## BASIC PRINCIPLES

A piezoelectric ceramic element is a sintered body of many crystals (Poly-crystals). Distortion of this crystal occurs when a stress is applied to the element, either thermally, mechanically or electrically. These distortions create many possible uses including alarm and sensor applications.

In using piezoelectric elements in audible output applications, a metal plate is attached to the ceramic element because the resonant frequency of the ceramic is too high to produce an audible tone by itself. This metal plate vibrates as shown in Fig. 70-1 due to the contraction and expansion of the piezo ceramic, and an audible signal is produced. The resonant frequency "$f_o$" at this stage is expressed by the following equation:

$$f_o = \frac{0.412t}{a^2}\sqrt{\frac{E}{P_0\,(1\text{-}o^2)}}$$

where, $f_o$ : fundamental resonant frequency
t : thickness
a : radius of disk
E : Young's modulus
$P_0$ : density
O : Poisson's ratio

In this case, if the sound element is considered as a homogenous disk consisting of the piezoelectric ceramic and metal plate, the resonant frequency shall be proportional to the thickness and inversely proportional to the square of the radius, namely:

$$f_o = \alpha\frac{t}{a^2} \text{ where } \alpha = .412\sqrt{\frac{E}{P_0\,(1\text{-}o^2)}}$$

Typical Example:

| | |
|---|---|
| Resonant frequency: | 2.8kHz |
| Metal plate: | 35mm dia. |
| Thickness: | 0.3mm |
| Piezoelectric ceramic: | 25mm dia. |
| Thickness: | 0.22mm |

## IMPEDANCE CHARACTERISTICS

The equivalent circuit for Murata Electronics' elements is shown in Fig. 70-3. The mechanical Resonance of the element is shown by R, L, C where L and C determine the Resonant frequency (Fig. 3).

$$f_o = \frac{1}{2\pi\sqrt{L_1C_1}}$$

Because the shunt capacitor is larger than the series combination the total impedance is capacitive.

## MODES OF VIBRATION AND SUPPORTING METHODS FOR THE SOUND ELEMENT

Three principal modes of vibration can be created in the element depending on the style of mounting. This is illustrated in Fig. 70-2.

## MOUNTING

### (1) Node Support

The sound element shown in Fig. 70-2(a) is node mounted, allowing it to vibrate in a free state. The node, a circumference where no vibration takes place, is created as shown by the broken line in Fig. 70-1.

Mounting at the node causes the least mechanical suppression of vibration, thus allowing the greatest amplitude. Hence this mounting method, as illustrated in Fig. 71-6(a), gives the highest sound pressure output and the most stable oscillation frequency of the three choices. As a result, this is the most appropriate design for high output, self-drive applications.

The dimensions of the node can be approximated by the equation illustrated in conjunction with Fig. 70-4. However, since the sound element is a combination of a piezoelectric

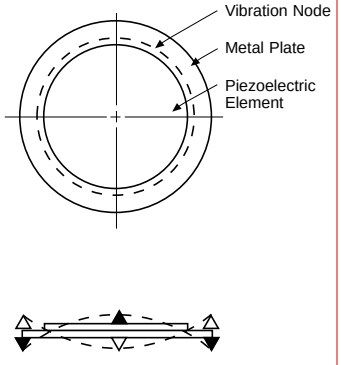



**Fig. 70-1**
Bending Vibration Node

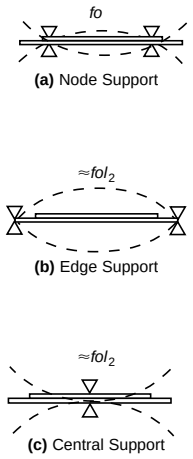



**Fig. 70-2**
Vibrating Mode of Piezo Alarm

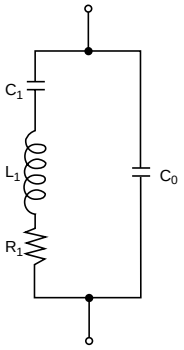



**Fig. 70-3**

**DIMENSIONS: in.**

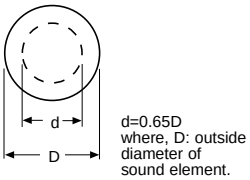



**Fig. 70-4**

ceramic element and a metal plate, each with tolerances, there is a deviation from theoretical values.

Some typical examples of these values would include:

| Murata Electronics Part # | Approximate Dia. |
|---|---|
| 7BB-35-3 | 22mm |
| 7BB-27-4 | 16mm |
| 7BB-20-6 | 13.5mm |

**(2) Edge Support**
Fig. 70-2(b) shows the mode of vibration when the sound element is supported at the edges. In this mounting configuration, the whole sound plate vibrates up and down as is illustrated by the broken line in the diagram. Hence, the edge method as illustrated in Fig. 71-6(b), suppresses the fundamental resonant frequency by moving the node. This offers the possibility of a wide frequency response, and is most advantageously used with external drive.

**(3) Center Support**
Fig. 70-2(c) shows the mode of vibration when the sound element is supported at the center. As the main vibration area is forcefully supported, large sound pressure levels are not possible when this method is used. This too is appropriate for external drive but due to design difficulties center support is not useful as an alarm.

## CIRCUIT DESIGN CONSIDERATIONS

**1. Driving Waveshape**
The piezo elements may be driven by either sinusoidal, pulsed, or square wave, depending upon the particular application. If a sine wave is used, the device will operate at a frequency lower than the resonant frequency ($f_o$) with a lower sound pressure level. The reason for this is the loss of energy, through the time lag between peak deflections as shown in Fig. 72-7. It is important that a clean sinusoidal signal be provided, as any clipping of the waveform can result in frequency instability. If square waves or pulsed waves are used to drive the elements, a higher acoustic output will be realized, along with an increase in harmonic levels. A parallel capacitor can reduce these harmonics.

**2. Driving Frequency:**
For maximum output, a frequency of between 500Hz and 4kHz should be used, as recommended by the specific part chosen.

**3. DC Precautions:**
In order to prevent depolarization of the ceramic elements it is necessary that every precaution be taken to prevent them from being subjected to direct current. Murata recommends the use of appropriate blocking capacitors for this purpose.

**4. High Voltage Precautions:**
Voltages higher than those recommended by Murata can damage the ceramic, even if applied for short durations. Due to the strength of the piezoelectric effect, high voltage can cause the crystals to break the sintered bonds, resulting in permanent damage. Significantly higher sound pressure levels will not be achieved by voltages higher than those recommended by Murata.

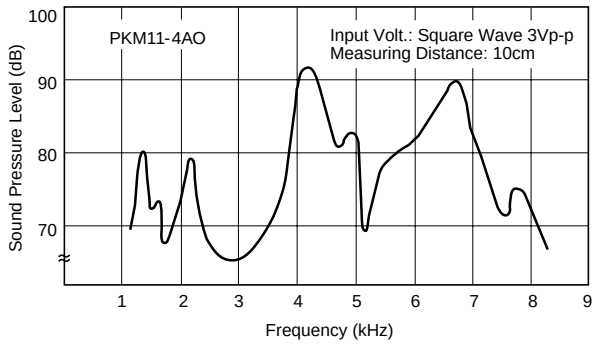



**Fig. 71-5**
Characteristics of
Sound Pressure Level vs. Frequency

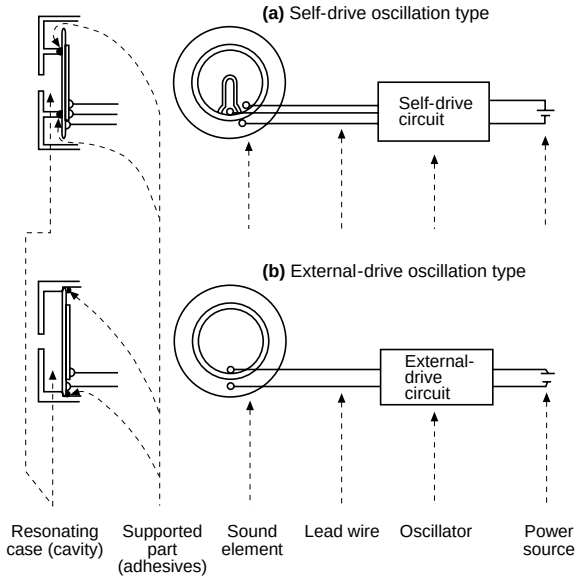



**Fig. 71-6**
Oscillation System of Piezo Buzzer

**5. Booster Coil Applications:**
When using a booster coil, do not exceed voltage recommendations as the coil will heat up, passing too much current to the transistor.

**6. Shock:**
Mechanical impact on buzzers or elements can generate high voltages that can seriously harm drive circuitry. Suitable diode protection is advisable in applications where mechanical shock is possible. Zener diode see Fig. 72-8(a); Schottky diode see Fig. 72-8(b).

**7. Mounting Glue:**
Proper application of mounting glue is necessary to produce adequate sound pressure levels.

**8. Design of Resonating Case:**
When an element is supported and has no case, the sound pressure level is small. This is because the acoustical impedance of the elements does not match that of any open air loading. However, by building a resonating case, the acoustical impedance of the element and encased air can be matched. This case can be designed using the following *(Helmholtz's equation)*:

$$f_o = \frac{c}{2\pi}\sqrt{\frac{4a^2}{d^2h\,(t + ka)}}$$

$f_o$ = Resonant frequency of Cavity (Hz)
c = Sound velocity 34.4x103 cm/sec @ 24°C
a = Radius of sound emitting hole (cm)
d = Diameter of support
h = Height of cavity (cm)
t = Thickness of cavity
k = Constant ≅ 1.3

**Typical Example (Node Mount):**
1) Determine element to use
   ex. 7BB-35-3C
2) Find Node diameter
   Node = .65 • 3.5cm
   where the Dia. of the element is 3.5cm and Node is 2.2cm
3) Determine thickness of cavity
   ex. t = 0.1cm
4) Determine h and a by shape balance. PKM8-3AO is designed on the basis of the above procedures.

**Note:** When designing the resonating case for the edge mount configuration, the case must be designed for approximately half the resonate frequency of the element.

