

Piezoelectric Sound Components

Introduction

Murata Electronics' piezoelectric sound components (piezo alarms) are designed for applications requiring a highly reliable acoustic alarm or audible tone signal. Their reliability extends from the fact that they are solid state construction so they have very few moving parts. These devices can produce either a single or multi-frequency output depending upon operating requirements. The tone is distinct due to the absence of harmonics, and gives an extremely clear, penetrating sound. Their high acoustic output versus low input power requirements make them ideal for a wide variety of applications, especially products powered by battery. They are used as indicators or alarms that call a person's attention to the product. These buzzers and speakers are used in products such as phones, pagers, smoke detectors, and appliances like microwaves.

How Does It Work

Sound is simply a wave of varying air pressure. These pressure waves cause a thin membrane in the ear to vibrate and the brain interprets these vibrations as sound. A decibel (dB) scale is used to describe the sound pressure level (SPL) or loudness of a sound. An increase of 20 dB means that the SPL increased by ten times. Figure 99 shows the dB scale.

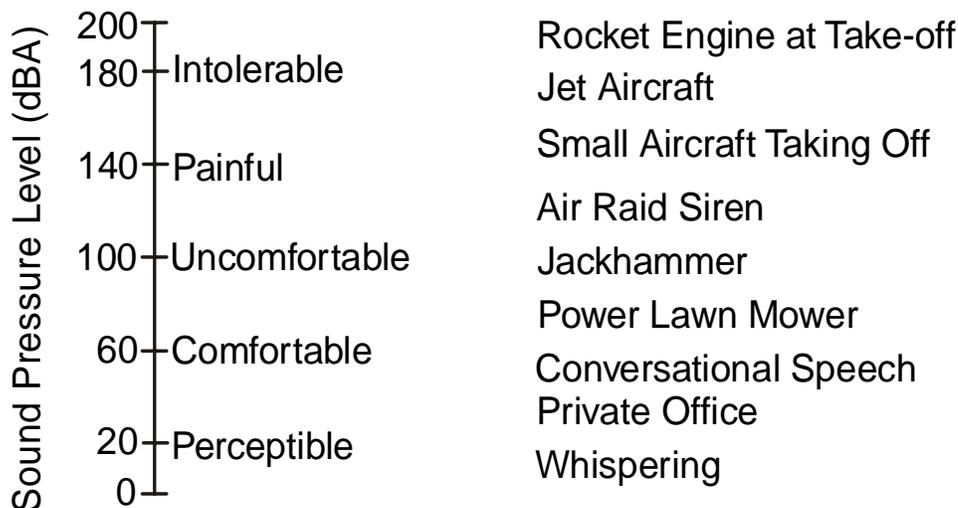


Figure 99: SPL Level Reference

The sound pressure level specification for a buzzer must have three additional pieces of information included. First is the distance from the sound emitting hole that the measurement was taken. The reason for this is that as the sound wave expands outward, it loses strength. The measurement will be louder 10cm from the buzzer hole than it would be 30cm from the buzzer hole. The second piece of information is the frequency at which the buzzer was driven. The buzzer has a resonant frequency that will produce the loudest sound and any other frequency will produce a lower SPL. The last piece of information is the input drive voltage. A higher input voltage will produce a louder sound up to the point at which the material breaks down. Without all of this information an accurate comparison cannot be made between two different buzzers.

The sound source of a piezoelectric sound component is the piezoelectric diaphragm. The piezoelectric diaphragm (bender plate) consists of a piezoelectric ceramic plate, with electrodes on both sides, attached to a metal plate (brass,

stainless steel etc) with conductive adhesive. Figure 100 shows the construction diagram of a piezoelectric diaphragm.

