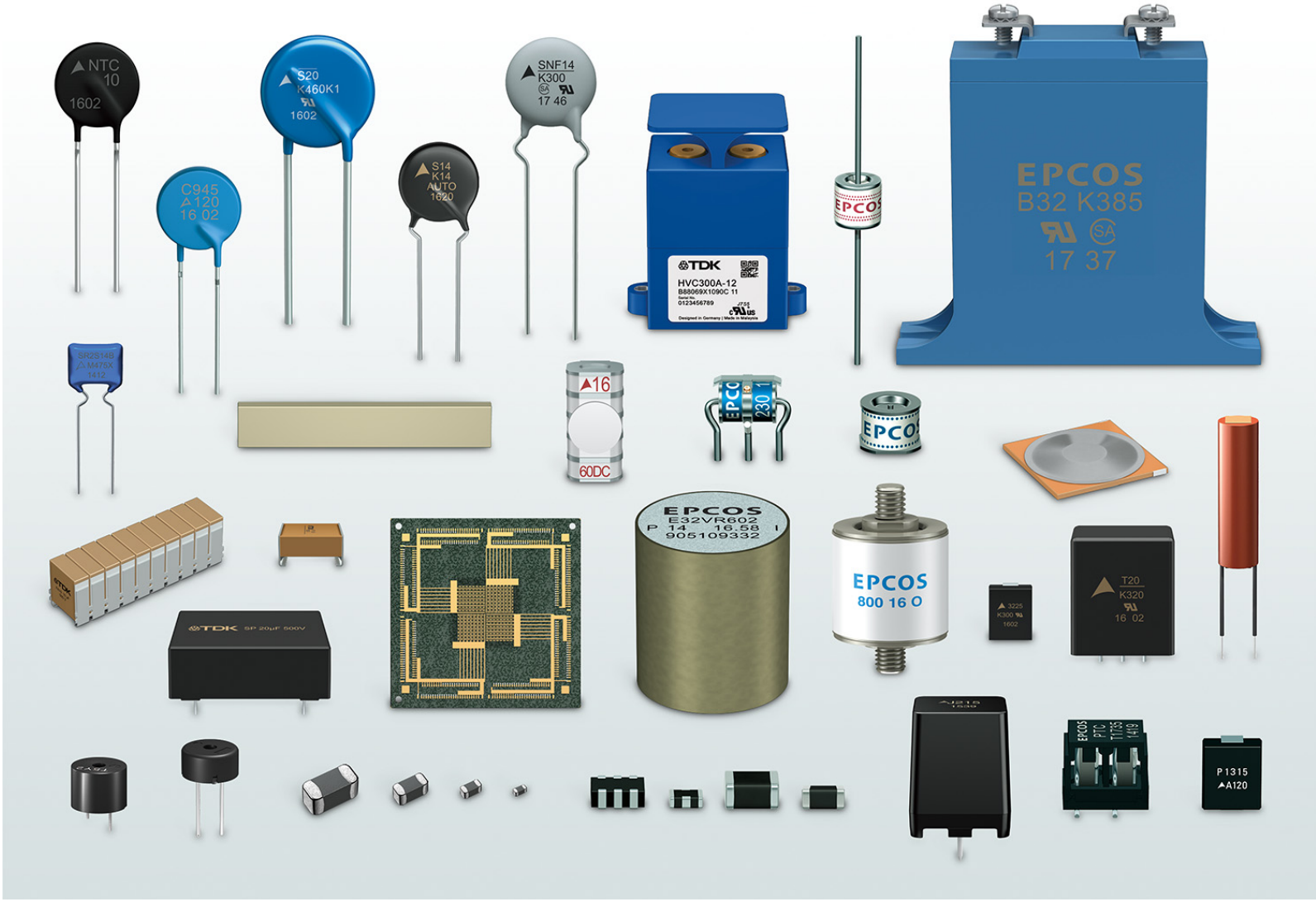
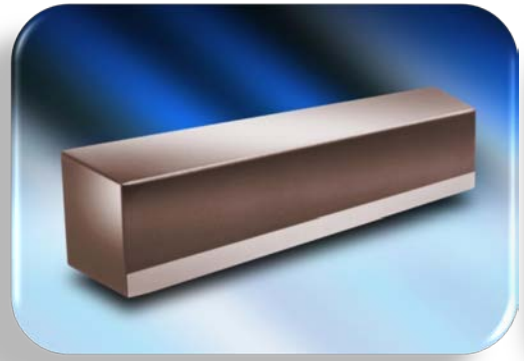
Piezo & Protection Devices

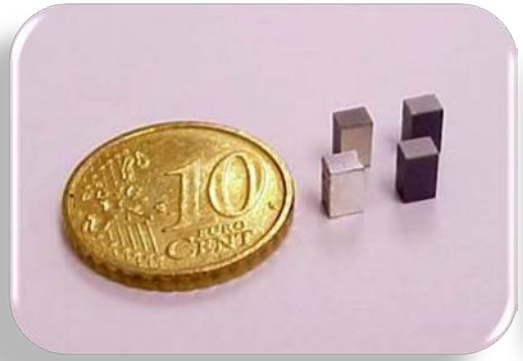
- Piezo actuators
- Piezo commodities
- PTC thermistors
- Inrush current limiters
- Disk varistors
- Multilayer varistors
- Multilayer NTC thermistors
- Surge arresters
- Switching spark gaps
- Ceramic ripple suppressors (CeraLink™ capacitors)
- Toner sensors
- Electric surface potential sensors
- Multilayer HF packages
- Die-sized SAW packages



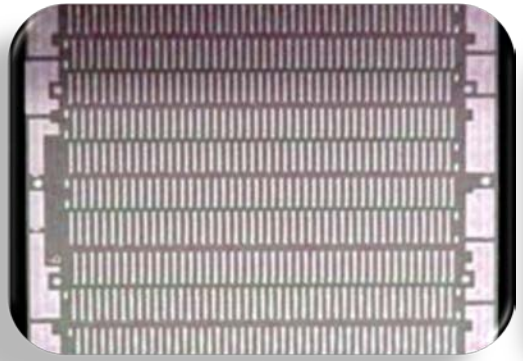
TDK Piezo Product Portfolio and Applications



Actuator for Fuel Injection Systems



Mini-Actuator for Piezo Motors



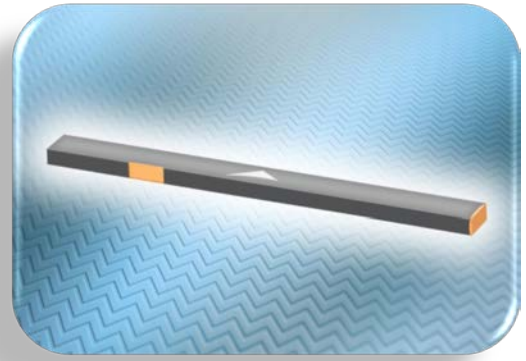
Bending Actuators for Ink Jet Printer Heads

Bending Actuator for Squiggle Motors

Piezo Beam for Autofocus Motors

Piezo transformers

Piezo disc for Ultrasonic Transducer



Piezo Transformer as Source for cold plasmas

Haptic feedback – Unlimited potential application

ICT

- Smartphone
- Smart watch
- Keyboard
- Touchpad

Game

- Display
- Controller
- Augmented Reality
- Virtual Relaity

Automotive

- Navigation
- Touchpad
- Smart key

Home Appliance

- Control Panel
- Push Button

2 types of haptic feedback usage

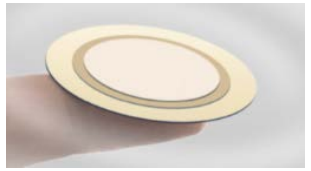
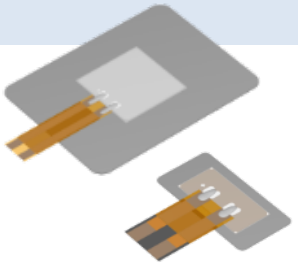
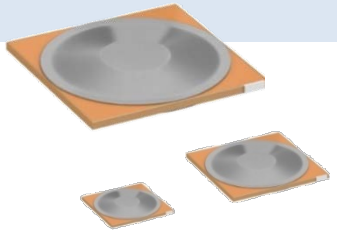
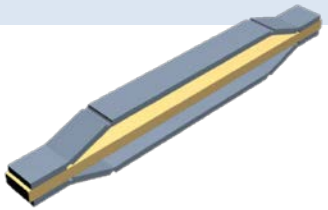
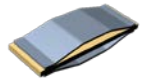
	Feedback to an area stroked with a fingertip	Feedback for pushing buttons
		
Response	**Pleasant response matching fingertip's sensitivity**	**Clear and strong response**
Application	• Smartphone display • Smart watch • Touch pad	• Navigation system's screen • Control panel

Piezo Haptic Product Lineup

Attracting Tomorrow TDK

PowerHap and **PiezoHapt L** are both based on advanced multi-layer piezo ceramics technology. **PiezoHapt S** however is based on a single layer monolithic piezo ceramic disk.

With this comprehensive product offering TDK is able to serve the complete market with piezo based actuators for active haptic solutions.

