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Piezoelectric Ceramic Sensors (PIEZOTITE®)

PIEZOELECTRIC CERAMICS SENSORS (PIEZOTITE®)

GLOBAL PART NUMBERS

JUNE 2001

muRata *Innovator in Electronics*

Murata Manufacturing Co., Ltd.

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Preface

Recently, with the remarkable advance of electronics technology, various new products have come into existence. Until this time, the effect of electronics was seen most clearly in television, radio and other communications equipment, but as semiconductor technology, and computer technology advance, the range of electronics' effect on our lives has increased dramatically. In particular, sensor technology and the greater intelligent functions of today's microcomputers have served as a basis for the trend toward combining electronics and mechanics into what is called mechatronics.

It is not merely the equipment itself, however, that has made all this possible. Within the equipment are highly sophisticated components with unique functions which can translate electrical to mechanical energy and mechanical to electrical energy and which play a large role in today's equipment modernization and advance. These are piezoelectric components. This catalog briefly introduces the basics of piezoelectric ceramics, Murata's piezoelectric ceramic materials, piezoelectric transducers and other products.

Please insure the component is thoroughly evaluated in your application circuit.

In case that the component is not mentioned in our statement, please contact your Murata representative for details.

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1 Introduction

1. What are Piezoelectric Ceramics?

Piezoelectric ceramics are known for what are called the piezoelectric and reverse piezoelectric effects. The piezo-electric effect causes a crystal to produce an electrical potential when it is subjected to mechanical vibration. In contrast, the reverse piezoelectric effect causes the crystal to produce vibration when it is placed in an electric field. Of piezoelectric materials, Rochelle salt and quartz have long been known as single-crystal piezoelectric substances. However, these substances have had a relatively limited application range chiefly because of the poor crystal stability of Rochelle salt and the limited degree of freedom in the characteristics of quartz. Later, barium titanate($BaTiO_3$), a piezoelectric ceramic, was introduced for applications in ultrasonic transducers, mainly for fish finders. More recently, a lead titanate, lead zirconate system($PbTiO_3 \cdot PbZrO_3$) appeared, which has electromechanical transformation efficiency and stability(including temperature characteristics)far superior to existing substances. It has dramatically broadened the application range of piezoelectric ceramics. When compared which other piezoelectric substances, both $BaTiO_3$ and $PbTiO_3 \cdot PbZrO_3$ have the following advantages:

■**Advantages**
①High electromechanical transformation efficiency.
②High machinability.
③A broad range of characteristics can be achieved with different material compositions (high degree of freedom in characteristics design).
④High stability.
⑤Suitable for mass production, and economical.

Murata, as a forerunner in the piezoelectric ceramic industry, offers an extensive range of products with piezoelectric applications.

2. Properties of Piezoelectric Ceramics

Piezoelectric ceramics are a type of multi-crystal dielectric with a high dielectric constant and are formed by two processes : first, high temperature firing. After firing, they have the characteristic crystal structure shown in Fig. 1 (a) but do not yet exhibit the piezoelectric property because the electrical dipoles within the crystals are oriented at random and the overall moment of the dipoles is canceled out. To make ceramics piezoelectric they must be polarized. A DC electric field of several kV/mm is applied to the piece of ceramic to align the internal electrical dipoles in a single orientation (see Fig. 1 (b)). Due to the strong dielectric property of the ceramic, the dipole moment remains unchanged after the electric field is removed, and the ceramic thus exhibits a strong piezoelectric property (see Fig. 1 (c)). When an AC signal is applied to a piezoelectric ceramic (piezoelectric transducer) in a frequency matching the specific elastic frequency of the ceramics (which depends on the shape of the material), the ceramic exhibits resonance. Since the ceramic has a very high electromechanical transforming efficiency at the point of resonance, many applications use this resonance point. Also piezoelectric ceramics when molded in certain shapes have more than one point of resonance depending on vibration mode. In such a case, the vibration mode most suited for the application is selected.
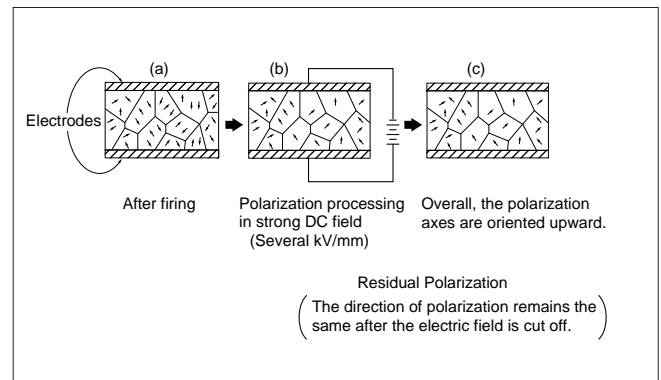

Fig. 1   Polarization Processing of Piezoelectric Ceramics

3. Application of Piezoelectric Ceramics

Product applications for piezoelectric ceramics include the following categories :
Murata has and is continuing to direct extensive research development efforts to the entire range of applications of piezoelectric ceramics listed in the right side. It is expected that the applications of piezoelectric ceramics will continue to extend into a broader range of industries as new piezoelectric materials are created.
This application manual concentrates on applications with mechanical power sources and sensors which are now finding broader applications.

■**Piezoelectric Applications**
①Mechanical power sources (electrical-to-mechanical transducers) :
   Piezoelectric actuators, piezoelectric fans, ultrasonic cleaners, etc.
②Sensors (mechanical-to-electrical transducers) :
   Ultrasonic sensors, knocking sensors, shock sensors, acceleration sensors, etc.
③Electronic circuit components (transducers) :
   Ceramic filters, ceramic resonators, surface acoustic wave filters, microforks, etc.

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2 Characteristics of Piezoelectric Ceramics (PIEZOTITE®)

For using piezoelectric ceramics, it is important to first have an adequate knowledge of the properties of different piezoelectric materials before choosing a suitable type for a specific application. The following sections describe the major characteristic which need to be evaluated to determine the properties of piezoelectric ceramic materials.

1. Resonant Frequency and Vibration Mode

If an AC voltage of varying frequency is applied to a piezo-electric ceramic (piezoelectric transducer) of a certain shape, it can be seen that there is a specific frequency at which the ceramic produces a very strong vibration. This frequency is called the resonant frequency, fr, and depends on the ceramic's specific elastic vibration (resonance) frequency, which is a function of the shape of the material.
Piezoelectric ceramics have various vibration modes (resonant modes) which depend on their shape, orientation of polarization, and the direction of the electric field. Each of these vibration modes have unique resonant frequencies and piezoelectric characteristics. Fig. 2 shows typical vibration modes in relation to the shapes of ceramic materials, the resonant frequency in each vibration mode, and the material constant symbols. In Fig. 2, the piezoelectric material constant symbols have the following meanings:

N : Frequency Constant (described in Section 1).
d : Piezoelectric Distortion Constant (described in Section 2).
g : Voltage Output Constant (described in Section 2).
k : Electromechanical Coupling Coefficient (described in Section 3).
Y^E : Young's Modulus (described in Section 5).
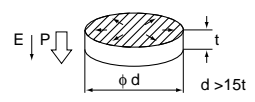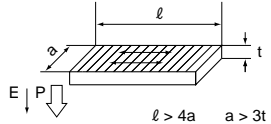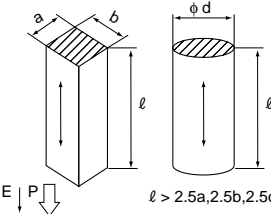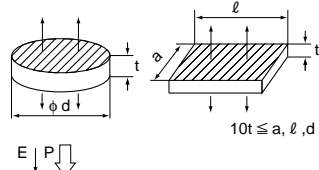ε^T : Dielectric Constant (described in Section 8).
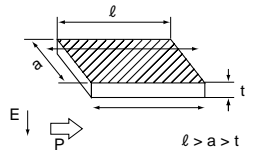
Vibration Mode	Shape/Vibration Mode	Resonant Frequency (fr)	Material Constant Symbol					
			k	d	g	Y^E	ε^T	N
Radial Mode	P : Direction of polarization E : Direction of electric field Thin disk with radial vibration mode. Polarization is oriented along the thickness of the disk. $d > 15t$	$\dfrac{Np}{d}$	kp	d_{31}	g_{31}	Y_{11}^E	ε_{33}^T	Np
Length Mode	Thin rectangular plate, with the direction of vibration orthogonal to the polarization axis and with a single point of resonance. $\ell > 4a$ $a > 3t$	$\dfrac{N_{31}}{\ell}$	k_{31}	d_{31}	g_{31}	Y_{11}^E	ε_{33}^T	N_{31}
Longitudinal Mode	Square and cylindrical columns. Vibration is oriented along the direction of polarization. Only a single point of resonance. $\ell > 2.5a, 2.5b, 2.5d$	$\dfrac{N_{33}}{\ell}$	k_{33}	d_{33}	g_{33}	Y_{33}^E	ε_{33}^T	N_{33}
Thickness Mode	Disk and rectangular plates which are thin compared to their surface areas. They have multiple points of resonance in longitudinal vibration mode. $10t \leqq a, \ell, d$	$\dfrac{Nt}{t}$	k_t	d_{33}	g_{33}	Y_{33}^E	ε_{33}^T	Nt
Shear Mode	Disk or rectangular plates, with the electric field orthogonal to the direction of polarization, causing a shear vibration along the surface. $\ell > a > t$	$\dfrac{N_{15}}{t}$	k_{15}	d_{15}	g_{15}	Y_{44}^E	ε_{11}^T	N_{15}

Fig. 2 Typical Vibration Modes, Resonant Frequencies, and Material Constant Symbols of Piezoelectric Ceramics

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2 **Characteristics of Piezoelectric Ceramics (PIEZOTITE®)**

When a piezoelectric material is subjected to stress T, it produces polarization P which is a linear function of T : P=dT (d : piezoelectric strain constant). This effect is called the normal piezoelectric effect. In contrast, when a piezoelectric substance has an electric field E applied across its electrodes, it produces distortion S which is a linear function of the electric field : S =dE. This effect is called the reverse piezoelectric effect. For an elastic material, the relationship of distortion S to the stress T is given by S =s^FT (s^E : compliance); for a dielectric substance, the relationship of electrical displacement D with electric field strength E is given by D=εE. For a piezoelectric ceramic, these relationships are given by the following equations, both being associated with piezoelectric strain constants :

$$S_i = s^E_{ij} T_j + d_{mi} E_m$$
$$D_n = d_{nj} T_j + \varepsilon^T_{nm} E_m$$

$$\left. \right\} \cdots\cdots (1)$$

$$(m,\ n = 1,\ 2,\ 3\ ;\ i,j = 1,\ 2\ \cdots\cdots,\ 6)$$

These equations are called the basic piezoelectric equations (type d), where the electric field E and electrical displacement D are represented in vector magnitudes ; whereas stress T and distortion S are given in symmetrical tensile magnitudes. When the symmetry of the crystals is taken into account, Eq. (1) is simplified because some constants in the equations are nullified and some other constants become equal to a third set of constants.

With piezoelectric ceramics, when the polarization axis is placed along the z (3) axis and two arbitrary orthogonal axes (which are also orthogonal to the z axis and assumed to be the x (1) and y (2) axis), the crystal structure of the ceramic can be represented in the same way as that of 6mm crystals, in which case the only independent non-zero coefficients are the following ten constants :

$$s^E_{11}\left(\frac{1}{Y^E_{11}}\right),\ s^E_{12}\left(\frac{1}{Y^E_{12}}\right),\ s^E_{13}\left(\frac{1}{Y^E_{13}}\right),\ s^E_{33}\left(\frac{1}{Y^E_{33}}\right),\ s^E_{44}\left(\frac{1}{Y^E_{44}}\right),$$

$$d_{31}, d_{33}, d_{15},\ \varepsilon^T_{11},\ \varepsilon^T_{33},$$

For example, the basic piezoelectric equations for longitudinal vibration of a rectangular ceramic strip is given by the following equations :

$$S_1 = s^E_{11} T_1 + d_{31} E_3$$
$$D_3 = d_{31} T_1 + \varepsilon^T_{33} E_3$$

$$\left. \right\} \cdots\cdots (2)$$

A piezoelectric ceramic transducer can be represented by an equivalent circuit which is derived from the basic piezoelectric equations representing its vibration mode. The circuit is called Maison's equivalent circuit. More generally, the equivalent circuit, as shown in Fig. 3, may be used to represent a piezoelectric ceramic. In this equivalent circuit, the serial resonant frequency fs, and parallel resonant frequency fp are given by the following equations :

$$fs = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$fp = \frac{1}{2\pi\sqrt{L_1 \cdot \dfrac{C_1 C_0}{C_1 + C_0}}}$$

$$\left. \right\} \cdots\cdots (3)$$

Constants fs and fp are necessary to determine the electromechanical coupling coefficient k.

L_1 : Serial Inductance
C_1 : Serial Capacitance
R_1 : Serial Resistance
C_0 : Parallel Capacitance
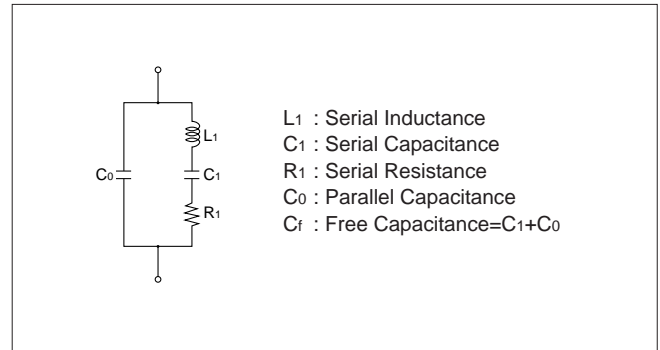C_f : Free Capacitance=C_1+C_0

Fig. 3   Equivalent Circuit for Piezoelectric Ceramic Transducer

Strictly speaking, the resonant frequency can be defined in the following three ways :
(1) Serial resonant frequency fs of the equivalent serial circuit for a piezoelectric ceramic transducer.
(2) Lower resonance frequency fr, the lower of the two frequencies, where the cross-electrode admittance or impedance of the piezoelectric ceramic transducer is in the null phase.
(3) Maximum admittance frequency fm where the cross-electrode admittance of the piezoelectric ceramic transducer is maximized (impedance minimized).
However, the differences between the three frequencies, fs, fr, and fm, is so small that it is negligible. In actual cases, therefore, when we measure frequency fm, it can be called resonant frequency fr. Also, the minimum admittance frequency fn may be called antiresonant frequency fa.
The resonant frequency fr can be measured with either of the following two circuits :

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Characteristics of Piezoelectric Ceramics (PIEZOTITE®) 2

2

■Measuring Method Using Constant Voltage Circuit

The fr measuring circuit using a constant voltage source is shown in Fig. 4.

The oscillator Osc and input resistors R_1 and R_2 are used to apply a constant voltage signal to the piezoelectric ceramic transducer. The current passing through the transducer is measured across output resistor R_2.

If the transducer's impedance is much greater than R_2, the voltmeter reading is proportional to the transducer's admittance. The frequency where the voltmeter reading is maximized is the resonant frequency fr, and the frequency where the reading is minimized is the antiresonant frequency fa.

Variable resistor Rv is used to determine the resonant resis-tance R_1, which is needed to calculate the mechanical Qm.

Osc : Oscillator
F.C.: Frequency Counter
Rv : Variable Resistor
T.P. : Transducer
V : Voltmeter
R_1 : 100Ω (Reference Value)
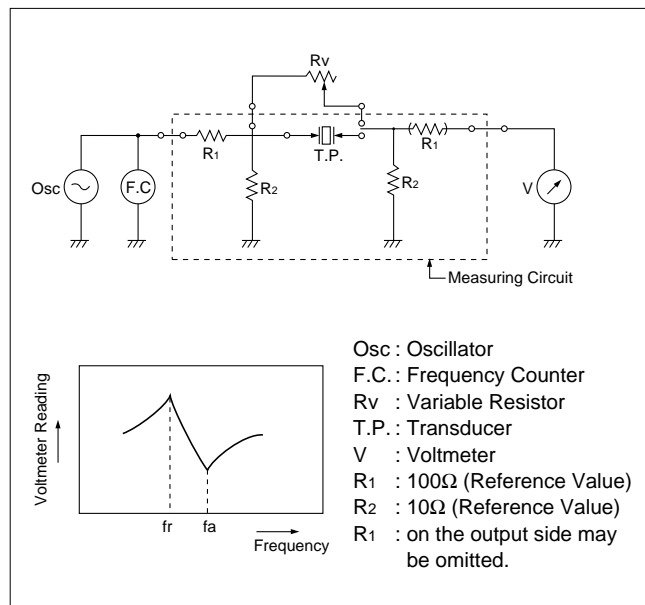R_2 : 10Ω (Reference Value)
R_1 : on the output side may be omitted.