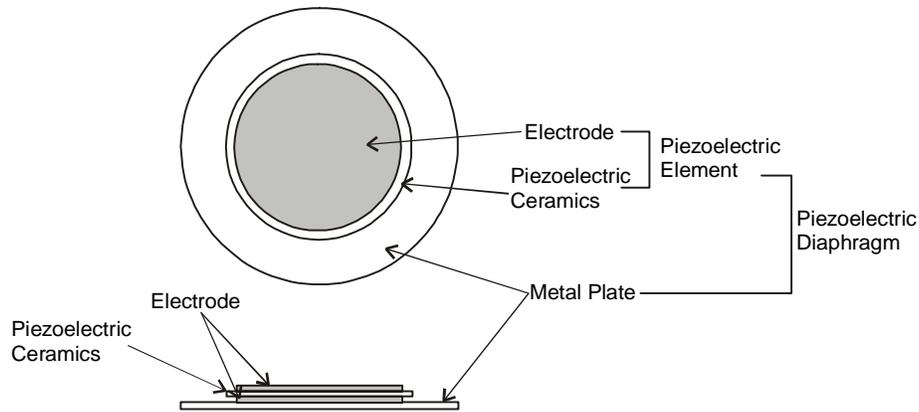


Figure 100: Piezoelectric Diaphragm

The sound is created from the movement of the metal plate. Applying a D.C. voltage between electrodes of the piezoelectric diaphragm causes mechanical distortion due to the piezoelectric effect. The distortion of the piezoelectric ceramic plate expands in the radial direction causing the metal plate to bend shown in Figure 101(a). Reversing the polarity of the D.C. voltage cause the ceramic plate to shrink, bending the metal plate in the opposite direction, shown in Figure 101(b). When an A.C. voltage is applied across the electrodes, the diaphragm alternates bending in the two directions. The repeated bending motion produces sound waves in the air.

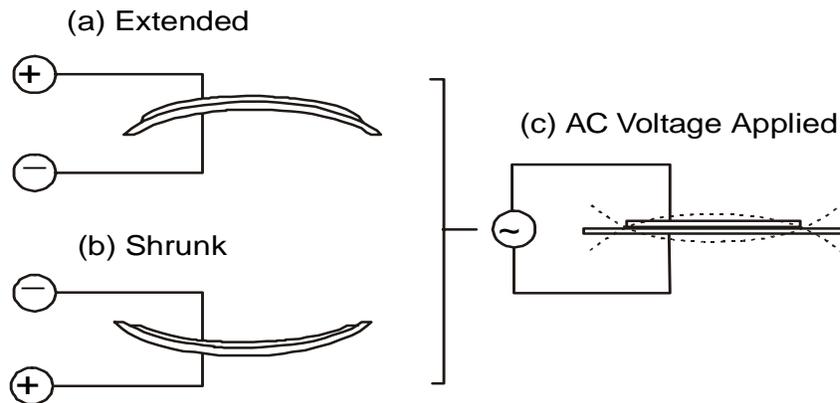


Figure 101: Diaphragm Operation

Note: Murata does not recommend using a drive signal with a DC bias because it could depolarize the ceramic and limit maximum SPL performance.

Typically, the piezoelectric diaphragm alone does not produce a high SPL. It is necessary to mount the diaphragm in a resonant cavity designed to enhance the SPL for a specific frequency.

Design Of The Resonating Cavity

The piezoelectric element alone can not produce a high sound pressure level (SPL). This is because the acoustical impedance of the element does not match that of any open air loading. Therefore a resonating cavity must be built to match the acoustical impedance of the element and the encased air. There are three methods in mounting the piezo diaphragm to a resonating cavity. The method of mounting the diaphragm will effect the sound output. The three methods of mounting are as follows:

- Node Support

The diaphragm is mounted at a node, a circumference where no vibration takes place. This method causes the least mechanical suppression of vibration and thus provides the highest SPL and the most stable oscillation frequency of the three methods. Node support enhances only a narrow range of frequencies but does so very well. The frequency of the sound output will equal the piezo diaphragm resonant frequency.

- Edge Support

The diaphragm is mounted at the outer edge of the disk causing the entire disk to vibrate. This method suppresses the fundamental frequency by moving the node but provides a possibility of a wide frequency response. The frequency output will be approximately half of the piezo diaphragms resonant frequency.

- Center Support

The diaphragm is mounted at the center of the disk causing the outer edge to vibrate. This method provides the lowest SPL since the main vibration area is forcefully supported. This method is not useful due to design difficulties.

Figure 102 illustrates the different support methods.