PiezoHapt™ S	**PiezoHapt™** L	**PowerHap™**	**PowerHap™** Lateral	**PowerHap™** Minilateral
				
• Very low insertion height • Cost effective solution • Ideal for switches and touchpads that require “button-like” feedback	• Very low insertion height • Operation at low voltages • Ideal for mobile devices and wearables, especially for OLED based displays	• Very low insertion height compared to similar strong non-piezo actuators • Large displacement, force and acceleration • Also suited to move medium and large weights	• Optimized for lateral displacement • Large displacement, force and acceleration • For lateral vibration in automotive center panel	• Small size • Low power consumption • Large displacement, force and acceleration • For sidebutton mobile phones/tablets

Why piezo as actuator?

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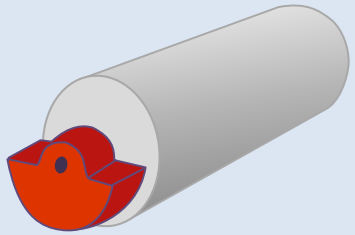
ERM

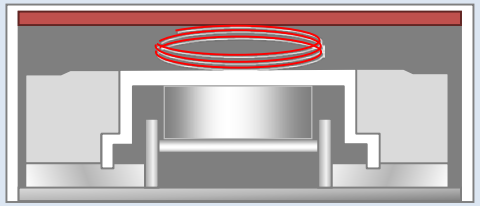
Eccentric rotating mass



- Long response time
- Only sine waves
- Large
- No sensing functionality
- Low driving voltage
- High power consumption

LRA

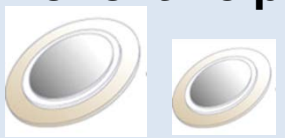
Linear resonant actuator



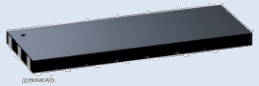
- Medium response time
- Large
- No sensing functionality
- Low driving voltage
- Medium power consumption

Piezo-based solutions

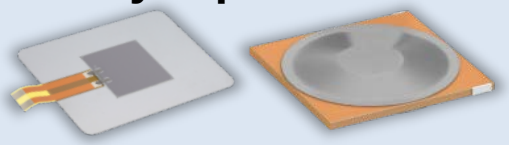
Monolithic piezo discs



Piezo bender



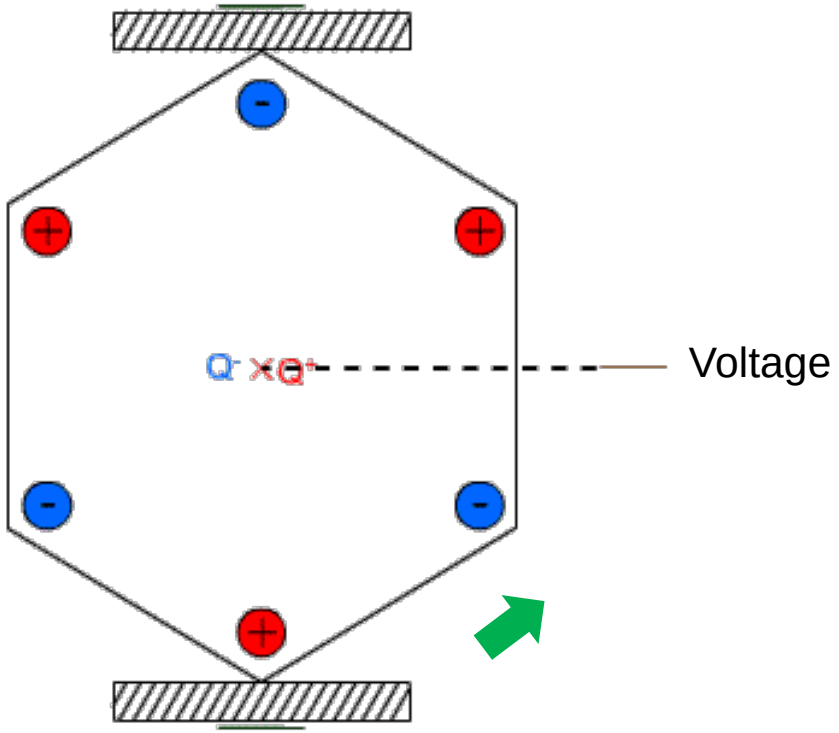
Multilayer piezo



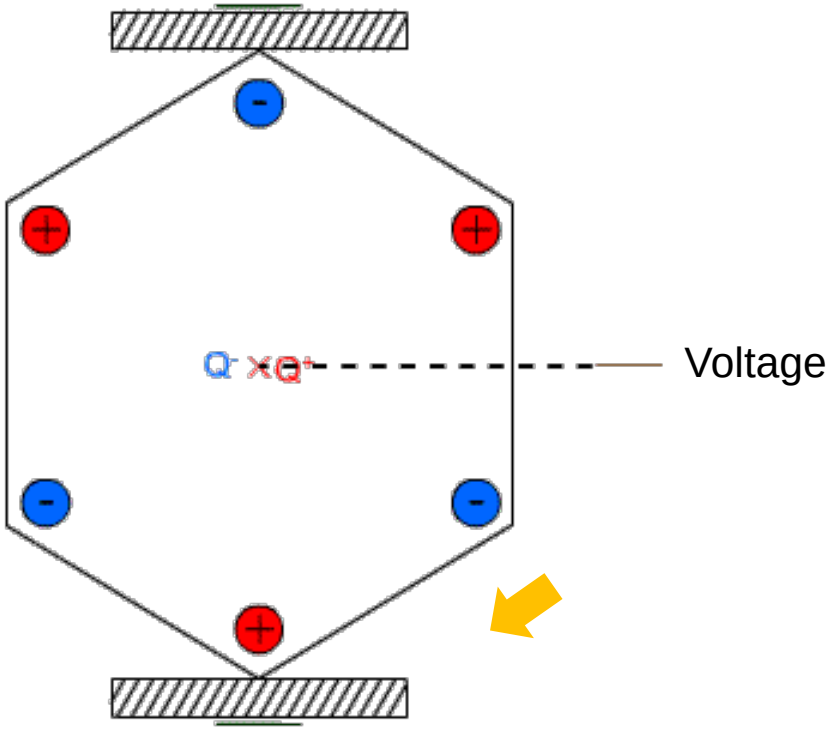
- **Thin**
- **Flexible wave design**
- **Short response time**
- **Sensing functionality**
- **Low power consumption**
- **High power**

Piezo effect: Sensor and actuator in one device

Sensing → **Trigger** → **Actuating**



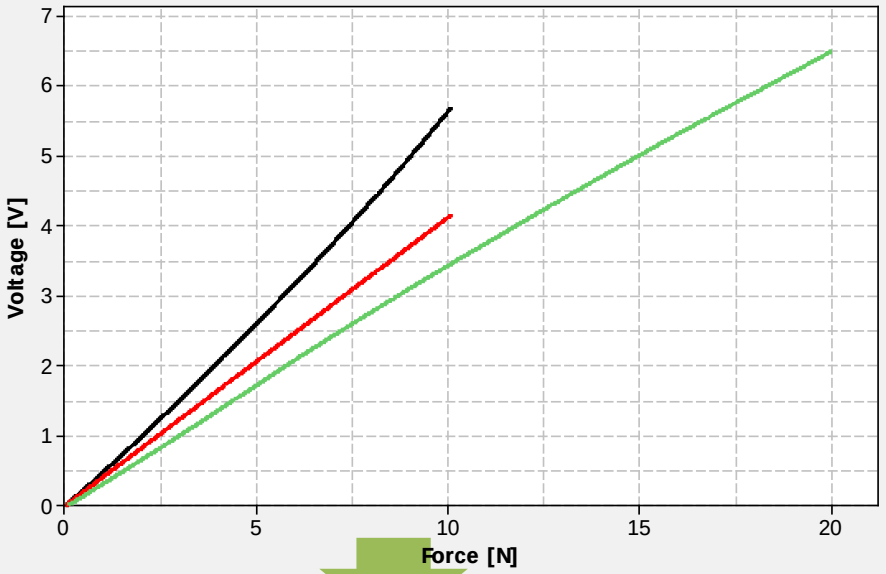
Force

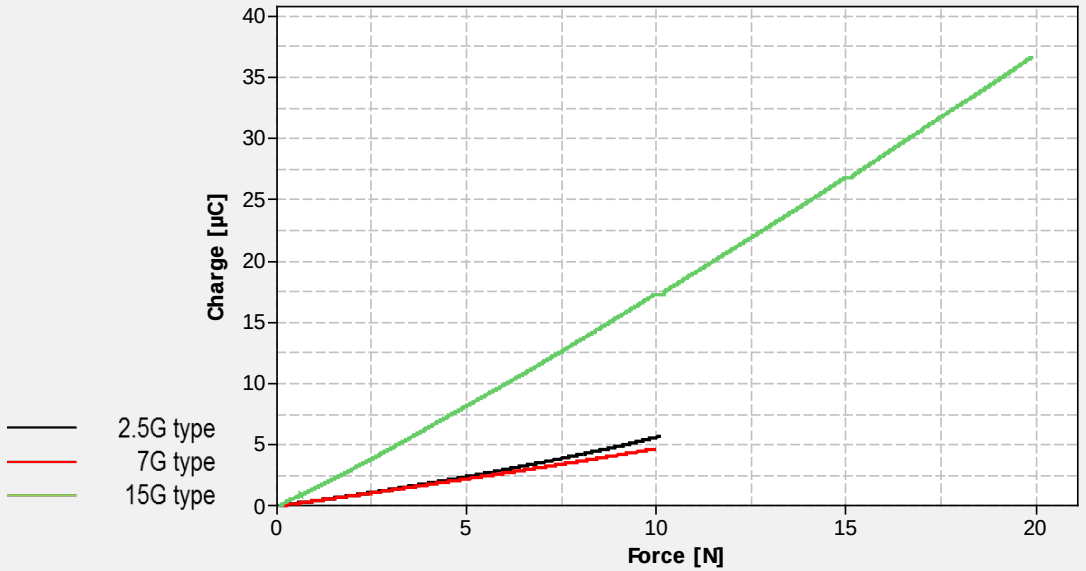


Contraction

Source: https://commons.wikimedia.org/w/index.php?curid=17309925

Ideal sensor for haptic applications

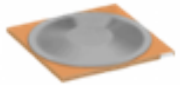




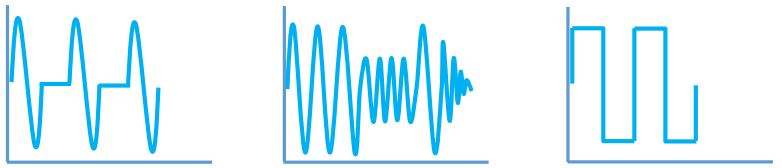
- Piezo actuator can detect a broad range of pressures up to 20 N
- Linear output in either V or C
- Tipping force can be set individually
- No additional touch sensor necessary

