

Product Introduction

Piezoelectric Haptics

V. C/202101

ENGINEERED SENSATION

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Members



Gao Feng



China



Mr. Asano



Japan

Introduction

Doctoral Candidate of RyuKoku University; the first piezoceramic earphones corresponding to high resolution sound source in China; with 3 invention patents and 10 utility model patents.

Doctoral Candidate of Kobe University, Japan; worked for Sumitomo Metal Industry Co., LTD., a fortune 500 company; engaged in piezoelectric ceramics industry for more than 30 years, material design specialist; overseas senior technical consultant

Members

Introduction



Mr. Watabe



Japan

Expert in acoustic applications; worked for World top 500 Companies including Japan Sunlure Corporation and SONY Corporation; technical minister; product design specialist; overseas senior technical consultant



Sun Qingchi



China

Tianjin University, Master tutor;
engaged in teaching and scientific research of inorganic non-metallic materials for more than 30 years; senior technical consultant.

Applications of Haptics



Consumer Electronics

- smart phone
- tablet
- notebook



Home Appliances

- control panel



Auto Electronics

- steering wheel
- touch screen
- dashboard



Game Console

- controller
- screen

Future Applications



wearable
device



haptic
gloves



virtual
keyboard



mouse



touch-
control
pen

Piezoelectric Haptics Principle

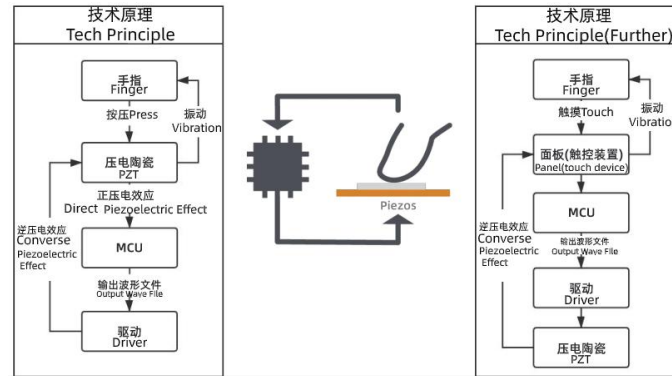
Technical Features

Piezoelectric ceramics have direct and Converse piezoelectric effects.

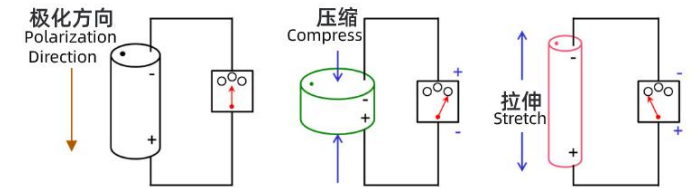
The pressure sense belongs to the direct piezoelectric effect. When an external force is applied to the PZT, the PZT deforms and the internal polarization state changes, thereby generating electric charge and being detected.

Vibration sense belongs to the converse piezoelectric effect, that is, when a driving voltage is applied to the PZT, and the PZT produces mechanical deformation, thereby causing vibration.

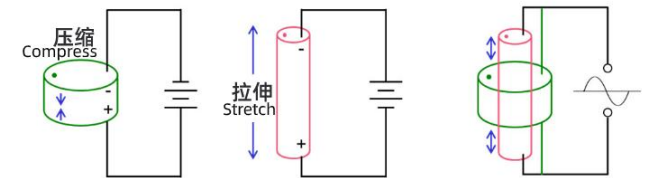
Working Principle



Direct Piezoelectric Effect



Inverse Piezoelectric Effect



Comparison of Piezoelectric Products

Multilayer PZT

- low driving voltage
- light pressure sense, and super strong vibration
- high displacement
- suitable for pressure detection and vibration

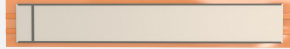

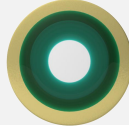
Bimorph PZT

- Low and medium driving voltage
- medium pressure sense, and medium strong vibration
- high displacement
- suitable for pressure detection and vibration

Single Layer PZT

- high driving voltage
- strong pressure sense, and strong vibration.
- medium displacement
- suitable for pressure detection and vibration

Product Introduction of PZT Haptics

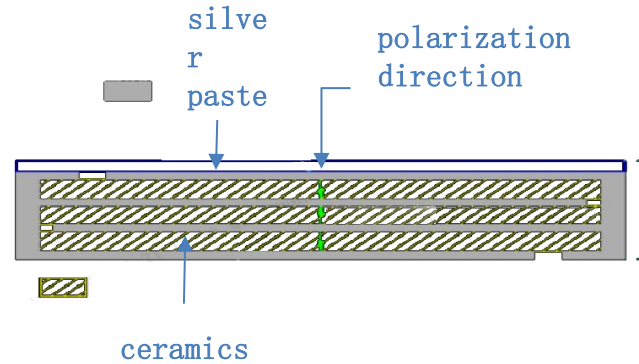
Product Name	Multi-layer PZT	Bimorph PZT	Single Layer PZT
			
Product Model	BPH-5509S-8.0MF-HF	BPH-6206S-2.0MF-HF	FT-15T-7.0A1-02
Piezoceramic Size (mm)	50×8×0.2	52×6×0.23	∅ 10×0.17
Total Size (mm)	55×9×0.5	62×6×0.56	∅ 15×0.31
Shape/Layer/ Single Layer Thickness	Rectangle or Circle/4 layers/0.05 mm	1 layer*2/0.23 mm	1 layer/0.13 mm
Driving Voltage (Vo-p)	-10~+60 low driver cost	-150~+150 medium driver cost	-100~+260 high driver cost
Pressure Sense	0.2V~0.8V light	2V~5V medium	10V~20V Strong

Conclusion

- More layers mean lighter pressure sense
- Driving voltage can be lowered down by multi-layer PZT
- The thickness of single layer determines the driving voltage

Multi-layer PZT

Multilayer piezoceramic device is a new ceramic structure with mechanical series connection and electrical parallel connection. It adopts advanced ceramic tape casting technology and ceramic/metal co-firing technology.

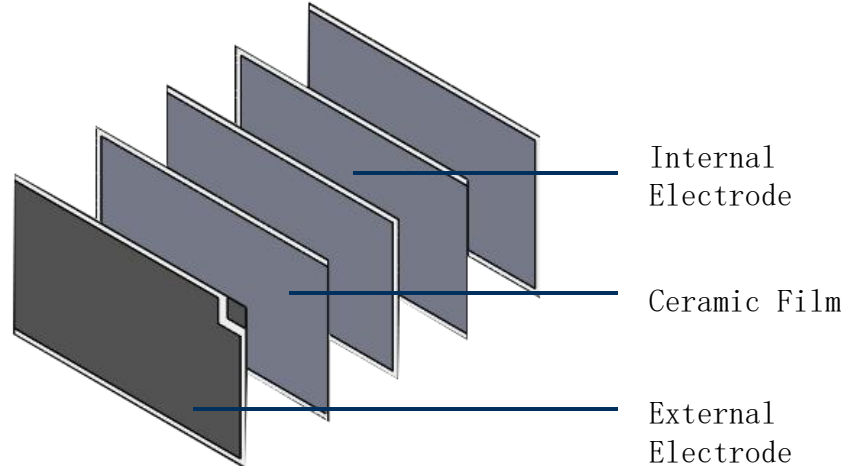


Product Code: BPH-5509S-8.0MF-HF



Features

- low power consumption
- high displacement
- haptics
- light, thin & small-sized
- RoHS, REACH, HF

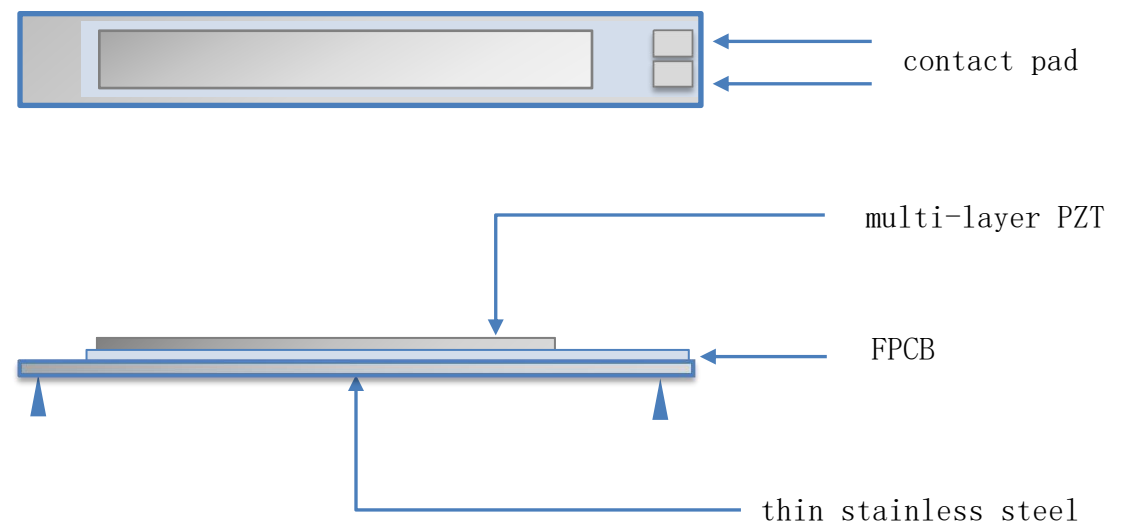
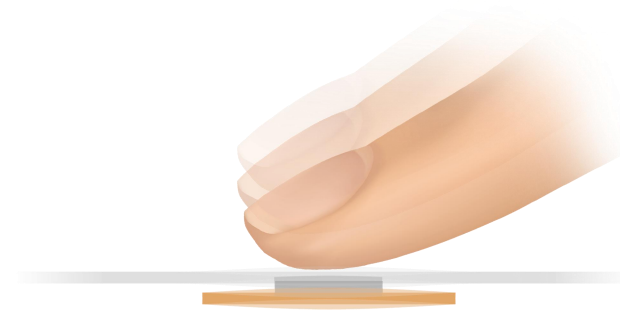
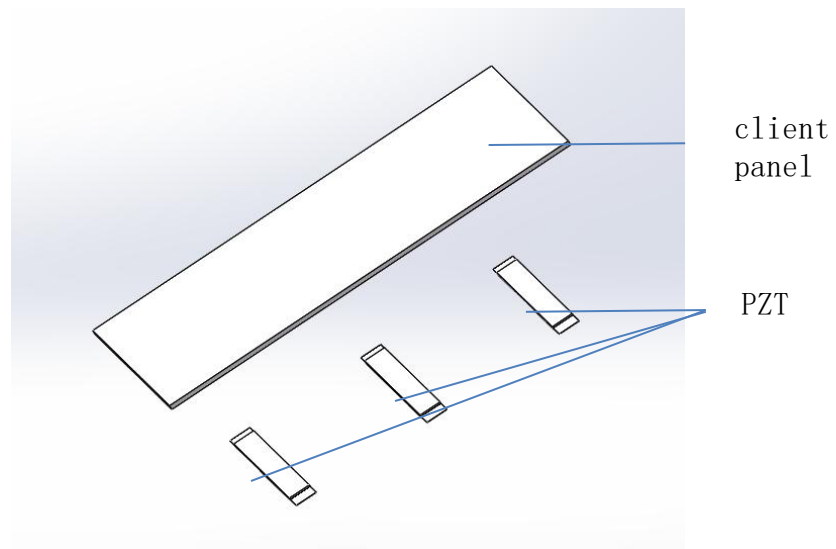


Items	Unit	Specification
Substrate Length	mm	55±0.2
Substrate Width	mm	9±0.2
Substrate Thickness	mm	0.1±0.01
PZT Length	mm	55±0.3
PZT Width	mm	8.0±0.15
Total Thickness	mm	0.4±0.05
Free Capacitance	nF	450 ±20% (120 Hz)
Operating Voltage	V _{p-p}	≤ 50
Insulation Resistance	MΩ	> 200 (50 V DC)
Silver Layer Adhesion Force	N/mm ²	> 2.5
Storage Temperature	°C	-40 ... +85
Operating Temperature	°C	-20 ... +65

Multi-layer PZT - Structure and Installation

Customer Bonding Method

- The back glue is fully pasted, and the vibration of the panel is driven by the vibration of the piezoelectric sheet
- Fix the edge of the PZT, and vibration is transmitted through the middle support point.