Fig.4 Resonant Frequency Measuring Method Using Constant Voltage Circuit

■Measuring Method Using Constant Current Circuit

The fr measuring circuit using a constant current source is shown in Fig. 5. Resistor R_3 regulates the current passing through the piezoelectric ceramic transducer. If R_3 is much greater than the transducer's impedance, the voltmeter reading is proportional to the transducer's impedance. The frequency where the voltmeter reading is minimized is the resonant frequency fr, and the frequency where the reading is maximized is the antiresonant frequency fa.

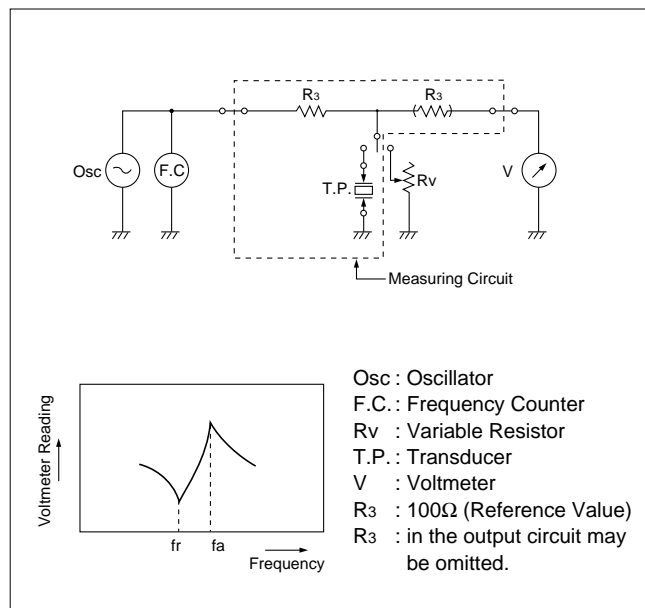Osc : Oscillator
F.C.: Frequency Counter
Rv : Variable Resistor
T.P. : Transducer
V : Voltmeter
R_3 : 100Ω (Reference Value)
R_3 : in the output circuit may be omitted.

Fig. 5 Resonant Frequency Measuring Circuit Using Constant Current Circuit

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2 Characteristics of Piezoelectric Ceramics (PIEZOTITE®)

2. Piezoelectric Material Constant Symbols

1 Frequency Constant N

The velocity of sound that propagates through a piezo-electric ceramic has a specific value in each vibration mode when the resonance of other vibration modes is not in the vicinity. For a piezoelectric ceramic with a certain shape, the relationship of wavelength λ of a vibration with propagation length ℓ at the resonant point is given by equation (4). Because the sound velocity is constant, we obtain the following equations (5) and (6) :

$$\frac{\lambda}{2} = \ell \quad \text{.............................. (4)}$$

$$\nu = fr \cdot \lambda \quad \text{......................... (5)}$$

$$fr \cdot \ell = \frac{\nu}{2} = N \, (\text{Hz} \cdot \text{m}) \quad \text{........ (6)}$$

where N is the frequency constant. The frequency constant depends on the vibration mode. The resonant frequency may also be determined by the equation, $fr = N/\ell$ as shown in Fig. 2.

2 Piezoelectric Constants d and g

① Piezoelectric Distortion Constant d

Piezoelectric distortion constant is the distortion resulting from the application of an electric field of uniform strength with no stress. It is given by equation (7) :

$$d = k \sqrt{\frac{\varepsilon^T}{Y^E}} \quad (\text{m/V}) \quad \text{.............. (7)}$$

where ε^T : Dielectric constant
  Y^E : Young's modulus (N/m²)
  k : Electromechanical coupling coefficient

$$d_{31} = k_{31}\sqrt{\frac{\varepsilon_{33}^T}{Y_{11}^E}}, \; d_{33} = k_{33}\sqrt{\frac{\varepsilon_{33}^T}{Y_{33}^E}}, \; d_{15} = k_{15}\sqrt{\frac{\varepsilon_{11}^T}{Y_{44}^E}} \quad \text{.............. (8)}$$

② Voltage Output Coefficient g

Voltage output coefficient refers to the field strength which results from a uniform stress applied under no electrical displacement. It is given by equation (9) :

$$g = \frac{d}{\varepsilon^T} \; (\text{V} \cdot \text{m/N}) \text{.................................... (9)}$$

$$g_{31} = \frac{d_{31}}{\varepsilon_{33}^T}, \; g_{33} = \frac{d_{33}}{\varepsilon_{33}^T}, \; g_{15} = \frac{d_{15}}{\varepsilon_{11}^T} \quad \text{....... (10)}$$

Constants d and g depend on the vibration mode, and the constants in each vibration mode are given by the subscripted symbols shown in Fig. 2.
Displacements generated under an electric voltage or a voltage generated under force can be determined by constants d and g. For example, the displacement $\Delta\ell$ caused by voltage V applied across the electrodes in the lengthwise vibration mode is given by :

$$\frac{\Delta\ell}{\ell} = d_{31} \cdot \frac{\ell}{t} \, V \quad \text{.............. (11)}$$

Conversely, the voltage V caused by force F applied along the direction of vibration is given by :

$$V = g_{31} \cdot \frac{1}{a} F \quad \text{.............. (12)}$$

3 Electromechanical Coupling Coefficient k

The electromechanical coupling coefficient is a constant representing the piezoelectric efficiency of a piezoelectric ceramic. More specifically, it represents the efficiency of converting electrical energy (applied across the electrodes of a piezoelectric ceramic) into mechanical energy, and it is defined as the root mean square of the energy accumulated within the crystal in a mechanical form. This accumulated energy reflects the total electrical input.

$$\text{Electromechanical Coupling Coefficient} = \sqrt{\frac{\text{Accumulated Mechanical Energy}}{\text{Supplied Electrical Energy}}}$$

The electromechanical coupling coefficient depends on the vibration mode, as shown in Fig. 2. It is determined by the following equations using the resonant frequency fr, anti-resonant frequency fa, and their difference $\Delta f = fa - fr$.

① Radial Vibration of Disk Transducer

$$\frac{kp^2}{1-kp^2} = \frac{(1 - \sigma^E)J_1\{\psi_1(1 + \Delta f/fr)\} - \psi_1(1 + \Delta f/fr)J_0\{\psi_1(1 + \Delta f/fr)\}}{(1 + \sigma^E)J\{\psi_1(1 + \Delta f/fr)\}} \quad \text{......... (13)}$$

where J_0, J_1 : Type 1 vessel functions of the 0th and 1st dimensions
  σ^E : Poisson's ratio
  ψ_1 : Lowest dimension of positive root of
  $(1 - \sigma^E) \, J_1(\psi) = \psi J_0(\psi)$

If kr is relatively small, equation (13) may be approximated as follows :

$$kp^2 \simeq 2.529 \cdot \frac{\Delta f}{fr} \quad \text{........... (14)}$$

② Lengthwise Vibration of Rectangular Plate Transducer

$$\frac{k_{31}^2}{1 - k_{31}^2} = -\frac{\pi}{2} \cdot \frac{fa}{fr} \cot\left(\frac{\pi}{2} \cdot \frac{fa}{fr}\right) \quad \text{........... (15)}$$

③ Longitudinal Vibration of Cylinder Transducer

$$k_{33}^2 = \frac{\pi}{2} \cdot \frac{fr}{fa} \cot\left(\frac{\pi}{2} \cdot \frac{fr}{fa}\right) \quad \text{........... (16)}$$

④ Vibration Along Thickness of Disk Transducer

$$k_t^2 = \frac{\pi}{2} \cdot \frac{fr}{fa} \cot\left(\frac{\pi}{2} \cdot \frac{fr}{fa}\right) \quad \text{........... (17)}$$

⑤ Shear Vibration of Rectangular Plate Transducer

$$k_{15}^2 = \frac{\pi}{2} \cdot \frac{fr}{fa} \cot\left(\frac{\pi}{2} \cdot \frac{fr}{fa}\right) \quad \text{........... (18)}$$

4 Mechanical Qm

Mechanical Qm gives the "steepness" of resonance of a mechanical vibration at and around the resonant frequency. It is given by the following equation :

$$Qm = \frac{1}{2\pi fr R_1 C_1} = \frac{1}{2\pi fr R_1 Cf\left\{1 - \left(\frac{fr}{fa}\right)^2\right\}} \quad \text{........... (19)}$$

where R_1 : Resonant resistance
  Cf : Free capacitance across electrodes

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Characteristics of Piezoelectric Ceramics (PIEZOTITE®) **2**

5 Young's Modulus Y^E

When stress T is applied to an elastic body within the proportional elastic range, strain S is given by the following formula :

$$S = s^E T$$

s^E is an elasticity constant (compliance), and Young's modulus is given as the inverse of compliance. For lengthwise vibrations shown in Fig. 3, for example, the Young's modulus is given by the following equation :

$$Y_{11}{}^E = (2 \ell fr)^2 \cdot \rho = \upsilon^2 \cdot \rho \, (N/m^2) \cdots\cdots (20)$$

where ρ : Density (kg/m²)
ν : Sound velocity (m/s)

6 Poisson's Ratio σ^E

When a constant stress is applied to an elastic body within its proportional elastic range, Poisson's ratio is defined as follows :

$$\sigma^E = -\ \frac{\text{Distortion Rate Orthogonal to Stress}}{\text{Distortion Rate along Stress}}$$

7 Density ρ

Density can be determined from the volume and mass of any piezoelectric ceramic as follows :

$$\rho = \frac{m}{V} \, (kg/m^3) \cdots\cdots (21)$$

where m : Mass (kg)
V : Volume (m³)

8 Relative Dielectric Constant $\frac{\varepsilon^T}{\varepsilon_0}$

Dielectric constant is an electrical displacement which results when a unity electric field is applied under no stress. It is given by the following formula :

$$D = \varepsilon^T \cdot E$$

where E : Field strength
D : Electrical displacement
ε^T : Dielectric constant

Dielectric constant εT divided by the dielectric constant in a vacuum ε_0 (=8.854×10⁻¹²F/m) is called the relative dielectric constant. For the lengthwise vibration mode shown in Fig. 2, if the free capacitance across the electrodes at 1 kHz is assumed to be Cf, the relative dielectric constant for an electric field in the same direction of polarization is given by the equation :

$$\frac{\varepsilon_{33}{}^T}{\varepsilon_0} = \frac{Cf \cdot t}{\ell \cdot a \cdot \varepsilon_0} \cdots\cdots (22)$$

For the vibration along thickness shown in Fig. 2, if the free capacitance across the electrodes at 1 kHz is assumed to be Cf, the relative dielectric constant for an electric field orthogonal to the direction of polarization is given by this equation :

$$\frac{\varepsilon_{11}{}^T}{\varepsilon_0} = \frac{Cf \cdot t}{\ell \cdot a \cdot \varepsilon_0} \cdots\cdots (23)$$

9 Curie Temperature Tc

Curie temperature refers to the critical temperature at which crystals in the piezoelectric ceramic lose their spontaneous polarization and hence their piezoelectric property. It is defined as the temperature at which the dielectric constant is maximized when the temperature is increased.

10 Coercive Field Ec

Ferroelectric materials have a domain structure, as shown in Fig. 1. The dipole moment in each domain is oriented in the same direction and causes spontaneous polarization. If a varying electric field E is applied to it, the overall variation of polarization draws a hysteresis loop, as shown in Fig. 6. Once the material has an electric field applied to it, it does not return to the original domain structure when the electric field is removed, resulting in remanent polarization Pr. To cancel Pr, a certain strength of reverse electric field must be applied. The field strength Ec required to cancel the remanent polarization is called a coercive field.
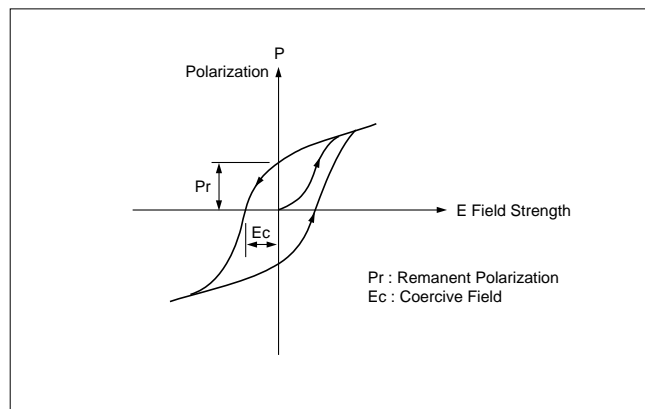

Fig. 6   Hysteresis Curve of a Ferroelectric Material

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3 Murata's Piezoelectric Ceramics (PIEZOTITE$^®$) Materials

1. Characteristics of Typical Materials

Table 1 shows the characteristics of typical Murata's piezo-electric ceramic materials.

Item	Symbol (Unit)		P–3	P–5C	P–5E	P–6C	P–6E	P–6F	P–7	P–7B
Relative Dielectric Constant	$\varepsilon_{11}^{T}/\varepsilon_0$		—	1230	1490	760	1260	1670	1930	3200
	$\varepsilon_{33}^{T}/\varepsilon_0$		1070	1550	1510	800	1380	1780	2100	4720
Loss Coefficient	$\tan\delta$	(%)	0.5	0.3	0.4	1.0	1.4	1.2	1.4	2.2
Electro-mechanical Coupling Factor	k_p Radial	(%)	22	56	56	39	46	57	65	65
	k_{31} Length	(%)	15	32	32	21	26	32	38	36
	k_{33} Longitudinal	(%)	44	54	62	50	60	65	71	68
	k_t Thickness	(%)	36	42	45	43	44	48	51	47
	k_{15} Shear	(%)	—	50	60	47	53	61	66	57
Piezoelectric Constant	d_{31}	$(10^{-12}m/V)$	−44	−131	−131	−3	−94	−148	−207	−303
	d_{33}	$(10^{-12}m/V)$	133	225	271	135	235	311	410	603
	d_{15}	$(10^{-12}m/V)$	—	294	400	196	309	431	550	592
	g_{31}	$(10^{-3}V·m/N)$	−5	−10	−10	−8	−8	−9	−11	−7
	g_{33}	$(10^{-3}V·m/N)$	14	16	20	19	19	20	22	14
	g_{15}	$(10^{-3}V·m/N)$	—	27	30	29	28	29	32	21
Frequency Constant	N_p Radial	(%)	3140	1920	2250	2520	2410	2210	2050	1960
	N_{31} Length	(%)	2270	1580	1610	1850	1730	1540	1430	1370
	N_{33} Longitudinal	(%)	2210	1670	1550	1820	1670	1540	1400	1350
	N_t Thickness	(%)	2590	2180	2060	2130	2110	2060	2000	1970
	N_{15} Shear	(%)	—	1020	1010	1150	1080	1000	930	930
Mechanical Q	Q_m		720	2070	970	680	410	110	80	70
Elastic constant	S_{11}^{E}	$(10^{-12}m^2/N)$	8.7	12.6	12.4	9.4	11.1	13.4	15.8	16.7
	S_{12}^{E}	$(10^{-12}m^2/N)$	−2.6	−4.7	−4.1	−3.0	−3.6	−4.8	−5.7	−5.9
	S_{13}^{E}	$(10^{-12}m^2/N)$	−2.9	−5.3	−5.2	−3.0	−4.3	−5.4	−7.0	−7.5
	S_{33}^{E}	$(10^{-12}m^2/N)$	9.6	12.8	14.3	10.3	12.7	14.5	18.1	18.8
	S_{44}^{E}	$(10^{-12}m^2/N)$	—	31.6	34.0	25.6	30.0	34.2	40.6	38.8
	S_{66}^{E}	$(10^{-12}m^2/N)$	22.7	34.6	33.0	24.8	29.3	36.5	43.0	45.4
	Y_{11}^{E}	$(10^{10}N/m^2)$	11.5	8.0	8.1	10.7	9.0	7.5	6.3	6.7
Poisson's Ratio	σ^{E}		0.30	0.37	0.33	0.32	0.33	0.36	0.36	0.36
Density	ρ	$(10^3kg/m^3)$	5.6	8.0	7.8	7.7	7.6	7.9	7.8	8.0
Temperature Coefficient	TK(fr)	(ppm/℃)	—	324	115	10	35	38	59	336
	TK(Cf)	(ppm/℃)	—	1500	3500	2500	3000	—	4500	13500
Curie Temperature	T_c	(℃)	120	360	280	320	270	280	300	180
Linear Expansion Ratio	α	$(10^{-6}/℃)$	5	2	4	2	3	4	2	2
Bending Strength	τ	$(10^6N/m^2)$	113	101	113	125	116	103	99	85
Compressive Strength	K_{1c}	$(10^6N/m^{1.5})$	—	0.7	1.1	1.3	1.2	0.9	0.8	0.9
Applications			Fish finders sonars	Ultrasonic cleaners Actuators for high power		Knock sensors	Sensors		Ultrasonic sensors Pickups Actuators Acoustic	Actuators Acoustics

Note : This table shows typical values measured on standard test piece. Qm, TK (fr) and TK (Cf) are measured for radial vibration mode.