PowerHap™ combines actuator and sensor in a single component

Piezo type vs electromagnetic type

	ピエゾ（圧電）式 / Piezoelectric			電磁式 / Electromagnetic	
	PowerHap™	PiezoHapt™ L	PiezoHapt™ S	ERM	LRA
					
厚み [mm] Thickness	1.2 - 2.4	0.30 / 0.35	0.26	3	3
加速度 [G] Acceleration **(20g mass)**	8 – 65	1.6 / 1.5	4	2	5
立ち上がり [ms] Rise time	<1	<1	<1	50	20
電圧 (max.) [V] Drive voltage	60 - 120	12/24	400	3	3
自由な波形デザイン Custom waveform	Yes	Yes	Yes	No	No
感圧 Force sensing	Yes	Yes	Yes	No	No

- **Small and thin. Good integration with flat panel.**
- **Generate various vibration.**
- **Fast response. Force and frequency can be adjusted individually.**
- **Responds to complex waveform design without delay.**

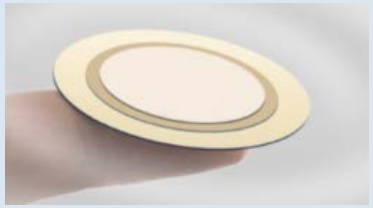


Our solutions: PiezoHapt™ and PowerHap™

PowerHap and **PiezoHapt L** are both based on advanced multi-layer piezo ceramics technology. **PiezoHapt S** however is based on a single layer monolithic piezo ceramic disk.

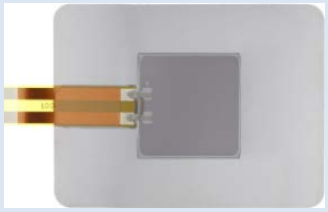
With this comprehensive product offering TDK is able to serve the complete market with piezo based actuators for active haptic solutions.

PiezoHapt™ S



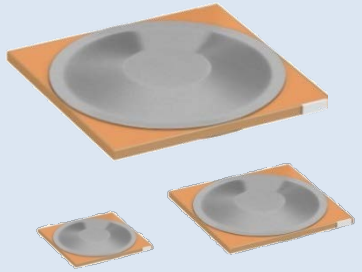
- Very low insertion height
- Cost effective solution
- Ideal for switches and touchpads that require “button-like” feedback
- Each size has 2 variations – for consumer/industry use, and for automotive use.

PiezoHapt™ L



- Very low insertion height
- Operation at low voltages
- Ideal to move low weights
- Ideal for mobile devices and wearables, especially for OLED based displays
- Release of automotive-compatible type (PHUB8060-35A-33-000) is planned in 2018.

PowerHap™



- Very low insertion height compared to similar strong non-piezo actuators
- Large displacement, force and acceleration
- Also suited to move medium and large weights
- Automotive qualification for all PowerHaps
- Ideal for automotive, industrial and consumer applications

PiezoHapt™ S

Key Infos

USP: „Cost effective solution!“

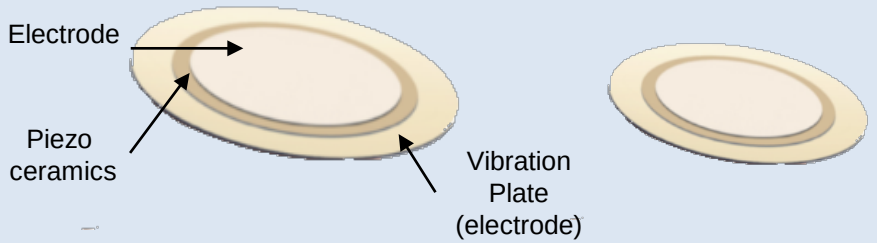
- → **Sample available for both types**
- → **SOP : TBD**
- → **Automotive qualification to be acquired in 2019**

Target Applications (Examples):

- **Automotive**
  - Steering wheel switches
  - Overhead consoles‘ switches
  - Touchpads
- **Industry**
  - Switches
  - Touchpads
- **Consumer**
  - Home appliance switches
  - PC trackpads
  - Remote control buttons

Product range:

φ15mm type **φ12 mm type**



Thickness: 0.26mm 0.26mm

Product Specification	Acceleration		Voltage	Capaci-tance	Max. Dis-placement	$T_{op,max}$
	20gr.	100gr.				
φ15mm type PHUA15-26A-10-000 (General use) PHUB15-26A-10-000 (Automotive)	4G	0.5G	400V*	7.0 nF	50µm	85°C
φ12mm type PHUA12-26A-9-000 (General use) PHUB12-26A-9-000 (Automotive)	TBD	TBD	400V*	5.5 nF	TBD	85°C

*400V with Aito system

Remark

For optimal operation of this actuator, use of AitoChip is strongly recommended.

PiezoHapt™ L

Key Infos

USP: „Ultra thin!“

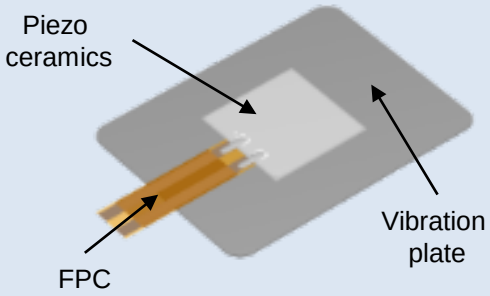
- → **L8060 (General use): Sample available**
- → **L3015 (General use): Sample available**
- → **Automotive grade sample: TBD**
- → **SOP: Y2018 (L8060/General)**
  Y2018 (L3015/General)

Target Applications (Examples):

- **Automotive**
  - Navigation system displays
  - Touchpads
- **Industry**
  - Control panels
- **Consumer**
  - Smartphones, tablets & wearable devices
  - Game console displays & controllers

Product range:

L8060 type



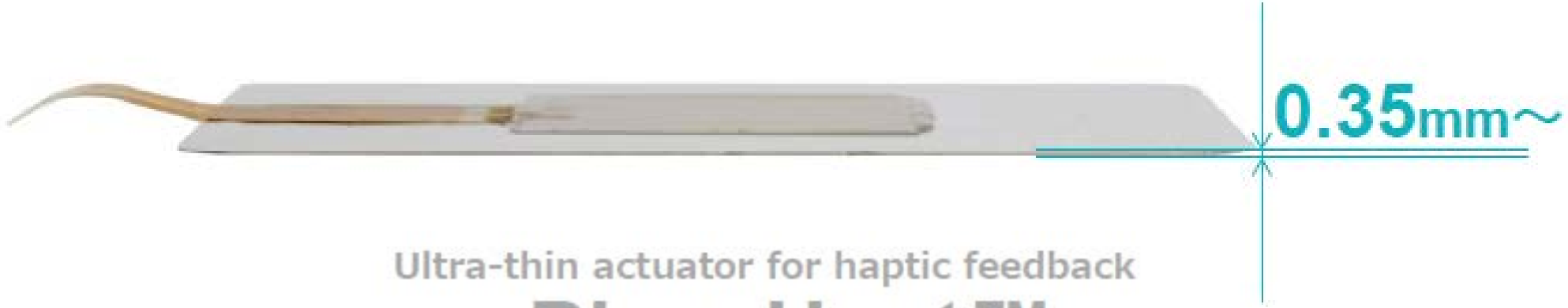
80mm x 60mm
Thickness: 0.35mm

L3015 type

30mm x 15mm
0.30mm

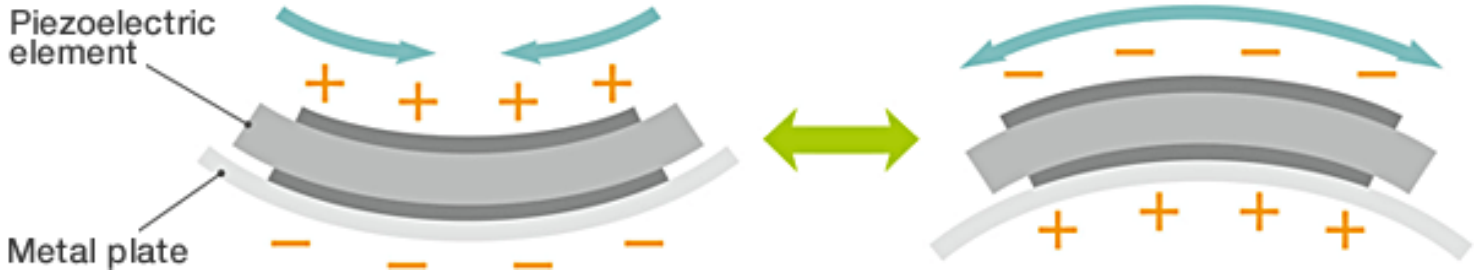
Product Specification	Acceleration		Voltage	Capaci-tance	Max. Dis-placement	$T_{op,max}$
	20gr.	100gr.				
L8060 (General use) PHUA8060-35A-33-000	1.5G	0.2G	24Vp-p max. (±12V)	0.6µF	65µm	60°C
L3015 (General use) PHUA3015-30A-21-000	TBD	TBD	12Vp-p max. (±6V)	TBD	TBD	60°C
L8060 (Automotive) PHUB8060-35A-33-000	1.5G	0.2G	24Vp-p max. (±12V)	0.6µF	65µm	85°C