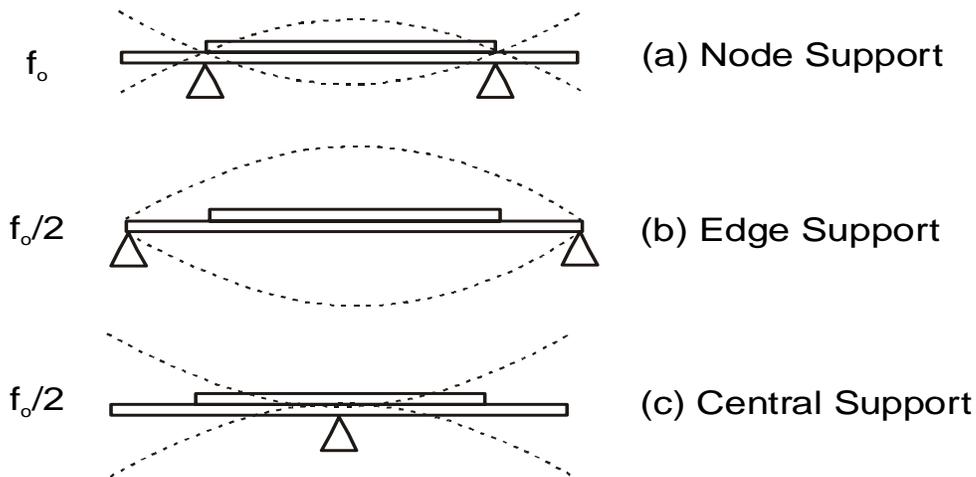


Figure 102: Mounting Methods

The resonant frequency of the cavity is obtained from Helmholtz's Formula.

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

f_0 = Resonant frequency of cavity (Hz)
 c = sound velocity 34.4×10^3 cm/sec @ 24°C
 a = radius of sound emitting hole (cm)
 d = diameter of support
 t = thickness of cavity
 k = constant $\cong 1.3$

The buzzer diagrams in Figure 103 show what is being specified by the equation variable “a”, “d”, “t”, and “h”.

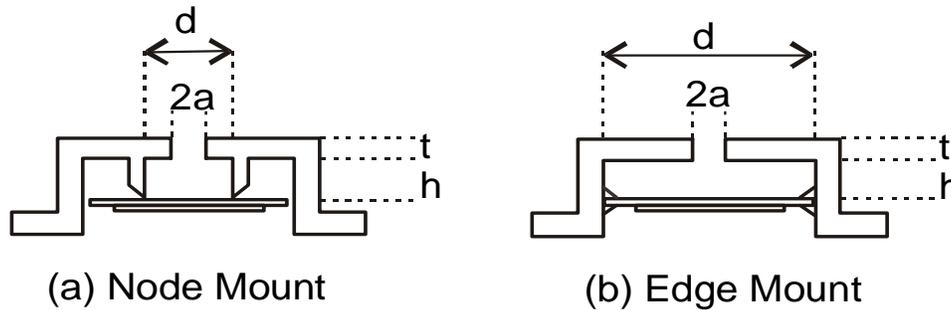


Figure 103: Cavity Measurements For Helmholtz's Formula

By designing the diaphragm and the cavity to have the same resonant frequency, the SPL is maximized and specific bandwidths can be provided.

Drive Procedure

There are two ways to drive piezoelectric sound components: External-Drive and Self-Drive

- External Drive

This drive method is typically used with edge mounted devices and uses an external oscillating circuit to produce sound. In this way the device can act as a speaker and produce frequencies over a specific bandwidth. This type of drive method is used when multiple tones are desired. Externally driven devices have found extensive use in watches, calculators, game machines, as well as appliances like microwave ovens, washing machines, and TVs.

- Self Drive

This method is used with node mounted devices. The diaphragm has a feedback tab on one of the electrodes that is used in closed loop Hartley types of oscillation circuits. When the circuit is closed to the resonant frequency, the conditions for oscillation are met and the diaphragm produces a single high-pressure tone. This type of drive procedure will produce only one tone but will have the highest SPL possible from the buzzer.

Figure 104 illustrates the two drive types.