Table 1   Characteristics of Murata's Typical Piezoelectric Ceramics (PIEZOTITE$^®$)

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Murata's Piezoelectric Ceramics (PIEZOTITE®) Materials **3**

2. Features of PIEZOTITE® Materials

Table 2 shows the features of PIEZOTITE® materials. Murata's piezoelectric ceramics include two types : barium titanate (BaTiO$_3$) and lead zirconate titanate

(PbTiO$_3$·PbZrO$_3$) Materials using lead zirconate titanate are available with different properties suitable for different applications.

Type	Type Number	Features
Barium Titanate	P– 3	The major constituent of P-3 is barium titanate, with titanate additives to improve the characteristics at room temperature. While it has a lower electromechanical coupling coefficient and Curie temperature compared to Lead Zirconate Titanate, it is practical in underwater applications and has the advantage of economy. With these features, P-3 is best suited for use in fish finders or sonar.
Lead Zirconate Titanate	P– 5E	Featuring a large electromechanical-coupling coefficient, mechanical Qm and minimal aging, P-5 is widely used for ultrasonic cleaners, high-power ultrasonic transducers, and other acoustic power applications.
	P– 6C	Features superior temperature characteristics of resonant frequency and minimal aging. P-6 is often used in ceramic filters, ceramic resonators requiring high stability.
	P– 7	Features large electromechanical coupling coefficient, constant d and small mechanical Qm. P-7 has applicaitons in piezoelectric buzzers, ultrasonic sensors, and other applications requiring non-resonance or broad bandwidth.

Table 2   Features of Piezoelectric Ceramics

3. Temperature Characteristics and Aging

Fig. 7 shows examples of temperature characteristics of various materials.

Fig. 8 shows examples of aging characteristics of various materials. These examples show small aging characteristics.
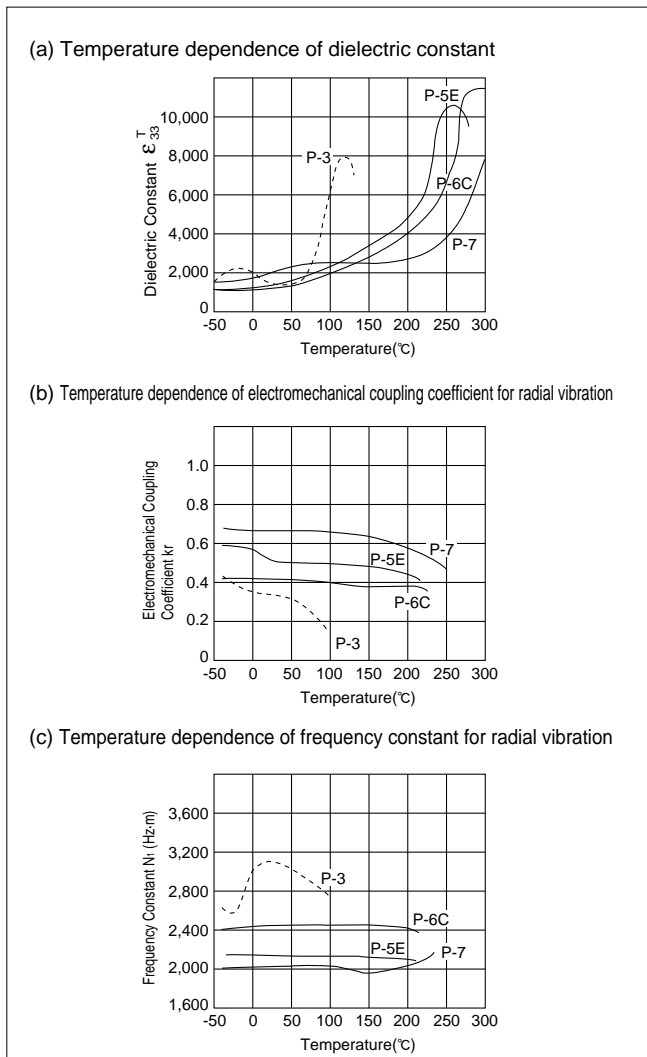
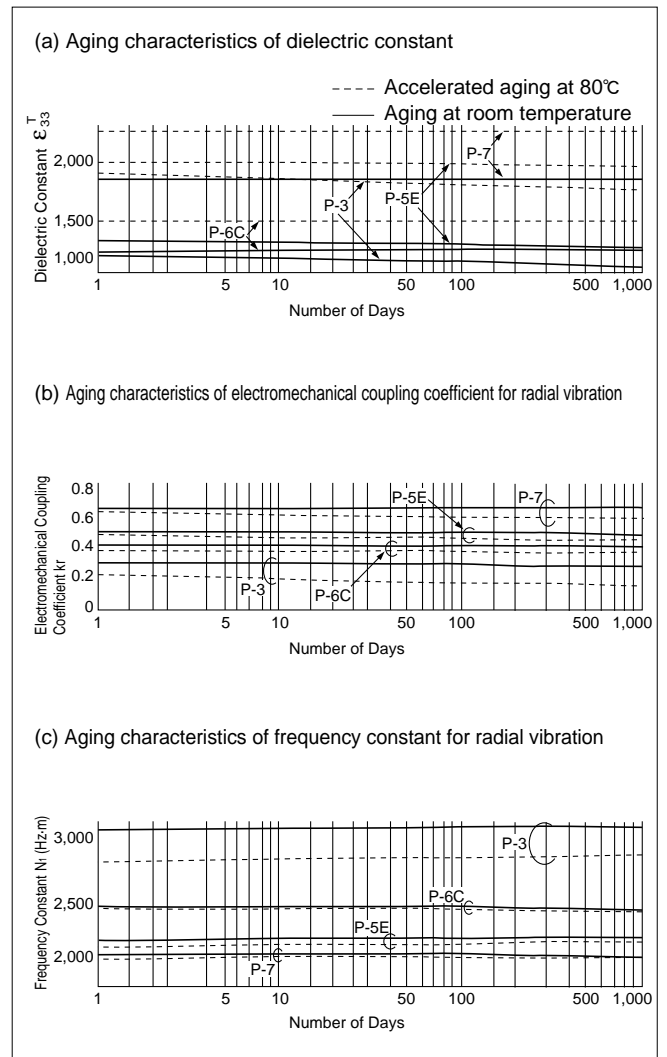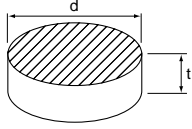

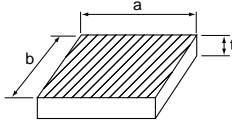Fig. 7   Temperature Characteristics of Various Materials

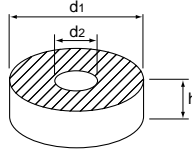
Fig. 8   Aging Characteristics of Various Materials

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4 Murata's Piezoelectric Ceramics Resonators (PIEZOTITE®)

1. Shapes

PIEZOTITE® by Murata is available in various forms as shown in table 3.

Shape	Diagram	Vibration Mode	Part Numbering (Ex.)
Disk		Radial Thickness	**7 D -15 -5400** ❶ ❷ ❸ ❹ ❶ Indicates material P–7. ❷ Indicates disk cylinder. ❸ Diameter d(mm) ❹ Resonant frequency (thickness mode) (kHz)
Rectangular Plate		Thickness Length	**7 R -34 -23 -6700 -1** ❶ ❷ ❸ ❹ ❺ ❻ ❶ Indicates material P–7. ❷ Indicates rectangular plate or pillar. ❸ Length a (mm) ❹ Width b (mm) ❺ Resonant frequency (thickness mode) (kHz) ❻ Product ID
Ring		Thickness	**6C C -10 -3R9 -1000** ❶ ❷ ❸ ❹ ❺ ❶ Indicates material P–6C. ❷ Indicates ring. ❸ Outer diameter d_1 (mm) ❹ Inner diameter d_2 (mm) ❺ Resonant frequency (thickness mode) (kHz)

The capital lettler "R" expresses significant digits.

Fig. 9   Shapes of Murata's Piezoelectric Ceramics PIEZOTITE®

2. Standard Specification Models

Table 3 shows standard specifications of PIEZOTITE® models.

Part Number		Dimensions (mm)	Resonant Frequency (kHz)	Coupling Coefficient (%)	Capacitance (pF)
Disks	7D-10-9000-2	ø10×0.2t	200 (Radial mode)	55 (kp)	5200
	7D-15-5400	ø15×0.4t	137 (Radial mode)	55 (kp)	7200
	7D-25-1600	ø25.5×1.27t	80 (Radial mode)	45 (kp)	6300
Rectangular Plates	7R-34-23-2500	33.3L×22.8W×0.8t	68 (Length mode)	50 (kp)	16000
	7R-34-23-4000-1	33.3L×22.8W×0.5t	42 (Length mode)	20 (kp)	26000
	7R-34-23-6700	32.8L×22.3W×0.3t	42 (Length mode)	20 (kp)	42000
Rings	6CC-21-15-700	ø21.1×ø15×2.85t	66 (Radial mode)	18 (kp)	450
	6CC-10-3R9-1000	ø10×ø3.9×2.1t	180 (Radial mode)	20 (kp)	230

Table 3   Standard Specifications of PIEZOTITE® Models

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Murata's Piezoelectric Ceramics Resonators (PIEZOTITE®) **4**

3. Notice

Do not touch the component with bare hand because
electrode may damaged.

4

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5 Piezoelectric Ceramic (PIEZOTITE®) Applications

Piezoelectric ceramics transform electrical energy into mechanical energy and vice versa. Fig. 10 shows our PIEZOTITE® in applications which utilize this basic function of piezoelectric ceramics as an electrical-mechanical energy transducer.

In addition to the current line of products, Fig. 10 also lists some prototypes still under development (*1).   Please consult us concerning custom specifications and production of these new products. The application products are shown in ⬜, which are explained details in the following pages. For other products not shown in Fig. 10, please contact us. Items marked with an asterisk (*1) in Fig. 10 are available with individual catalogs and application manuals. For more details, refer to those related materials.
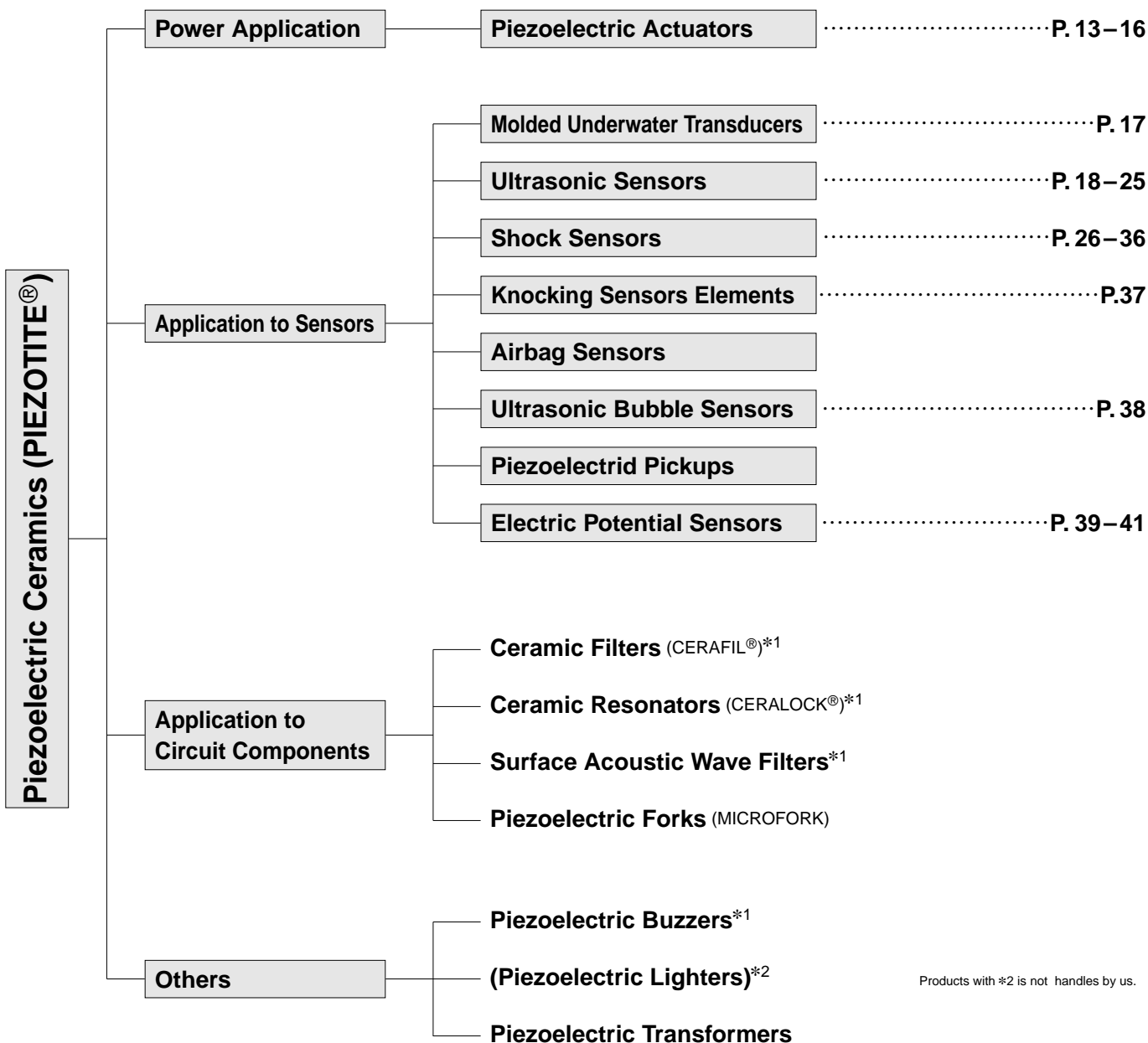
Piezoelectric Ceramics (PIEZOTITE®)

- **Power Application** — **Piezoelectric Actuators** ·············· **P. 13−16**

- **Application to Sensors**
  - **Molded Underwater Transducers** ·············· **P. 17**
  - **Ultrasonic Sensors** ·············· **P. 18−25**
  - **Shock Sensors** ·············· **P. 26−36**
  - **Knocking Sensors Elements** ·············· **P.37**
  - **Airbag Sensors**
  - **Ultrasonic Bubble Sensors** ·············· **P. 38**
  - **Piezoelectrid Pickups**
  - **Electric Potential Sensors** ·············· **P. 39−41**

- **Application to Circuit Components**
  - **Ceramic Filters** (CERAFIL®)*1
  - **Ceramic Resonators** (CERALOCK®)*1
  - **Surface Acoustic Wave Filters***1
  - **Piezoelectric Forks** (MICROFORK)

- **Others**
  - **Piezoelectric Buzzers***1
  - **(Piezoelectric Lighters)***2   Products with *2 is not handles by us.
  - **Piezoelectric Transformers**

Fig. 10   Piezoelectric Ceramics (PIEZOTITE®) Applications

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

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Piezoelectric Actuator

Exact displacement of 0.01μm to several hundreds μm can be obtained by controling the applied voltage.
Piezoelectric actuators are used in the tracking adjustment of VCR heads, focus adjustment of VCR cameras, shutter drives of cameras, ink-jet printers and braille cells.
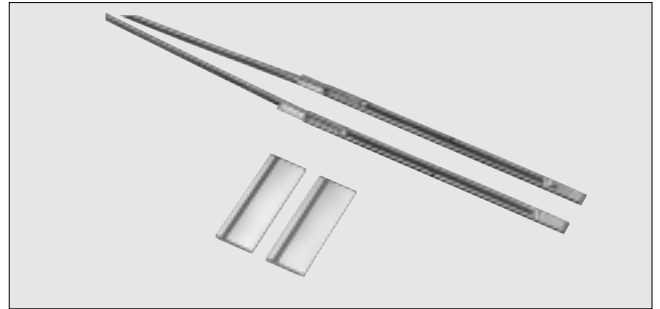
Material	Piezoelectric Strain Constant		Corrective Coefficient	Elastic Constant (corrected value)		Coercive Field	Relative Dielectric Constant	Hysteresis
	$d_{31}(10^{-12}m/V)$	$d_{33}(10^{-12}m/V)$	$M(10^{-16}m^2/V_2)$	$Y_{11}^E(10^{10}N/m^2)$	$Y_{33}^E(10^{10}N/m^2)$	$E_c(V/mm)$	$\varepsilon_{33}^T/\varepsilon_0$	$h(\%)$
P-5E	131	271	0.06	7.5	8.0	1500	1510	3
P-7	207	410	1.08	5.5	5.5	800	2100	10
P-7B	303	603	3.89	5.0	5.5	500	4720	20

Hysteresis vary according to the applied voltage or shape (See Fig.2)

5

■ Notice

Please note that the component may be damaged if excess stress input voltage is applied. Please refer to the individual specification for the max. input voltage.