**9. Electrostatic Capacitance**
It is necessary to match the output impedance of the oscillator with the transducer impedance in order to get maximum sound pressure level from the transducer. The actual electrostatic capacitance can be calculated from the following formula.

$$C = \frac{132.064D^2}{t}\ pF$$

D = Diameter of electrode (cm)
t = Thickness of ceramic (cm)

Example: The electrostatic capacitance of a 7BB-20-6 can be found by knowing D and t.
Assuming D = 1.28cm
t = .022cm

$$C = \frac{132.064\ (1.28)^2}{.022}\ pF$$
$$= 9{,}835pF$$

**10. Soldering Recommendations**
The desired location for soldering lead wires on an element is the point nearest to the edge of the silver surface. The desired location for soldering a lead to the metal plate is the area between the end of the plate and the end of the ceramic. Below are the conditions for soldering.

| | Ceramic (AG) | Metal Plate |
|---|---|---|
| Soldering Iron | 25W | 25W |
| Temperature | 330°C±30°C | 330°C±30°C |
| Time | 0.5 sec. max. | 2-4 sec. |
| Solder | Ag solder | Ag solder |

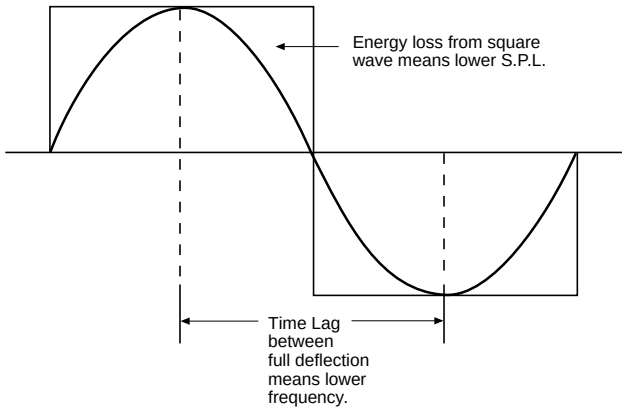



**Fig. 72-7**
Deflection Diagram of Piezoelectric Element

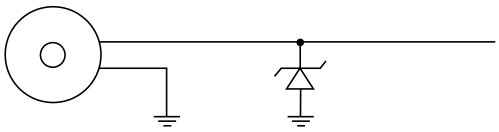


**Fig. 72-8(a)**

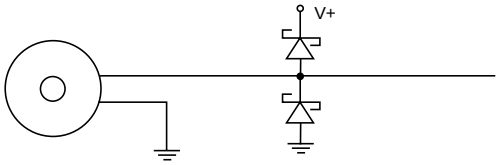



**Fig. 72-8(b)**


**(a)** Node Mount

**(b)** Edge Mount

**Fig. 72-9**

# CIRCUITRY
## SELF-DRIVE (with feedback electrode)

Fig. 73-1 shows a modified Hartley oscillator with a grounded emitter in which the equivalent inductance and capacitance of the sound element replaces the function of the coil and capacitor of the Hartley circuits. Stable tone generation at high sound pressure levels, combined with a low cost is the basic feature of this circuit which uses one transistor and three resistors.

Basic oscillating conditions for the self-driven circuit are:

A. The phase difference between $V_o$ and $V_f$ in Fig. 73-1 should not be less than 180°.

B. $\frac{V_f}{V_o} \geq \frac{R_2 + H_{ie}}{h_{fe} \bullet R_3}$ should be satisfied.

C. $R_1$ should be set so that the DC bias point $V_{ce}$ of Tr is 50% of the supply voltage.

D. $R_2$ must be adjusted to avoid any spurious emission in the output.

Typical values based on the above conditions:
$R_1$ = 200DΩ, $R_2$ = 10kΩ, $R_3$ = 510kΩ and $h_{fe}$ for Tr = 160 to 320. The output-supply voltage characteristics for a typical circuit satisfying these conditions are shown in Fig. 73-2.

(This circuit is not appropriate for switched operation with the input switching signal connected at the transistor base, (shown as X), since the feedback voltage is not disconnected and switching may not occur.)

### INTEGRATED CIRCUIT DESIGN

A driving circuit, utilizing a CMOS inverter IC is illustrated in Fig. 73-3. Using an inverter or NAND gate IC, an astable, modified, multi-vibrator driving circuit, as shown in Fig. 73-3, can also be designed.

A significant increase in the sound pressure level may be realized by this circuit design, if a feedback electrode is employed. In Fig. 73-3, the phase of the feedback voltage is inverted 180° by going through $R_1$, to inverter B, thus forming a positive feedback loop. Figs. 73-4 and 5 show how the oscillation frequency and sound pressure react to changes in $R_1$ and $C_1$.



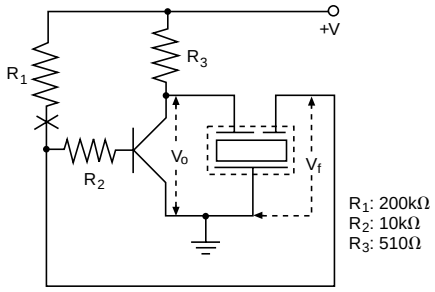



**Fig. 73-1**
Self-Drive Circuit

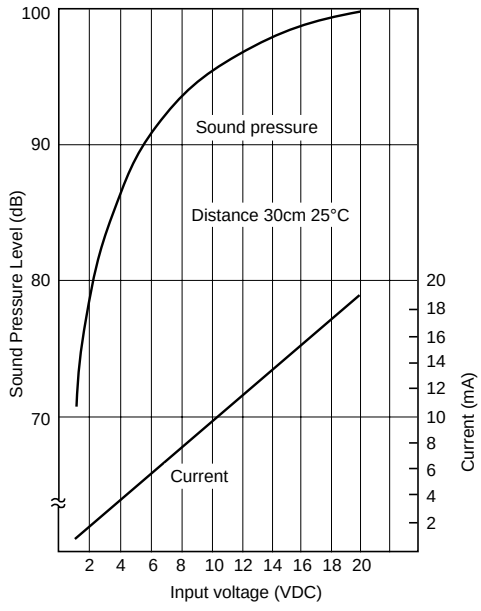



**Fig. 73-2**
Typical Output vs. Supply Voltage Characteristics

**Fig. 73-3**
IC Oscillation Circuit

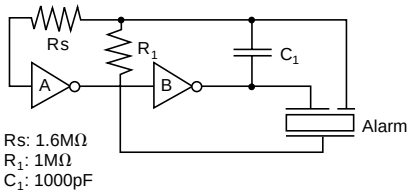



**Fig. 73-4**
Relationship of $R_1$ and $C_1$ to Oscillation Frequency

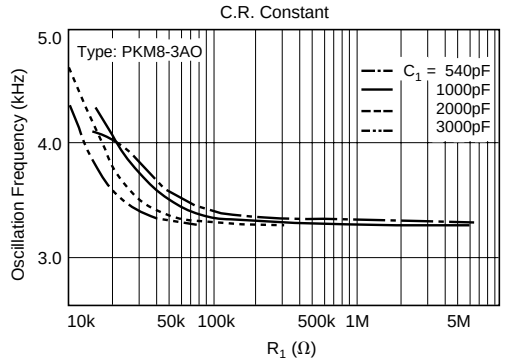
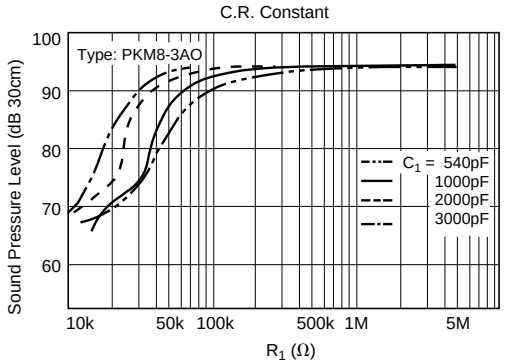



**Fig. 73-5**
Relationship of $R_1$ and $C_1$ to Sound Pressure Level



# CIRCUITRY
# EXTERNAL-DRIVE (without feedback electrode)

Over the last several years piezo alarms have found extensive use in watches, calculators, game machines and other applications due to their low current requirements and small size. Their use has become widespread in such products as microwave ovens, clothes dryers, washing machines, automobile warning systems, TV's and games. Recent developments in LSI technology will enable the use of piezo elements in facsimile and data transmission applications.

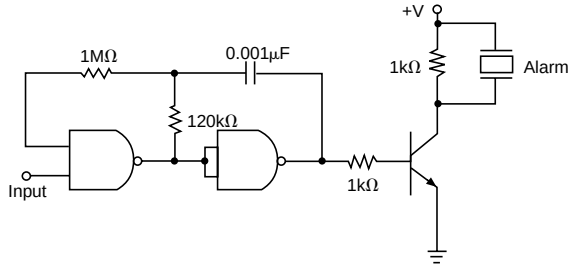
As LSI technology has improved, more and more applications, other than telecommunications, have opened up for piezo devices. Some of the typical applications and circuit designs using this are shown in Fig. 74-6. As illustrated, there are a number of variations in these externally driven oscillators. For instance, Fig. 74-6(a), is an oscillating circuit with two NAND gates which oscillates or stops by the **On and Off** change-over of the input signals. Fig. 74-6(b), describes a ringing tone circuit (telephone sound) which produces a ring with $f_3$ cycles between $f_1$ and $f_2$. Fig. 74-6(c), illustrates a typical watch circuit with LSI. Fig. 74-6(d), a circuit that can be used to produce outputs resembling insect sounds.

There are a multitude of applications for these externally driven devices. Essentially, the possible uses for these externally driven piezo elements is limited only by the imagination of the user.

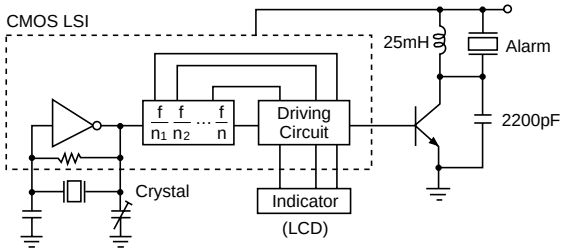
## BOOSTER COILS

In applications such as wrist watches and calculators, a booster coil may be used to compensate for sound pressure attenuation caused by casing external to the piezo element. For instance, Fig. 74-7 shows a typical circuit where this is applied.

When Tr is switched **On and Off** by the output voltage of an LSI with t sec. of rise or fall time, a back voltage proportional to L is also generated in the inductance. The sound pressure level is increased in proportion to the back voltage with a V p-p more than several times larger than the supply voltage.

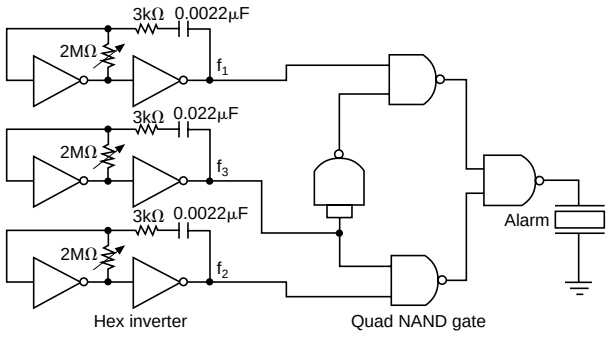



**(a)** I.C. oscillation circuit without feedback

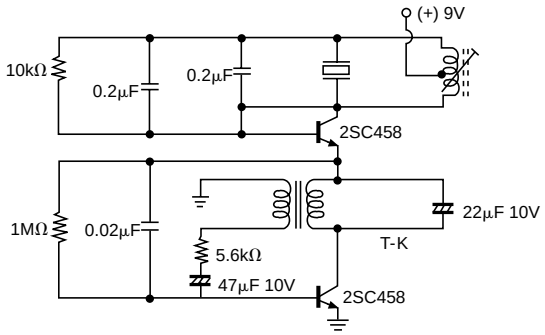



**(c)** Watch circuit

**Fig. 74-6**
Examples of
External-drive circuits




**(b)** Ringing circuit (for telephone)




**(d)** Oscillation circuit for cricket sound (onomatopoeia)

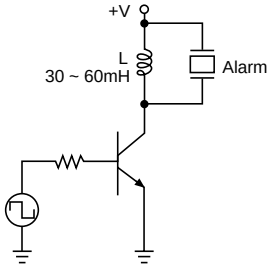



**Fig. 74-7**
Circuit with Booster Coil

# ENCASED PIEZO ALARMS
# TAPING TYPE

Innovator in Electronics

## PKM Series

Taking advantage of our extensive automatic insertion designing technology and materials experience, we have developed standard taping type piezoelectric sounder. This Murata technology supports labor and cost saving activities.