Multi-layer PZT (Rectangle or Circle)

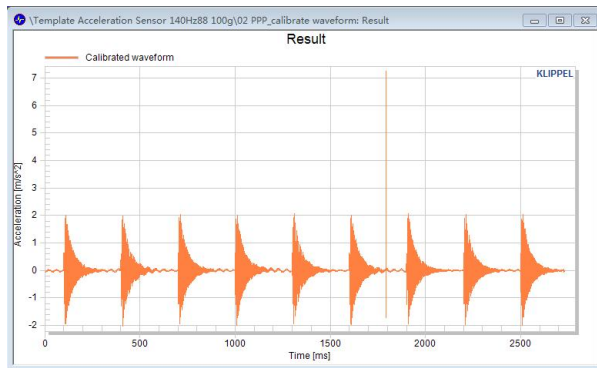
Model	BPM-Y20TS0.35-L05-K1-HF	BPM-Y20TS0.35-L05-K1-HF	BPM-F3204TN0.65-LD09-HU-K1
Pictures			
Dimension	Ø 20*0.35	Ø 27*0.3	32*4.5*0.65
Capacitance	270nf ± 20%	260nf ± 20%	900nf ± 20%
Layers	5	3	18
Single Layer Thickness / μm	38	45	27
Driving Voltage Frequency	30Vpp 200Hz @19g	30Vpp 200Hz @19g	30Vpp 200Hz @60g
Acceleration p-p	4.7m/s ²	5m/s ²	2m/s ²

Ø 27*0.33 Motor Testing Equipment & Method

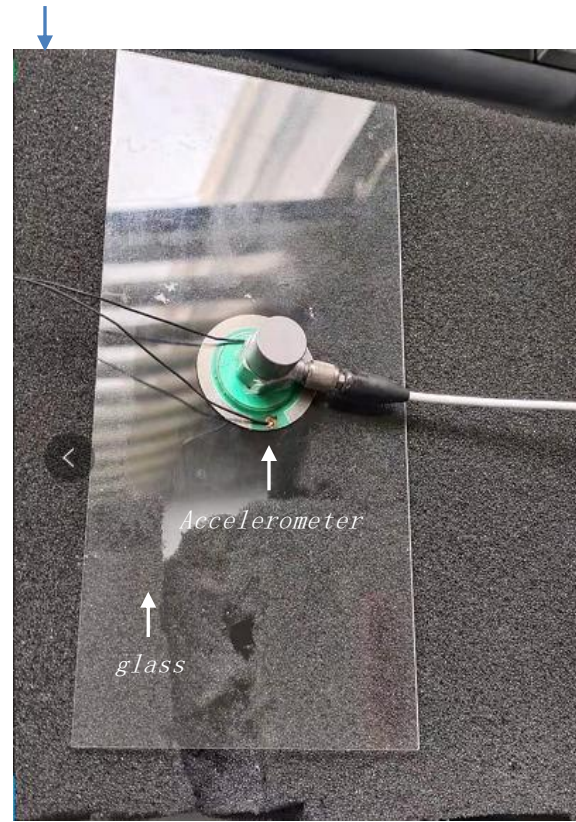
Klippel



Output Acceleration Signal



Sponge



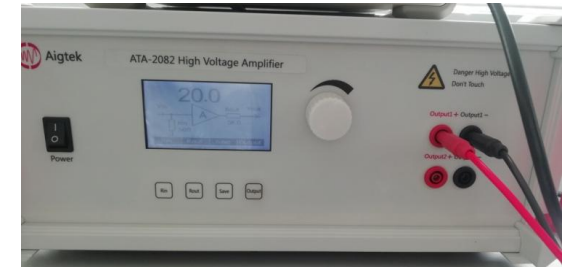
Accelerometer

glass

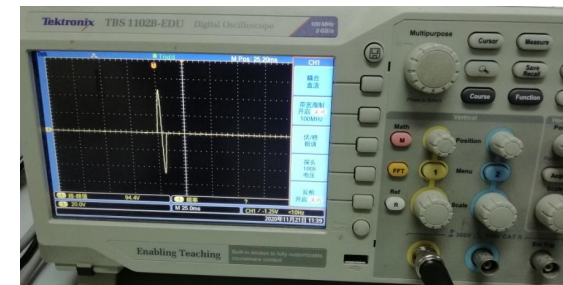
Waveform Generator



High Voltage Amplifier



Oscilloscope



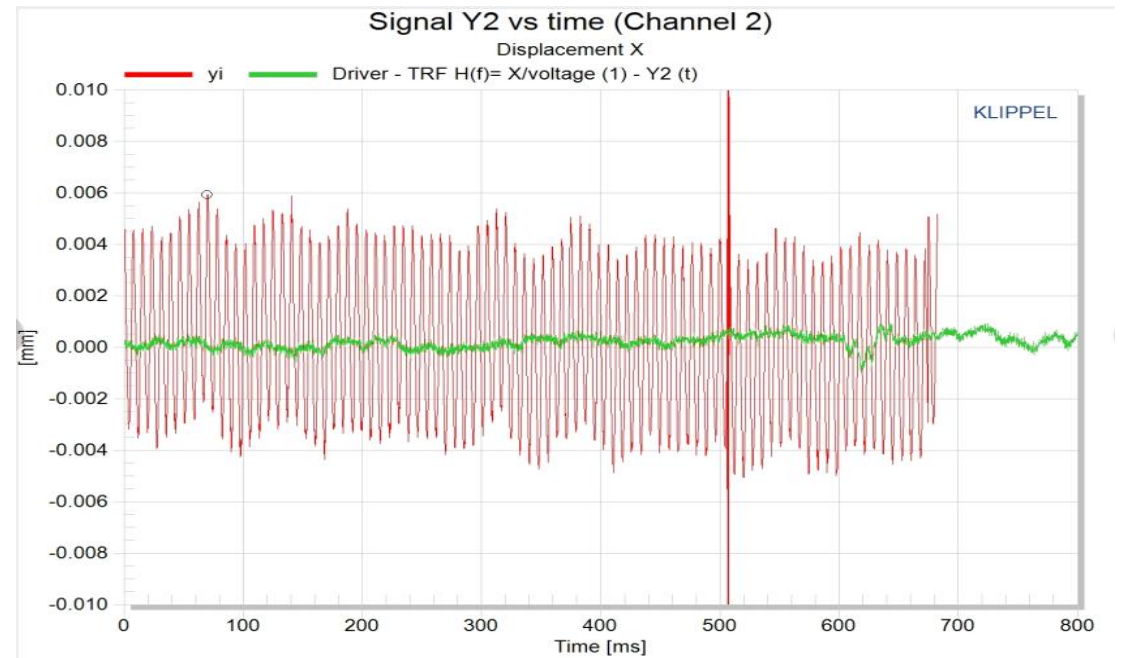
Ø 27*0.33 Displacement Testing Method & Result

PZT Fix Method

150um9448A back glue



*Ø 27*0.33@30 V_{p-p}, 200 Hz Displacement: 12 μm (displacement)*



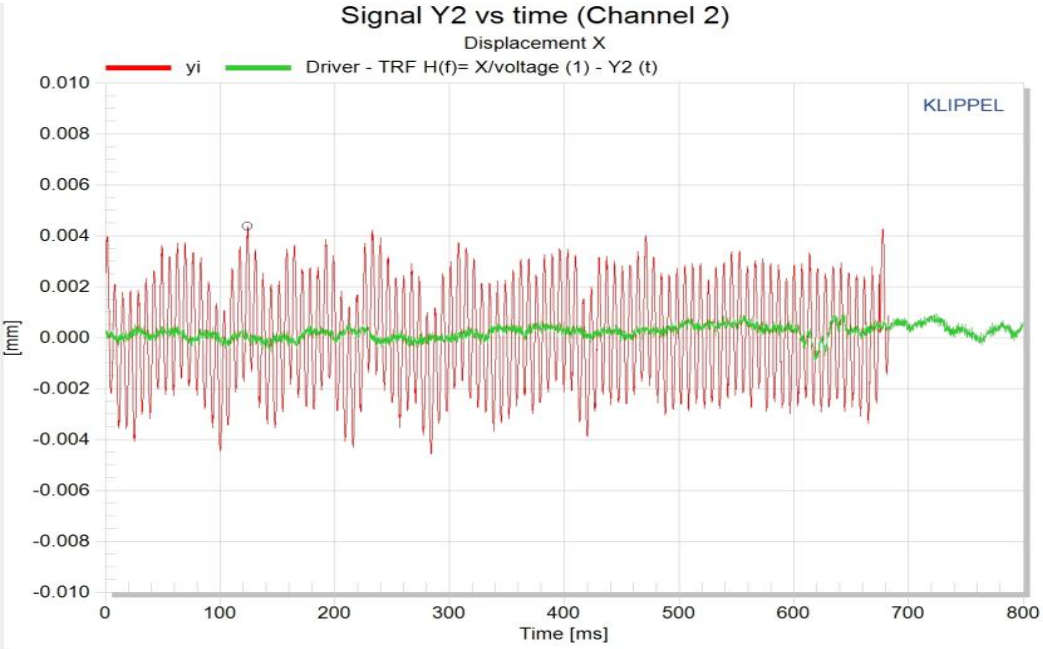
Ø 20*0.33 Displacement Testing Method & Result

PZT Fix Method

150um9448A back glue



Ø 20*0.33@30Vp-p, 200Hz Displacement: 8um (displacement)

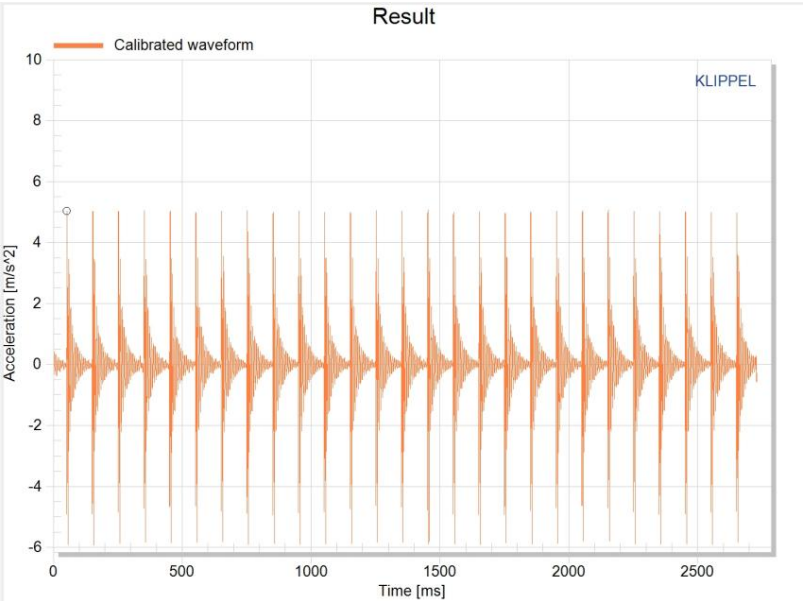


Acceleration Test Method & Result

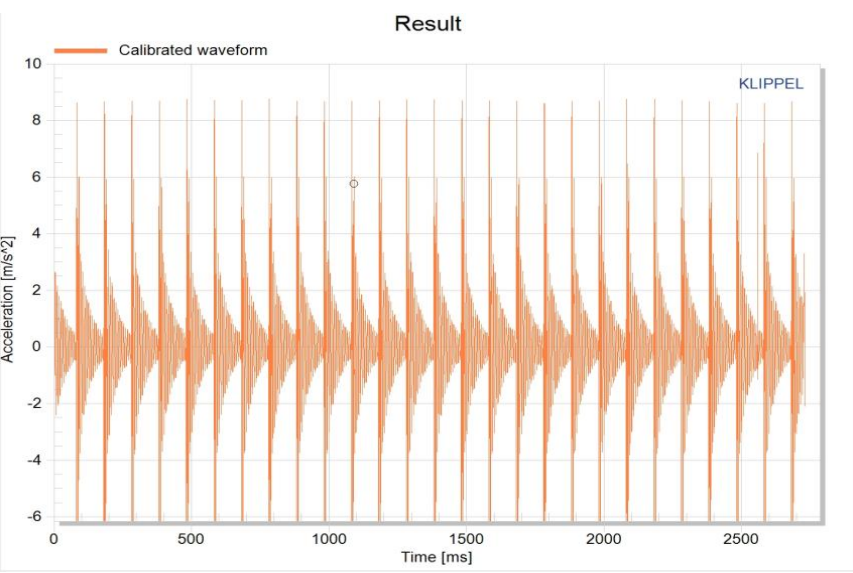
Series Number	State	Diameter	Vibration Sense /30Vp-p	Vibration Sense /50Vp-p
1	3 layers	Ø 27 mm	5 m/s ²	8.6 m/s ²

Place the accelerometer in the center of the PZT for testing.

Ø27*0.33 Acceleration Test Result@200Hz, 30Vp-p



Ø27*0.33 Acceleration Test Result@200Hz, 50Vp-p



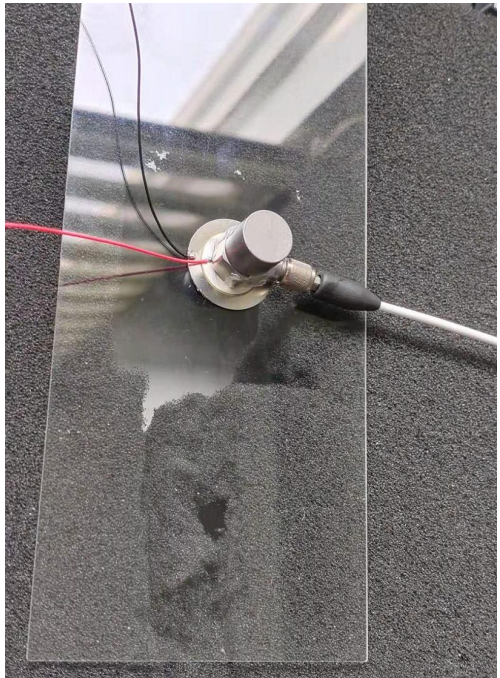
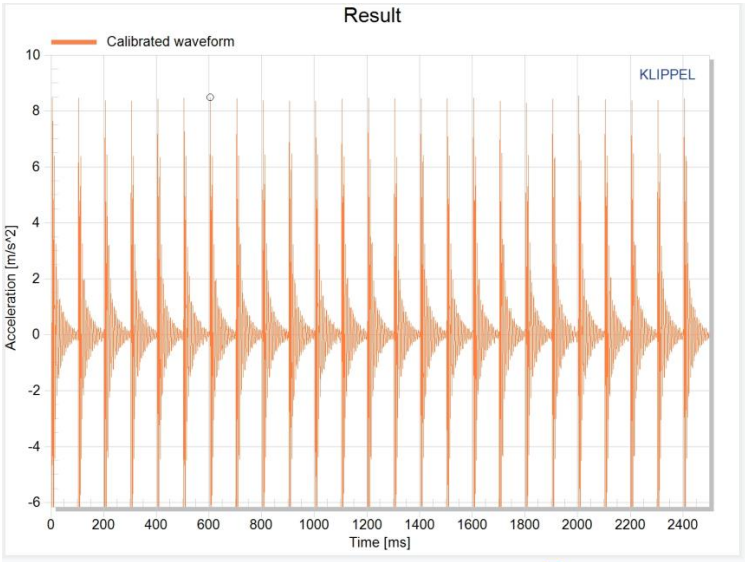
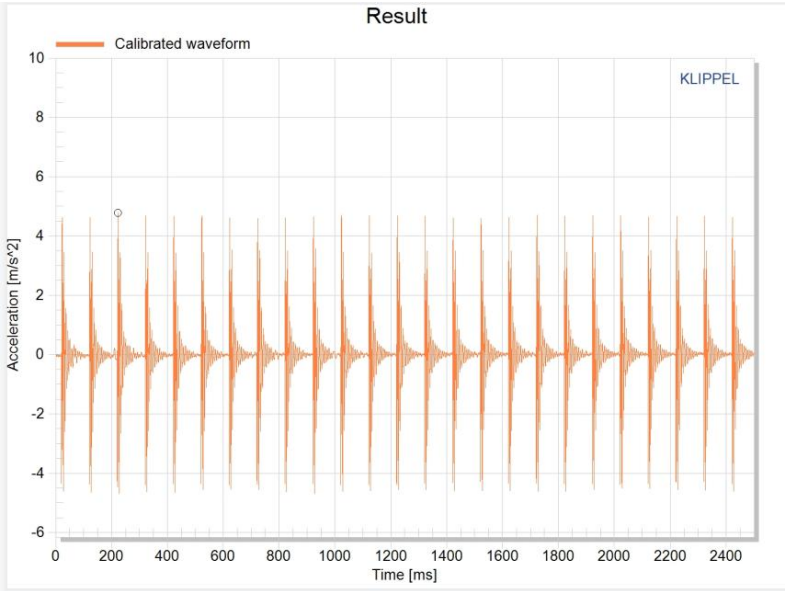
Acceleration Test Method & Result

Series Number	State	Diameter	Vibration Sense /30Vp-p	Vibration Sense /50Vp-p
1	5 layers	Ø 20 mm	4.7 m/s ²	8.4 m/s ²

Place the accelerometer in the center of the PZT for testing.