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Bimorph Type Actuator

■ Features

1. Large displacement achieved with low voltage.
2. Compact, low-cost design.
3. High response speed.

■ Applications

1. braille cells
2. shutter drives of cameras

Figure (dimensional drawing):

Electrode Ni
Conductive Material
2.2±0.05
(1.0)
36.0±1
40.5±1
42.4±0.5
47.4±0.4
1±0.5

25.4±3
7.5±1
.5
(Red)
Conductive Material
Ni Alloy
P-7B
0.6±0.02
0.66±0.05
(Black)
25.4
A
B :12.0
C :12.76
(in mm)
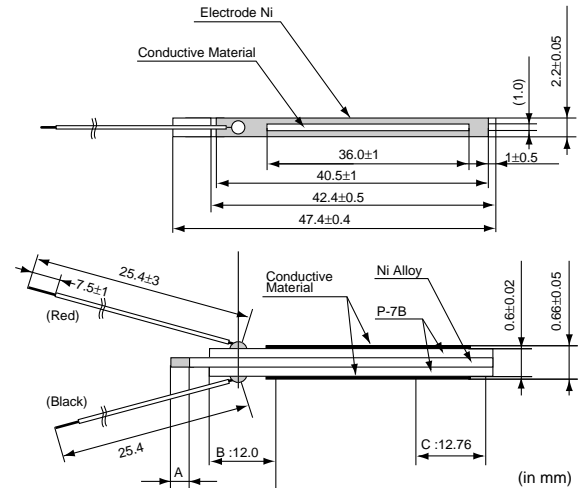
∗ A : The length of pre-coating is more than 2.0mm from edge.
∗ There are protect-coating on the surface of ceramic.
  Above dimensions don't include coating thickness,
  The dimension included is as bellow,
    Point B : 0.7mm
    Point C : 0.74mm
∗ Lead wire : UL1571, AWG32

Part Number	Deflection	Input Voltage (V)	Blocked Force (mN)	Capacitance (nF)
PKF02C5	min. 1200 μm (1300 μm typ.) (at 200 V)	200 V max.	83.3 ±19.6mN (at 200 V)	5.7 ± 2.0nF (at 1 Vms., 1 kHz)

■ Construction

Figure:

ℓ
2t
δ
F
V
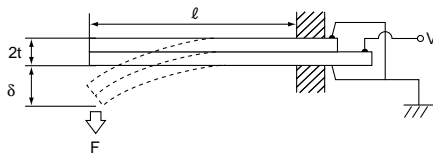
ℓ (Length).   : 25mm
W (Width).   : 10.0mm
2t (Thickness). : 10.4mm

Fig. 1

(Mechanical strength can be increased with metal plate.)

■ Characteristics (Construction in Fig.1)

1. Hysteresis

Figure 2 (hysteresis graph):

Displacement (μm)
400
300
200
100
-150 -100 -50 0 50 100 150
Voltage (Vp-p)
-100
-200
-300
-400
δ
δh
Hysteresis
h=δh/δ×100
Material : P-7

Fig. 2

Figure 3 (hysteresis vs temperature graph):

Hysteresis (%)
15
10
5
0
-20 0 20 40 80
Temperature (°C)
P-7B
P-7
P-5E

Fig.3

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5

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2. Displacement

Fig. 4

Material : P-7
Voltage : 100Vp-p
Displacement : $\delta \fallingdotseq 3 \cdot D_{31} \cdot V \cdot \left(\dfrac{R}{2t}\right)^2$

Generated force : $F \fallingdotseq \dfrac{3}{4} \cdot D_{31} \cdot V \cdot \left(\dfrac{2tW}{R}\right) \cdot Y_{11}$

$\left(\begin{array}{l} D_{31}=d_{31}+M \cdot V/2t \\ F : \text{Load at 0 displacement} \end{array}\right.$

Maximum allowable voltage : $Vmax. \fallingdotseq 0.7 \cdot Ec \cdot t$
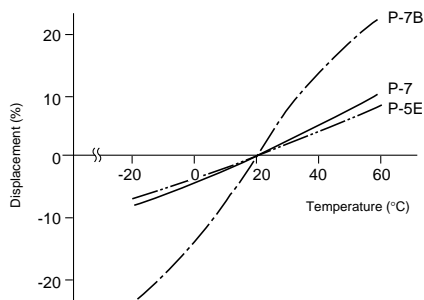
Fig.5

3. Material · shape-Displacement

Material : P-7
Voltage : 60Vp-p
Thickness : 2t (mm)

Fig.6

Material : P-7B
Voltage : 40Vp-p
Thickness : 2t (mm)

Fig.7

Material : P-5E
Voltage : 100Vp-p
Thickness : 2t (mm)
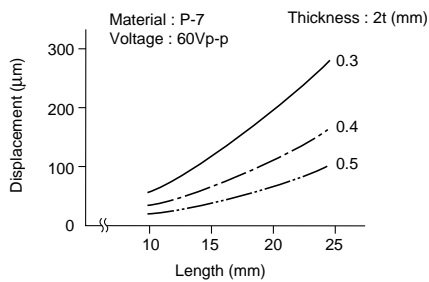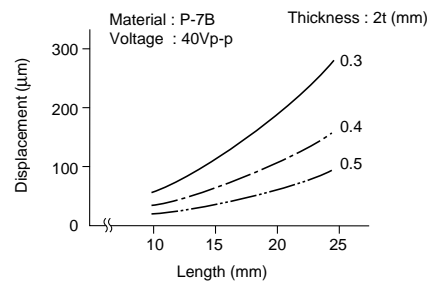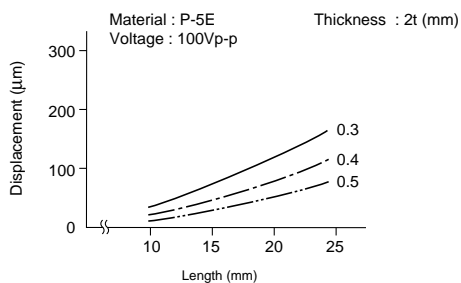
Fig.8

■ Notice

Please avoid applying an excessive stress to the
transducer because it might be damaged.

5

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Multilayer Type Actuator

■ Features

1. Superior load-sustaining performance.
2. Precise micro-displacement.
3. High displacement response speed.

■ Applications

1. braille cells
2. shutter drives of cameras
3. Ink-jet Printer head
4. Location control for HDD MR-head

■ Construction
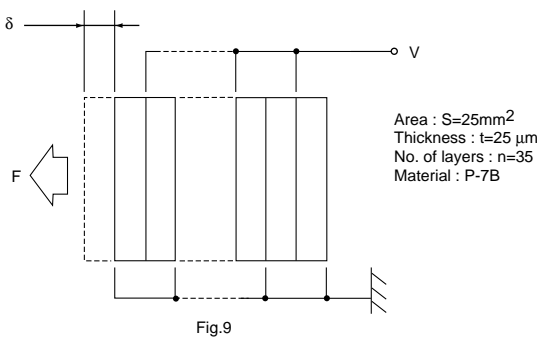
Area : S=25mm^2
Thickness : t=25 μm
No. of layers : n=35
Material : P-7B

Fig.9

■ Characterisitics

1. Hysteresis

Fig.10

2. Displacement

Fig.11

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

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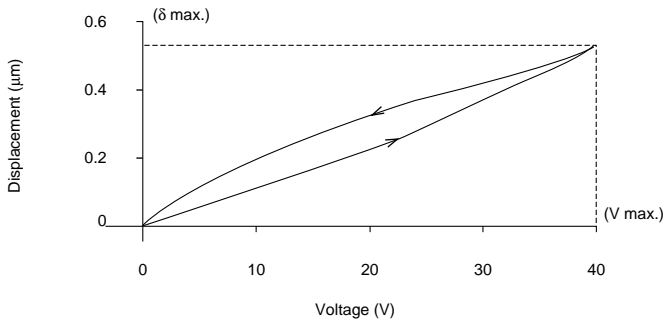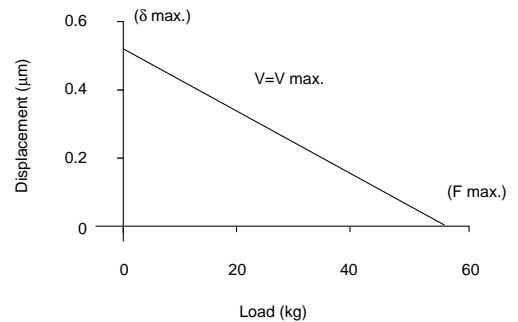
Molded Underwater Transducer

The molded underwater transducer is often used in fish finders and depth sounders. It emits an ultrasonic wave into the water so that the appropriate receiving device can detect the reflected wave in order to prove for fish or determine depth. Designed specifically for underwater use, this vibrator features not only high sensitivity but superior waterproof performance.The rugged design easily gives excellent performance even under high water pressure and waves.

■ Features
1. Unique mold technique using rubber, urethane, epoxy resin and other materials assures high sensitivity and dependability.
2. Many models are available for different driving frequencies, allowable input powers, and shapes.

LF type (UT200LF8)

7/8-14UNF
Resin nut (with Washer)
Rubber washer
Plastic case
Label
Resin mold
(10) 120
36
(in mm)

BA type (UT200BA8)

7/8-16UNF
Resin nut (with Washer)
Rubber washer
Plastic case
Label
Resin mold
120
8
27
(in mm)
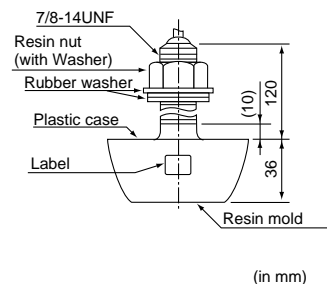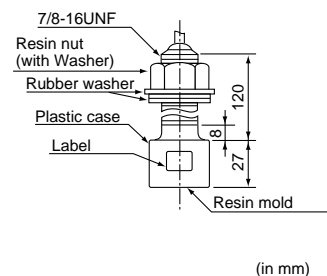
Part Number	Resonant Frequency (kHz)	Capacitance (pF)	Resonant Impedance (Ω)	Directivity (deg)	Allowable Input Power (W)
UT200BA8	200	1700	310 - 590	22	50
UT200LF8	200	2700	230 - 430	12	200

Wire length is 8 m.
Directivity: The degree when sound pressure level is 6 dB down compared with the value at 0 degree.
Allowable input power : Denotes the instantaneous input power applied to Molded underwater transducer driven underwater.
The driving duty radio is assumed to be 1/200 (the values in the table above are guidelines)

■ Notice
1. Pay close attention to directional characteristics when mounting.
2. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.
3. Do not use in the air.

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

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Ultrasonic Sensors

Open Structure Type

■ Features
1. Compact and light weight.
2. High sensitivity and sound pressure.
3. Less power consumption.
4. High reliability.

■ Applications
Burglar alarms, Range finders, Automatic doors, Remote control.

MA40B8R/S
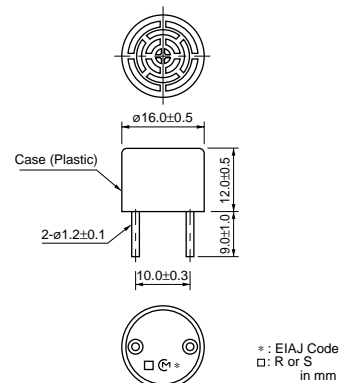
Case (Plastic)

ø16.0±0.5
12.0±0.5
9.0±1.0
2-ø1.2±0.1
10.0±0.3

∗ : EIAJ Code
□ : R or S
in mm

MA40S4R/S

ø9.9±0.3
7.1±0.3
10.0±1.0
2-ø0.64 ±0.1
5.0±0.3

∗ : EIAJ Code
□ : R or S
in mm

MA40S5

ø9.9±0.3
7.1±0.25
5.0±0.2
2 - 0.64□ ±0.1
5.0±0.25

Sealed by Silicone glue

∗ : EIAJ Code
(in mm)
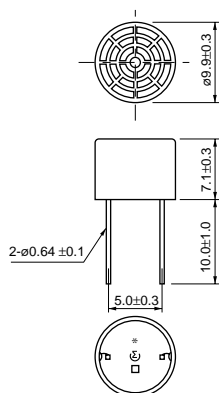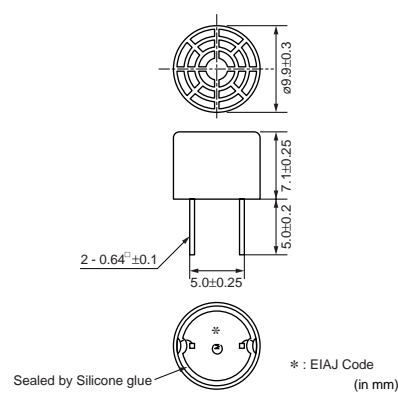
Part Number	Construction	Using Method	Nominal Freq. (kHz)	Overall Sensitivity (mVp-p)	Sensitivity (dB)	S.P.L. (dB)	Directivity (°)	Cap. (pF)	Operating Temp. Range (°C)	Detectable Range (m)	Resolution (mm)	Max. Input Voltage (Vp-p)
MA40B8R	Open struct.	Receiver	40	-	-63 typ. (0dB=10V/Pa)	-	50	2000	-30 to 85	0.2 to 6	9	-
MA40B8S	Open struct.	Transmitter	40	-	-	120 typ. (0dB=0.02mPa)	50	2000	-30 to 85	0.2 to 6	9	40 Continuous signal
MA40S4R	Open struct.	Receiver	40	-	-63 typ. (0dB=10V/Pa)	-	80	2550	-40 to 85	0.2 to 4	9	-
MA40S4S	Open struct.	Transmitter	40	-	-	120 typ. (0dB=0.02mPa)	80	2550	-40 to 85	0.2 to 4	9	20 Continuous signal
MA40S5	Open struct.	Dual Use	40	20 typ.	-	-	60 typ.	2550	-30 to 85	0.5 to 2	9	20 Pulse width 0.4ms Interval 100ms

Distance:30cm, Overall sensitivity:0dB=10Vp-p, Sensitivity:0dB=1Vrms/μbar, Sound pressure level:0dB=2x10⁻⁴μbar, 1μbar=0.1Pa

The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.
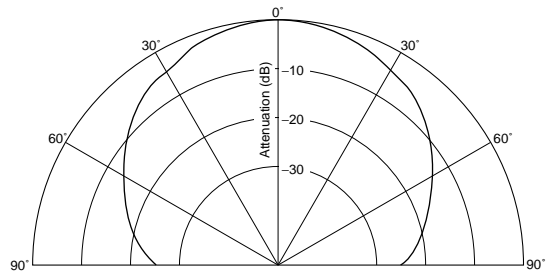
Directivty, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.
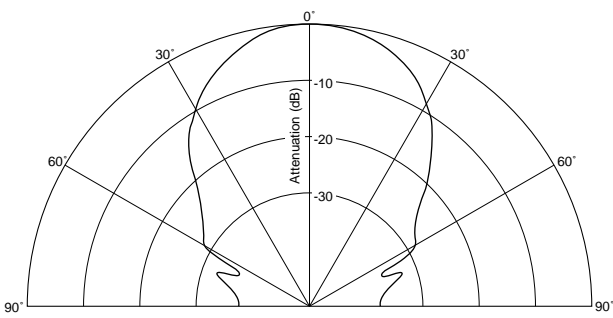
5

muRata

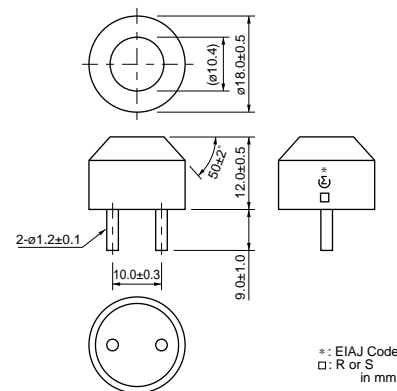⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
This catalog has only typical specifications. Therefore, you are requested to approve our product specification or to transact the approval sheet for product specificaion before ordering.