### FEATURES

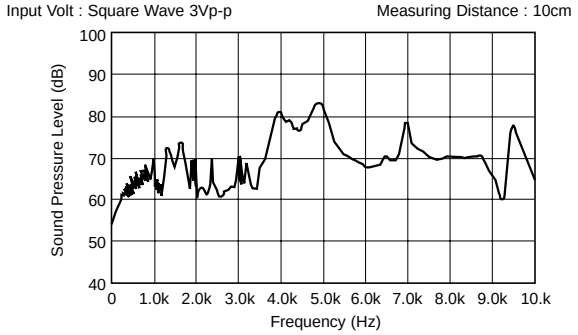
- High and stable mountability
- Flat packaging
- Packaging quantity: 500pcs



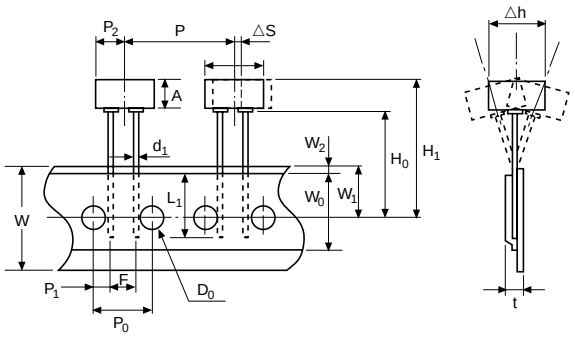
### SPECIFICATIONS

| Part Number | PKM13EPY-4000-TF01 |
|---|---|
| Sound Pressure Level (3Vp-p square wave 10cm) | 70dB min. (4kHz) |
| Capacitance | 5500pF ± 30% (1kHz) |
| Max. Input Voltage | 25Vp-p |
| Operating Temp. Range | –20°C ~ +70°C |
| Storage Temp. Range | –30°C ~ +80°C |
| Packaging Quantity | 500pcs/1 pack |

### FREQUENCY RESPONSE




### TAPE AND AMMO BOX




### DIMENSIONS: mm

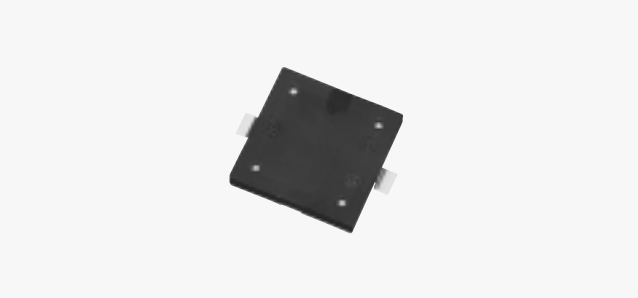
| Item | Code | Nominal Value | Tol. | Remarks |
|---|---|---|---|---|
| Width of Diameter | D | ϕ12.6 | ±0.5 | |
| Height of Resonator | A | 6.9 | ±0.5 | |
| Dimension of Terminal | $d_1$ | ϕ0.5 | ±0.1 | |
| Lead Length Under the Hold Down Tape | $L_1$ | 8.0 min. | — | |
| Pitch of Component | P | 25.4 | ±0.5 | |
| Pitch of Sprocket | $P_0$ | 12.7 | ±0.2 | Tolerance for Pitches 10 x $P_0$ = 127 ± 2mm |
| Length from Hole Center to Lead | $P_1$ | 3.85 | ±0.7 | |
| Length from Hole Center to Component Center | $P_2$ | 6.35 | ±0.7 | |
| Lead Spacing | F | 5.0 | ±0.5 | |
| Slant to the Forward or Backward | Δh | 0 | ±1.0 | 360° : 1mm max. |
| Width of Carrier Tape | W | 18.0 | ±0.5 | |
| Width of Hold Down Tape | $W_0$ | 12.5 min. | — | Hold down tape does not exceed the carrier tape |
| Position of Sprocket Hole | $W_1$ | 9.0 | ±0.5 | |
| Gap of Hold Down Tape and Carrier Tape | $W_2$ | 2.0 max. | — | |
| Distance Between the Center of Sprocket Hole and Lead Stopper | $H_0$ | 18.0 | ±0.5 | |
| Total Height of Resonator | $D_0$ | ϕ4.0 | ±0.2 | |
| Diameter of Sprocket Hole | $H_1$ | 26.0 max. | — | |
| Total Thickness of Tape | t | 0.6 | ±0.2 | |
| Body Tilt | ΔS | 0 | ±1.0 | |

# PIEZO ALARMS
# ENCASED SMD PIEZOELECTRIC SOUNDER

NEW

muRata
Innovator in Electronics

## PKMC Series



Taking advantage of extensive acoustic and mechanical designing technology and high performance ceramics, Murata has developed an SMD piezoelectric sounder that suits thin, high-density design of electronic equipment.

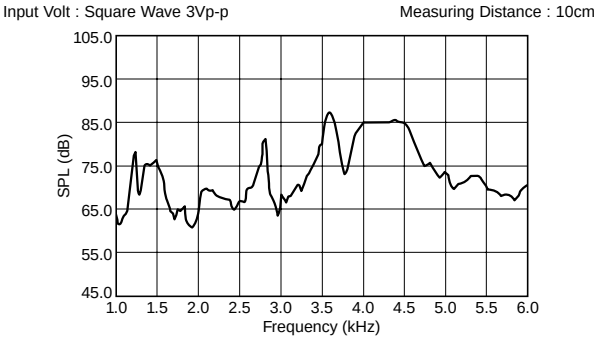
### FEATURES

- High S.P.L. and clear sound
- Reflowable
- Tray packaging
- Minimum quantity (order in sets only): 1,200 pcs.

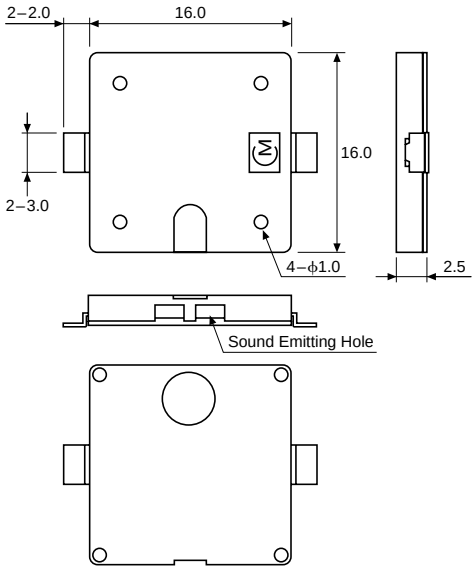
### SPECIFICATIONS

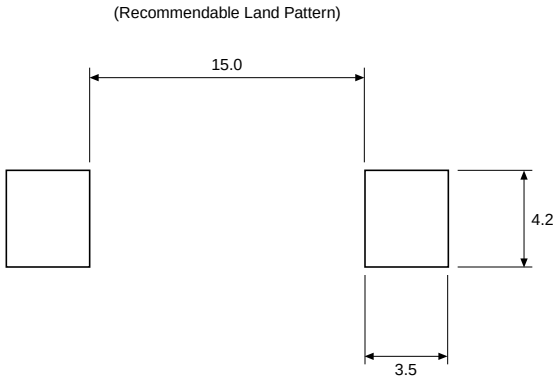
| Part Number | PKMC16E-4000-TY |
|---|---|
| **Sound Pressure Level (3Vp-p square wave 10cm)** | 75dB min. (4kHz) |
| **Capacitance** | 14nF ± 30% (1kHz) |
| **Max. Input Voltage** | 25Vp-p |
| **Operating Temp. Range** | –20°C ~ +70°C |
| **Storage Temp. Range** | –30°C ~ +80°C |

### FREQUENCY RESPONSE




### DIMENSIONS: mm




Tolerance: ±0.3

# ENCASED EXTERNAL DRIVE (no internal circuitry)

muRata
Innovator in Electronics

## PKM Series

The piezo alarms described on this page have no “feedback” tab and are particularly suited for the generation of both single tones and the unusual sound effects that are possible with specifically designed driving circuits. These sounds may include musical melodies, insect sounds, etc.

All mechanical and electrical components are designed to be compatible with most standard PC board assembly and wave soldering techniques.

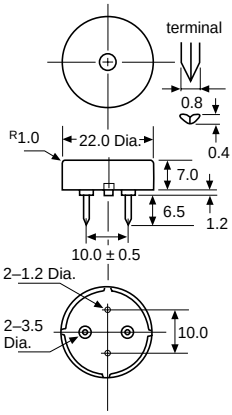
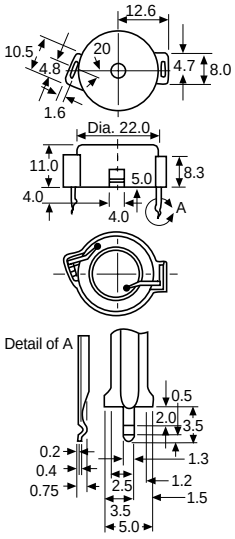
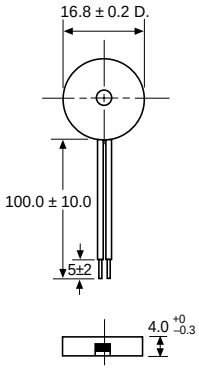
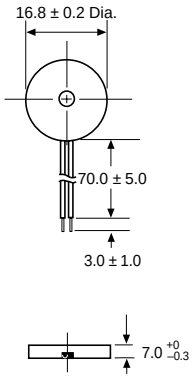
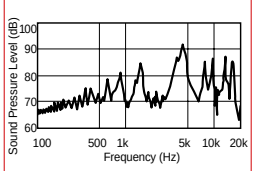
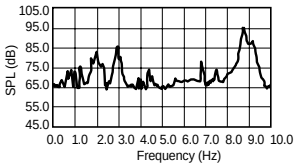
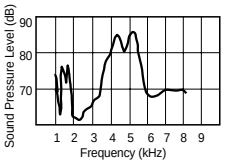
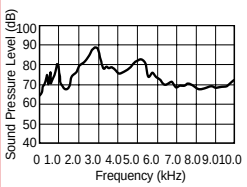
### FEATURES

- Rugged construction
- Compatible with wave soldering techniques
- Low cost
- High reliability
- Variable tone outputs
- No EMI

### APPLICATIONS

- Musical toys
- Home appliances (microwave ovens, refrigerators, etc.)
- Communications equipment
- Computer peripherals and office equipment
- Instrumentation, etc.