Ø 20*0.33 Acceleration Test Result@200Hz, 30Vp-p

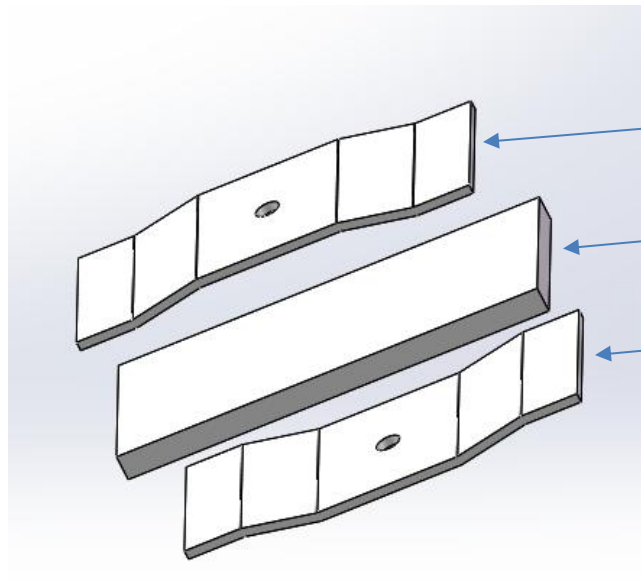
Ø 20*0.33 Acceleration Test Result@200Hz, 50Vp-p



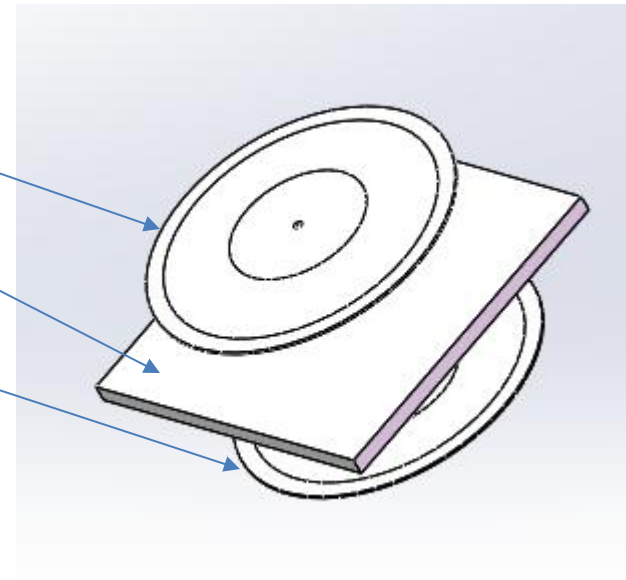
Multilayer PZT+Cymbal Structure

Bestar Sensortech piezoelectric haptics actuator series is composed of multilayer PZT and metal cymbals with strong vibration and extremely quick response.

rectangle



square



Metal
Symbal

Multi-layer PZT

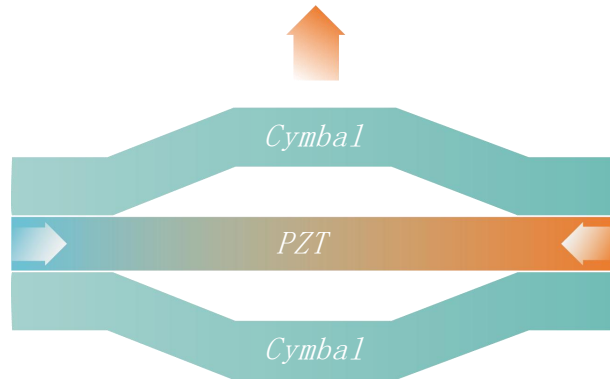
Metal
Symbal

Multilayer PZT + Cymbal Structure

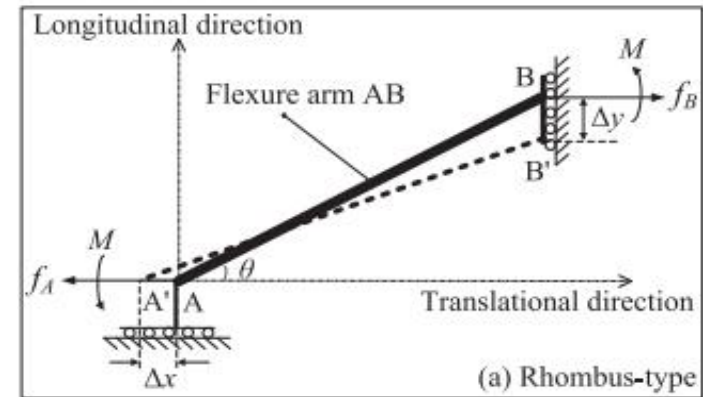
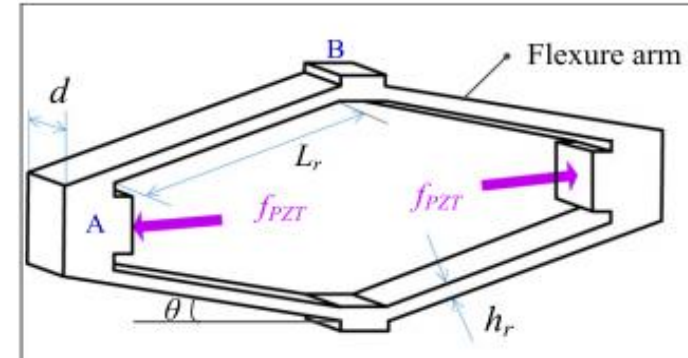
Device Structure

When a voltage is applied to the PZT, the PZT expands and contracts, and vibrates in the horizontal direction. The compression structure of the cymbal converts the horizontal X/Y force of the PZT into the Z direction force of the cymbal, thereby generating vertical acceleration.

Structure



The Way of Force Transmission



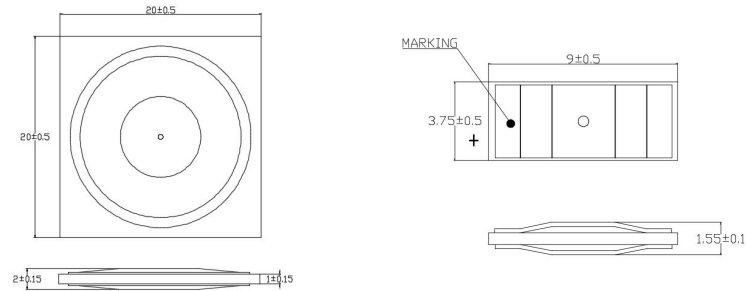
Multilayer PZT + Cymbal Structure

Customer Bonding Method: fix the product in the upper and lower structure by adhesive.

When designing, pay attention to the weight matching of the clamping surface.

Generally, the vibration will be transmitted to the lighter side

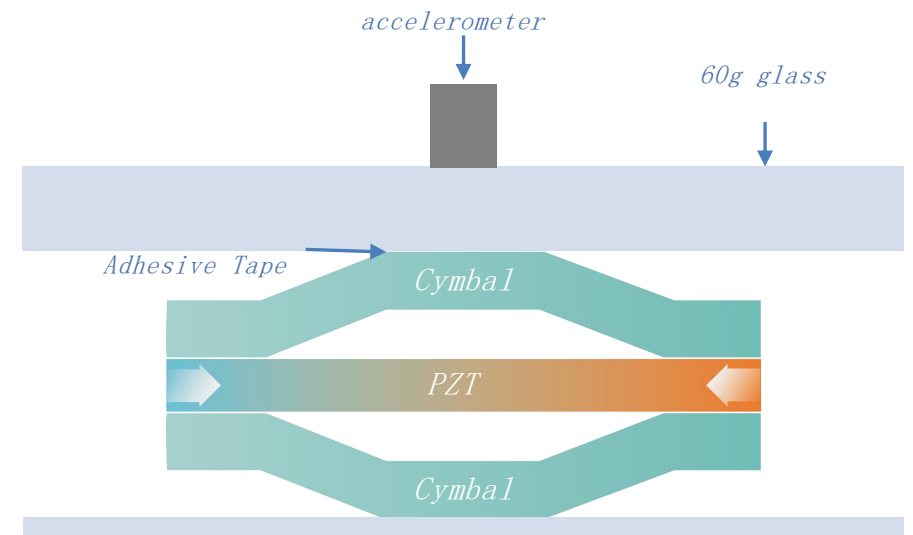
Dimension	20*20	09*04
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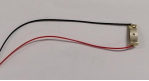

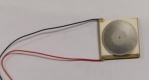
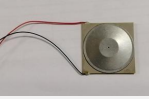
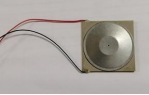
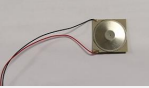
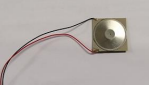
Peak-peak@200 Hz, 60 g	1.6 g	0.6 g
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Peak-peak@200 Hz, 60 g	0.6 g	1.2 g
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Test Instrument Klippel



Multilayer PZT + Cymbal Structure

Product Model	Pictures	Max Driving Voltage	Dimension	Capacitance	Layers	Single Layer Thickness	Testing Voltage Frequency	Acceleration
BPH0904T181MW100 HF		0~60V	9*3.75*0.5	280±20% nF	19	27um	-10V~10V/200HZ/60g	peak-peak: 1.4g
BPH1204T138MW100 HF		0~60V	12*4*0.5	420±20% nF	19	27um	-10V~10V/200HZ/60g	peak-peak: 1.8g
BPH2020T82MW100 HF		0~120V	20*20*1.0	1.9±20%uF	19	54um	-10V~10V/200HZ/60g	peak-peak: 3.2g
BPH2626T78MW200 HF		0~120V	26*26*0.55	2.5±20%uF	13	43um	-10V~10V/200HZ/60g	peak-peak: 4.4g
BPH2626T112MW200 HF		0~120V	26*26*1.0	4.7±20%uF	23	43um	-10V~10V/200HZ/60g	peak-peak: 1.4g
BPH2020T91MW200 HF		0~120V	20*20*0.55	1.7±20%uF	13	43um	-10V~10V/200HZ/60g	peak-peak: 3.8g
BPH2020T130MW200		0~120V	20*20*1.0	2.6±20%uF	23	43um	-10V~10V/200HZ/60g	peak-peak: 4.0g
6005 (under development)		0~120V						

Multilayer PZT + Cymbal Structure

Product Specification

20*20*0.55

Titanium Alloy Thickness:
0.15 mm

Acceleration testing condition

Driving Voltage: 200 Hz、20 V_{p-p} sine wave

Cycle: 100 ms

Load: 60 g



Multilayer PZT + Cymbal Structure

Test Instrument Klippel



*Place the accelerometer directly above the motor for testing.
Acceleration Model: 352C33 SNCW186433*



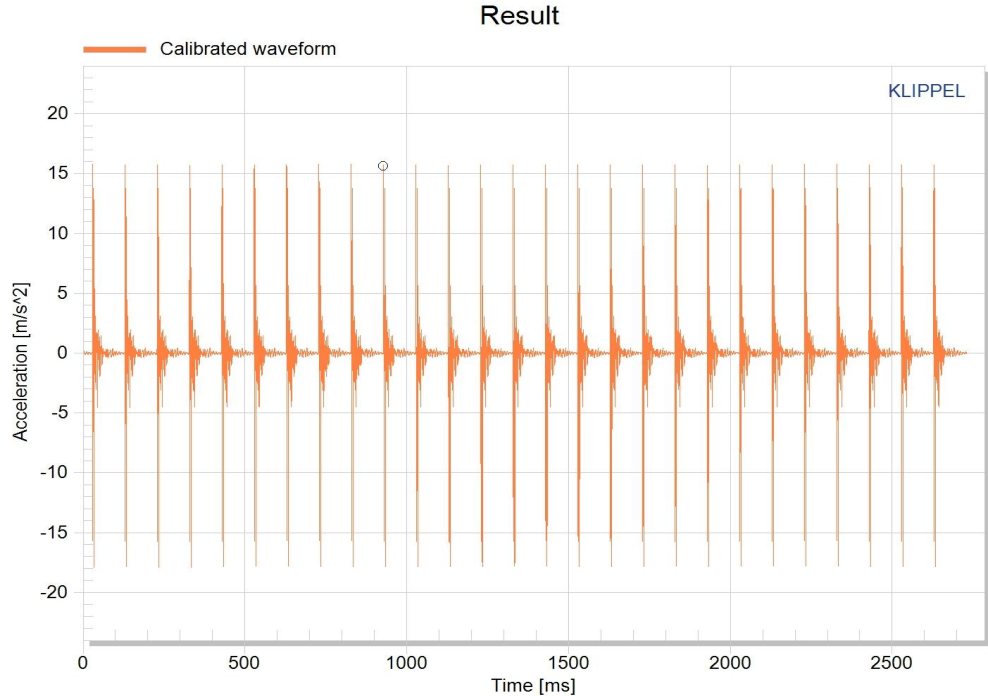
*Glass Panel Size: 320*130*2 mm
Weight: 60 g*

Multilayer PZT + Cymbal Structure

Acceleration Testing Data

NO.	Peak@200Hz	Peak-Peak@200Hz
1	1.7 g	3.4 g
2	1.6 g	3.2 g

Acceleration-Time Graph

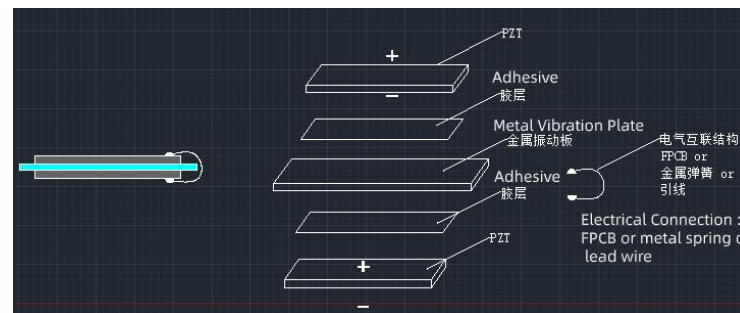


Bimorph PZT

Feature

- low power
- high displacement
- haptics
- high reliability
- RoHS, REACH, HF

Bimorph PZT refers to bonding the same type of PZT with epoxy or UV glue on each side of the metal vibration plate, and the exposed electrodes of the two PZT are electrically connected to realize mechanical series connection and electrical parallel connection. Under the same driving voltage, the amplitude of bimorph PZT is greater than that of single layer PZT.