Ultra-thin actuator for haptic feed back



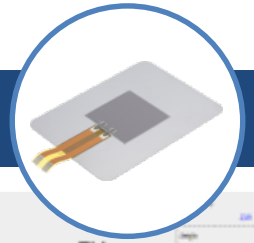
Ultra-thin actuator for haptic feedback

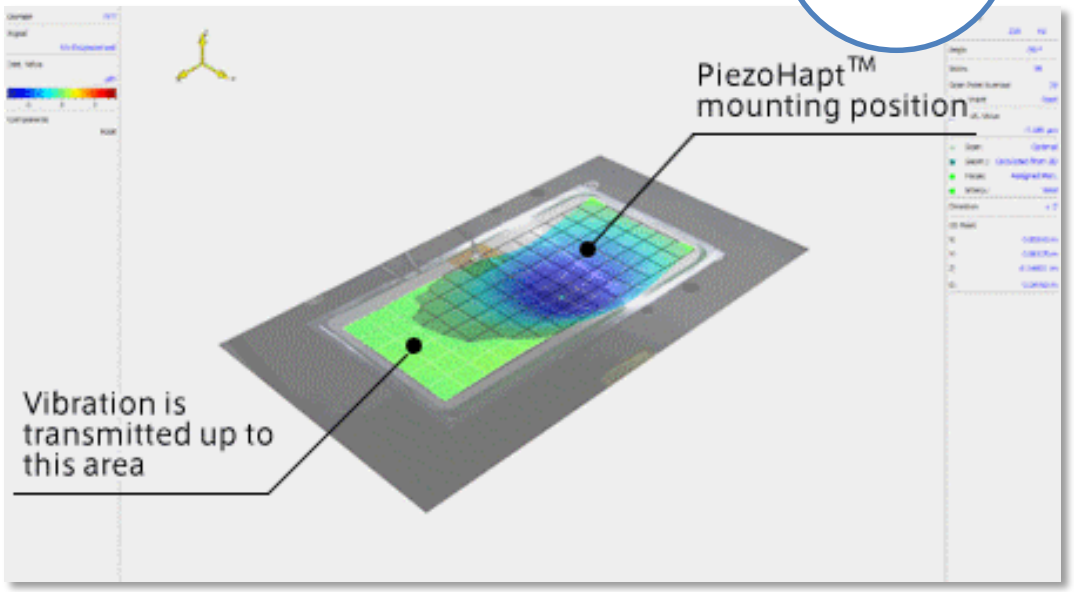
PiezoHapt™



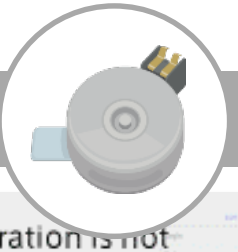
Comparison of ERM and TDK PiezoHapt™ actuator

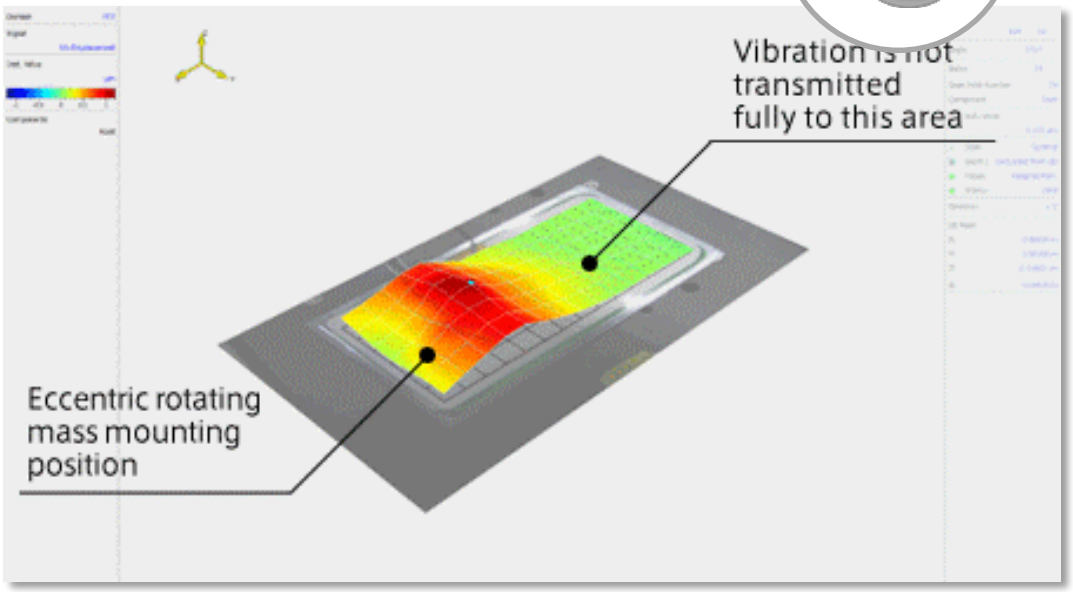
PiezoHapt™ L





ERM





PiezoHapt™ vibration mode can excite a large area.

PiezoHapt™ (L) overview

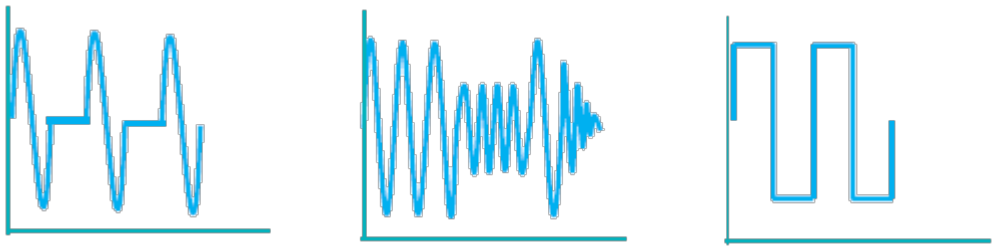
PiezoHapt™ (L) is a thin-type vibration unit consisting of a multi-layered piezoelectric element and a vibration plate.

POINT 1

Driven with low voltage and transmits tactile sensation to wide area

POINT 2

Delivers various kinds of vibration patterns since amplitude and frequency can be freely changed by pulse control

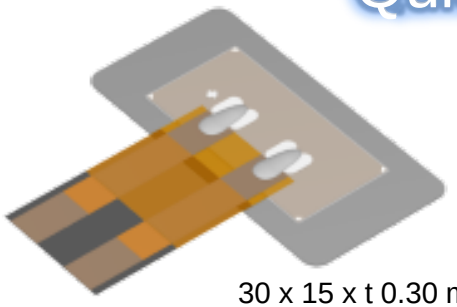


Ultra-thin

Quick response

Low drive voltage

Quiet



30 x 15 x t 0.30 mm

80 x 60 x t 0.35 mm

PowerHap™

Attracting Tomorrow

Key infos

USP: „Powerful but thin!“

- **Samples available**
- **Release and SOP early 2018**
- **Release based on AEC-Q200**

Target applications (examples)

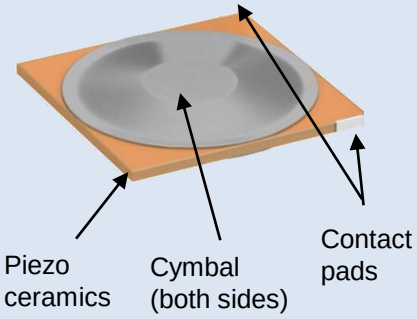
Automotive
- Displays
- Touch pads / buttons