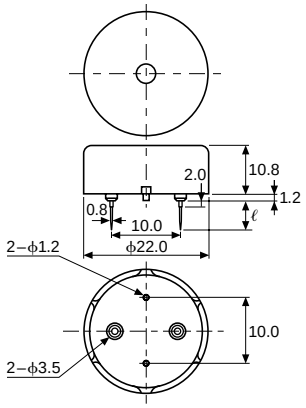
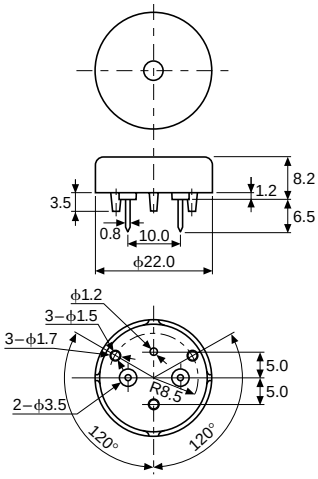
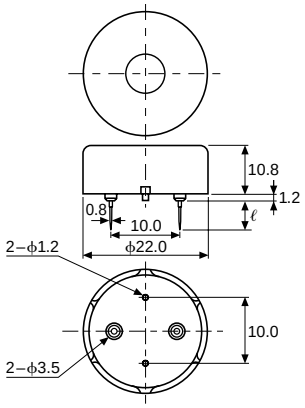
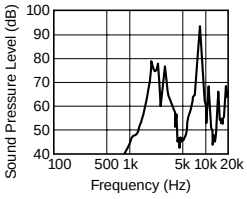
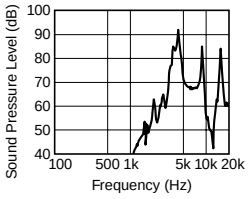
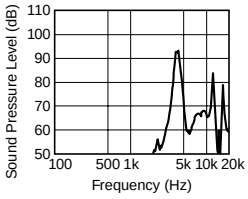


| Part Number | ★PKM22EPP-4001* | ★PKM22EP-2001 | NEW ★PKM22EP-2001R | ★PKM35-4A0 | ★PKM17EW-2001 |
|---|---|---|---|---|---|
| Sound Pressure Level | 75dB@10cm@3Vp-p | 75dB@10cm@3Vp-p | 75dB@10cm@3Vp-p | 75dB@10cm@3Vp-p | 72dB@10cm@3Vp-p |
| Oscillating Frequency | 4kHz | 2kHz | 2kHz | 4kHz | 2kHz |
| Operating Voltage | 25Vp-p | 25Vp-p | 25Vp-p | 25Vp-p | 7Vp-p max. |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –40°C to +125°C | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –40°C to +80°C | –40°C to +125°C | –30°C to +80°C | –30°C to +80°C |
| Capacitance | 12,000pF ± 30% at 1kHz | 17,000pF ± 30% at 120Hz | 17,000pF ± 30% at 120Hz | 9,500pF ± 30% at 1kHz | 40,000pF ± 30% at 120Hz |
| Leads | — | — | — | 32AWG (UL-1685) | 32AWG (UL-1685) |
| DIMENSIONS: mm |  |  Tolerance: ±0.5 |  |  |
| SOUND PRESSURE LEVEL VS. FREQUENCY |  Input Voltage: Square wave 3Vp-p Measuring Distance: 10cm |  Input Voltage: Square wave 3Vp-p Measuring Distance: 10cm |  Input Voltage: Square wave 3Vp-p Measuring Distance: 10cm |  Input Voltage: Square wave 3Vp-p Measuring Distance: 10cm |

*These parts are available as sealed units for washing with tape covering the sound emitting hole. The part number should have an “S” suffix added.
★Available as standard through authorized Murata Electronics Distributors.

# ENCASED EXTERNAL DRIVE (no internal circuitry)



| Part Number | *PKM22EPP-2001 | NEW PKM22EPP-2002R | PKM22EPP-4005 | PKM22EPP-4007 |
|---|---|---|---|---|
| Sound Pressure Level | 70dB@10cm@3Vp-p | 70dB@10cm@3Vp-p | 75dB@10cm@3Vp-p | 85dB@10cm@3Vp-p |
| Oscillating Frequency | 2kHz | 2kHz | 4kHz | 4kHz |
| Operating Voltage | 25Vp-p | 25Vp-p | 25Vp-p | 25Vp-p |
| Operating Temp. Range | –20°C to +70°C | –40°C to +125°C | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –40°C to +125°C | –30°C to +80°C | –30°C to +80°C |
| Capacitance | 19nF ± 30% at 120Hz | 19nF ± 30% at 120Hz | 12nF ± 30% at 1kHz | 12nF ± 30% at 1kHz |
| Leads | — | — | — | — |
| DIMENSIONS: mm |  | |  |  |
| | Part Number / ℓ(mm): PKM22EPP-2001 6.5; PKM22EPP-2002 3.5 | | | Part Number / ℓ(mm): PKM22EPP-4007 6.5; PKM22EPP-4012 3.5 |
| SOUND PRESSURE LEVEL VS. FREQUENCY |  | |  |  |

*Available as standard through authorized Murata Electronics Distributors.

# ENCASED EXTERNAL DRIVE (no internal circuitry)

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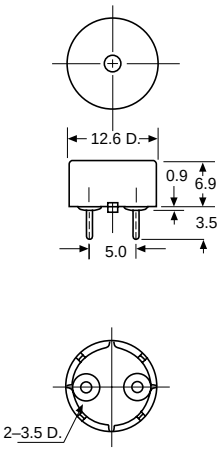
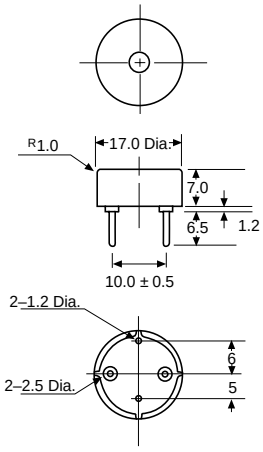
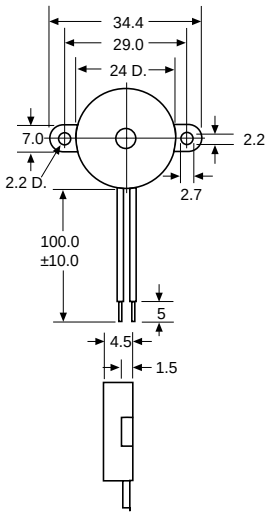
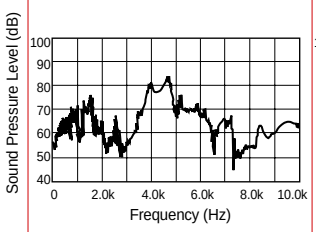
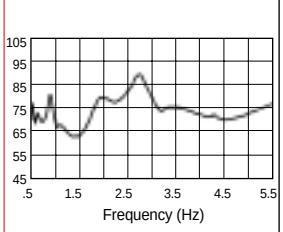
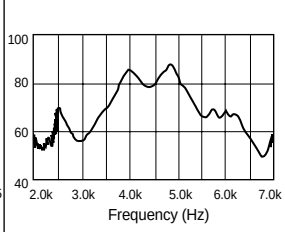
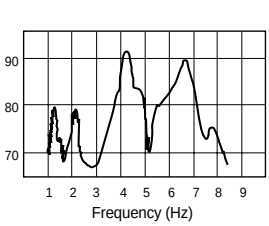
## PKM Series

### TYPICAL PART NUMBERING

| PKM | 22 | E | PP | — | 4 | 001 |
|---|---|---|---|---|---|---|
| External circuitry required | Case diameter | External drive required (Vp-p req.) | Pins for PC mounting | | Resonant frequency | Suffix for special requirements |

NEW

| Part Number | ★PKM13EPY-4002 | PKM17EPP-2002 | ★PKM17EPP-4001* | ★PKM11-4AO |
|---|---|---|---|---|
| Sound Pressure Level | 70dB@10cm@3Vp-p | 70dB@10cm@3Vp-p | 72dB@10cm@3Vp-p | 75dB@10cm@3Vp-p |
| Oscillating Frequency | 4.0kHz | 2kHz | 4kHz | 4kHz |
| Operating Voltage | 25Vp-p | 25Vp-p | 25Vp-p | 25Vp-p |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –20°C to +70°C | –20°C to +60°C |
| Storage Temp. Range | –30°C to +80°C | –40°C to +80°C | –30°C to +80°C | –30°C to +70°C |
| Capacitance | 5,500pF ± 30% | 3,400pF ± 30% | 7,000pF ± 30% | 10,000pF ± 30% |
| Leads | — | — | — | 30AWG (UL-1571) |
| DIMENSIONS: mm |  |  | |  |
| SOUND PRESSURE LEVEL VS. FREQUENCY<br>Input Voltage:<br>Square wave 3Vp-p<br>Measuring Distance: 10cm |  |  |  |  |

*These parts are available as sealed units for washing with tape covering the sound emitting hole. The part number should have an "S" suffix added.
★Available as standard through authorized Murata Electronics Distributors.

# ENCASED PIEZO ALARMS
# SELF DRIVE (no internal circuitry)



As the use of microprocessors in consumer products has become increasingly popular, so too has the use of piezo alarms as the accepted means of audio alarm generation. Their ability to be driven by IC's, small size, low cost and high reliability, make them ideal for such applications.

The units shown on this page are equipped with a feedback tab for use with self-oscillating circuit designs. By utilizing the feedback, the part's individual resonant frequency is found to optimize sound pressure level.

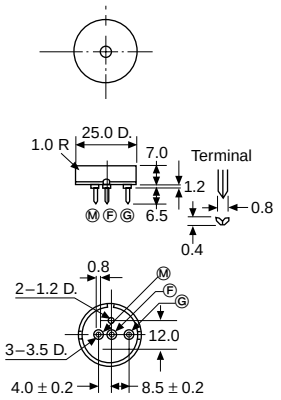
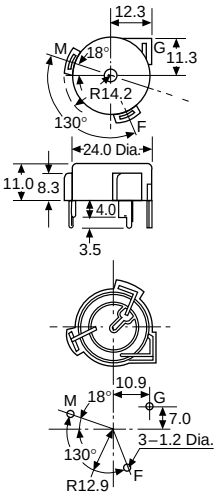
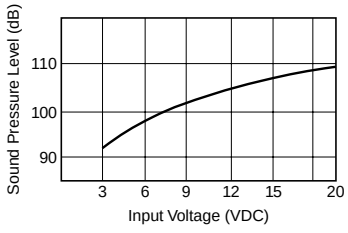
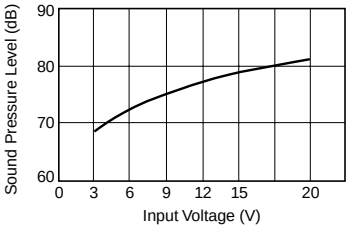
All mechanical and electrical components are designed to be compatible with most standard PC board assembly and wave soldering techniques.