Product Model	BPH-6206S-2.0MF-HF
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Item	Unit	Specification
Substrate Length	mm	60±0.2
Substrate Width	mm	6±0.2
Substrate Thickness	mm	0.10±0.01
PZT Length	mm	52±0.3
PZT Width	mm	5.9±0.2
Total Thickness	mm	1.0±0.1
Free Capacitance	nF	22 ±20% (1 Hz)
displacement	um	≥3 mm (155 Hz)
Silver Layer Adhesion Force	N/mm ²	> 2.5
Storage Temperature	° C	-40 ... +85
Operating Temperature	° C	-20 ... +65

Structure Design & Installation

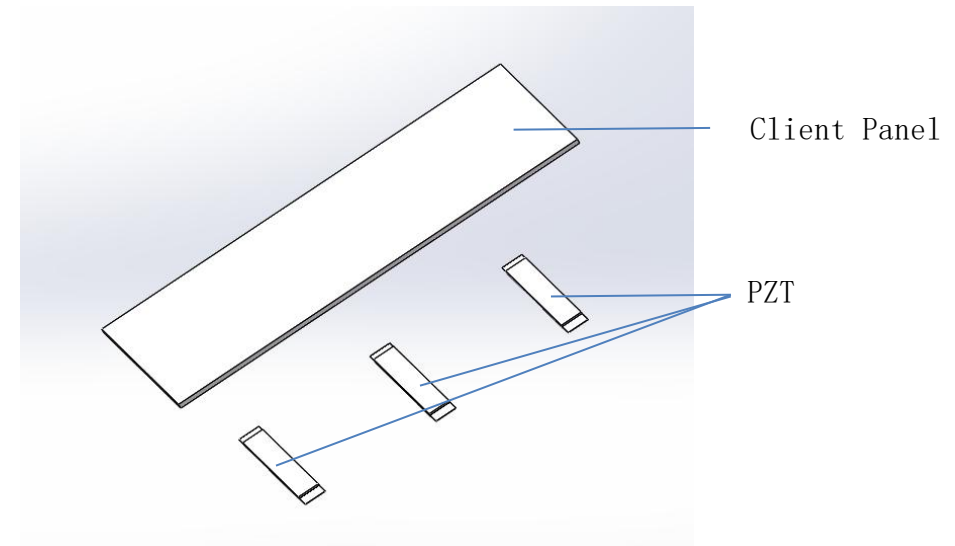
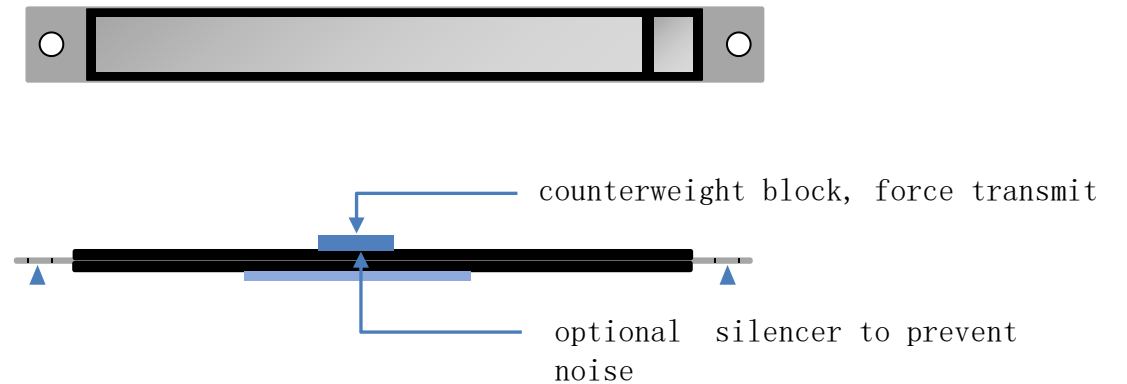
The piezoelectric vibration unit is mechanically fixed by fixing at both ends. Tighten it with screws, or glue it firmly.

The electrical connection adopts the FPCB method.

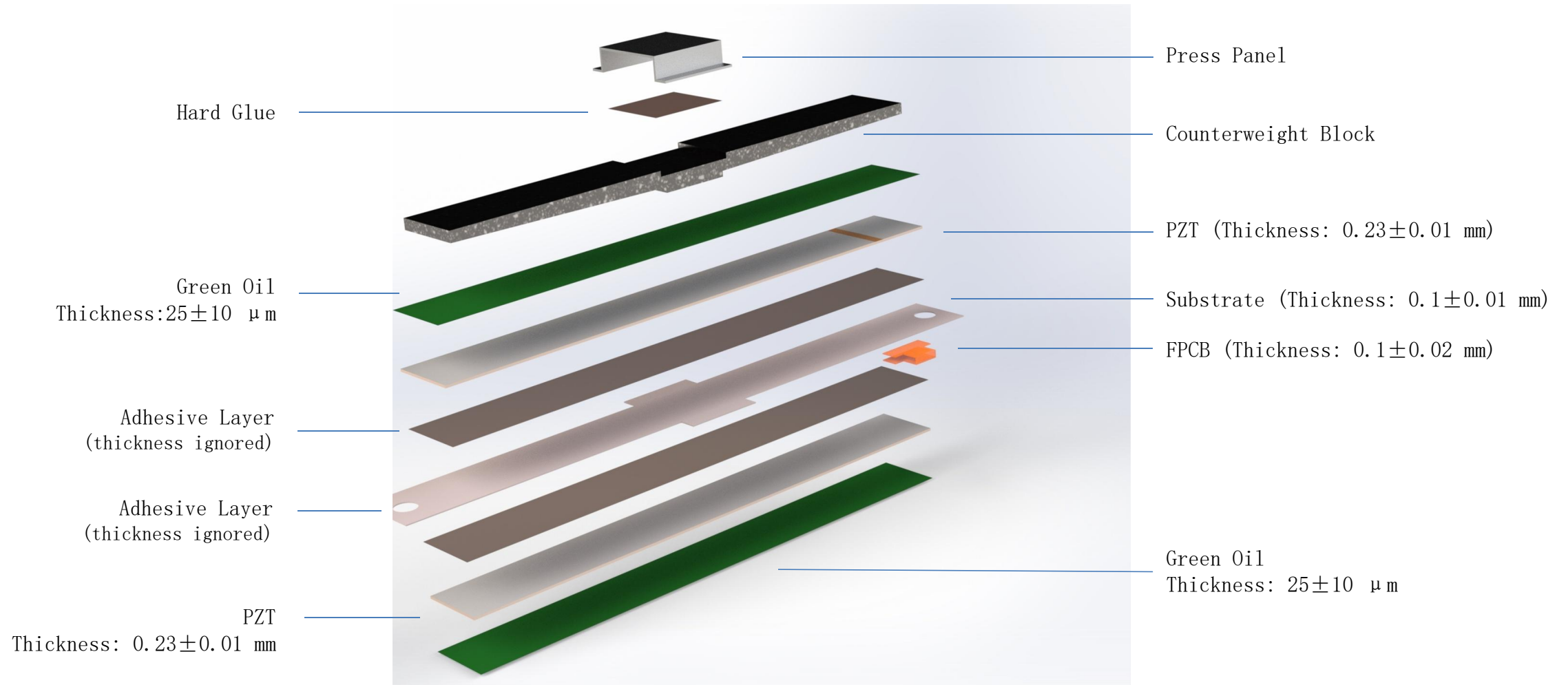
The two ends are fixed to convert the force in the X/Y direction of the PZT into the force in the Z direction.

Customer bonding method

- fixed at both ends, increase acceleration through mass counterweight, and vibration is transmitted through two support points.



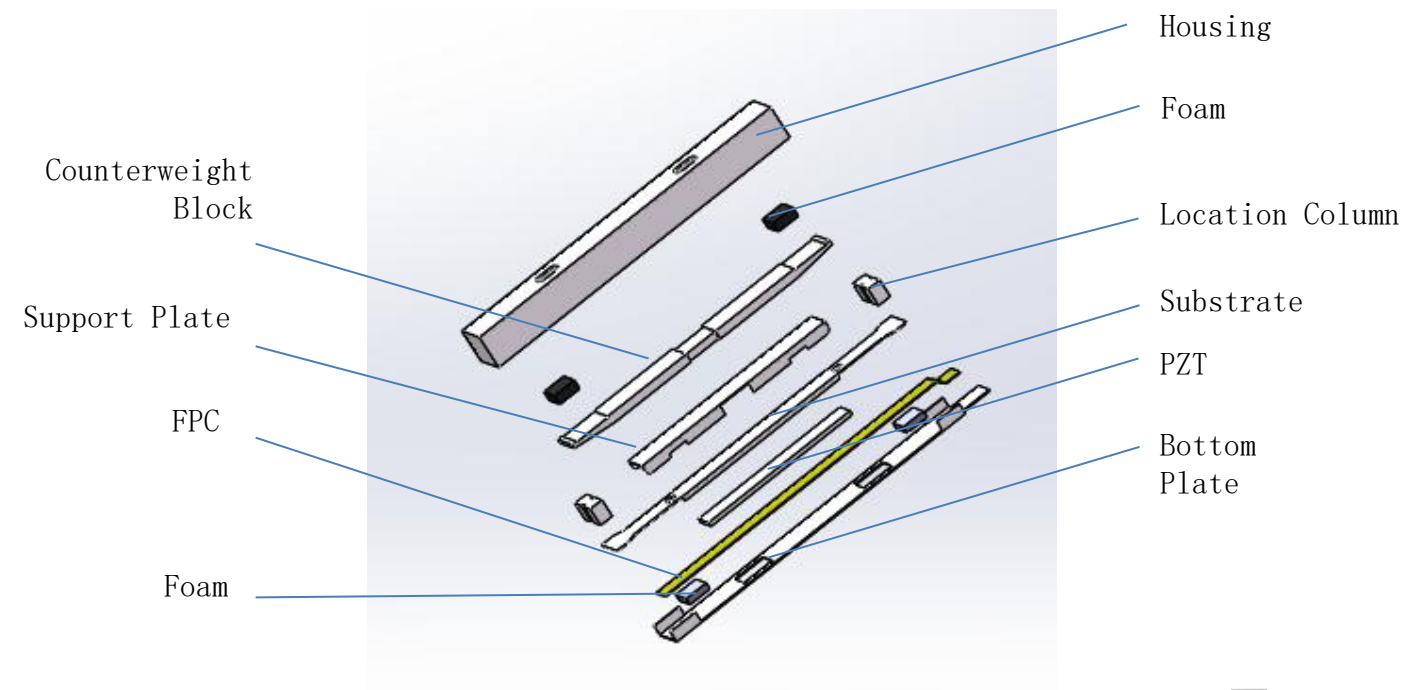
6206 Motor Simulation Entry Condition



3504 Motor Simulation Entry Condition

Process Initial Analysis

- The substrate is welded to the support plate by laser spot welding.
- The support plate and the counterweight block are welded together by laser spot welding.
- Location column, housing and substrate are welded together by laser spot welding.
- FPC, substrate and PZT are bonded together by double-sided adhesive, and then connected by conductive silver glue.
- Housing and the bottom plate are welded together by laser welding.



装配体2.IGS

3D 图

Simulation Entry Condition

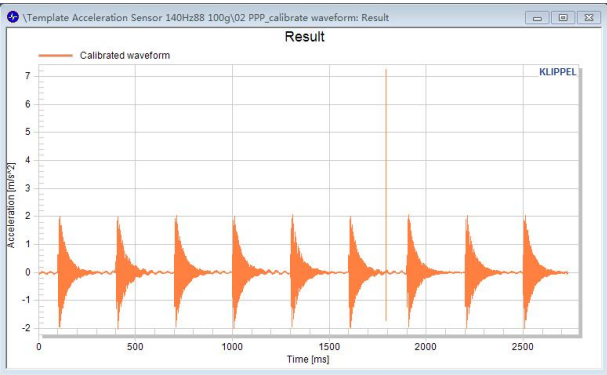
Num	Parts	Material Mode	Elastic Modulus /MPa	Poisson's Ratio	CTE(1e-6)	Tg Temperature /°C	Yield Strength (MPa)	Breaking Strength (MPa)	Bonding Strength (MPa)
1	Housing	304ss	194020	0.3	17	/	310	520	/
2	Counterweight Block	Tungsten Steel	390000	0.3	6.2	/			
3	Location Column	Cast Iron	150000	0.3	12.2	/			
4	Support Plate	304ss	194020	0.3	17	/	310	520	/
5	Glue for PZT & Substrate	high temperature resistant glue				Below Tg: 87 after Tg :209	160		
6	Substrate	304ss	194020	0.3	17	/	310	520	/
7	Ceramics	PZT5	117000	0.32	6	/	30		
8	Bottom Plate	304ss	194020	0.3	17	/	310	520	/