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■ Directivity in Sensitivity
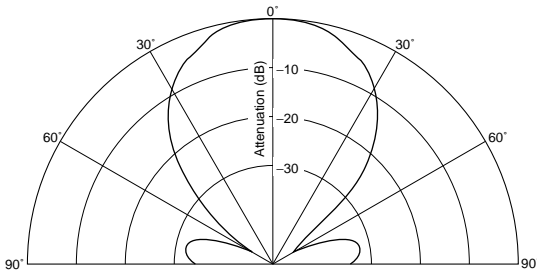
MA40B8R

MA40S4R

■ Directivity in S. P. L.

MA40B8S

■ Directivity in S. P. L.

MA40S4S
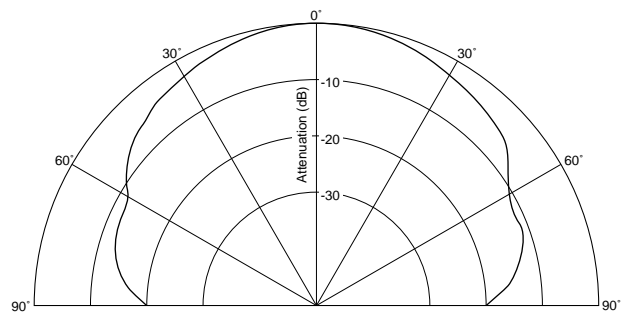
■ Directivity in Overall Sensitivity

MA40S5

Beam Pattern

5

⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
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P19E7.pdf 02.6.26
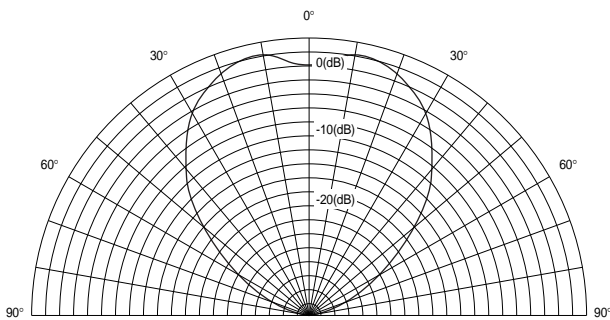
■ S. P. L. -Freq. Characteristics
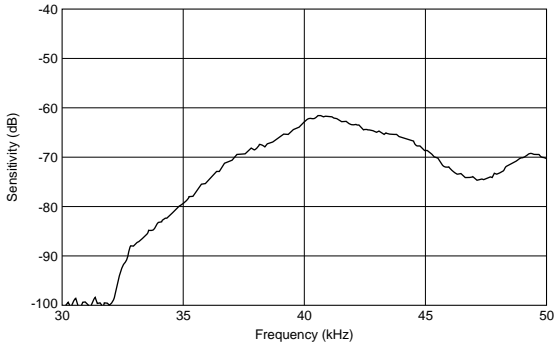
MA40B8R

MA40S4R
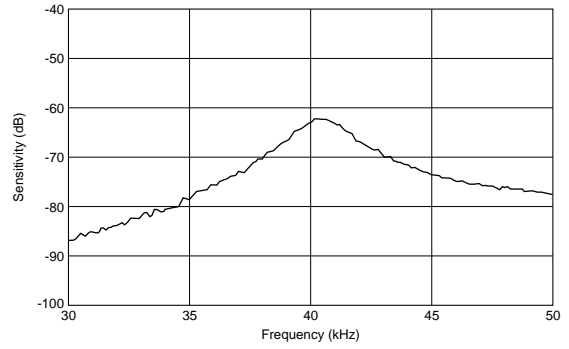
■ Sensitivity-Freq. Characteristics

MA40B8S

MA40S4S

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Water Proof Type Symmetric Directivity

■ Features

1. Compact and light weight.
2. High sensitivity and sound pressure.
3. Less power consumption.
4. High reliability.

■ Applications

Back sonar of automobiles, Parking meters, Water level meters.

MA40E7R/S
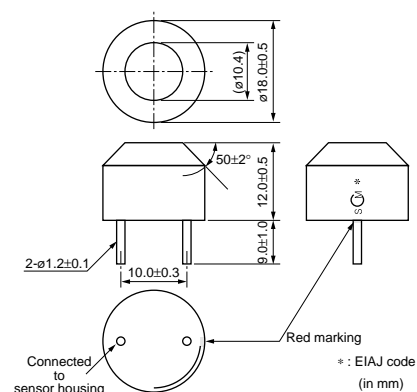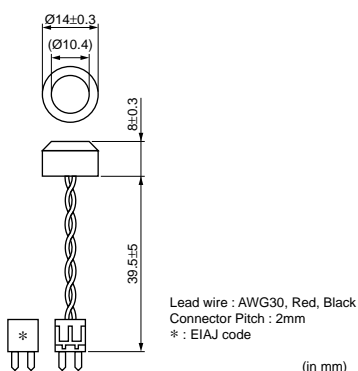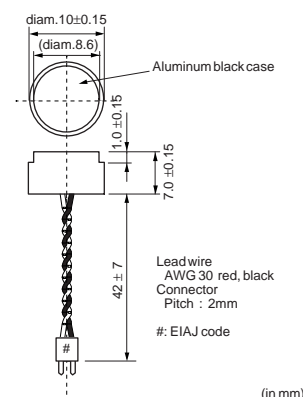
*: EIAJ Code
□: R or S
in mm

MA40E7S-1

*: EIAJ code
(in mm)

5

MA40E8-2

Lead wire : AWG30, Red, Black
Connector Pitch : 2mm
* : EIAJ code

(in mm)

MA40MC10-1B

Lead wire
AWG 30 red, black
Connector
Pitch : 2mm

#: EIAJ code

(in mm)

Part Number	Construction	Using Method	Nominal Freq. (kHz)	Overall Sensitivity	Sensitivity (dB)	S.P.L. (dB)	Direc tivity (°)	Cap. (pF)	Operating Temp. Range (°C)	Detectable Range (m)	Resolu tion (mm)	Max. Input Voltage (Vp-p)
MA40E7R	Water proof	Receiver	40	-	-74 min. (0dB=10V/Pa)	-	100	2200	-30 to 85	0.2 to 3	9	-
MA40E7S	Water proof	Transmitter	40	-	-	106 min. (0dB=0.02mPa)	100	2200	-30 to 85	0.2 to 3	9	100 Pulse width 0.4ms Interval 100ms
MA40E7S-1	Water proof	Dual Use	40	-	-72 min. (0dB=10V/Pa) : reference only	106 min. (0dB=0.02mPa)	75	2200	-30 to 85	0.2 to 3	9	100 Pulse width 0.4ms Interval 100ms
MA40E8-2	Water proof	Dual Use	40	-	-85 min. (0dB=10V/Pa)	106 min. (0dB=0.02mPa)	75	2800	-30 to 85	0.2 to 1.5	9	160 Pulse width 0.8ms Interval 60ms
MA40MC10-1B	Water proof	Dual Use	40	-	-86 min. (0dB=10V/Pa)	104 min. (0dB=0.02mPa)	100 typ.	2400	-30 to 85	0.2 to 1.5	9	160 Pulse width 0.8ms Interval 60ms

Distance:30cm, Overall sensitivity:0dB=10Vp-p, Sensitivity:0dB=1Vrms/μbar, Sound pressure level:0dB=2x10⁻⁴μbar, 1μbar=0.1Pa
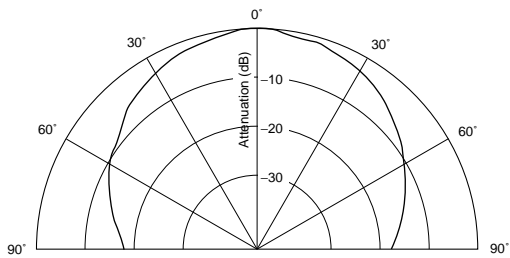
The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

Directivty, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.
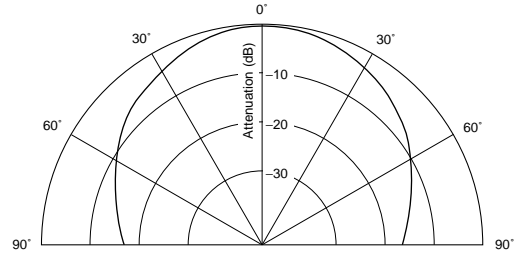
⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
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■ Directivity in Sensitivity

MA40E7R

■ Directivity in S. P. L.

MA40E7S

■ Directivity in Overall Sensitivity

MA40E7S-1
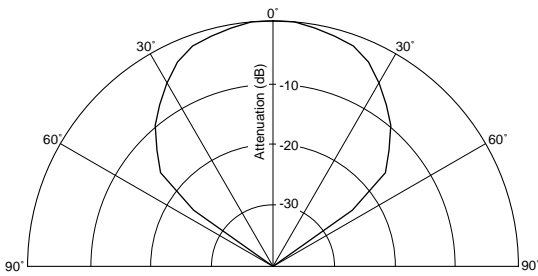
MA40E8-2
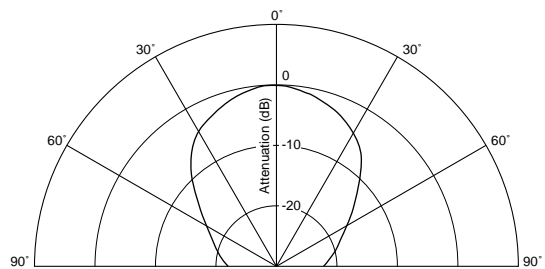
MA40MC10-1B

Beam Pattern
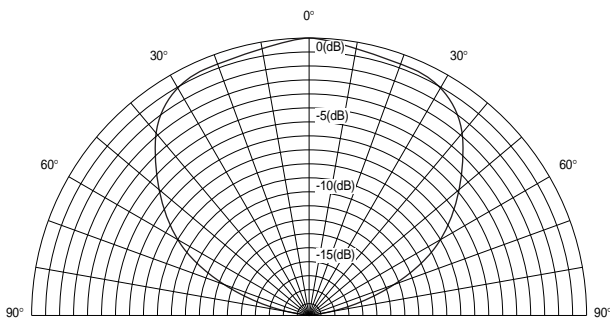
■ S. P. L. -Freq. Characteristics

MA40E7R

■ Sensitivity-Freq. Characteristics

MA40E7S

muRata

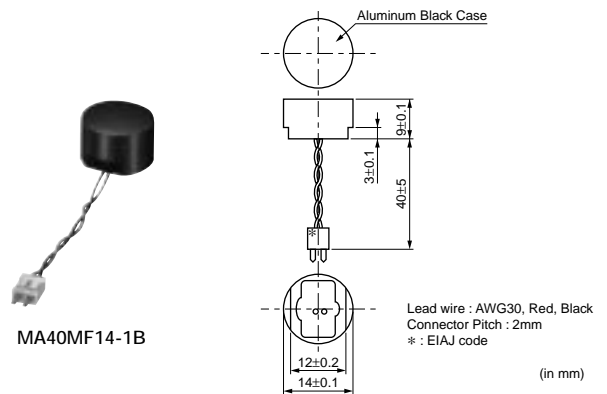⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
This catalog has only typical specifications. Therefore, you are requested to approve our product specification or to transact the approval sheet for product specificaion before ordering.

P19E7.pdf 02.6.26
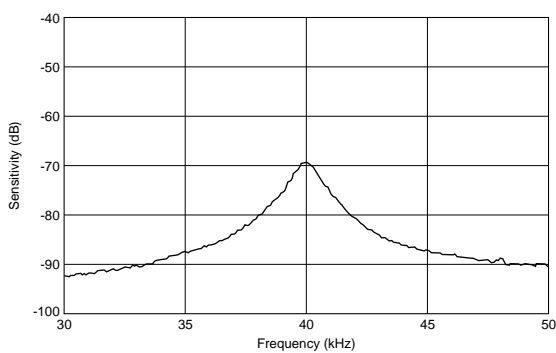
Water Proof Type Asymmetric Directivity

■ Features
1. Compact and light weight.
2. High sensitivity and sound pressure.
3. Less power consumption.
4. High reliability.
5. Compressed directivity by itself

■ Applications
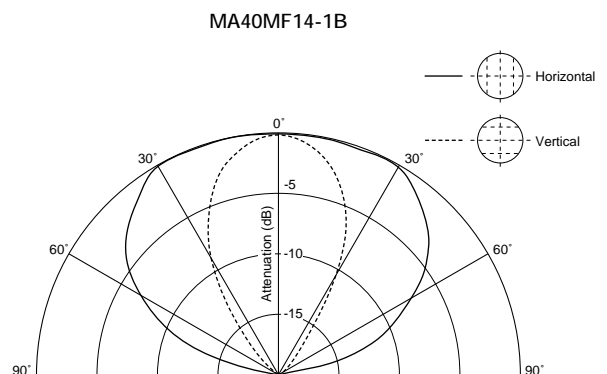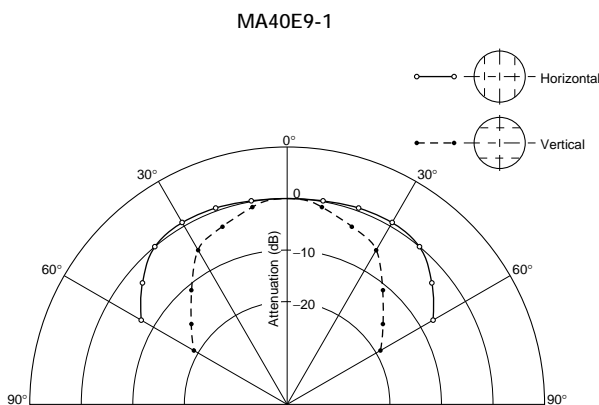Vack sonar of automobiles, Parking meters, Water level meter.
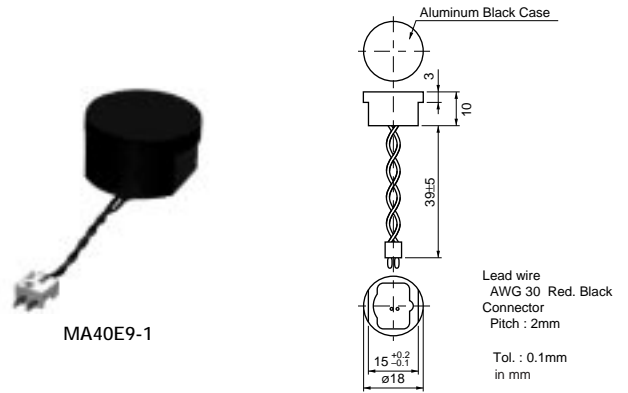
Aluminum Black Case

MA40E9-1

Lead wire
AWG 30 Red. Black
Connector
Pitch : 2mm

Tol. : 0.1mm
in mm

Aluminum Black Case

MA40MF14-1B

Lead wire : AWG30, Red, Black
Connector Pitch : 2mm
∗ : EIAJ code

(in mm)

5

Part Number	Construction	Using Method	Nominal Freq. (kHz)	Overall Sensitivity	Sensitivity (dB)	S.P.L. (dB)	Direc tivity (°)	Cap. (pF)	Operating Temp. Range (°C)	Detectable Range (m)	Resolu tion (mm)	Max. Input Voltage (Vp-p)
MA40E9-1	Water proof	Dual Use	40	-	-85 min. (0dB=10V/Pa)	103 min. (0dB=0.02mPa)	100 x50°	4000	-30 to 85	0.2 to 1.5	9	160 Pulse width 0.8ms Interval 60ms
MA40MF14-1B	Water proof	Dual Use	40	-	-87 min. (0dB=10V/Pa)	103 min. (0dB=0.02mPa)	110 x50°	4400	-30 to 85	0.2 to 1.5	9	160 Pulse width 0.8ms Interval 60ms

The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

Directivty, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.
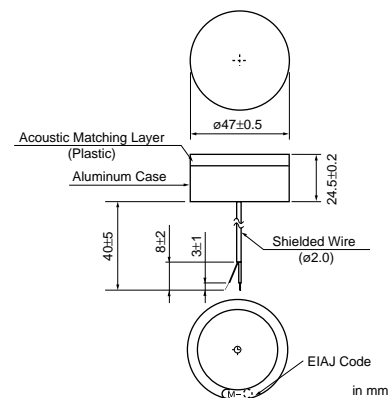
■ Directivity in Overall Sensitivity

MA40E9-1

MA40MF14-1B

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High-frequency Type

■ Features

Using longitudinal vibration and matching with the air by acoustic matching layer, this type realized high sensitivity. Because of short wavelength, this type has sharp directivity and can be used high precise measurement.

■ Applications

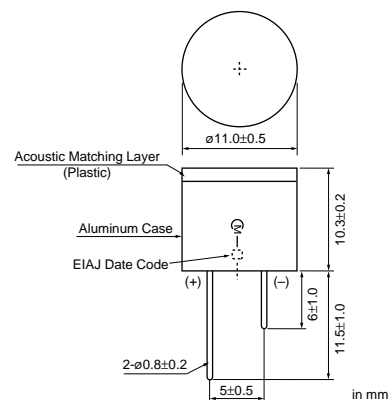Approach switch for FA, Distance meter, Water or liquid level meters.