Industry
- Human machine interface
- Building automatization

Consumer
- Mobile devices
- Game controllers

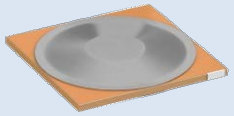
Product range

15G type



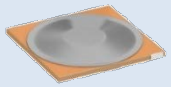
26 mm x 26 mm
Thickness: 2.4 mm

7G type



12.7 mm x 12.7 mm
Thickness: 1.9 mm

2.5G type

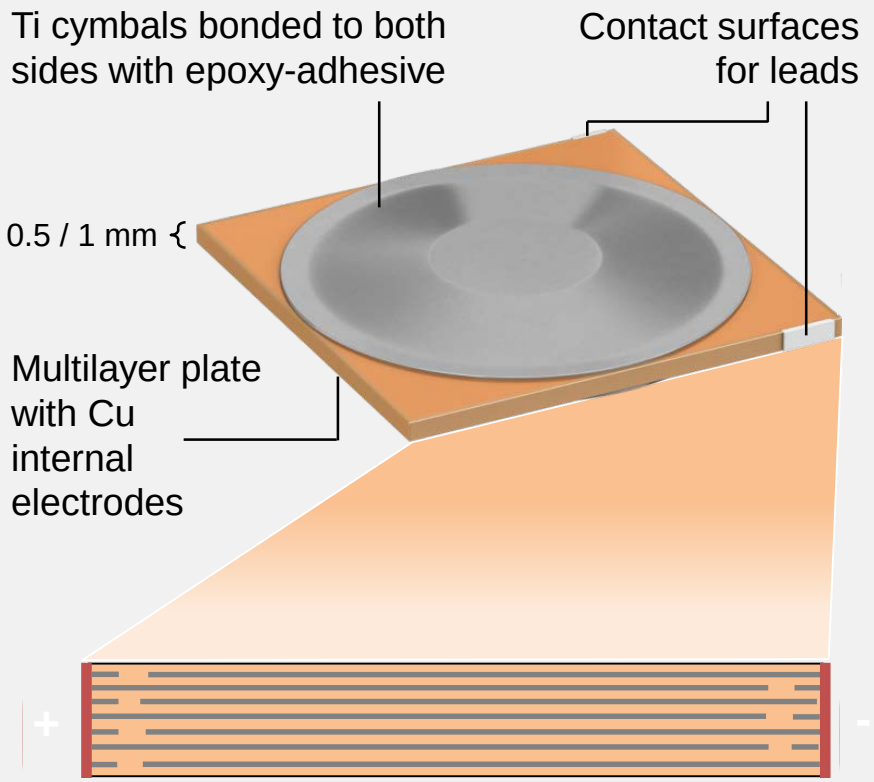


9 mm x 9 mm
Thickness: 1.2 mm

Product Specification	Acceleration		Voltage	Capaci-tance	Max. Dis-placement	$T_{op,max}$
	20gr.	100gr.				
PowerHap 15G Z63000Z2910Z 1Z 4	65G	15G	120V	3.6µF	200µm	85°C
PowerHap 7G Z63000Z2910Z 1Z 5	30G	7G	120V	0.9 µF	65µm	85°C
PowerHap 2.5G Z63000Z2910Z 1Z 2	8G	2.5G	60V	0.8 µF	35µm	85°C

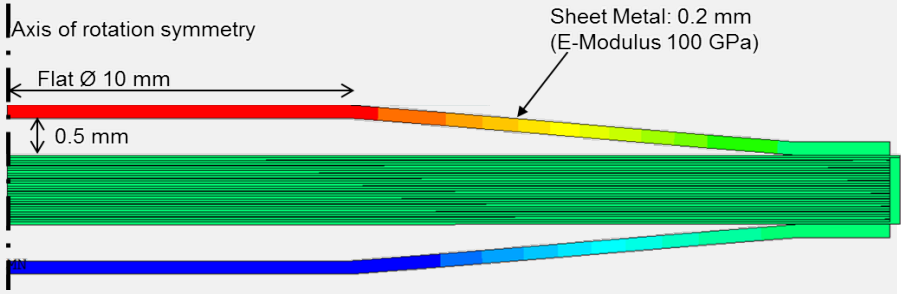
The cymbal acts as a lever to convert the contraction of the x- and y-axes into amplified displacement in the z-axis.

PowerHap™: Construction



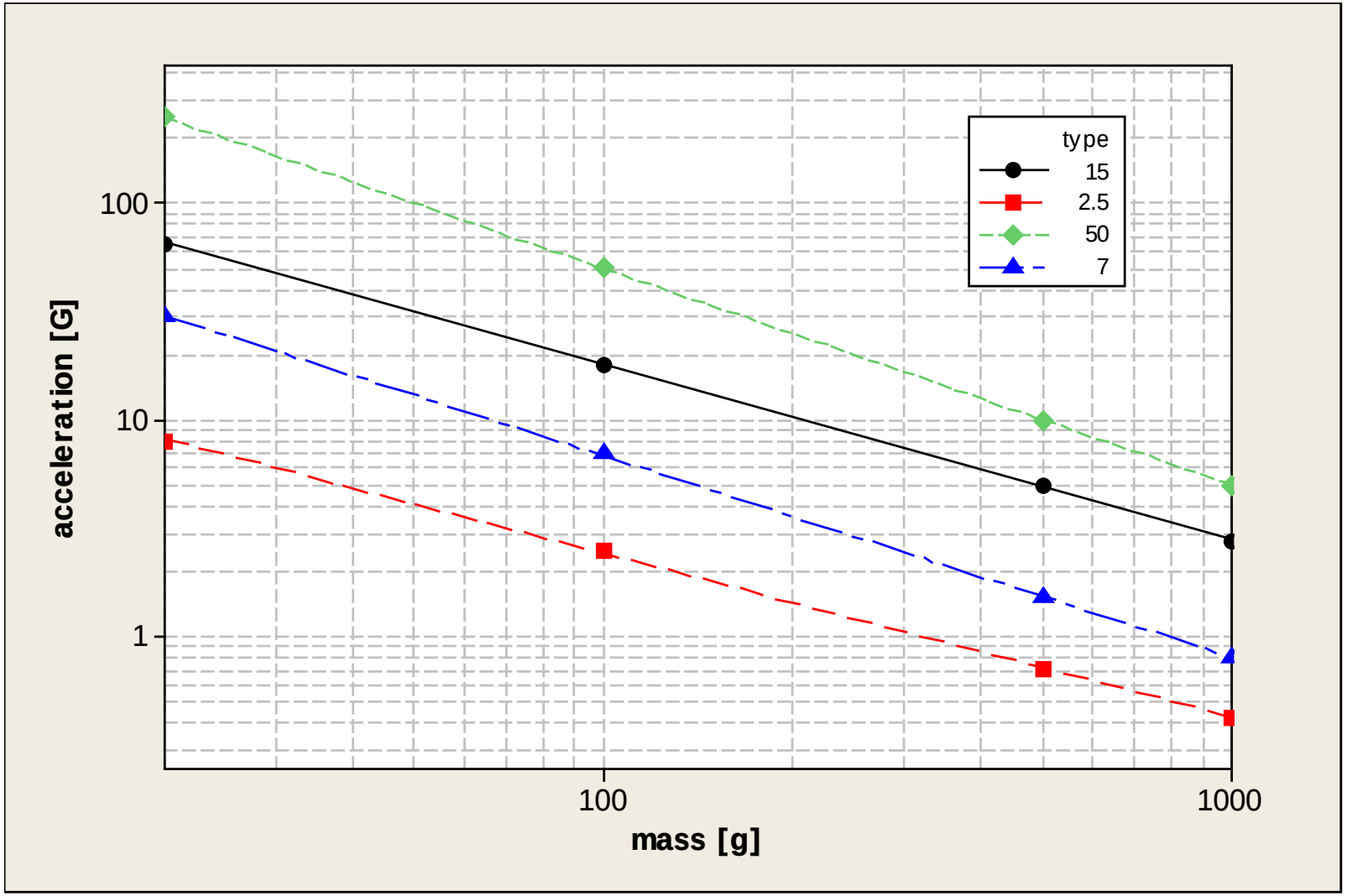
Internal layout: 23 active layers

Piezo actuator	2.5G type	7G type	15G type
Footprint [mm]	9.0 x 9.0	12.7 x 12.7	26.0 x 26.0
Insertion height [mm]	1.2	1.9	2.4
Operating voltage [V]	≤ 60	≤ 120	
Operating temperature [°C]	-40 °C to +85 °C		
Storage temperature [°C]	-40 °C to +125 °C		
Displacement amplifier (cymbal)			
Sheet thickness [mm]	0.1	0.15	0.2
Diameter [mm]	8.7	12.4	25.6
Recess [mm]	0.2	0.26	0.5

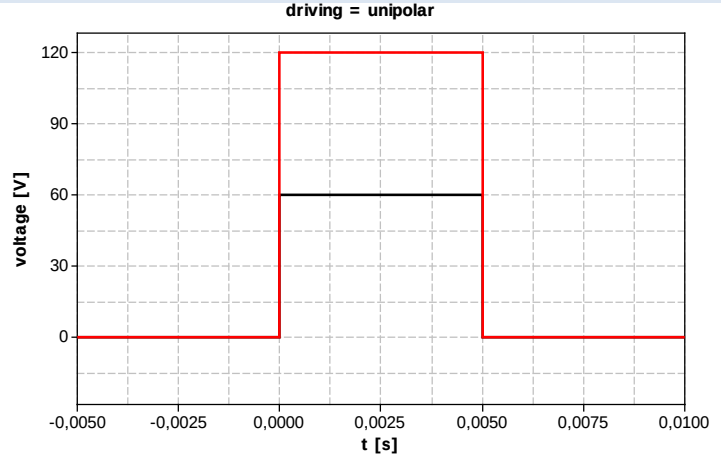


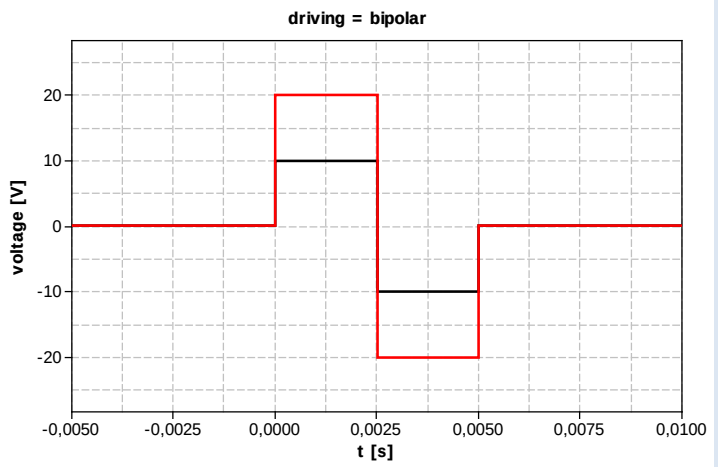
Multilayer structure enables operation at low voltages.