3504 Motor & 6206 Motor Acceleration Test Comparison

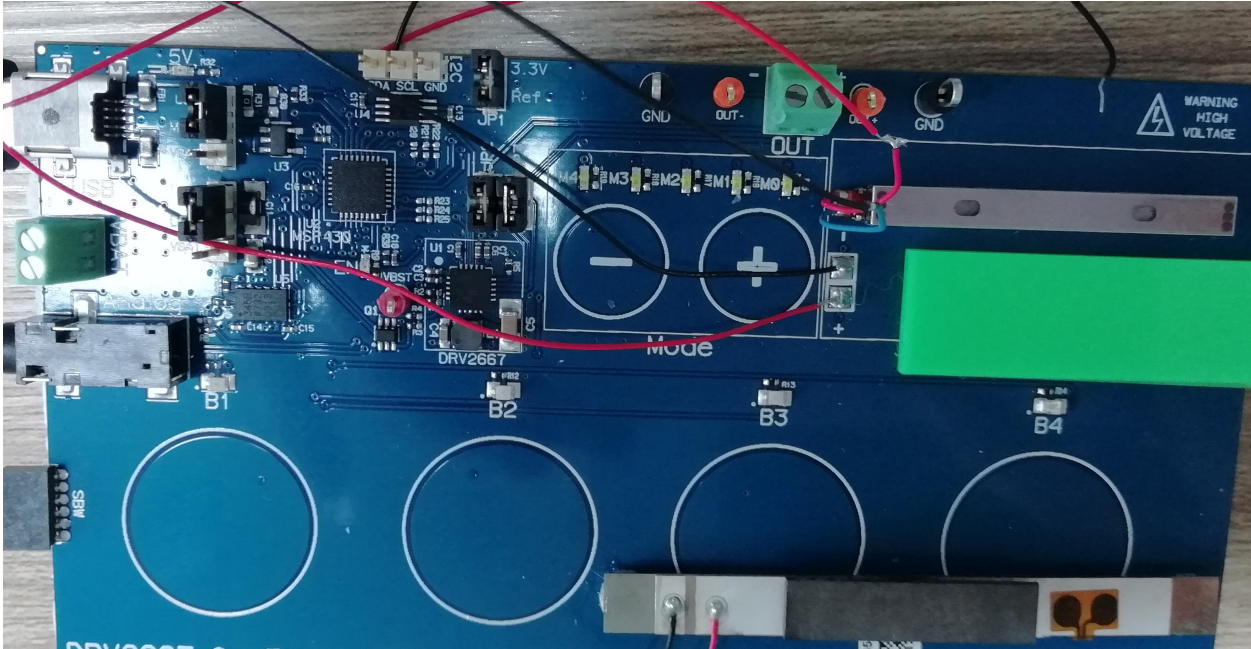
Klippel



Output Acceleration Signal



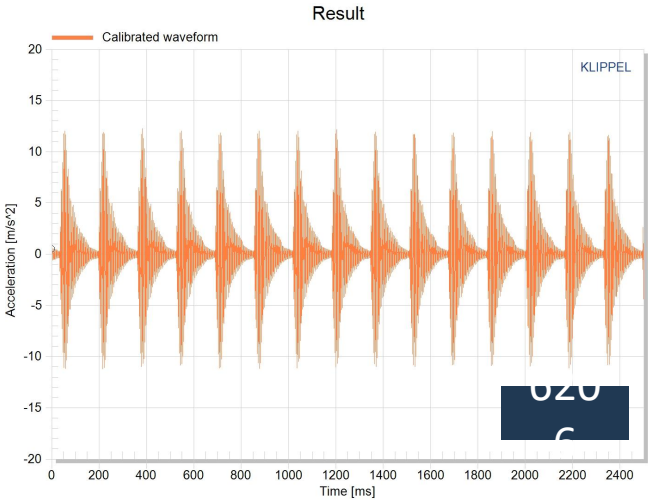
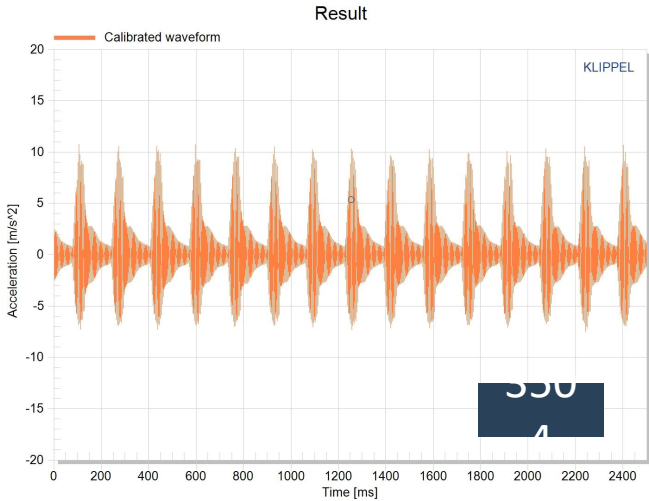
Accelerometer Location Area



3504 Motor & 6206 Motor Acceleration Test Comparison

Mode	Acceleration (one side)	Acceleration (peak-peak value)
3504 (Multilayer PZT)	11 m/s ²	18.5 m/s ²
6206 (Bimorph PZT)	12 m/s ²	23m/s ²

the Same Tests Signals



Single Layer PZT

Product Model	BFT-15T-7.0A1-02
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It provides new piezoelectric touch, full-area pressure sense feedback, precise and sensitive performance, comfortable pressing experience, and light and flexible vibration feedback.



Feature

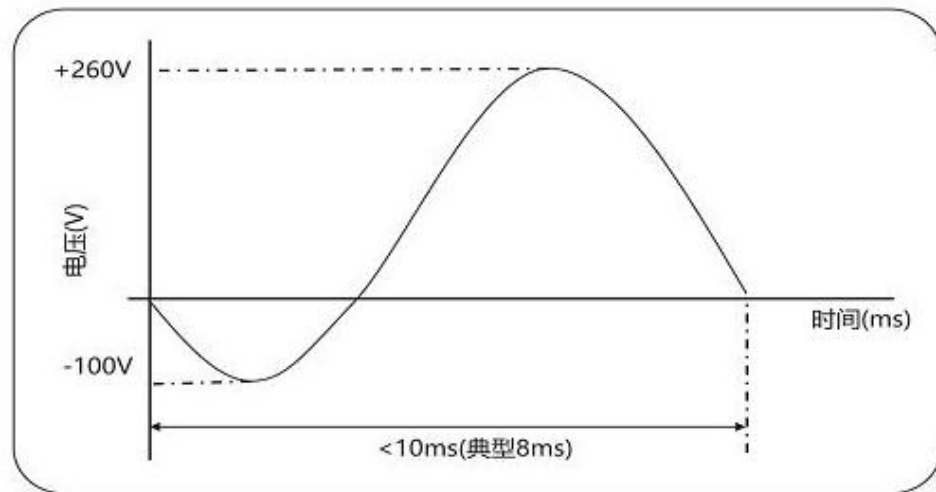
- high sensitivity
- high reliability
- low power
- haptics
- RoHS, REACH, HF



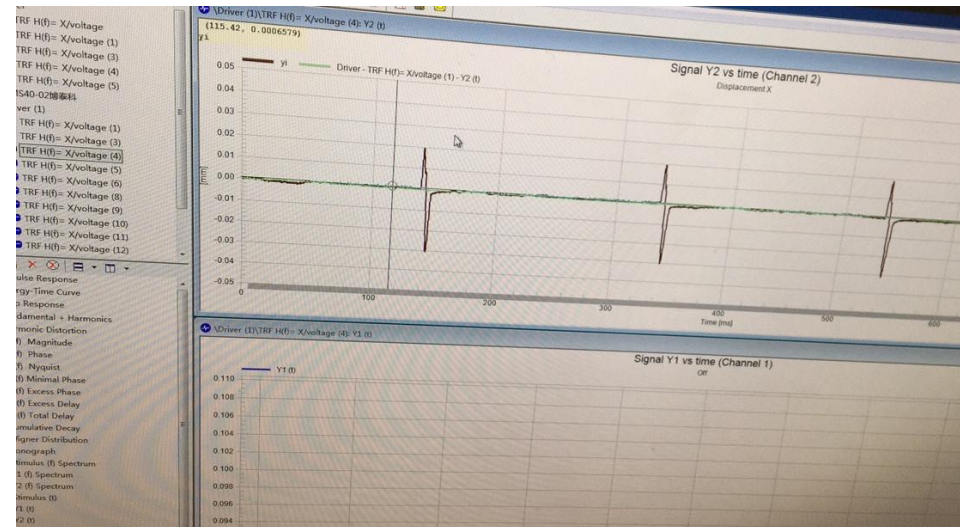
Items	Specifications
Resonant Frequency (Before Printing Green Oil)	7.0±1.0KHz
Resonant Impedance (Before Printing Green Oil)	800 ohm Max
Static Capacitance @120 Hz/1 V	6.5±20% nF
Permitted Voltage Range	-100~+260V(15ms Max.)
Rated Operating Voltage	-100~200V
Displacement Deformation @300V (125Hz) φ12.5 Support	>60um
Operating Temperature	-20...+65°C
Storage Temperature	-40...+85°C
Operating Humidity (Test Acc. to Reliability Test)	95% @45°C
Storage Humidity (Test Acc. to Reliability Test)	95% @60°C
Metal Material	Brass

Single Layer PZT

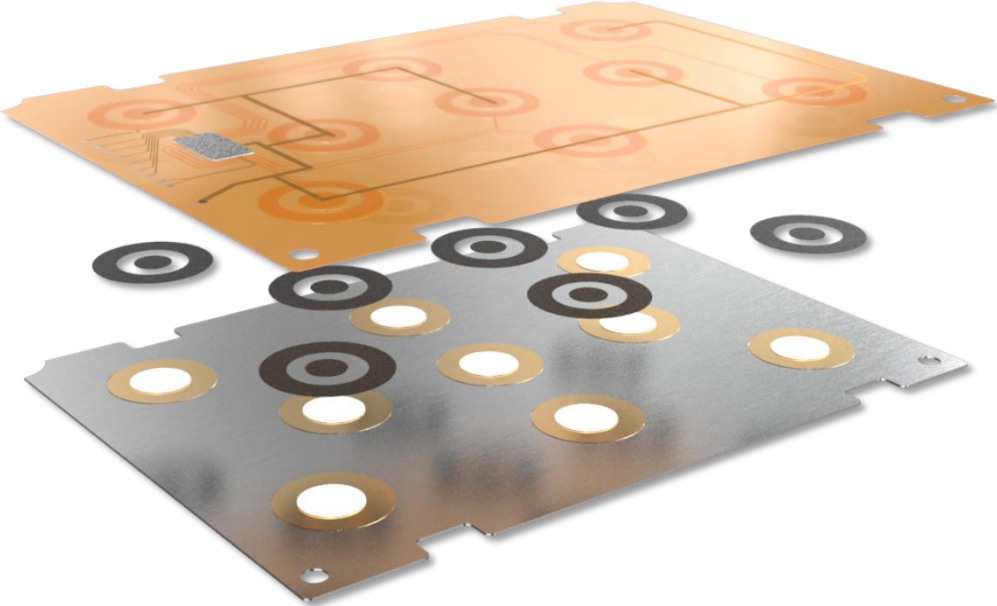
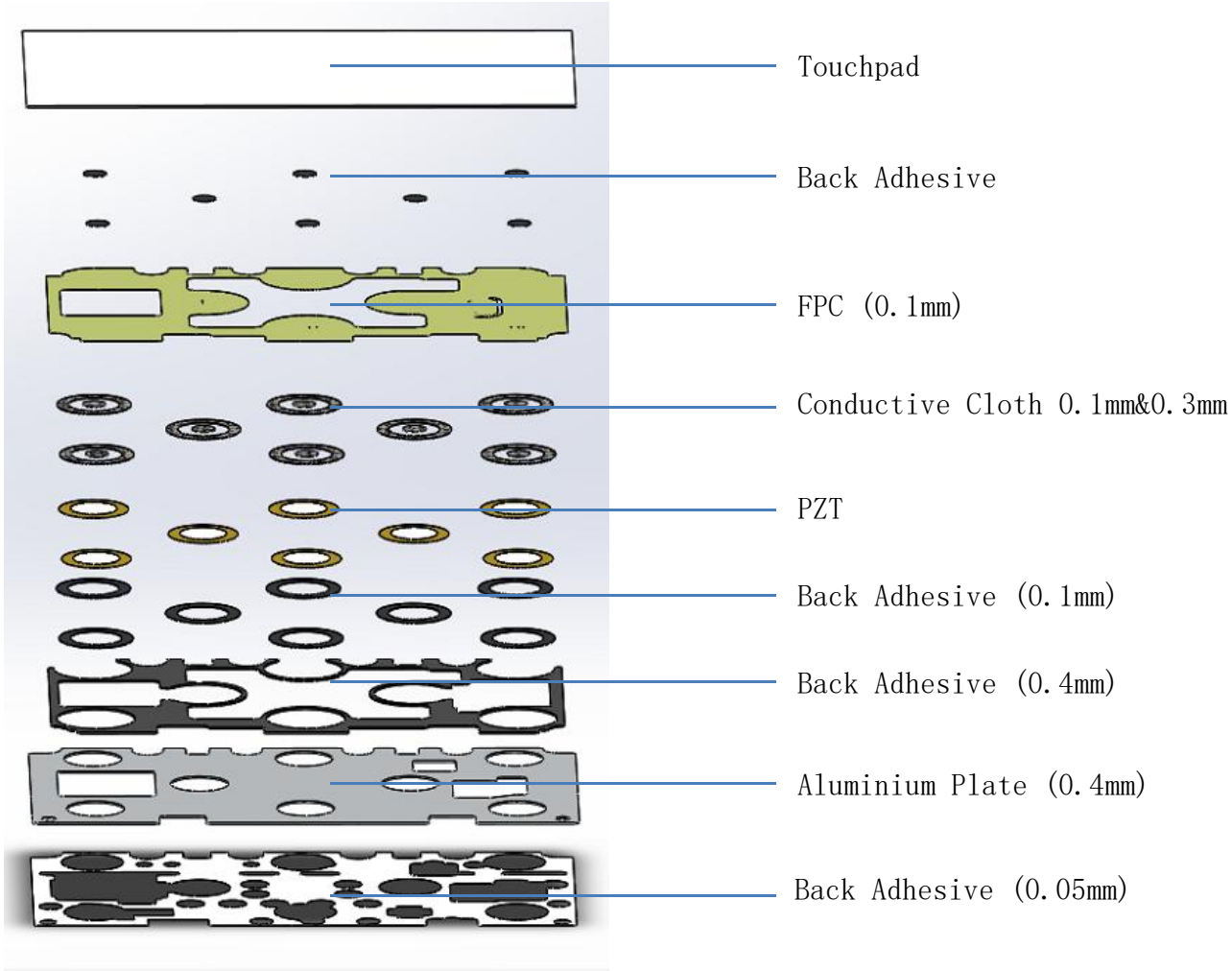
- Recommend $\leq 260V_{p-p}$ driving voltage, and the voltage bias can be performed since the driving voltage is high.
- The characteristic is that it can achieve both pressure sense and touch sense at the same time.
- Knock or press the PZT, the pressure sense is strong, and the feedback voltage value is high.
- High vibration displacement.