MA80A1

MA200A1
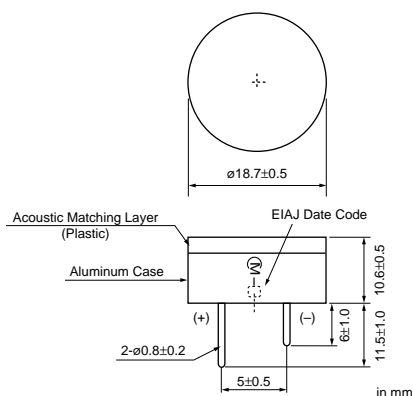
MA400A1

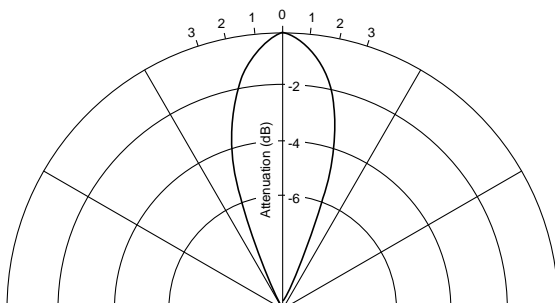| Part Number	Construction	Using Method	Nominal Freq. (kHz)	Overall Sensitivity (dB)	Sensitivity	S.P.L.	Direc tivity (°)	Cap.	Operating Temp. Range (°C)	Detectable Range (m)	Resolu tion (mm)	Max. Input Voltage (Vp-p)
MA80A1	High frequency type	Dual Use	75 +/-5	-47 min. 0dB=18Vpp (at 50cm)	-	-	7	-	-10 to 60	0.5 to 5	4	120 Pulse width 0.6ms Interval 50ms
MA200A1	High frequency type	Dual Use	200 +/-10	-54 min. 0dB=18Vpp (at 20cm)	-	-	7	-	-30 to 60	0.2 to 1	2	120 Pulse width 250μs Interval 20ms
MA400A1	High frequency type	Dual Use	400 +/-20	-74 min. 0dB=18Vpp (at 10cm)	-	-	7	-	-30 to 60	0.06 to 0.3	1	120 Pulse width 125μs Interval 10ms

The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

Directivty, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.
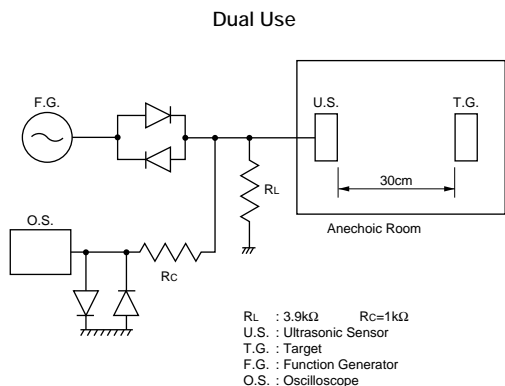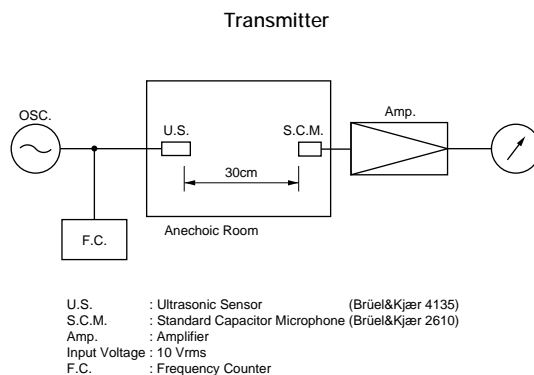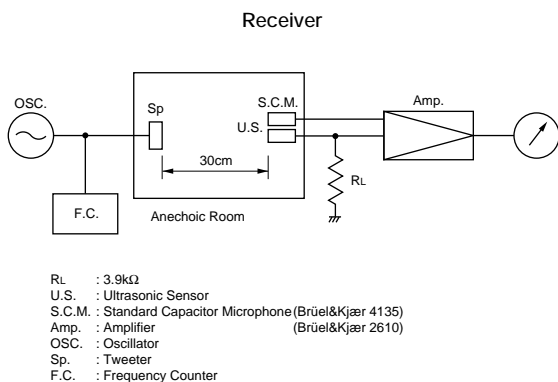
■ Directivity in Overall Sensitivity

MA_A1 Series

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Data/Notice/Part Numbering

■ Test Circuit

Receiver

RL   : 3.9kΩ
U.S. : Ultrasonic Sensor
S.C.M. : Standard Capacitor Microphone (Brüel&Kjær 4135)
Amp. : Amplifier   (Brüel&Kjær 2610)
OSC. : Oscillator
Sp.   : Tweeter
F.C. : Frequency Counter

Transmitter

U.S.   : Ultrasonic Sensor   (Brüel&Kjær 4135)
S.C.M.   : Standard Capacitor Microphone (Brüel&Kjær 2610)
Amp.   : Amplifier
Input Voltage : 10 Vrms
F.C.   : Frequency Counter

Dual Use

RL   : 3.9kΩ   Rc=1kΩ
U.S. : Ultrasonic Sensor
T.G. : Target
F.G. : Function Generator
O.S. : Oscilloscope

■ Notice (Soldering and Mounting)

1. Pay attention to the mounting position as these sensors have directivity.
2. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.
3. Do not use in water.

● Part Numbering (The structure of the "Global Part Numbers" that have been adopted since June 2001 and the meaning of each code are described herein. If you have any questions about details, inquire at your usual Murata sales office or distributor.)

Ultrasonic Sensors

(Global Part Number) | **MA** | **40MF** | **14** | **-1N** | **-M** |
| | ❶ | ❷ | ❸ | ❹ | ❺ |

❶Product ID

❷Series

❸Characteristics

❹Individual Specification Code

❺Packaging

* Global Part Number shows only an example which might be different from actual part number.
* Any other definitions than "❶Product ID" might have different digit numbers from actual Global Part Number.

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

Shock Sensors

The shock sensor, PKGS series, is acceleration sensor
with 2 terminals and detects acceleration & shock to
be applied from outside, as electrical signal.
By bimorph piezo elements clamped at the two-end with
original polarization technology, the shock sensor
has high sensitivity and excellent durability.
The shock sensor is reflow solderable SMD type.
The shock sensor can have inclined primary axis so
that appropriate shock sensor can be chosen for shock
detection in HDD (Hard Disk Drive) and optical pick-up
control in optical drive & optical-magnetic Drive.

■ Features
1. Small size, low profile, high sensitivity
   and excellent durability.
2. Excellent linearity.
3. High resonance frequency and wide bandwidth.
4. Available tape and reel packaging.
5. Reflowable.
6. In addition to the voltage sensitivity type shock
   sensor (ME, LB and LC series), new type, the
   electrical charge sensitivity type shock sensor
   (NB, MF and LD series) are released. NB, MF and LD
   series have better anti-reflow temperature.

■ Applications
1. HDD data writing protection, while shock is
   applied from outside.
2. Shock detection and protection in DVD, CD-R,
   CD-RW etc.
3. Pick-up control for disk type storage in Digital
   camera, Camcorder etc.
4. Other applications requiring acceleration detection.

△Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
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■ Primary Axis Inclined Angle

The acceleration detection direction with the shock sensor can be inclined relative to the PCB. This inclination is called the primary-axis-inclined angle and can be selected from the four variations that are shown in the diagram on the right-0, 25, 45, and 90 degrees, respectively.

The acceleration detection sensitivity is greatest with the acceleration in the primary axis direction (direction D). With the 25- and 45-degree sensor types, the detection sensitivity is available in both the Y and Z directions.

■ Polarity

The shock sensor has polarity. Referring to the diagram on the right, when acceleration is applied in direction D, a positive voltage (relative to the voltage on electrode A) occurs on electrode B.
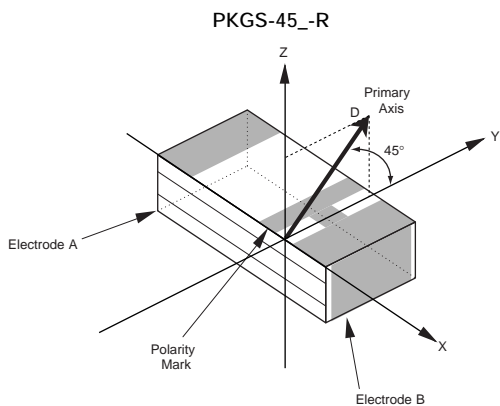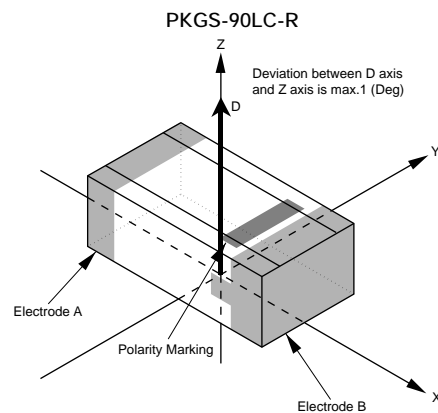
■ Primary Axis Inclined Angle (0 degree)

PKGS-00_-R
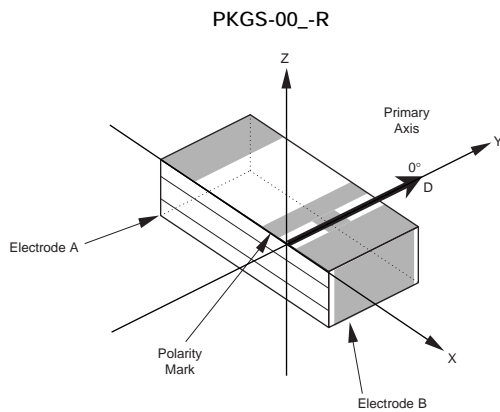
■ Primary Axis Inclined Angle (25 degree)

PKGS-25_-R
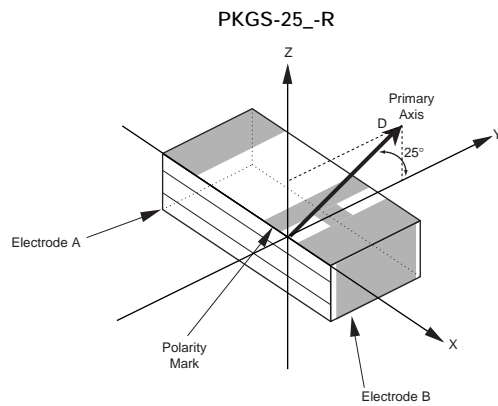
■ Primary Axis Inclined Angle (45 degree)

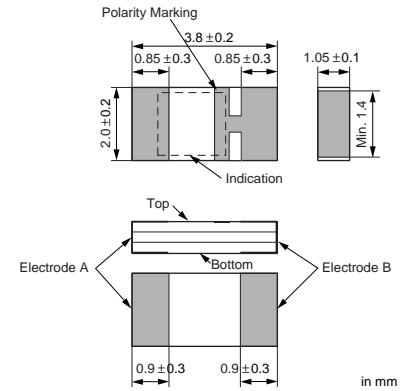PKGS-45_-R

■ Primary Axis Inclined Angle (90 degree)

PKGS-90LC-R

Under bar shown in part number is filled with two letters of Charactristics codes.

5

⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
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Charge Sensitvity Type PKGS-_NB-R

PKGS-_NB-R

Part Number	Primary Axis Inclined Angle (°)	Sensitivity* (pC/G)	Capacitance (pF)	Insulation Resistance (M ohm)	Resonant Frequency (kHz)	Non-linearity (%)
PKGS-00NB-R	0	0.153 typ.	480 typ.	500 min.	44 typ.	1 typ.
PKGS-25NB-R	25	0.168 typ.	520 typ.	500 min.	44 typ.	1 typ.
PKGS-45NB-R	45	0.133 typ.	440 typ.	500 min.	43 typ.	1 typ.

Operatig Temperature Range : -40°C to 85°C   Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

Charge Sensitvity Large Type PKGS-_MF-R Series
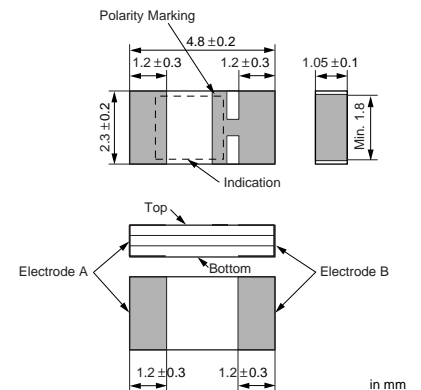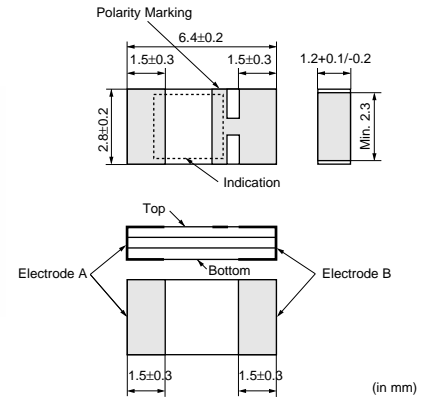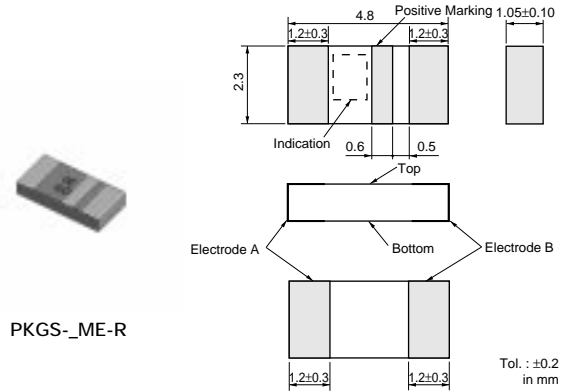
5

PKGS-_MF-R

Part Number	Primary Axis Inclined Angle (°)	Sensitivity* (pC/G)	Capacitance (pF)	Insulation Resistance (M ohm)	Resonant Frequency (kHz)	Non-linearity (%)
PKGS-00MF-R	0	0.325 typ.	570 typ.	500 min.	27 typ.	1 typ.
PKGS-25MF-R	25	0.350 typ.	610 typ.	500 min.	27 typ.	1 typ.
PKGS-45MF-R	45	0.285 typ.	490 typ.	500 min.	26 typ.	1 typ.

Operatig Temperature Range : -40°C to 85°C   Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

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Charge Senstitvity Type PKGS-_LD-R Series

PKGS-_LD-R

Polarity Marking
6.4±0.2
1.5±0.3 1.5±0.3
1.2+0.1/-0.2
2.8±0.2
Min. 2.3
Indication

Top
Electrode A
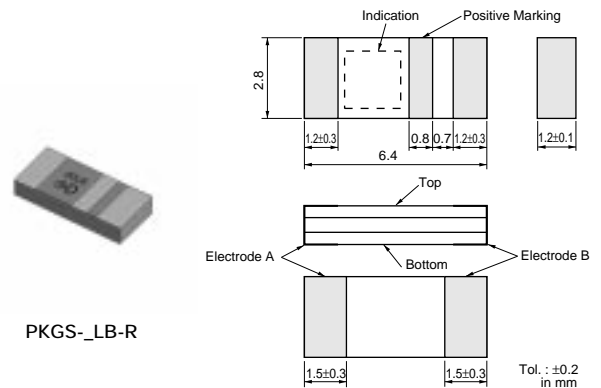Bottom
Electrode B
1.5±0.3 1.5±0.3
(in mm)

Part Number	Primary Axis Inclined Angle (°)	Sensitivity* (pC/G)	Capacitance (pF)	Insulation Resistance (M ohm)	Resonant Frequency (kHz)	Non-linearity (%)
PKGS-00LD-R	0	0.840 typ.	770 typ.	500 min.	20 typ.	1 typ.
PKGS-45LD-R	45	0.790 typ.	690 typ.	500 min.	18 typ.	1 typ.