Acceleration vs. mass



Two driving modes: Unipolar and bipolar





PowerHap™:
Specified for two different driving modes

Unipolar: Highest possible performance

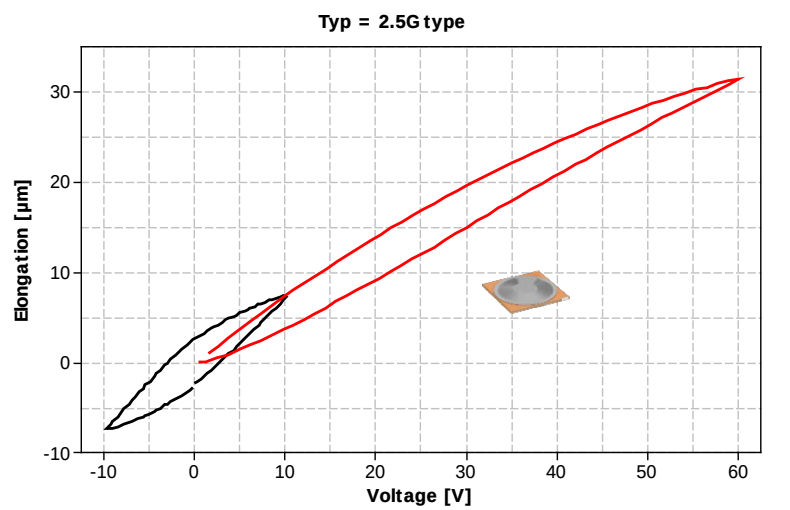
Unipolar means to drive PowerHap™ from **0 V to the max. rated voltage** (60 V for 2.5G type and 120 V for 7G and 15G types)

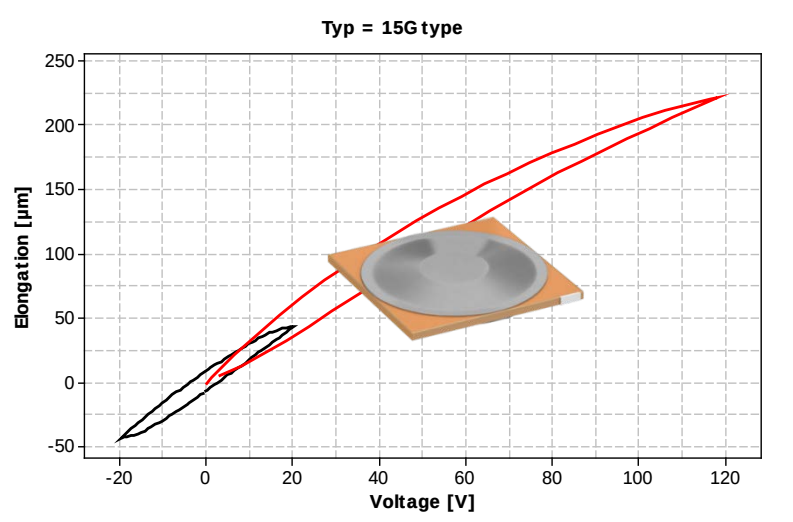
Bipolar: Much lower driving voltage

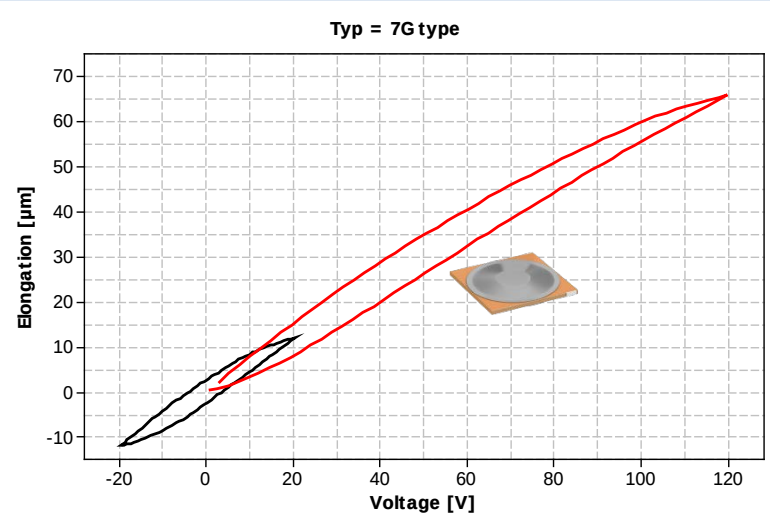
Bipolar means to drive PowerHap™ between **+/-10 V** for 2.5G type and **+/-20 V** for 7G and 15G types

Different driving modes possible, depending on customer requirements.

Large displacement: Up to 200 µm







Driving mode
bipolar
unipolar

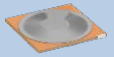
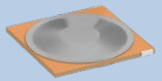
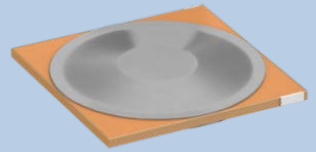
Unipolar: Elongation up to 30 µm, 65 µm and 200 µm

Bipolar: Elongation up to 15 µm, 25 µm and 85 µm, respectively, for the 2.5G, 7G and 15G types

*) Actuator is fixed on one side with vacuum; triangular pulses up to U_{max}; t = 10 s

Large displacement range enables stimulation of all human mechanoreceptors for both driving modes.

PowerHap™: Superior to all conventional haptic technologies

PowerHap™						
Size x, y, z [mm]	**2.5G type** 9 x 9 x 1.2 mm 		**7G type** 12.7 x 12.7 x 1.9 mm 		**15G type** 26 x 26 x 2.4 mm 	
Voltage [V]	0 ... 60	+/-10	0 ... 120	+/-20	0 ... 120	+/-20
Acceleration [*g*] (20 g mass)	8	6	30	13	65	28
Acceleration [*g*] (100 g mass)	2.5	1.5	7	2.5	15	7
Elongation [*µm*]	30	15	65	25	200	85
Energy per click [mJ]	1	0.1	3	0.4	8	1.0
Custom waveforms	YES					
Force sensing	YES					

The bipolar driving mode needs 80% less energy per click compared to the already very low energy consumption in unipolar driving mode.

Active haptic feedback for larger LCD displays

„Normal movement“
Actuator behind display

„Lateral movement“
Actuator aside the display

?

Lateral movement: Requirements for the actuator

Has to be mounted at the side of the display:

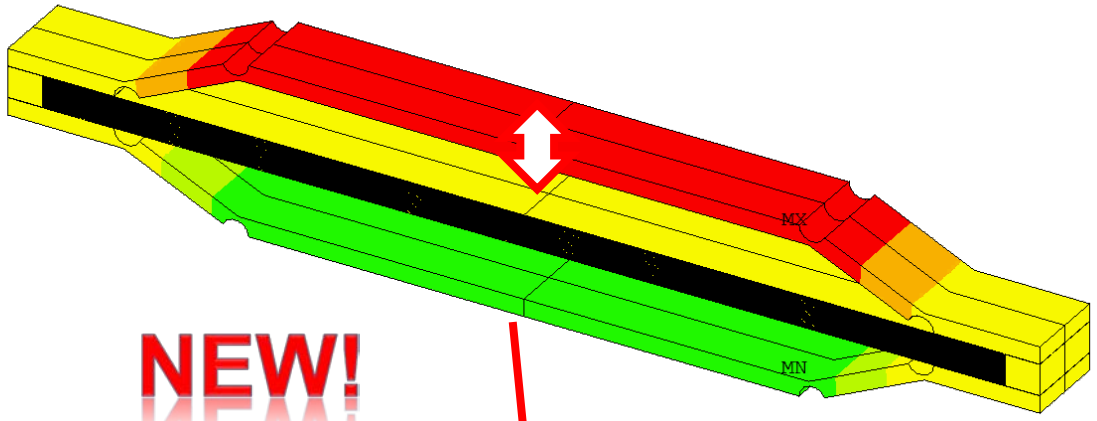
→ Can be long

→ Small in other dimensions

Displays get larger and therefore more heavy

→ Actuator needs to be „strong“

Our solution: The 50G type



NEW!

The bow acts as a lever to convert the contraction of the y-axes into amplified displacement in the z-axis.