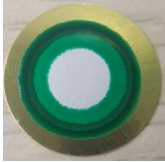


Test Instrument Klippel



Mechanical Structure Design & Installation



Single Layer PZT

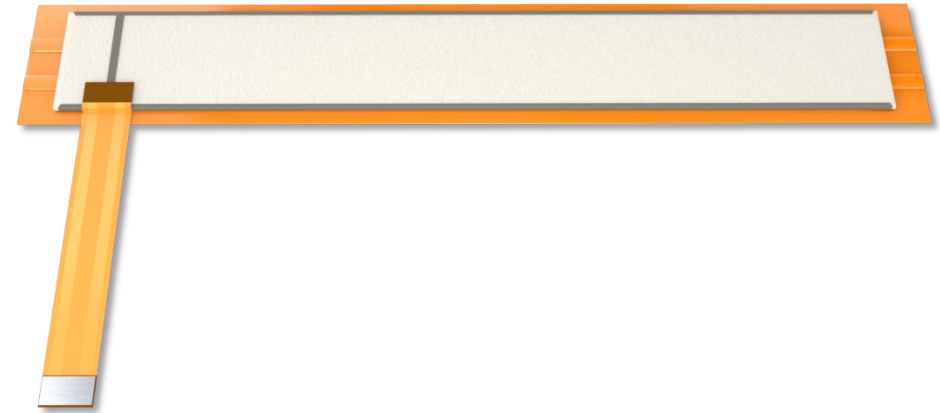
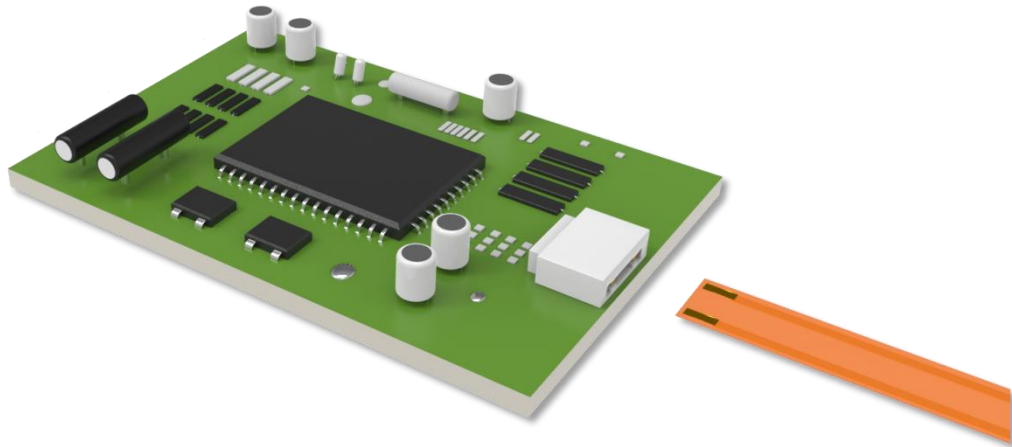
Product Model	Picture	Max. Driving Voltage	Dimension	Capacitance	Layers	Single Layer Thickness	Testing Voltage Frequency	Acceleration
FT-15T-7.0A1-02		-100~260V	$\Phi 15 \times 0.31$	$6.5 \pm 20\% \text{ nF}$ (@ 120Hz /1V)	single layer	0.13mm	-100~200V/ 15ms	$60 \sim 80 \mu\text{m}$
FT-15T-5.5A1-A		-100~260V	$\Phi 15 \times 0.23$	$10 \pm 30\% \text{ nF}$ (@ 120Hz /1V)	single layer	0.10mm	-150~400V/ 10ms	$60 \sim 80 \mu\text{m}$
FT-15T-5.5A1-AG		-100~260V	$\Phi 15 \times 0.23$	$10 \pm 30\% \text{ nF}$ (@ 120Hz /1V)	single layer	0.10mm	-150~400V/ 20ms	$60 \sim 80 \mu\text{m}$

Haptics – Key Products and Reliability

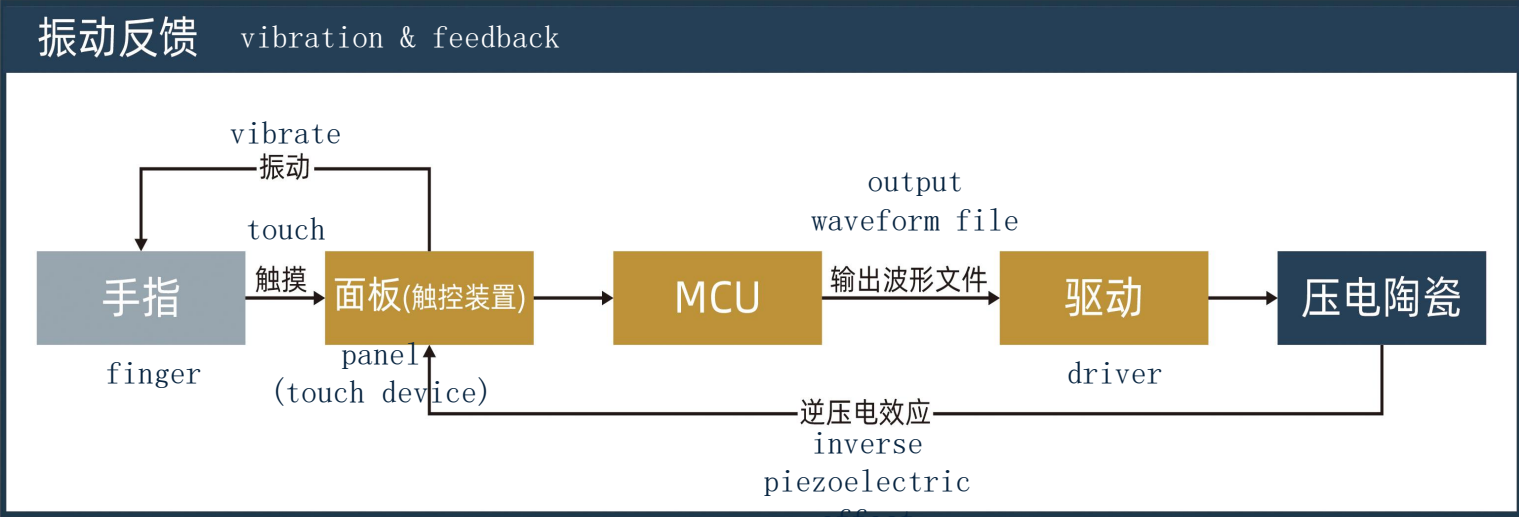
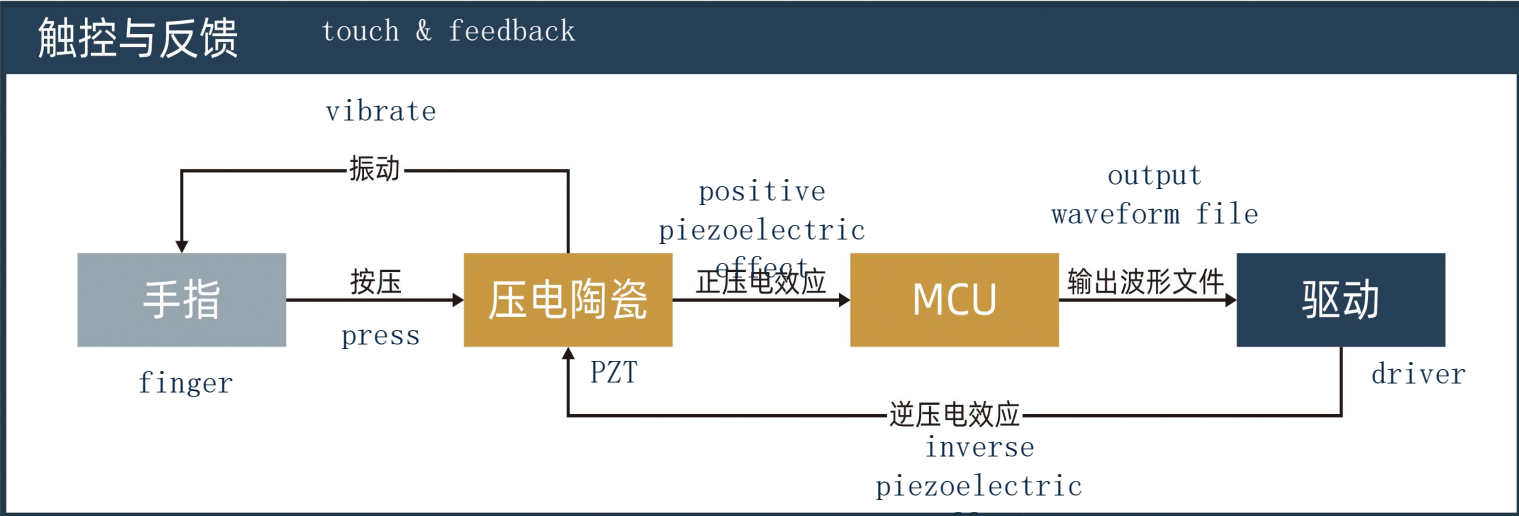
Mass Production Application	Client	Project State	Reliability
Notebook	H	1.5 years of mass production	pass the environmental test, life test 500k times
Smart Central Control Panel	/	mass production	pass the environmental test, life test 300k times
Mouse	/	mass production	pass the environmental test, life test 600k times
OLED Screen	Pad Class	pre-research project	/
Side Button	Cellphone Class	pre-research project	/

Electrical Connection—FPC wiring

Piezoelectric actuator with FPC wiring
needs no solder connection;
and supports connector connection, which saves
assembly time.



Piezoelectric Haptics Driver Circuit Example



Piezoelectric Haptics Driver Circuit Example

- V_{max} : 200Vp-p
- No pressure detection, only vibration after pressing.

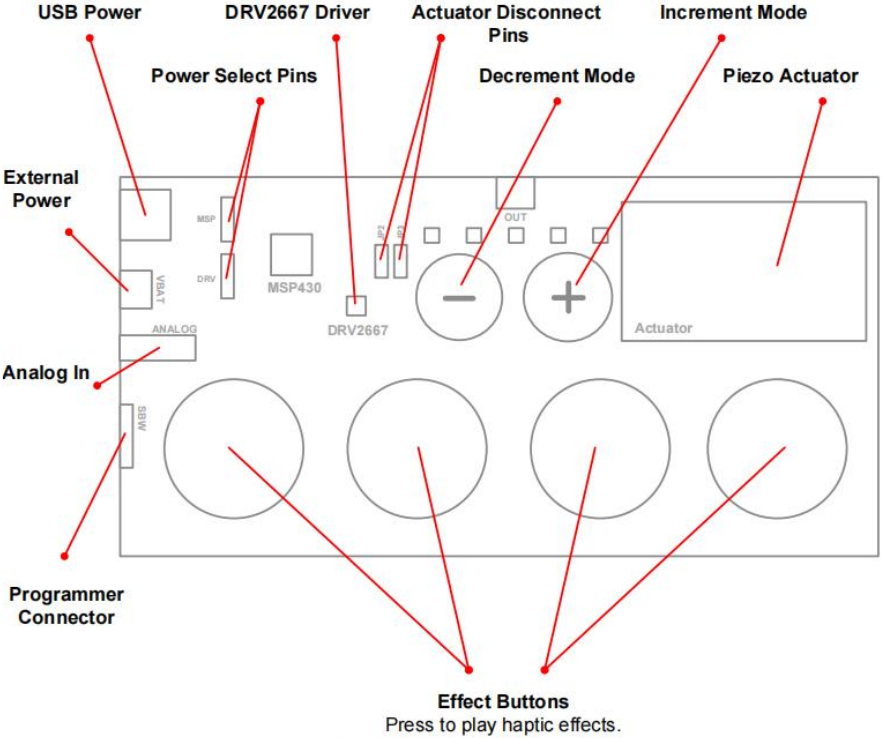
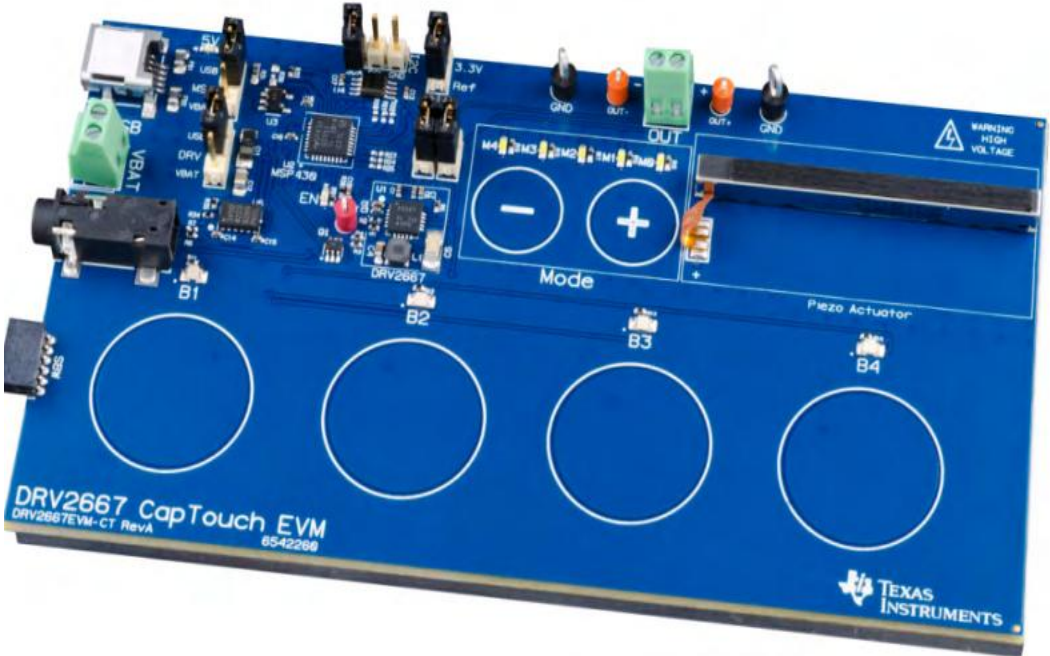