## FEATURES

- Small size
- Low cost
- High sound pressure level
- Low input voltage
- Low current consumption

## APPLICATIONS

- Clocks
- Office equipment, machine tools, toys, games, etc.
- Automatic controlling devices instrumentation, calculators
- Home appliances (microwave ovens, refrigerators, etc.)
- Smoke alarms

| Part Number | ★PKM25-6AO | ★PKM24SP-3805 |
|---|---|---|
| Sound Pressure Level | 90dB@12V@10cm | 90dB@12V@10cm |
| Oscillating Frequency | 6.8 ± 0.7kHz | 3.8 ± 0.4kHz |
| Current | 10mA | 12mA |
| Operating Voltage | 3 to 20V | 3 to 20V |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –30°C to +80°C |
| DIMENSIONS: mm |   |   |
| SOUND PRESSURE LEVEL VS. INPUT VOLTAGE |   |   |

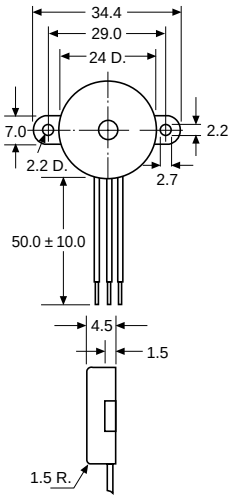
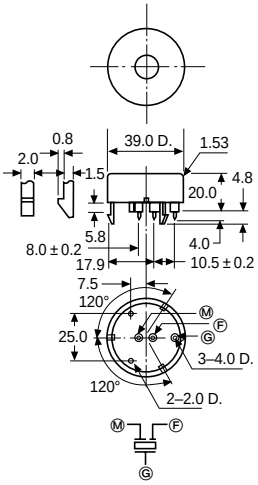
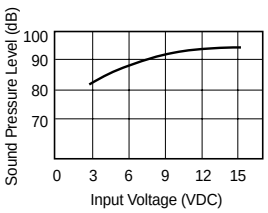
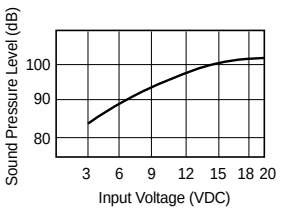
★Available as standard through authorized Murata Electronics Distributors.

# ENCASED EXTERNAL DRIVE (no internal circuitry)



## TYPICAL PART NUMBERING

| PKM | 30 | S | W | — | 3 | 001 |
|---|---|---|---|---|---|---|
| External circuitry required | Case diameter | Self drive required ($V_{DC}$ req.) | Lead wires | | Resonant frequency | Suffix for special requirements |

| Part Number | ★PKM11-6AO | ★PKM29-3AO |
|---|---|---|
| Sound Pressure Level | 80dB@12V@10cm | 105dB@9V@1M |
| Oscillating Frequency | 6.5 ± 0.7kHz | 3.4 ± 0.4kHz |
| Current | 8mA | 20mA |
| Operating Voltage | 3 to 15V | 4.5 to 18.0V |
| Operating Temp. Range | –20°C to +60°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +70°C | –30°C to +80°C |
| Leads | 30AWG (UL-1571) | — |
| DIMENSIONS: mm |  |  |
| SOUND PRESSURE LEVEL VS. INPUT VOLTAGE |  |  |









★Available as standard through authorized Murata Electronics Distributors.

# PIEZO ALARMS
# ENCASED WITH INTERNAL CIRCUITRY

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## PKB Series

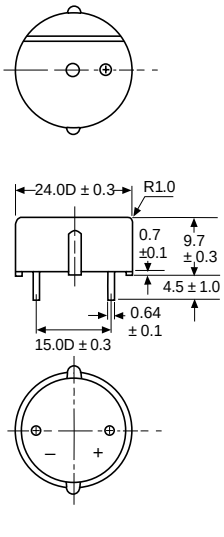
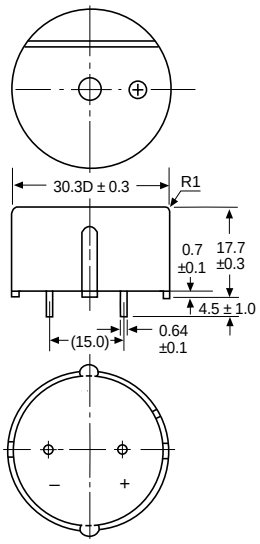
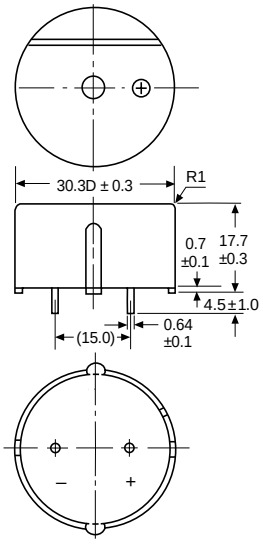
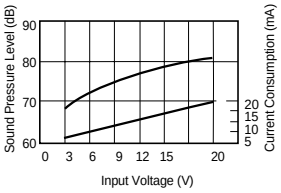
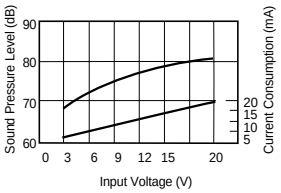
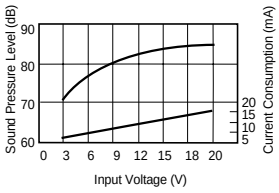
The PC board mountable piezo alarms described on this page are completely self-contained alarms requiring only a DC voltage source for operation. Providing the user with high audio output while requiring very low power, these devices can be operated over a broad range of input voltages. Their small size, high reliability and low cost make them ideal for a number of applications.

### FEATURES

- PC board mountable
- Completely self-contained
- Produce an extremely clear and penetrating sound output
- Compact size
- No electrical noise
- Very low power consumption
- Operable over a broad voltage range

### APPLICATIONS

- Data processing equipment (i.e., keyboards, disk drives, circuit board malfunction alarms)
- Electronic instrumentation
- Medical equipment
- Automatic control devices
- Cash registers

| Part Number | ★PKB24SPC-3601* | ★PKB30SPC-2001* | ★PKB30SPC-3001* |
|---|---|---|---|
| Sound Pressure Level | 90dB@10cm@12V | 92dB@10cm@12V | 92dB@10cm@12V |
| Oscillating Frequency | 3.6 ± 0.5kHz | 2.0 ± 0.4kHz | 2.7 ± 0.5kHz |
| Current | 16mA | 15mA | 15mA |
| Operating Voltage | 3 to 15V | 3 to 15V | 3 to 15V |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –30°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –30°C to +80°C | –30°C to +80°C |
| DIMENSIONS: mm |  |  |  |
| SOUND PRESSURE LEVEL VS. INPUT VOLTAGE / CURRENT CONSUMPTION VS. INPUT VOLTAGE |  |  |  |



*These parts are also available as washable parts with tape covering the sound emitting hole and epoxy seal at the case bottom. These parts are denoted with "W" suffix.

★Available as standard through authorized Murata Electronics Distributors.

# PIEZO ALARMS
## ENCASED WITH INTERNAL CIRCUITRY

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## PKB Series

The piezo alarms described on this page are completely self-contained alarms requiring only a DC voltage source for operation. Providing the user with surprisingly high audio outputs while requiring very low input power, they can be operated over a broad range of input voltages.

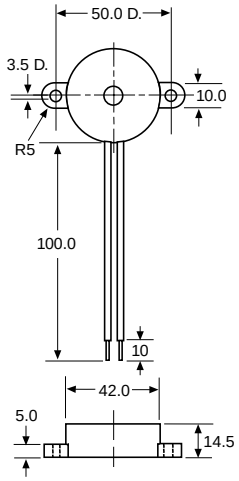
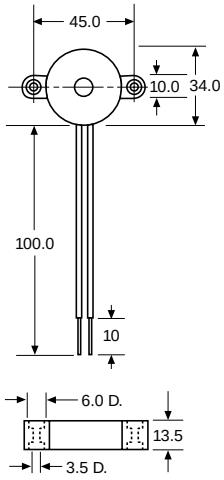
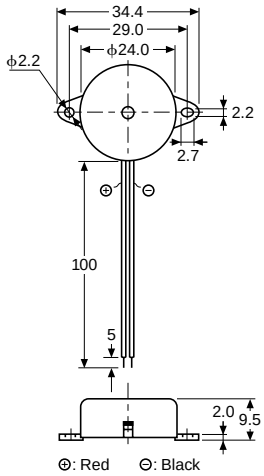
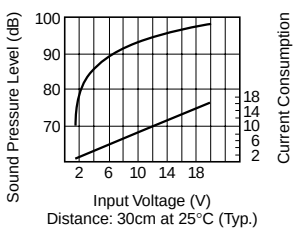
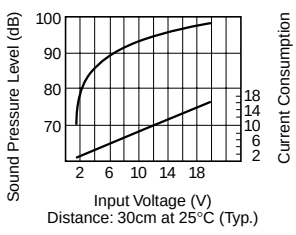
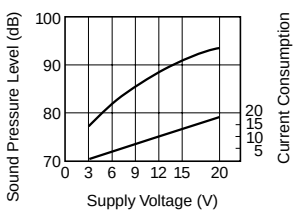
### FEATURES

- Completely self-contained
- Produce an extremely clear and penetrating sound which is audible through surrounding noises
- Audio output reaches long distances
- Compact size
- Light weight
- No electrical noise
- Very low power consumption
- Operable over a broad voltage range

### APPLICATIONS

- Fire alarms, burglar alarms, gas detectors
- Automotive alarms
- Toys, game machines, etc.
- Electrical appliances
- Automatic control devices, conveyors, medical equipment

PIEZO ALARMS

| Part Number | ★PKB5-3AO | ★PKB6-5AO | ★PKB24SW-3301 |
|---|---|---|---|
| Sound Pressure Level | 85dB@30cm@9V | 85dB@30cm@9V | 80dB@10cm@12V |
| Oscillating Frequency | 2.8 ± 0.5kHz | 4.7 ± 0.7kHz | 3.3 ± 0.5kHz |
| Current | 12mA @ 9V | 12mA @ 9V | 12mA max. |
| Operating Voltage | 3 to 20V | 3 to 20V | 3 to 20V |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –30°C to +80°C | –30°C to +80°C |
| Capacitance | — | — | — |
| Leads | 24AWG (UL-1007) | 24AWG (UL-1007) | 24AWG (UL-1007) |
| DIMENSIONS: mm |  |  |  |
| SOUND PRESSURE LEVEL VS. INPUT VOLTAGE / CURRENT CONSUMPTION VS. INPUT VOLTAGE<br><br>Measurements made with recommended measuring circuit. |  |  |  |

★Available as standard through authorized Murata Electronics Distributors.