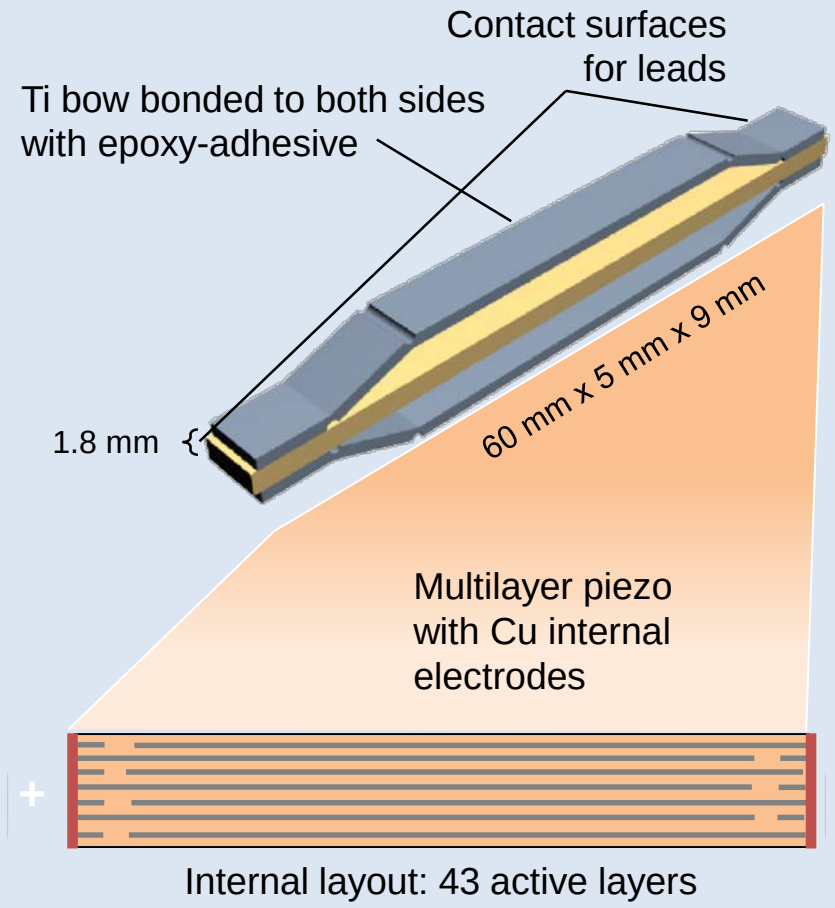
Movement direction

Leaf-spring

Leaf-spring

60 mm x 5 mm x 9 mm

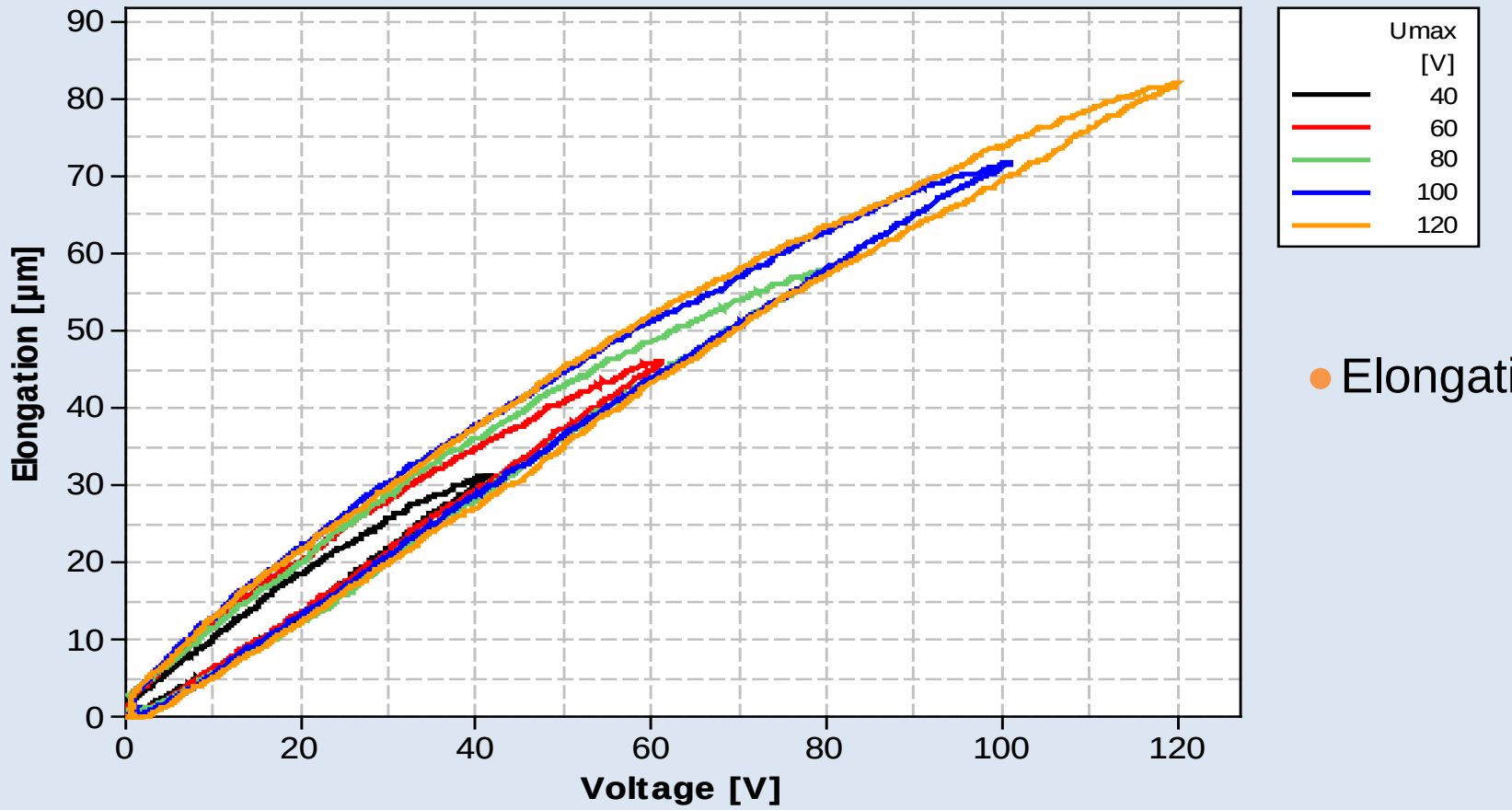
New 50G type



Piezo actuator	50G type
Footprint [mm]	60 x 5.0
Insertion height [mm]	9.0
Operating voltage [V]	≤120
Operating temperature [°C]	-40 °C to +85 °C
Storage temperature [°C]	-40 °C to +125 °C
Displacement amplifier (cymbal)	
Sheet thickness [mm]	1.0
Length [mm]	59.0
Recess [mm]	2.6

Multilayer structure enables operation at relatively low voltages.

Large displacement

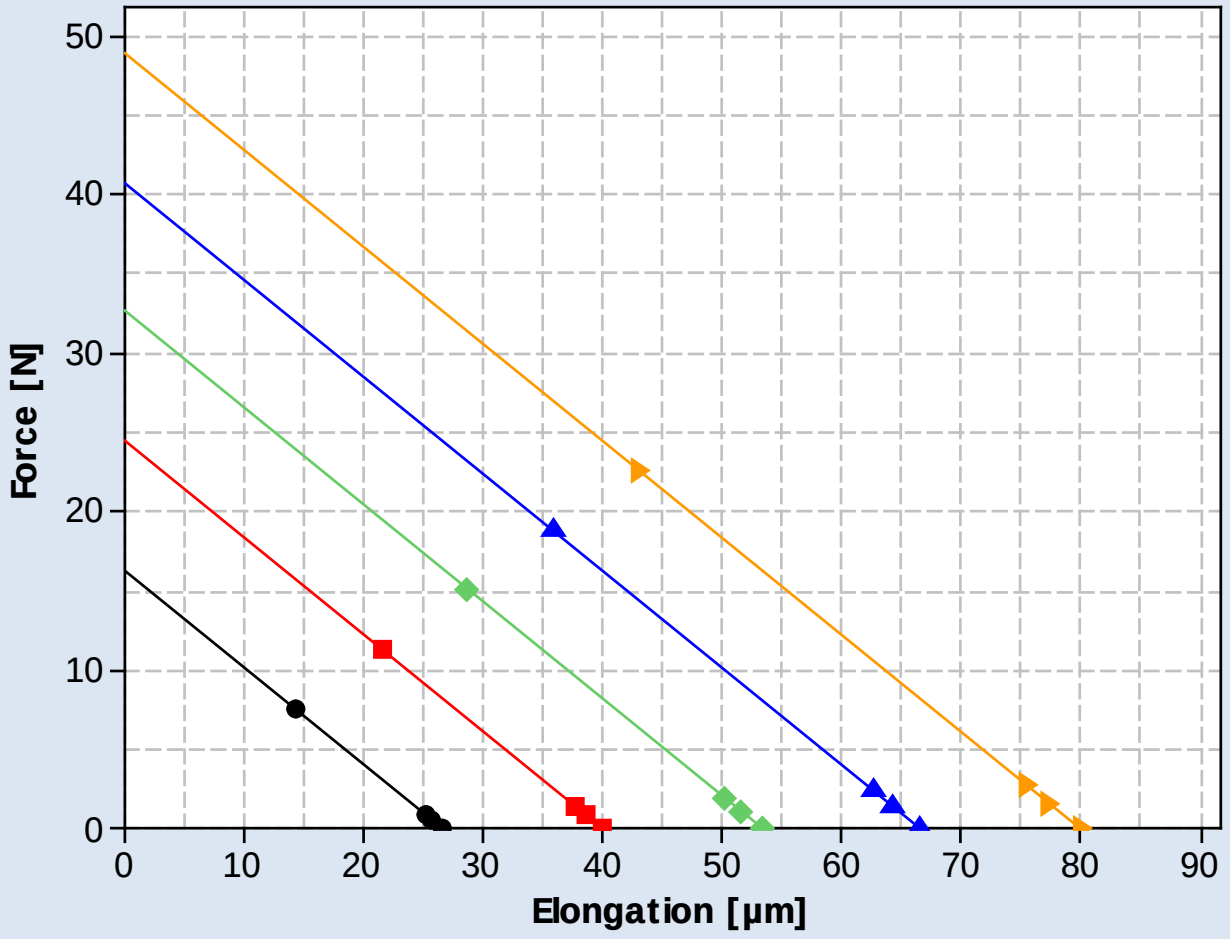


*) Actuator is fixed on one side with vacuum; triangular pulses up to U_{max}; t = 10 s

- Elongation up to 80 µm

Large displacement range enables stimulation of all human mechanoreceptors.