Figure 1. Board Diagram

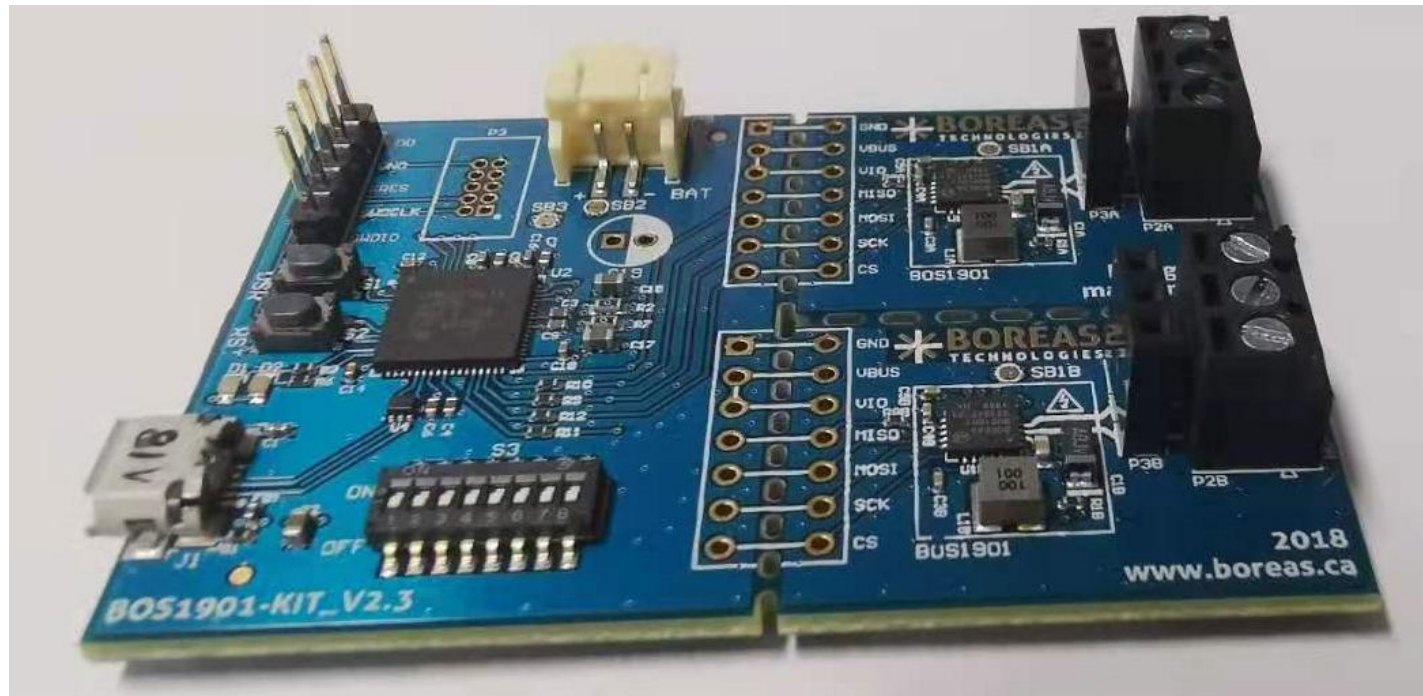


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Piezoelectric Haptics Driver Circuit Example

- V_{max} : 190Vp-p
- With functions of pressure detection and vibration feedback



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boreas操作



BOS1901D atasheet_BT

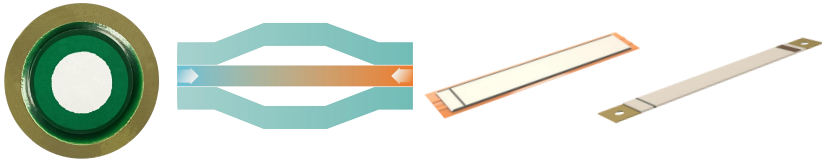

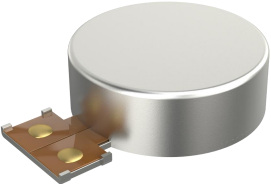
BOS1901

Piezoelectric Haptics Driver Circuit Example

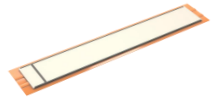
- **Drive Voltage:** $-100V \sim 400V$, voltages can be adjusted according to cutomers requirements
- With functions of pressure detection and vibration feedback
- **Dimension:** 40mm*60mm, the size of low voltage drive circuit board can be reduced
- **Numbers of driving ceramics:** 1 ~ 8



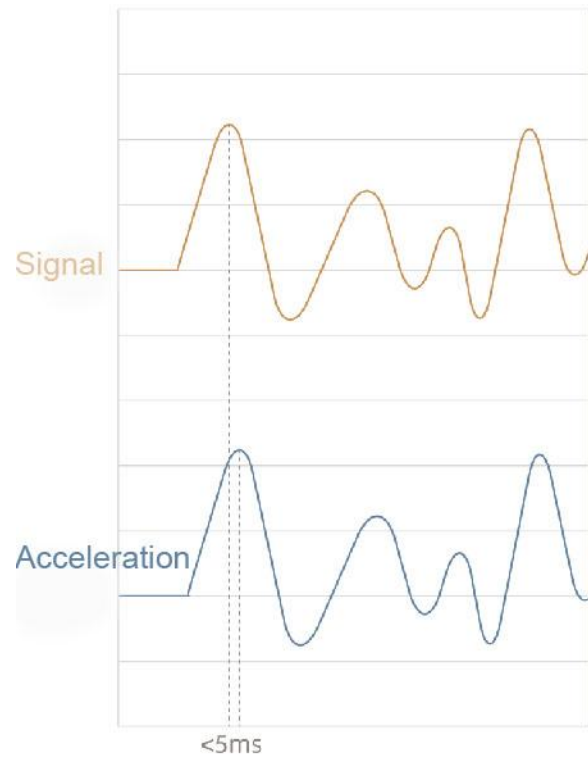
Haptics Application Comparison-Piezoelectric Haptics vs. Exciter/Linear Motor

Product Name	Piezoelectric Devices	Exciter	Linear Motor
structure			
response	faster	fast	slow
vibration	overall uniform vibration	partial vibration	partial vibration
displacement	higher	high	high
vibration form	control vibration through wave file	control vibration through wave file	control vibration through wave file
power consumption	lower	low	low

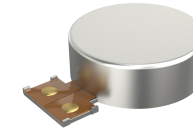
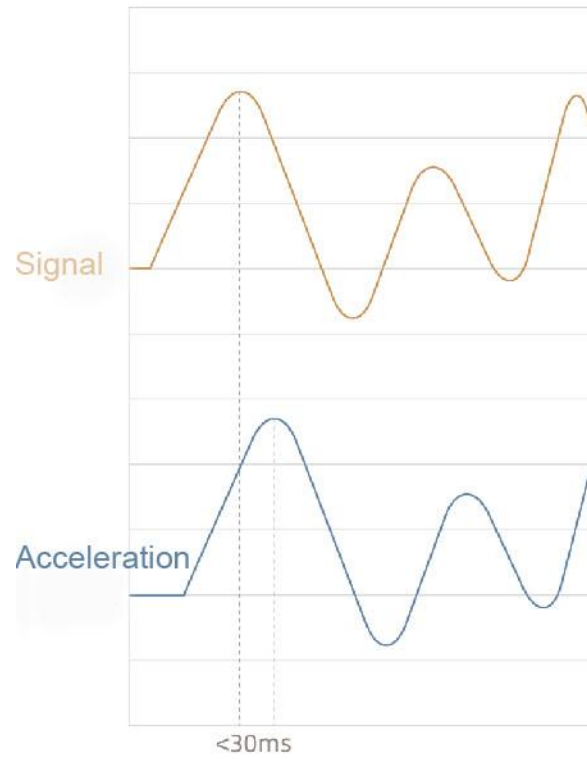
Haptics Application Comparison-Response Speed



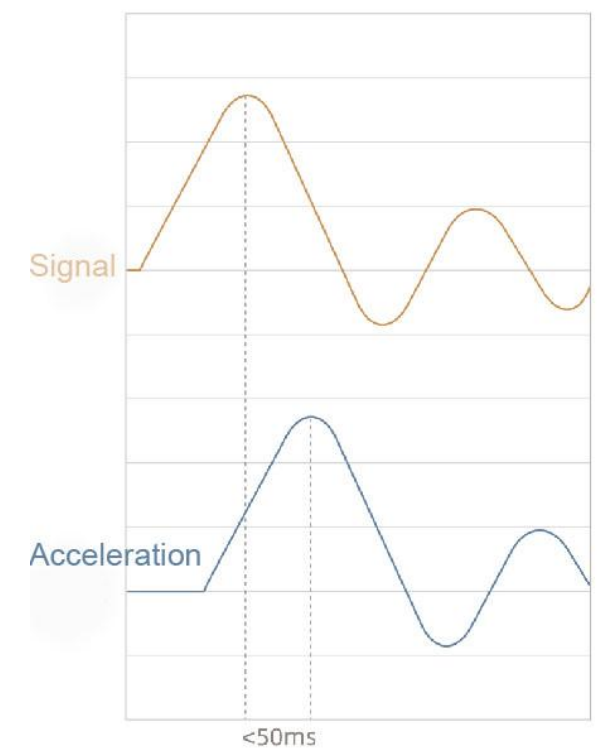
Piezoelectric Haptics



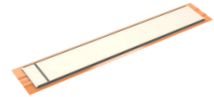
Exciter



Linear Motor

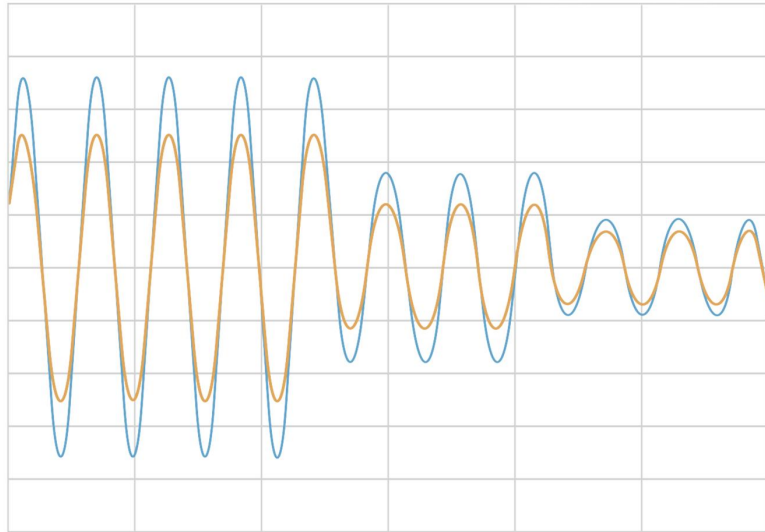


Haptics Application Comparison–Vibration Form & Displacement



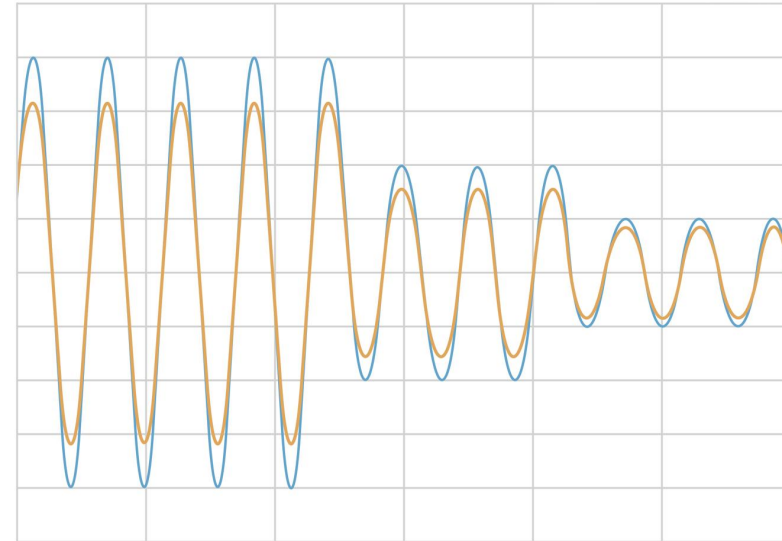
Multi-layer PZT

— Drive Voltage — Displacement



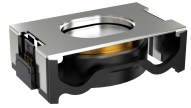
Bimorph PZT

— Drive Voltage — Displacement

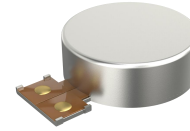


The amplitude and displacement are changed by the value of the driving voltage.
With other conditions remain unchanged, the driving voltage is proportional to the displacement.