# PIEZO ELEMENTS FOR TELEPHONE APPLICATIONS

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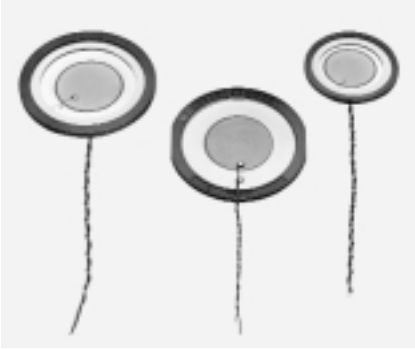
## VSB Series

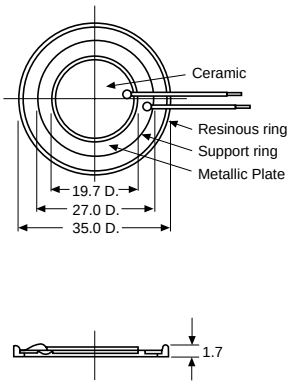
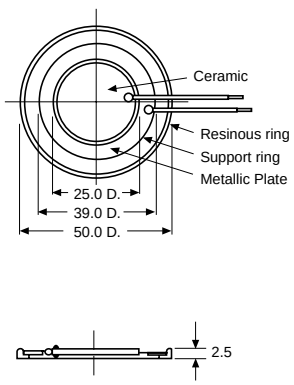
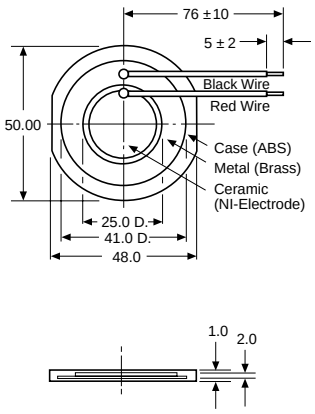
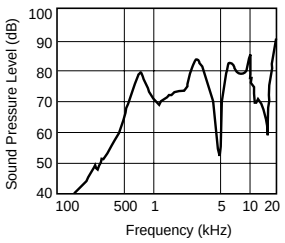
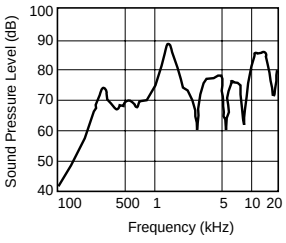
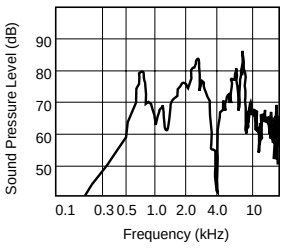


Recent advances in manufacturing technology have enabled Murata Electronics to mass produce piezoelectric ceramic elements as thin as 01mm. This capability has permitted the use of these devices in a variety of applications including speech synthesis and telecommunications.

The Model VSB41D25-07ARO piezo speaker unit has been designed to accurately reproduce speech patterns. Due to its small size, rugged construction and wide response curve, this element is suitable for voice synthesis applications such as clocks, vending machines, automobiles, toys and translating machines.

### FEATURES

- High efficiency compared to electro-magnetic devices
- Ultra-thin and lightweight
- High impedance, low power consumption requirements
- High reliability and durability
- No electric noise or EMI
- Can be driven directly by an IC

| Part Number | ★VSB35EW-0701B | ★VSB50EW-0301B | ★VSB41D25-07ARO |
|---|---|---|---|
| Frequency Range | 600Hz to 20kHz | 250Hz to 20kHz | 500Hz to 20kHz |
| Allowable Input | 75mW | 150mW | 30Vp-p |
| Free Resonance | 950Hz | 400Hz | 900Hz |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –30°C to +80°C | –30°C to +80°C |
| Capacitance | 340nF @ 120kHz ± 35% | 600nF @ 120kHz ± 35% | 140nF @ 120kHz ± 30% |
| Leads | 32AWG | 32AWG (UL-1685) | 32AWG (UL-1685) |
| DIMENSIONS: mm |  |  |  |
| SOUND PRESSURE LEVEL VS. FREQUENCY |  |  |  |

★Available as standard through authorized Murata Electronics Distributors.

# PIEZO RECEIVERS FOR TELEPHONE APPLICATIONS

PKD Series

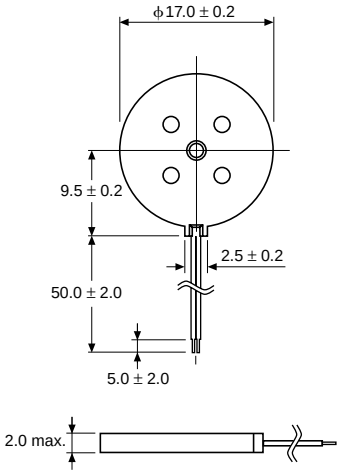
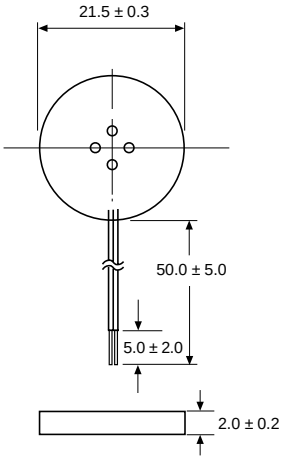
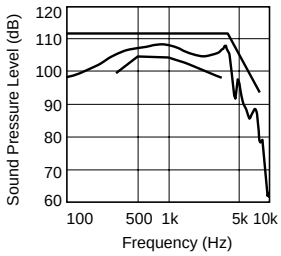
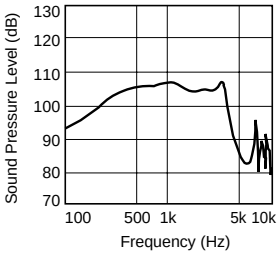
According to the progress of LSI and digital technology, more sophisticated and multi-functioning telephones have been developed for office automation.

The piezoelectric receiver PKD series for telephone (CERAMIPHONE®) use was developed to function as an electroacoustic transducer, especially for portable equipment such as mobile communication requiring small and thin components.

## FEATURES

- Thin shape, light weight
- Low current consumption and good matching impedance for a voltage drive



| Part Number | ★PKD17EW-01R | ★PKD22EW-01R |
|---|---|---|
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +70°C | –30°C to +70°C |
| Leads | 32AWG (UL-1685) | 32AWG (UL-1685) |
| DIMENSIONS: mm |  |  |
| At 1kHz, 1Vrms Sine Wave | 107 ± 3dB | 109 ± 3.5dB |
| SOUND PRESSURE LEVEL VS. FREQUENCY |  |  |

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# PIEZO RINGERS FOR TELEPHONE APPLICATIONS

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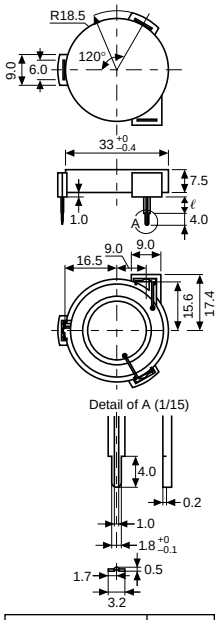
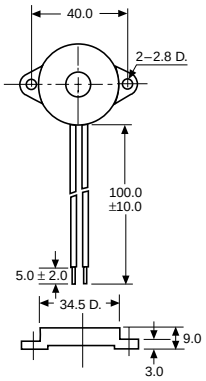
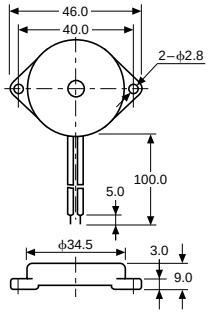
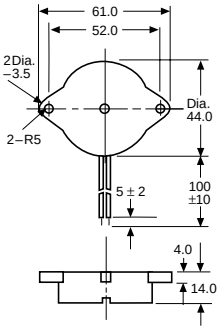
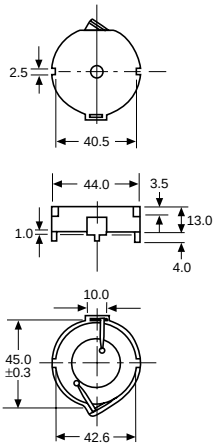
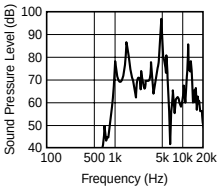
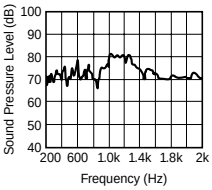
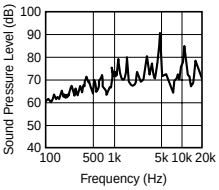
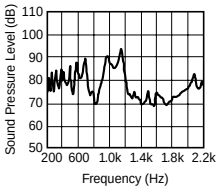
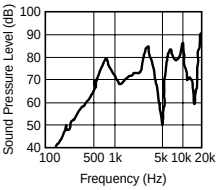
## PKM Series

As the number of telephones using IC's has increased dramatically during the past several years, there has been a corresponding increase in the number of telephone manufacturers using piezo transducers as telephone ringers. Designed to replace the more expensive and larger electromechanical devices, these ringers are small, emit clear penetrating sounds, offer wide frequency ranges and are low cost.

Representative models of the Murata Electronics offering in this area are shown below.

### FEATURES

- Emit a clear penetrating sound
- Low power consumption
- Can be driven directly by IC's
- Extremely thin and lightweight
- Low frequency and multi-frequency capability
- No EMI/RFI

| Part Number | PKM33EP-1201C | ★PKM34EW-1101C | PKM34EW-1201C | ★PKM44EW-1001C | ★PKM44EP-0901 |
|---|---|---|---|---|---|
| Sound Pressure Level | 70dB@1M@30Vp-p | 70dB@1M@30Vp-p | 70dB@1M@30Vp-p | 75dB@1M@30Vp-p | 70dB@1M@30Vp-p |
| Oscillating Frequency | 1kHz | 1.1kHz | 1.2kHz | 1.0kHz | 1.0kHz |
| Operating Voltage | 40Vp-p max. | 40Vp-p max. | 60Vp-p max. | 30Vp-p max. | 40Vp-p max. |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –20°C to +70°C | –30°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –30°C to +80°C | –30°C to +80°C | –40°C to +80°C | –30°C to +80°C |
| Capacitance | 40nF ± 30% at 120Hz | 40nF ± 25% at 120Hz | 32nF ± 30% at 120Hz | 68nF ± 30% | 68nF ± 30% |
| Leads | — | 30AWG (UL-1571) | — | 28AWG (UL-1571) | — |
| DIMENSIONS: mm |  |  |  |  |  |
| SOUND PRESSURE LEVEL VS. FREQUENCY |  |  Input Voltage: 9.00Vp-p Square Wave Distance : 30.0cm |  |  |  |