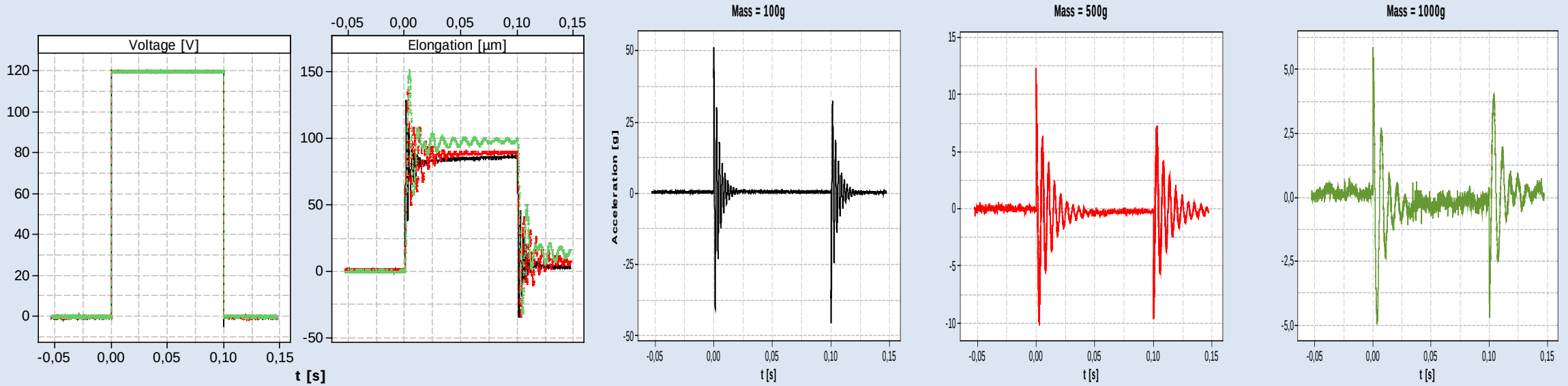
Strong force



- High max. force
- Large range of forces
- High stiffness of ≥0.6 N/µm
- High linearity

Maximum force with small component insertion height.

Short response time and high acceleration



Mass	100 g	500 g	1000 g
Acceleration [*g*]	50	10	5
Rise time [ms] *)	<1		
Power consumption per click [mJ]	10		

*) Time between voltage switched on to vibration amplitude reaching 50% maximum G

Even weights above 1 kg can be accelerated and still create a good haptic feedback.

PowerHap Minilateral

Key Infos

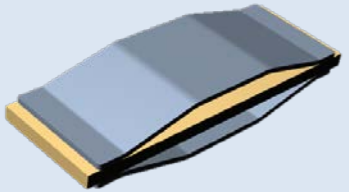
USP: „Small & Powerful!“

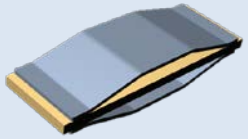
- → **Low power consumption**
- → **Supports force sensing**
- → **Samples available**

Target Applications (Examples):

- **Industry**
  - Touchpads
  - Control Panels
- **Consumer**
  - Smartphones
  - Tablets
  - Keyboards & Mice
  - Mobile devices
  - Game controllers

Product range:





NEW!

12mm x 4mm

Thickness: 2.4mm

NEW!

9mm x 3.75mm

1.8mm

Product Specification	Acceler-ation 100gr.	Voltage Unipolar/ (bipolar)	Capacit-ance	Max. Displace-ment	$T_{op,max}$
PowerHap Lateral 12x4 Z63000Z2910Z1 Z39	4.5G	60V / (±10V)	0.45µF	25µm	85°C
PowerHap Lateral 9x3.75 Z63000Z2910Z 1Z 41	3G	60V / (±10V)	0.32 µF	15µm	85°C

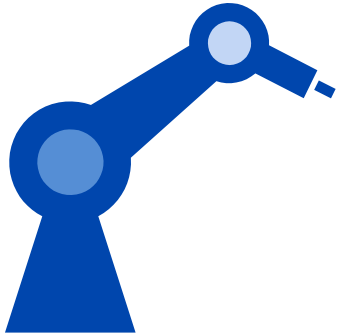
PowerHap™ is superior to all conventional haptic technologies

	ERM Eccentric rotary mass	LRA Linear resonant actuators	Piezo benders	PowerHap™		
Size x, y, z [mm]	8x3x3	Ø10x3	3x4x3	9x9x1.2	12.7x12.7x1.9	26x26x2.4
Acceleration [*g*] (20 g mass)	2	5	2.5	8	32	65
Acceleration [*g*] (100 g mass)	0.6	1.7	0.65	2.5	7	15
Rise time [ms]	50	25	10	<1		
Voltage	3	3	-100…100	60	120	
Energy per click [mJ]	17	15	4	1	3	8
Custom waveforms	No	No	Yes	Yes		
High-definition haptics	No	No	No	Yes		
Force sensing	No	No	No	Yes		

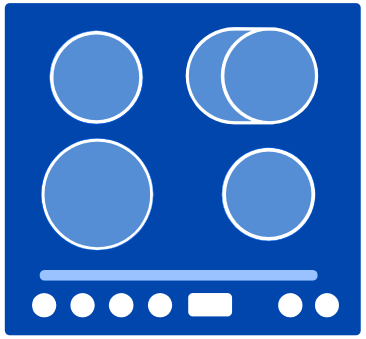
Piezo actuator adds the haptic dimension to a comprehensive range of HMIs

Attracting Tomorrow

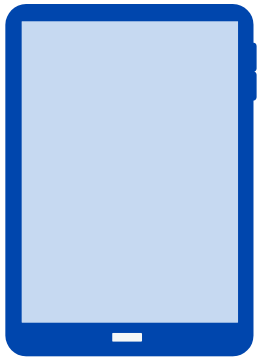
Multifunctional automotive HMIs



Industrial equipment



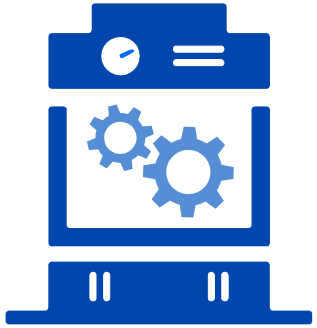
Household appliances



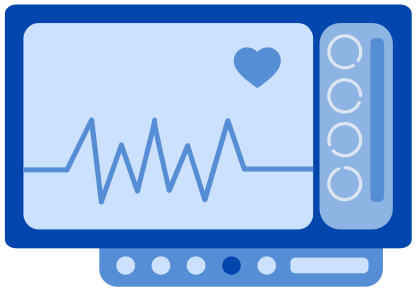
Displays

BROAD APPLICATION SPECTRUM

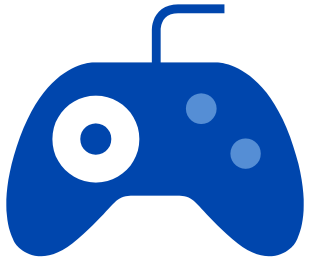
ATMs and vending machines



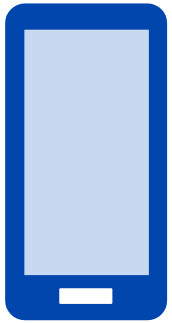
Medical apparatus



Game controllers



Smartphones



Selection table

Attracting Tomorrow

	Driving Voltage			Actuator Thickness		Required Area (in mm)				Max. moveable weight --> min. 3G acceleration				Automotive Qualification
	24V	60V - 120V	>200V	<0.5mm	>1.2mm	9 x 9 - 12 x 12	12 x 12 - 15 x 15	30 x 15 - 30 x 30	80 x 60	<30gr.	30gr. - 100gr.	250gr.	1.000gr.	
PiezoHapt S φ15mm			X	X			X			X				
PiezoHapt S φ12mm			X	X		X				X				
PiezoHapt S φ15mm – Auto			X	X			X			X				X
PiezoHapt S φ12mm – Auto			X	X		X				X				X
PiezoHapt L L8060-General	X			X					X	X				
PiezoHapt L L8060 – Auto	X			X					X	X				X
PiezoHapt L L3015-General	X			X				X		X				
PowerHap 15G		X			X			X					X	X
PowerHap 7G		X			X		X					X		X
PowerHap 2.5G		X			X	X					X			X

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