Operatig Temperature Range : -40°C to 85°C   Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

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Voltage sensitivity Type PKGS-_ME-R Series

PKGS-_ME-R

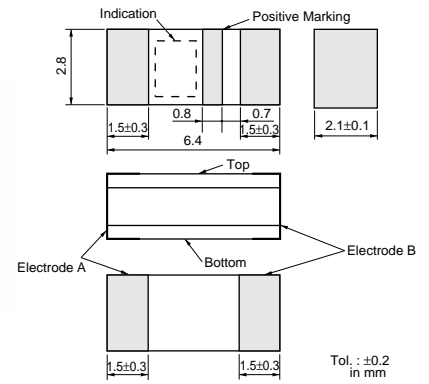| Part Number	Primary Axis Inclined Angle (°)	Sensitivity* (mV/G)	Capacitance (pF)	Insulation Resistance (M ohm)	Resonant Frequency (kHz)	Non-linearity (%)
PKGS-00ME-R	0	1.00 typ.	160 typ.	500 min.	27 typ.	1 typ.
PKGS-25ME-R	25	1.0 typ.	170 typ.	500 min.	27 typ.	1 typ.
PKGS-45ME-R	45	1.00 typ.	210 typ.	500 min.	27 typ.	1 typ.

Operatig Temperature Range : -40°C to 85°C   Storage Temperature Range : -40°C to 85°C
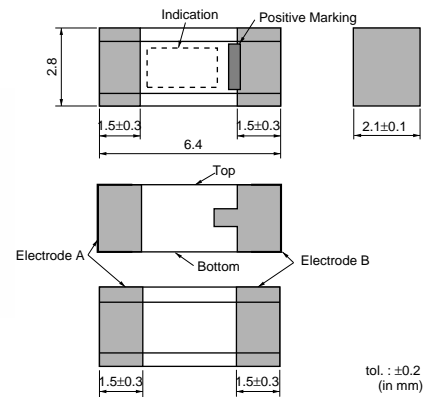*1G=9.80665m/s²

Voltage sensitivity Type PKGS-_LB-R Series

PKGS-_LB-R

Part Number	Primary Axis Inclined Angle (°)	Sensitivity* (mV/G)	Capacitance (pF)	Insulation Resistance (M ohm)	Resonant Frequency (kHz)	Non-linearity (%)
PKGS-00LB-R	0	1.85 typ.	210 typ.	500 min.	20 typ.	1 typ.
PKGS-25LB-R	25	1.85 typ.	240 typ.	500 min.	20 typ.	1 typ.
PKGS-45LB-R	45	1.93 typ.	295 typ.	500 min.	20 typ.	1 typ.

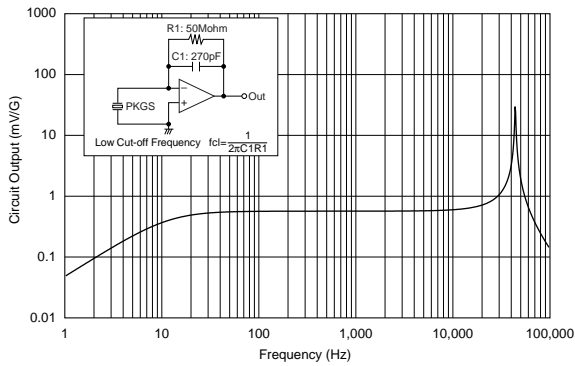Operatig Temperature Range : -40°C to 85°C   Storage Temperature Range : -40°C to 85°C
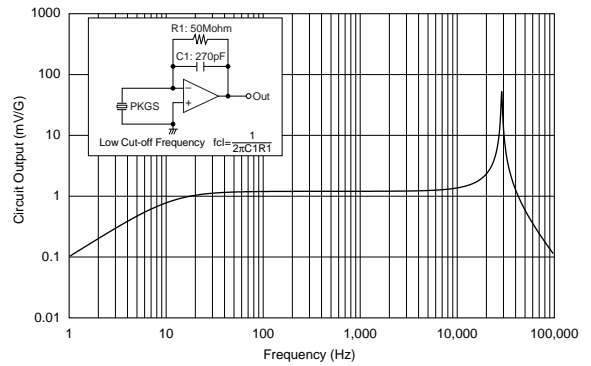*1G=9.80665m/s²

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Voltage sensitivity Type PKGS-_LC-R Series

PKGS-00LC-R

PKGS-90LC-R

Part Number	Primary Axis Inclined Angle (°)	Sensitivity* (mV/G)	Capacitance (pF)	Insulation Resistance (M ohm)	Resonant Frequency (kHz)	Non-linearity (%)
PKGS-00LC-R	0	2.10 typ.	420 typ.	500 min.	20 typ.	1 typ.
PKGS-90LC-R	90	2.10 typ.	420 typ.	500 min.	20 typ.	1 typ.

Operatig Temperature Range : -40°C to 85°C   Storage Temperature Range : -40°C to 85°C

*1G=9.80665m/s²

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Reference Data
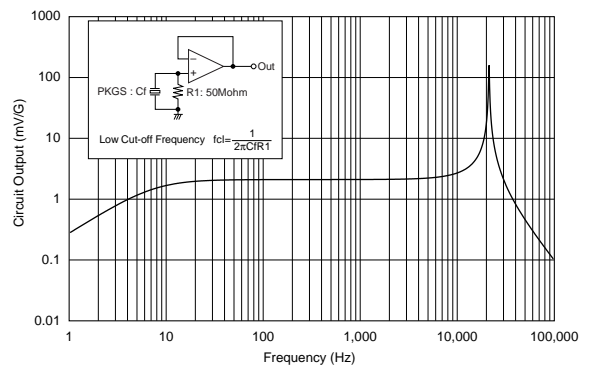
■ Freq. Characteristics (Typical)

PKGS-_NB-R

PKGS-_MF-R

PKGS-_LD-R
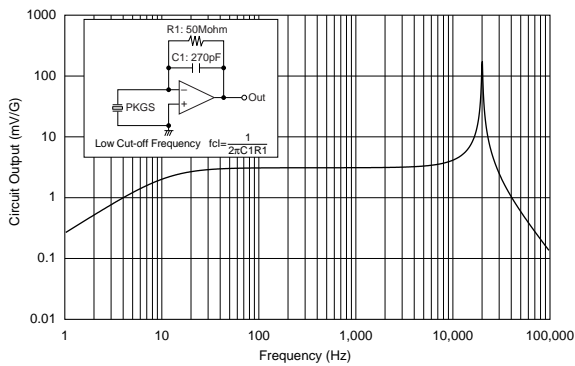
PKGS-_ME-R
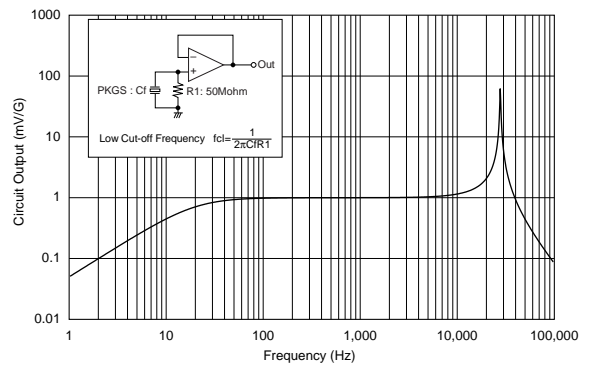
PKGS-_LB-R
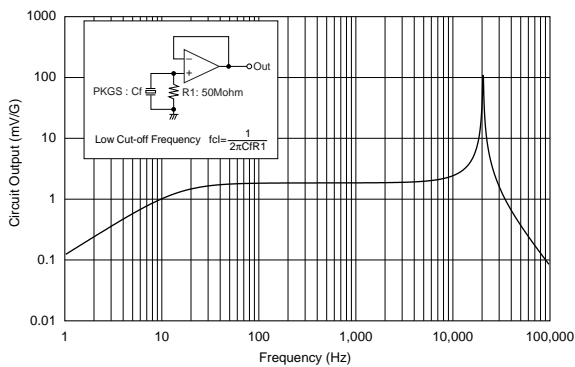
PKGS-_LC-R

Under bar shown in part number is filled with two figures of inclined angle.

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PKGS Series Mounting/Notice/Part Numbering

■ Standard Land Pattern

Standard Land Pattern
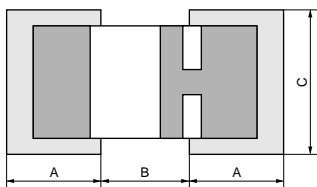
Dimensions

	PKGS-□□NB-R	PKGS-□□MF-R/ME-R	PKGS-□□LD-R/LB-R/LC-R
A	1.4 mm	1.7 mm	2.0 mm
B	2.0 mm	2.4 mm	3.4 mm
C	2.0 mm	2.3 mm	2.8 mm

■ Standard Reflow Profile

PKGS-_NB-R/MF-R/LD-R

PKGS-_ME-R/LB-R/LC-R
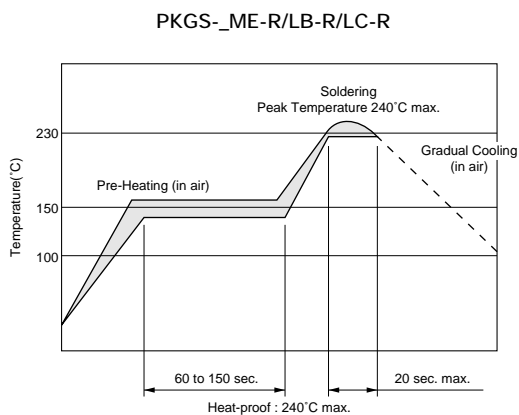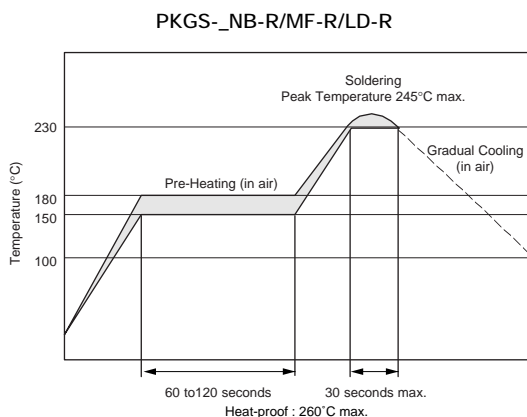
■ Notice (Rating)
Please do not apply DC voltage for this shock sensor.

■ Notice (Soldering and Mounting)
1. Depending on the factors such as the system for securing the PCB or the rigidity of the vibration member, a new resonance system can occur, which adversely affects the accuracy of the acceleration measurement with the shock sensor.
   Therefore, be very careful to eliminate factors that can affect accuracy.
2. Please inquire Murata for washing conditions.

● Part Numbering (The structure of the "Global Part Numbers" that have been adopted since June 2001 and the meaning of each code are described herein.
If you have any questions about details, inquire at your usual Murata sales office or distributor.)

Shock Sensors

(Global Part Number) **PK** **GS-25** **ME** **1** **-R**
                        ❶   ❷   ❸   ❹   ❺

❶Product ID
❷Series
❸Characteristics
❹Individual Specification Code
❺Packaging

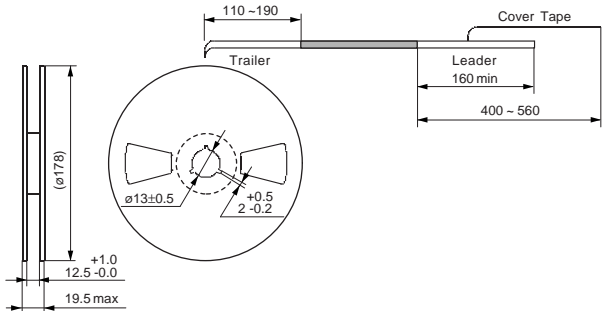* Global Part Number shows only an example which might be different from actual part number.
* "❸Characteristics" , "❹Individual Specification Code" and "❺Packaging" might have different digit number from actual Global Part Number.
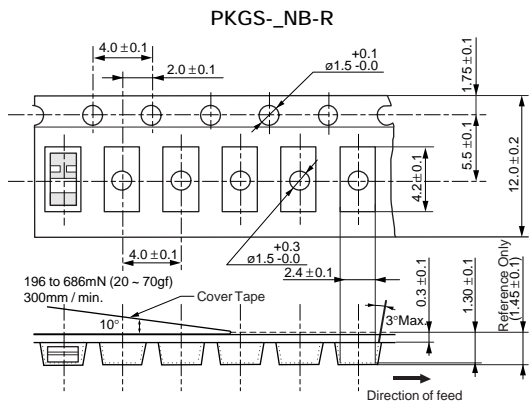
⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
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Package

■ Minimum Quantity
PKGS-_NB-R:180mm dir. reel/3000 pcs.
PKGS-_MF-R:180mm dir. reel/3000 pcs.
PKGS-_LD-R:180mm dir. reel/2000 pcs.
PKGS-_ME-R:180mm dir. reel/3000 pcs.
PKGS-_LB-R:180mm dir. reel/2000 pcs.
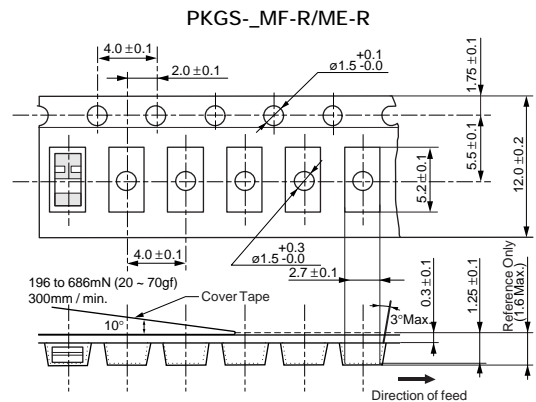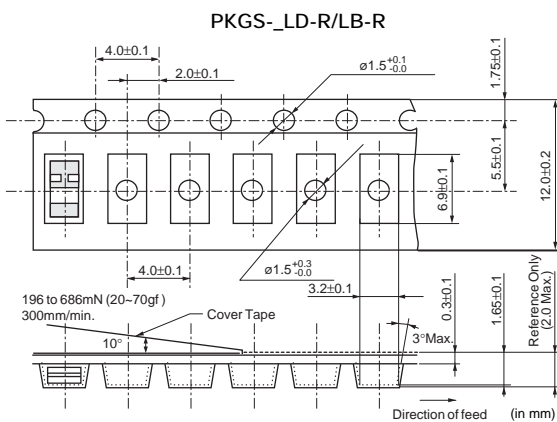PKGS-_LC-R:180mm dir. reel/1500 pcs.

■ Dimensions of Reel
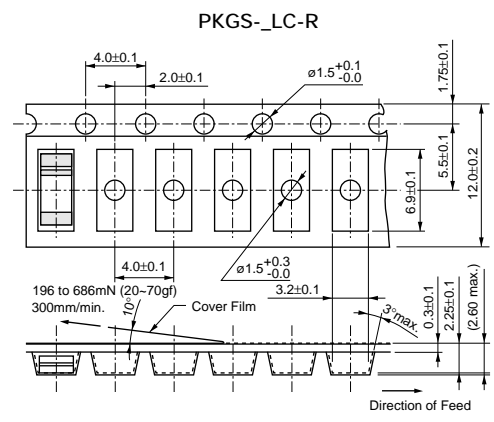
(in mm)

5

■ Dimensions of Taping

PKGS-_NB-R

PKGS-_MF-R/ME-R

PKGS-_LD-R/LB-R

PKGS-_LC-R

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# Piezoelectric Ceramic Sensors (PIEZOTITE®)

Shock Sensor

The piezoelectric element produces a voltage which is proportional to the acceleration of an impact or a vibration to which it is exposed. The shock sensor utilizes piezoelectric ceramics to convert the energy of impact into a proportional electrical signal. The piezoelectric shock sensor uses a "unimorph" diaphragm which consists of a piezoelectric ceramic disk laminated to a metal disk. The diaphragm is supported along its circumference in a housing. The sensor features compact, lightweight design, and is suitable for a wide range of applications requiring impact and vibration sensing.

PKS1-4A1

■ Features

1. Compact, lightweight design.
2. High sensitivity assures it picks up even microlevel impact and vibration.
3. Rugged construction survive impact and vibration stresses.
4. Requires no bias voltage.