| Part Number | ℓ (mm) |
|---|---|
| PKM33EP-1201C | 5.0 |
| PKM33EP-1202C | 0 |

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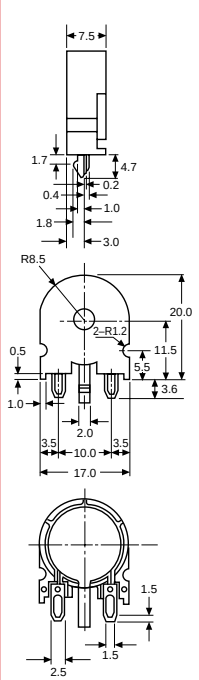
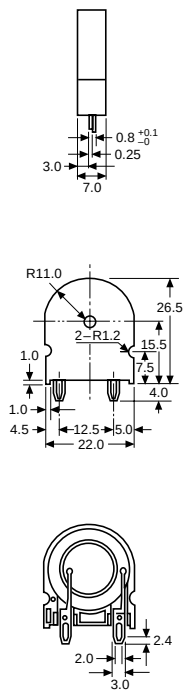
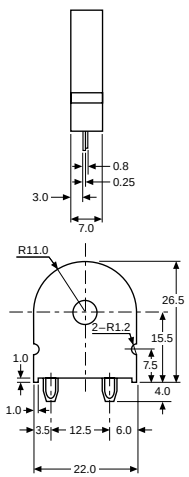
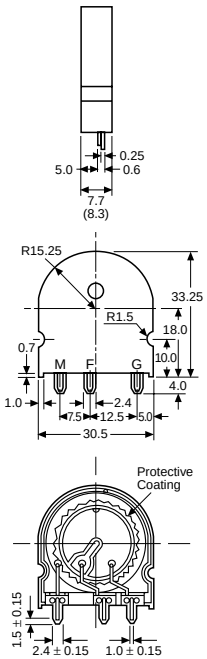
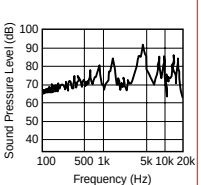
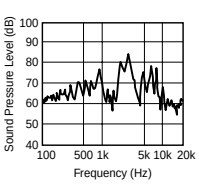
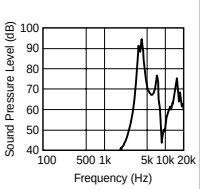
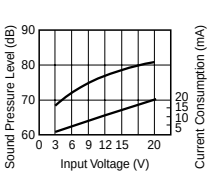
Murata Electronics produces piezo alarms meeting the requirements of special applications. These special requirements may be for specific physical and/or mounting configurations, frequency response characteristics or input drive parameters. The units illustrated on this page are a sampling of the special alarm configurations available from Murata.

Contact us with your specifications and requirements and we will be happy to work with you to meet them.

NEW

| Part Number | ★PKM17EPT-4001 | ★PKM22EPT-2001 | ★PKM22EPT-2001R | PKM22EPT-4001 | PKM30SPT-2501 | ★PKM30SPT-2001 |
|---|---|---|---|---|---|---|
| Sound Pressure Level | 75dB@10cm@3Vp-p | 70dB@10cm@3Vp-p | 70dB@10cm@3Vp-p | 85dB@10cm@3Vp-p | 80dB@10cm@12V | 75dB@10cm@12V |
| Oscillating Frequency | 4.0kHz | 2.0kHz | 2.0kHz | 4.0kHz | 2.5 ± 0.3kHz | 2.0 ± 0.3kHz |
| Current | — | — | — | — | 20mA max. | 20mA max. |
| Max. Operating Voltage | 25Vp-p | 25Vp-p | 25Vp-p | 25Vp-p | 3.0 to 20V | 3 to 20Vp-p |
| Operating Temp. Range | –20°C to +70°C | –20°C to +70°C | –40°C to +125°C | –20°C to +70°C | –20°C to +70°C | –20°C to +70°C |
| Storage Temp. Range | –30°C to +80°C | –30°C to +80°C | –40°C to +125°C | –30°C to +80°C | –30°C to +80°C | –30°C to +80°C |
| Capacitance | 9,500pF ± 30% | 19,000pF ± 30% | 19,000pF ± 30% | — | — | — |
| DIMENSIONS: mm |  |  | |  |  | |
| SOUND PRESSURE LEVEL VS. FREQUENCY OR INPUT VOLTAGE |  |  | |  | |  |

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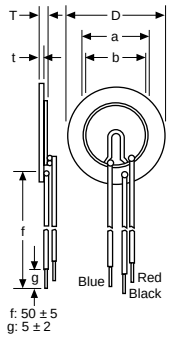
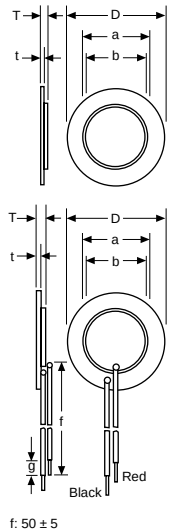
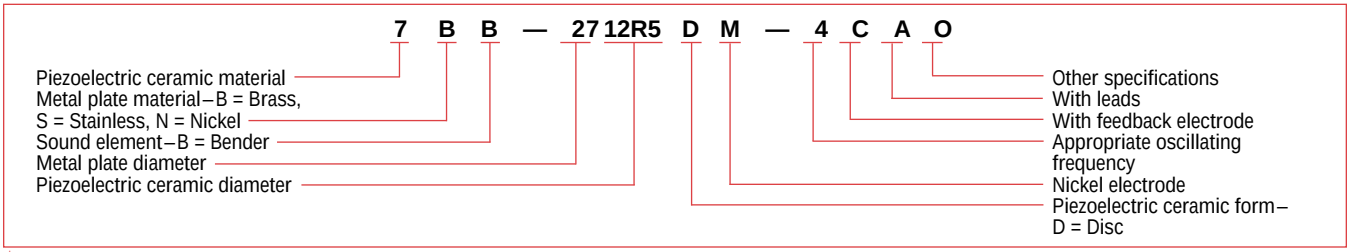
# 7BB, 7NB, 7SB Series

Murata Electronics offers a wide selection of piezo alarm elements capable of meeting virtually any application requirement. This includes both self-driven units, with a feedback electrode, and externally driven units that are designed to be driven by an external signal source.

For customers who choose not to use encased alarms from our wide selection, Murata also offers elements which can be designed into your own injection mold assemblies or other packages.

| | Part Number | Characteristics (*1, *2) | | | Dimensions: mm | | | | | NOTES |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Resonant Frequency (kHz) | Resonant Impedance (Ohms) | Capacitance (pF) ±30% | D | a | b | T | t | |
| **SELF-DRIVEN (with feedback electrode)** | | | | | | | | | | |
|  | ★7BB-20-6C | 6.3±0.6 | ≤500 | 8500 | 20.0±0.2 | 14.0±0.6 | 12.8±0.2 | 0.42±0.1 | 0.20±0.05 | — |
| | 7BB-27-3C | 3.0±0.5 | ≤300 | 35000 | 27.0 | 19.7 | 18.2 | 0.27 | 0.15 | — |
| | ★7BB-27-4C | 4.6±0.5 | ≤200 | 18000 | 27.0±0.2 | 19.7±0.6 | 18.2±0.2 | 0.54±0.1 | 0.30±0.05 | — |
| | ★7BB-35-3C | 2.8±0.5 | ≤200 | 24000 | 35.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.53±0.1 | 0.30±0.05 | — |
| | ★7BB-41-2C | 2.2±0.3 | ≤250 | 24000 | 41.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.63±0.1 | 0.40±0.05 | — |
| | ★7SB-34R7-3C | 3.1±0.3 | ≤150 | 24000 | 34.7±0.2 | 25.0±0.6 | 23.4±0.2 | 0.50±0.1 | 0.25±0.05 | — |
| | 7NB-27-2C | 2.2±0.5 | ≤300 | 27000 | 27.0 | 19.7 | 18.2 | 0.22 | 0.10 | — |
| | 7NB-27-3C | 3.0±0.5 | ≤300 | 24000 | 27.0 | 19.7 | 18.2 | 0.32 | 0.15 | — |
| | 7NB-27-4C | 3.8±0.5 | ≤300 | 19000 | 27.0 | 19.7 | 18.2 | 0.42 | 0.20 | — |
| | ★7BB-20-6CA0 | 6.3±0.6 | ≤800 | 8500 | 20.0±0.2 | 14.0±0.6 | 12.8±0.2 | 0.42±0.1 | 0.20±0.05 | AWG32 wire |
| | ★7BB-27-4CA0 | 4.6±0.5 | ≤200 | 18000 | 27.0±0.2 | 19.7±0.6 | 18.2±0.2 | 0.54±0.1 | 0.30±0.05 | |
| | ★7BB-35-3CA0 | 2.8±0.5 | ≤200 | 24000 | 35.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.53±0.1 | 0.30±0.05 | |
| | ★7BB-41-2CA0 | 2.2±0.3 | ≤350 | 24000 | 41.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.63±0.1 | 0.40±0.05 | |
| **EXTERNAL DRIVE (without feedback electrode)** | | | | | | | | | | |
|  | ★7BB-12-9 | 9.0±1.0 | ≤1000 | 8000 | 12.0 | 9.0 | 8.0 | 0.22 | 0.10 | — |
| | ★7BB-15-6 | 6.0±1.0 | ≤350 | 10000 | 15.0 | 10.0 | 9.0 | 0.22 | 0.10 | — |
| | 7BB-20-3 | 3.6±0.6 | ≤500 | 20000 | 20.0 | 14.0 | 12.8 | 0.22 | 0.10 | — |
| | ★7BB-20-6 | 6.3±0.6 | ≤300 | 10000 | 20.0±0.2 | 14.0±0.6 | 12.8±0.2 | 0.42±0.1 | 0.20±0.05 | — |
| | 7BB-27-3 | 3.6±0.6 | ≤600 | 10000 | 27.0 | 14.0 | 12.8 | 0.52 | 0.30 | — |
| | 7BB-27-3R5 | 3.0±0.6 | ≤300 | 26000 | 27.0 | 19.7 | 18.2 | 0.32 | 0.15 | — |
| | ★7BB-27-4 | 4.6±0.5 | ≤200 | 20000 | 27.0±0.2 | 19.7±0.6 | 18.2±0.2 | 0.54±0.1 | 0.30±0.05 | — |
| | ★7BB-35-3 | 2.8±0.5 | ≤200 | 30000 | 35.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.53±0.1 | 0.30±0.05 | — |
| | ★7BB-41-2 | 2.2±0.3 | ≤250 | 30000 | 41.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.63±0.1 | 0.40±0.05 | — |
| | 7BB-50M-1 | 1.0±0.3 | ≤1200 | 28000 | 50.0 | 25.0 | 23.0 | 0.44 | 0.20 | — |
| | ★7SB-20-7 | 7.2±0.8 | ≤350 | 10000 | 20.0±0.2 | 14.0±0.6 | 12.8±0.2 | 0.42±0.1 | 0.20±0.05 | SUS plate |
| | 7MB-15-11 | 11.0±3.0 | ≤400 | 5000 | 15.0 | 10.0 | 9.0 | 0.42 | 0.20 | — |
| | 7MB-20-7 | 7.2±1.0 | ≤350 | 10000 | 20.0 | 14.0 | 12.8 | 0.42 | 0.20 | — |
| | 7MB-27-3 | 3.4±0.5 | ≤500 | 10000 | 27.0 | 14.0 | 12.8 | 0.42 | 0.20 | — |
| | 7MB-27-4 | 4.6±0.6 | ≤300 | 18000 | 27.0 | 19.7 | 18.2 | 0.44 | 0.20 | — |
| | ★7BB-20-6A0 | 6.3±0.6 | ≤550 | 10000 | 20.0±0.2 | 14.0±0.6 | 12.8±0.2 | 0.42±0.1 | 0.20±0.05 | AWG32 wire |
| | ★7BB-27-4A0 | 4.6±0.5 | ≤200 | 20000 | 27.0±0.2 | 19.7±0.6 | 18.2±0.2 | 0.54±0.1 | 0.30±0.05 | |
| | ★7BB-35-3A0 | 2.8±0.5 | ≤200 | 30000 | 35.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.53±0.1 | 0.30±0.05 | |
| | ★7BB-41-2A0 | 2.2±0.3 | ≤300 | 30000 | 41.0±0.2 | 25.0±0.6 | 23.0±0.2 | 0.64±0.1 | 0.40±0.05 | |
| | 7NB-31R2-19R7DM-1 | 1.3±0.5 | ≤500 | 40000 | 31.2±0.2 | 19.7±0.6 | 18.2±0.2 | 0.22±0.1 | 0.10±0.05 | Ni-plate electrode |
| | 7NB-35-1 | 1.16±0.2 | ≤500 | 38000 | 35.0 | 19.7 | 18.2 | 0.27 | 0.15 | — |
| | 7SB-20-7A1 | 7.2±0.8 | ≤350 | 10000 | 20.0 | 14.0 | 12.8 | 0.42 | 0.20 | — |
| | *1 Insulation resistance 100MΩ min. (at 100VDC) *2 Maximum applied voltage 30Vp-p | | | | | | | | | |