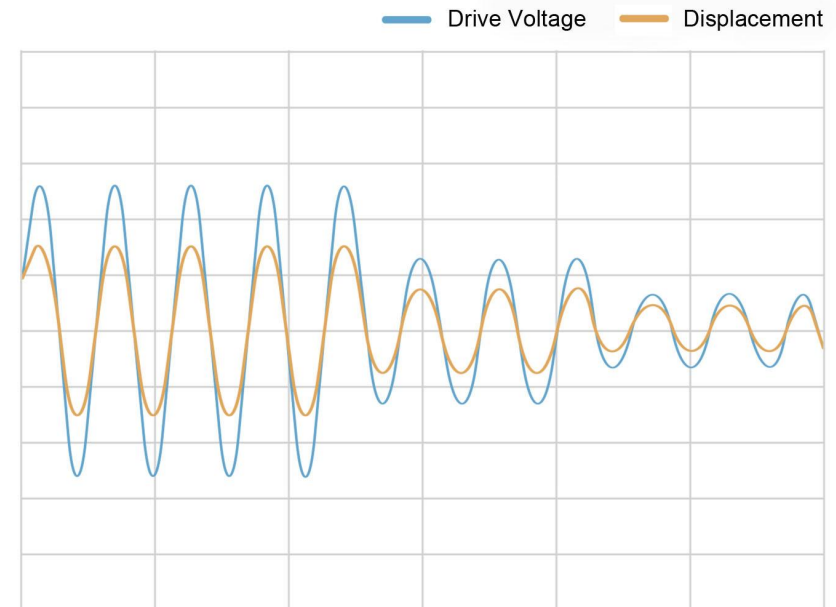
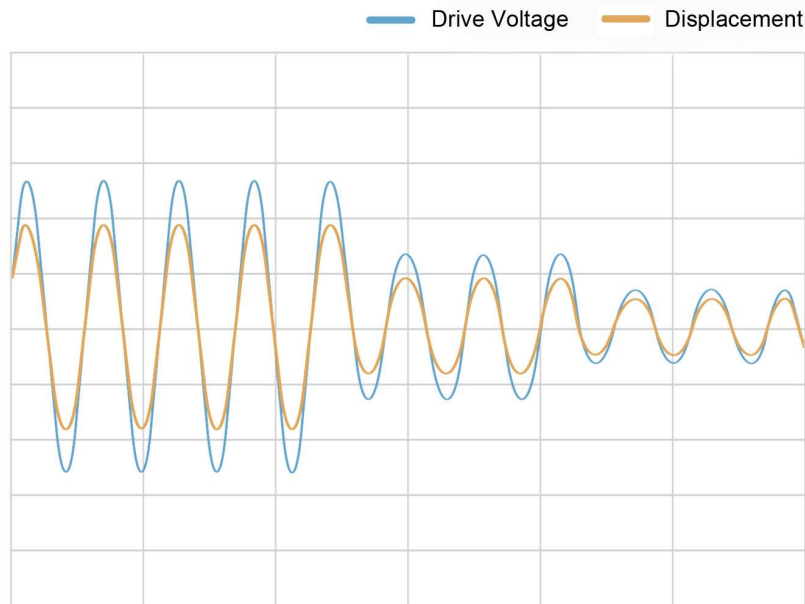
Haptics Application Comparison-Vibration Form & Displacement



Exciter _____



Linear Motor _____

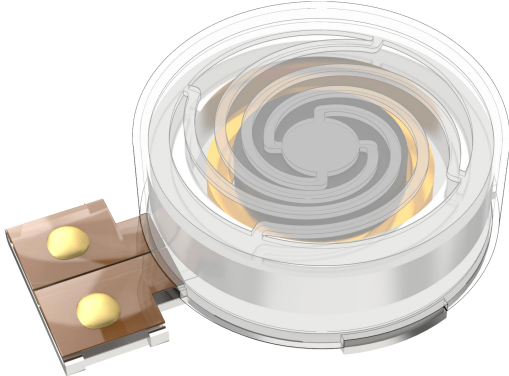
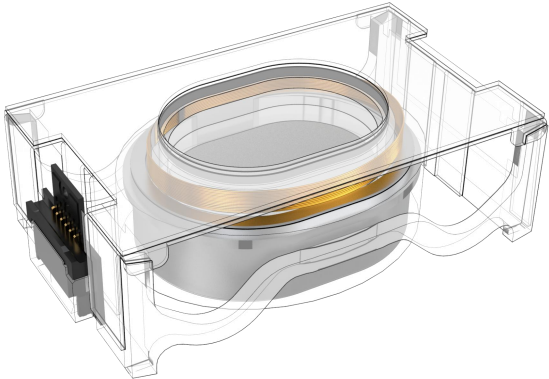


The amplitude and displacement are changed by the value of the driving voltage.
With other conditions remain unchanged, the driving voltage is proportional to the displacement.

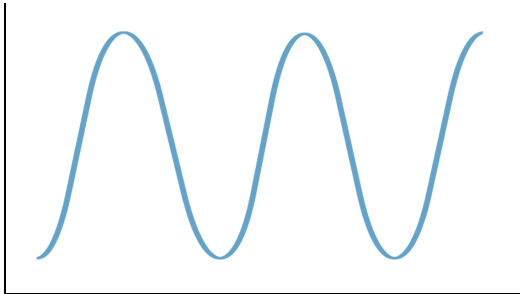
Haptics Application Comparison-Exciter vs. Linear Motor in Structure

Exciter

Linear Motor

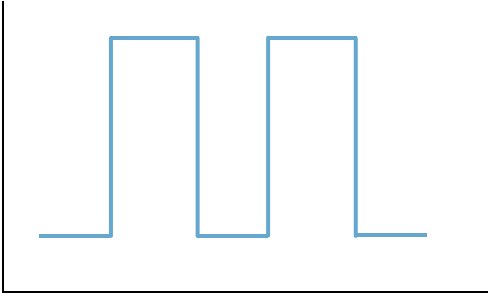


Displacement



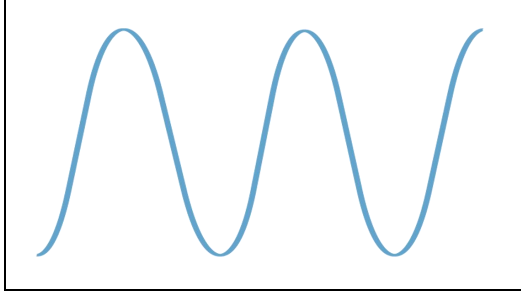
sine wave

Displacement



square wave

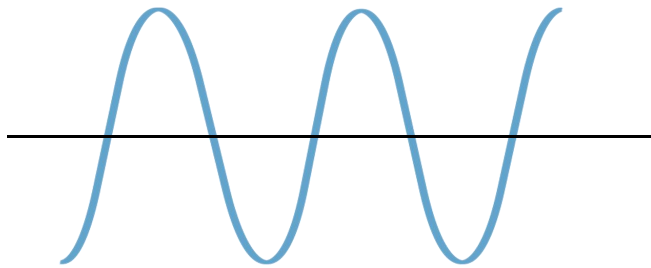
Displacement



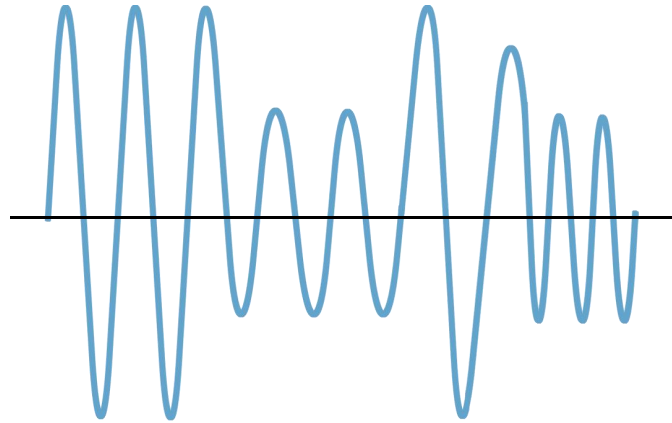
sine wave

Haptics Application Comparison–Piezoelectric Haptics Wave Form

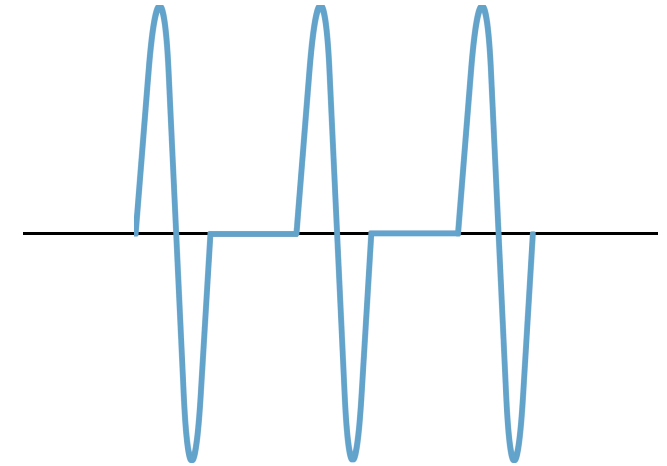
Pattern1: sine wave



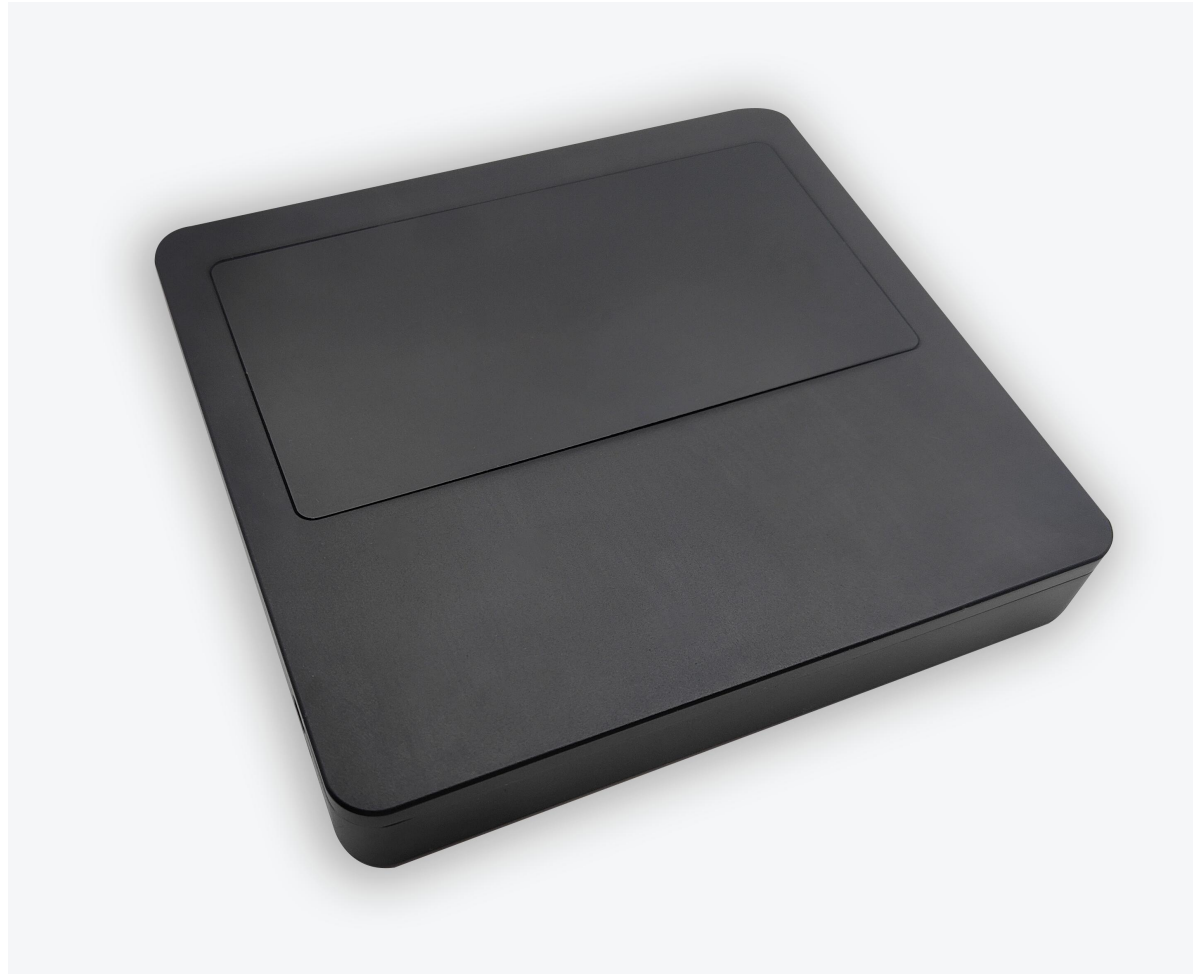
Pattern2: free designed wave



Pattern3: set interval between pulses



Single Layer PZT DEMO



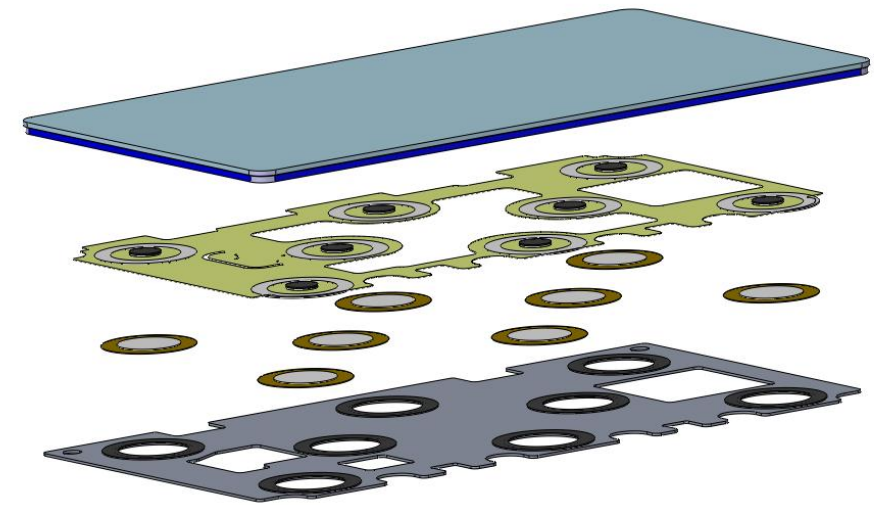
Touch Panel Solution

Touch Panel > 160*100mm

	8	2	4
Ceramics	8 single layer ceramics	2 multi-layer ceramics	4 multi-layer ceramics
Installation Thickness	3.7mm	3.3mm	3.5mm
Haptics Intensity Range	Average (>3.5G)	High (>5G)	High (>5G)

Recommended Plan for Installation of Touch Panel

	8
ceramics	8 single-layer ceramics
installation thickness	3.7mm
haptic intensity range	1.5G-4G



Data Test

Klippel Test Instrument

Test Position	Acceleration 1	Acceleration 2	Acceleration 3	Mean Value	Test Sample
1	2.4g	2.3g	2.4g	2.4g	
2	2.2g	2.1g	2.3g	2.2g	
3	2.9g	2.9g	3g	2.9g	
4	2.6g	2.5g	2.5g	2.5g	
5	2.4g	2.4g	2.4g	2.4g	
6	2.3g	2.2g	2.4g	2.3g	
7	2.8g	2.7g	2.8g	2.8g	
8	2.3g	2.4g	2.3g	2.3g	
9	2.9g	3g	2.9g	2.9g	

Single Layer PZT DEMO - Demonstration Steps



01/ insert one end of the power cord into the 12V power supply port and the other end of the power cord into the demo power hole

02/ click the power switch

○ off — on



03/ click the demo surface to feel the haptics

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