■ Applications

1. Car burglar sensors on doors.
2. Intruder sensors at windows or doors.
3. Burglar alarms for showcases and safes.
4. Vibration sensors for car audio equipment
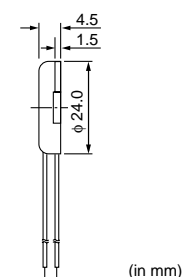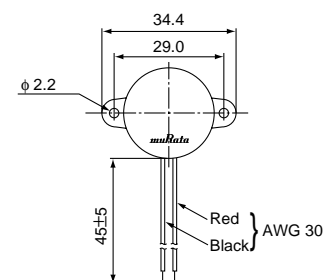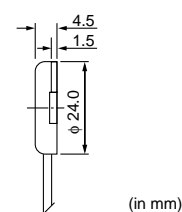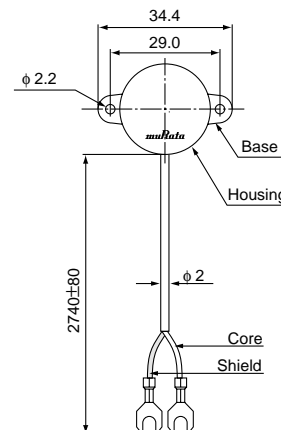
PKS1-4A10

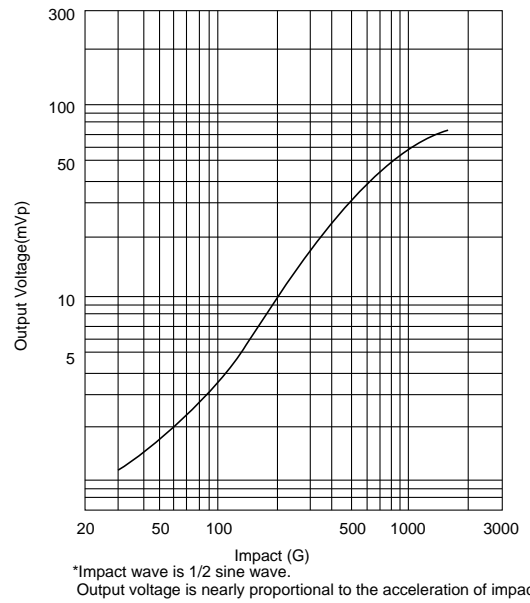| Part Number	Output Voltage	Capacitance	Insulation Resistance
PKS1-4A1	40mV0p /G TYP. 4.08mV0p/ (m/s²) TYP. (at 25°C, 20MΩ Load, 10Hz - 1kHz)	10000pF±30%	30MΩmin. (at 100V D.C.)
PKS1-4A10		9000pF±30%	

1G=9.8m/s²
Output Voltage is reference value.

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■ Characterisitics Data

● Frequency Response

Vibration Frequency (Hz)

Frequency Response is nearly flat at vibration frequencies up to 1kHz.
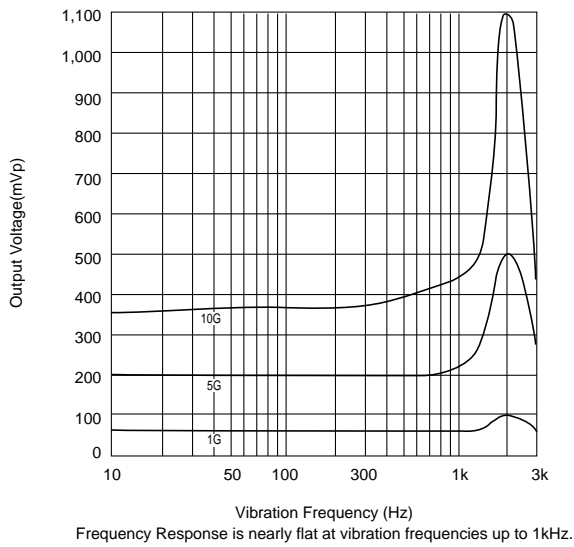
● Output Voltage vs. Impact Response

Impact (G)

*Impact wave is 1/2 sine wave.
Output voltage is nearly proportional to the acceleration of impact.

■ Notice

1. The component should be fixed at the place where the main axis of sensor has same direction as the vibration axis.

2. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

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Knocking Sensor Elements

The knocking sensor senses abnormal vibrations in an automobile engine. The sensor provides a feedback signal to the engine control system to suppress the knocking. Knocking sensors include a resonant type and a non-resonant type--both of which use piezoelectric elements. Murata offers highly-stable piezoelectric elements for use in knocking sensors which are directly mounted on the engine. Design emphasis is placed on heat-resistant, stress-resistant performance to ensure endurance in the harsh operation environment under the hood. Shape and dimensions are variable according to customer needs.
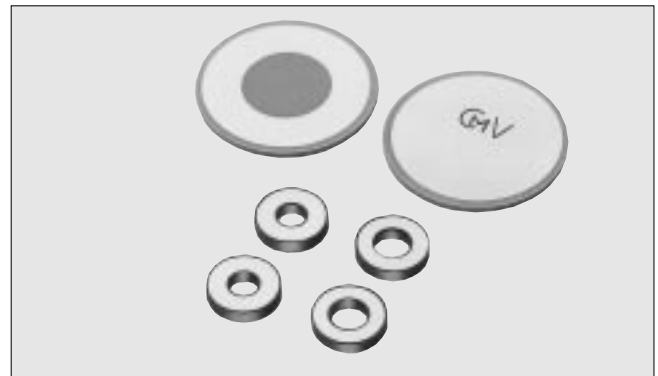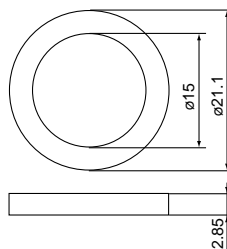
■ Features
1. Provides output voltage proportional to acceleration of vibration.
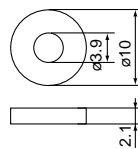2. Flat frequency response makes these sensors applicable to any type of engine (for non-resonant type).

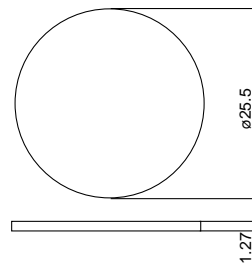### ■ Applications
Knocking sensors for automobile engines.
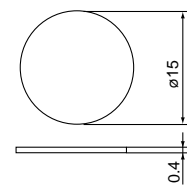
■ Dimensions (Typical value)

| 6CC-21-15-700 | 6CC-10-3R9-1000 | 7D-25-1600 | 7D-15-5400 |

ø15 ø21.1 2.85

ø3.9 ø10 2.1

ø25.5 1.27

ø15 0.4

(in mm)

Part Number	Resonant Frequency (kHz)	Capacitance (pF)	Electromechanical Coupling Coefficient (%)	Applications
6CC-21-15-700	66	450	18	Non-Resonant Type
6CC-10-3R9-1000	180	230	20	Non-Resonant Type
7D-25-1600	80	6300	45	Resonant Type
7D-15-5400	137	7200	55	Resonant Type

■ Notice
1. Do not touch the component with bare hand because the electrode may be damaged.
2. The component may be damaged if it is used in any application that deviates from its intended use noted within the specification.
3. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

Ultrasonic Bubble Sensor

The ultrasonic bubble sensor emits an ultrasonic wave into a fluid then senses waves reflected from bubbles.
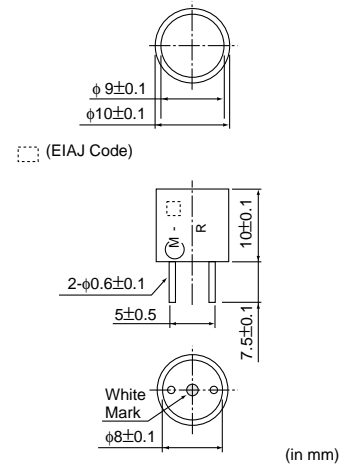
■ Features
1. Small and light
2. High sensitivity
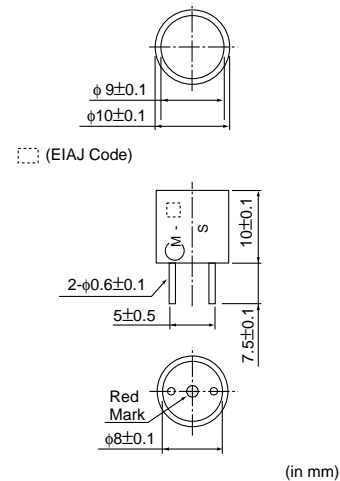3. Low power consumption
4. High durability

■ Applications
Senses the bubbles or fluids in tubes, e.g. vending machines.
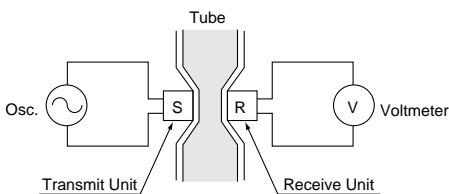
PKH 3-512B1R

φ 9±0.1
φ10±0.1
(EIAJ Code)
10±0.1
2-φ0.6±0.1
5±0.5
7.5±0.1
White Mark
φ8±0.1
(in mm)

PKH 3-512B1S

φ 9±0.1
φ10±0.1
(EIAJ Code)
10±0.1
2-φ0.6±0.1
5±0.5
7.5±0.1
Red Mark
φ8±0.1
(in mm)

Part Number	Nominal Frequency (kHz)	Capacitance (pF)	Electromechanical Coupling Coefficient (%)
PKH3-512B1R	512	280	55
PKH3-512B1S	512	220	56

■ Test Method

Tube
Osc. — S R — V Voltmeter
Transmit Unit / Receive Unit

■ Notice
1. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.
2. Characteristics can be changed by fixing method. Please contact us.

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Piezoelectric Ceramic Sensors (PIEZOTITE®)

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Electric Potential Sensors

Every object has its own surface electrical charges or charges given to it from other objects. These electrical charges cause the object to have a certain electric potential with respect to other objects. The electric potential sensor is designed to measure this surface potential.

There are two major surface potential detection methods : The field-mill method and the vibrating capacitance method.

The former method synchronously shuts off the electrical flux from the object surface and modulates the electric field incident to the sensing electrode to induce an AC current on the electrode, proportional to the surface potential (DC). The latter method forms a capacitance across the surface of the object and the sensing electrode, and vibrates the sensing electrode vertically the surface of object to induce electrical charges which are proportional to the capacitance and surface potential, thereby obtaining an AC current proportional to the surface potential (DC).

Murata's potential sensors, use a high-precision, piezoelectric tuning fork ("MICROFORK") with a proven production record, to achieve field shut-off vibration and electrode vibration. Integrating all of the signal processing circuit, Murata's electric potential sensor assures high operating stability and reliability.

in mm

■ Features
1. Compact, low-profile design.
2. DC voltage output.
3. High-precision liner output and highly stable.
4. Integrates all signal processing blocks, including oscillation, amplifying and rectifying circuit.
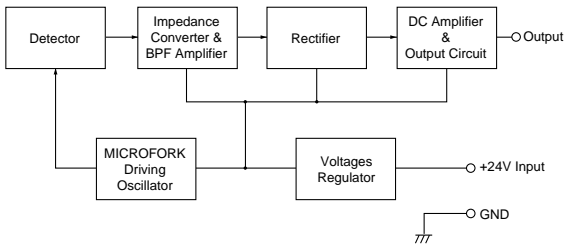
■ Applications
1. Sensing of surface electric potential for photosensitive drums used in PPC machines and laser beam printers.
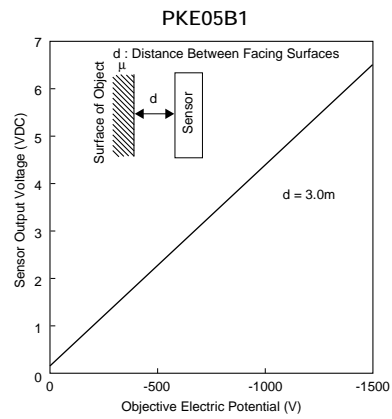2. High voltage measurement and detection for high voltage equipment.
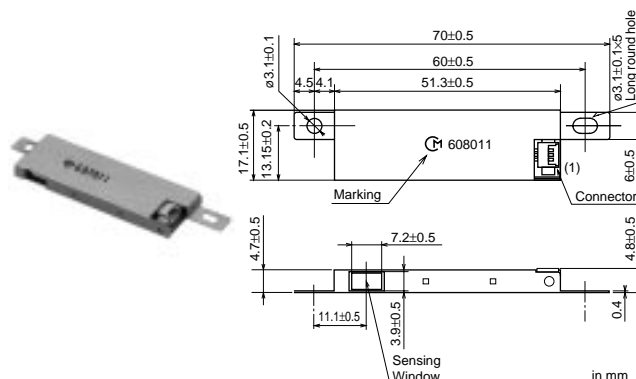
Part Number	Supply Voltage (Vdc)	Current Consumption (mA)	Min. Detectable Electric Potential (V)	Max. Detectable Electric Potential (V)	Output Voltage	Linearity (%)
PKE05A1	24 +/-10%	50 max.	0	1500	1/240Vdc of the objective potential	+/-1.5 max.(at 50V~1500V)
PKE05B1	24 +/-10%	50 max.	0	-1500	1/240Vdc of the objective potential	+/-1.5 max.(at -50V~-1500V)

Operation Temperature Range : 0°C to 60°C   Storage Temperature Range : -30°C to 80°C
Detection for negative electric potential are also available.

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■ Circuit Configuration

■ Output Voltage-Objective Potential

PKE05A1

PKE05B1
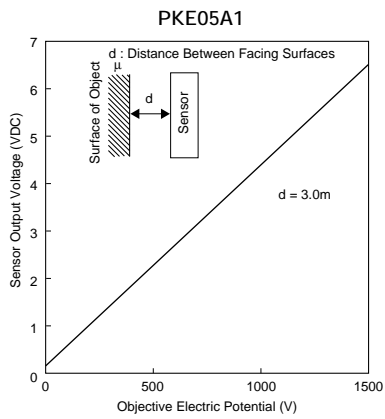
■ Temperature Characteristics
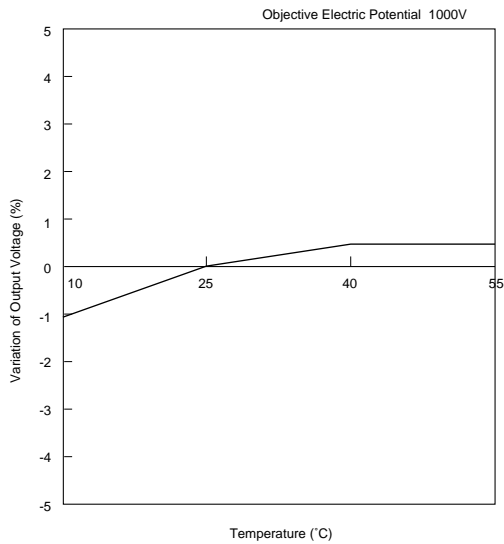
■ Notice (Rating)

Using conditions such as source voltage, temperature range mentioned in this drawing should be kept.

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■ Notice (Handling)

1. Electro-static voltage and excessive voltage or reverse voltage may damage the sensor.

2. The sensor should be kept from excessive shock.

3. Please insure the component is thoroughly evaluated in your application circuit because the output voltage and the distance are correlated.

● Part Numbering (The structure of the "Global Part Numbers" that have been adopted since June 2001 and the meaning of each code are described herein. If you have any questions about details, inquire at your usual Murata sales office or distributor.)

Electric Potential Sensors

(Global Part Number) | PK | E05 | A | |
❶ ❷ ❸ ❹

❶Product ID
❷Series
❸Characteristics
❹Individual Specification Code

* Global Part Number shows only an example which might be different from actual part number.
* Any other definitions than "❶Product ID" might have different digit number from actual Global Part Number.

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⚠Note Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this PDF catalog to prevent smoking and/or burning, etc.
This catalog has only typical specifications. Therefore, you are requested to approve our product specification or to transact the approval sheet for product specificaion before ordering.

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1. Export Control
   〈For customers outside Japan〉
   Murata products should not be used or sold for use in the development, production, stockpiling or utilization of any conventional weapons or mass-destructive weapons (nuclear weapons, chemical or biological weapons, or missiles), or any other weapons.
   〈For customers in Japan〉
   For products which are controlled items subject to the "Foreign Exchange and Foreign Trade Law" of Japan, the export license specified by the law is required for export.

2. Please contact our sales representatives or product engineers before using our products listed in this catalog for the applications listed below which require especially high reliability for the prevention of defects which might directly cause damage to the third party's life, body or property, or when intending to use one of our products for other applications than specified in this catalog.
   ① Aircraft equipment   ② Aerospace equipment
   ③ Undersea equipment   ④ Power plant equipment
   ⑤ Medical equipment   ⑥ Transportation equipment (vehicles, trains, ships, etc.)
   ⑦ Traffic signal equipment   ⑧ Disaster prevention / crime prevention equipment
   ⑨ Data-processing equipment   ⑩ Application of similar complexity and/or reliability requirements to the applications listed in the above

3. Product specifications in this catalog are as of May 2002. They are subject to change or our products in it may be discontinued without advance notice. Please check with our sales representatives or product engineers before ordering. If there are any questions, please contact our sales representatives or product engineers.

4. Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this catalog to prevent smoking and/or burning, etc.

5. This catalog has only typical specifications because there is no space for detailed specifications. Therefore, please approve our product specification or transact the approval sheet for product specification before ordering.

6. Please read CAUTION and Notice in this catalog for safety. This catalog has only typical specifications. Therefore you are requested to approve our product specification or to transact the approval sheet for product specification, before ordering.

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