## PART NUMBERING SYSTEM




★Available as standard through authorized Murata Electronics Distributors.

# ENVIRONMENTAL TEST DATA FOR PIEZO ALARMS



Data on various environmental tests for PKB5-3AO (>BB-35-3C + Case + Circuit) are shown in Fig. 89-1 to 90-12.

For additional information, Murata Electronics offers engineering assistance in its Smyrna, Georgia facility.

## ENVIRONMENTAL TEST CONDITIONS

| Test Name | Condition | Figure |
|---|---|---|
| **Damp Heat Test (Steady State)** | +60°C RH90 to 95% 1000 hrs. | Fig. 1 |
| **Cold Test** | –20°C 1000 hrs. | Fig. 2 |
| **Dry Heat Test** | +70°C 1000 hrs. | Fig. 3 |
| **Vibration Test** | 10 to 500 to 10Hz 15min. sweep 3 directions for 2 hours each | Fig. 4 |
| **Mechanical Shock Test** | 100G half sin. 3 directions for 3 times each | Fig. 5 |
| **Salt Mist Test** | +35°C 5% 96 hrs. | Fig. 6 |
| **Temperature Change Test** | –20°C 30 min. to +25°C 15 min. to +70°C 30 min., 5 cycles | Fig. 7 |
| **Damp Heat (Cyclic) Test** | +25°C RH 60% to +65°C. RH 90%, 10 cycles | Fig. 8 |
| **Damp Heat (Steady State) Test** | +40°C RH 90 to 95% DC 9V | Fig. 9 |
| **Dry Heat Test** | +70°C DC 9V | Fig. 10 |
| **Intermittent Sound Test** | +25°C 1.5 sec. ON — 1.5 sec. OFF DC 9V, 30,000 times | Fig. 11 |
| **Operating Temperature Range** | –20°C to 60°C | Fig. 12 |

**Fig. 89-1**
Damp Heat (Steady State) Test

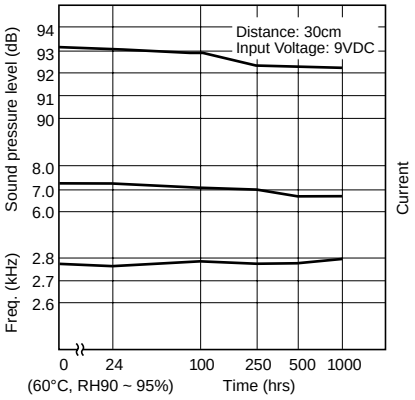



**Fig. 89-2**
Cold Test

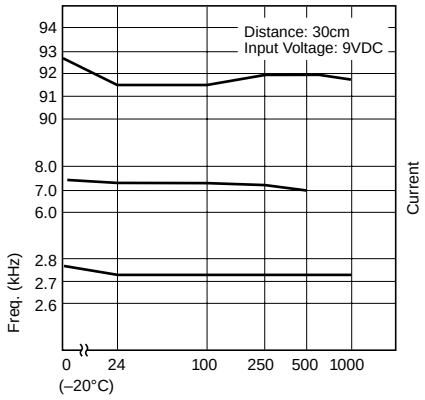



**Fig. 89-3**
Dry Heat Test

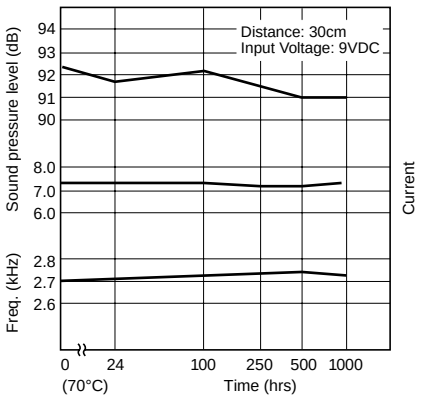



**Fig. 89-4**
Vibration Test

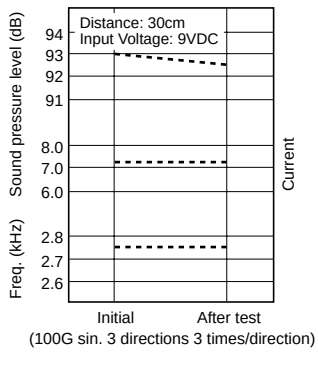



**Fig. 89-5**
Mechanical Shock Test

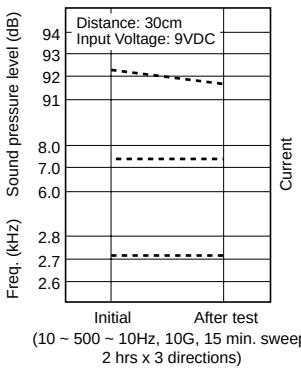
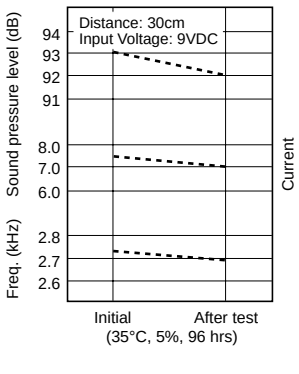
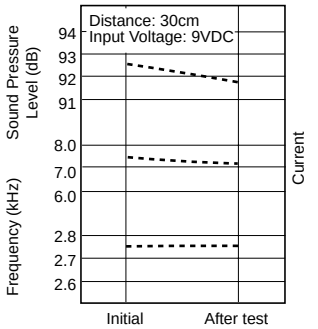



**Fig. 89-6**
Salt Mist Test



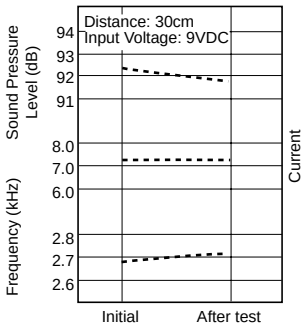
# ENVIRONMENTAL TEST DATA FOR PIEZO ALARMS

**Fig. 90-7**
Temperature Change Test



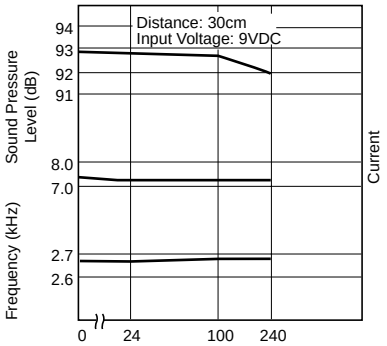

(–20°C, 30 min. ~ +25°C,
15 min. ~ +70°C, 30 min. 5 cycles)

**Fig. 90-8**
Damp Heat (Cyclic) Test




(25°C, RH 60% 65°C, RH 90%, 10 cycles)
(MIL-STD-202-106, JIS-C5024)

**Fig. 90-9**
Damp Heat (Steady State) Test




(9VDC, +40°C, RH 90 ~ 95%)

**Fig. 90-10**
Dry Heat Test

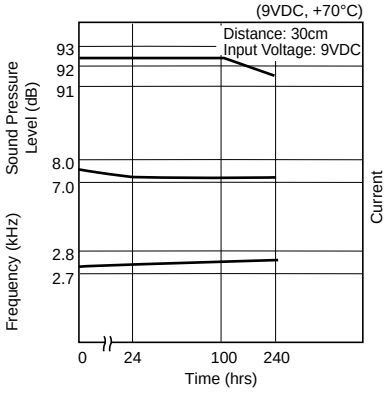



**Fig. 90-11**
Intermittent Sound Test

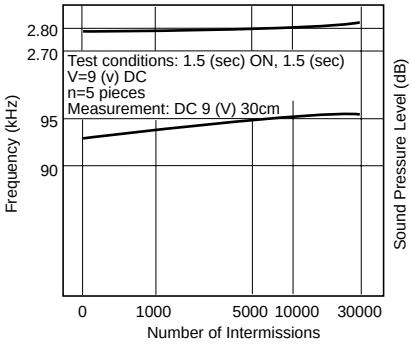



**Fig. 90-12**
Ambient Temperature

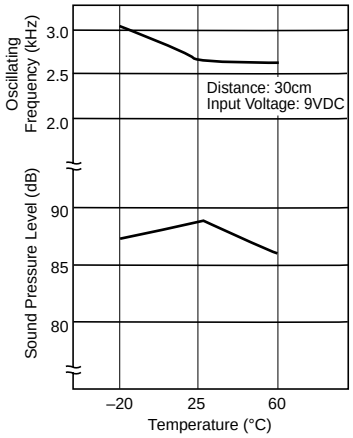



**Fig. 90-13**
Relationship of Distance and Sound Pressure

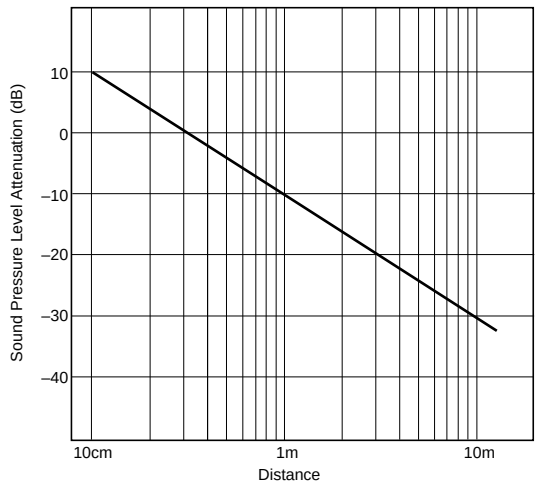



**Fig. 90-14**
Typical Human Auditory Response