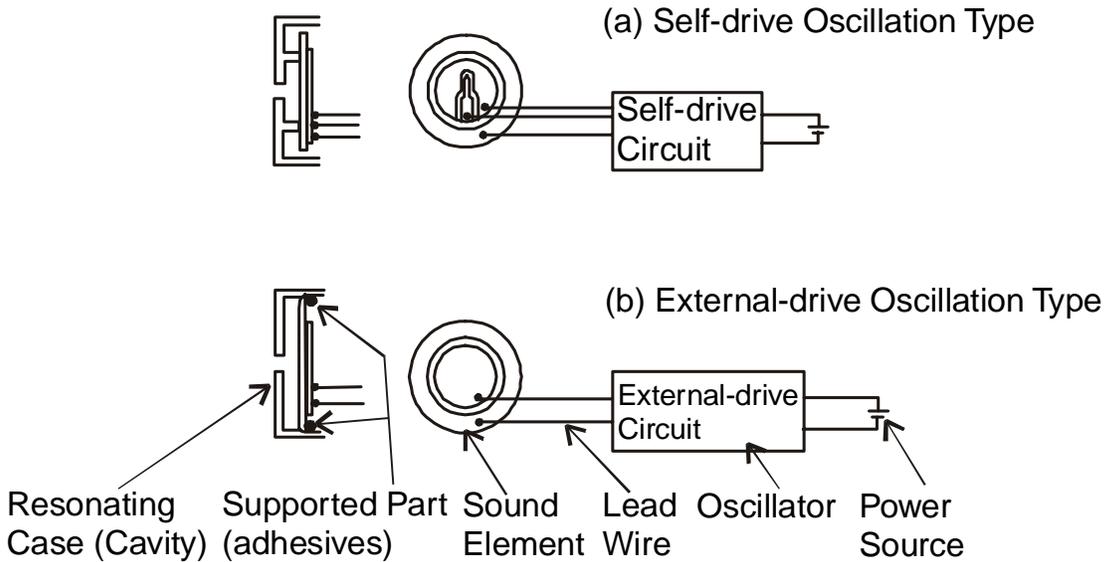


Figure 104: Two Drive Oscillation Types

Figure 105 gives a simple example of an external drive circuit.

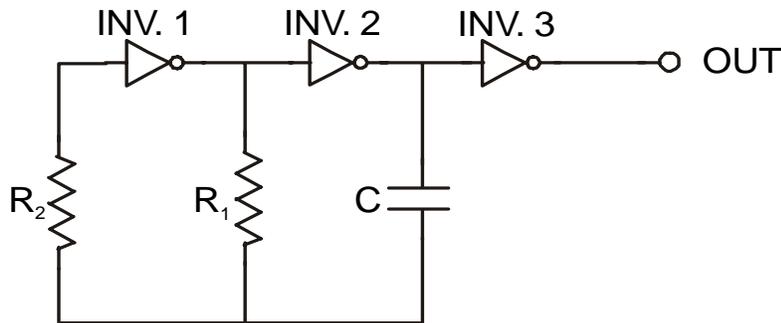


Figure 105: Example of External Drive Circuit

INV.1 and INV. 2 Make an astable oscillator while INV. 3 acts as a buffer and a waveform shaper, providing a sharp square wave output. The equation for the circuit is:

$$f_{osc} = \frac{1}{2.2R_1C}$$

$$R_2 \cong 10R_1$$

Resistor values can range from about 3kΩ to about 10MΩ. Capacitor values can range from 50pF up, though below 1000pF the frequency will be somewhat lower than predicted by the equation. The input resistor, R₂, is normally made 10 times the timing resistor, R₁, to minimize the output curving effect of the protection diodes in the inverter.

By adding a fourth inverter between the leads of the external drive buzzer, a push-pull circuit is made (Figure 106). If one terminal of the buzzer were connected to ground and the other to the output of the inverter, the buzzer would see a voltage only on one terminal. The element would only deflect in one direction. By adding the fourth inverter, a voltage can be applied to both pins and the element will deflect in both directions. This doubles the voltage across the buzzer and increases the SPL.

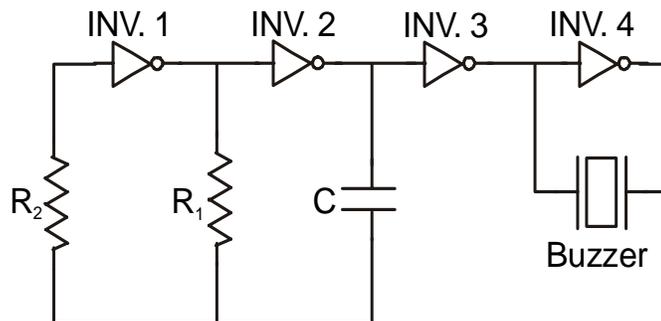


Figure 106: Inverter Push-Pull Circuit

For drive voltages greater than what can be provided by an IC, a transistor circuit can be made (Figure 107).

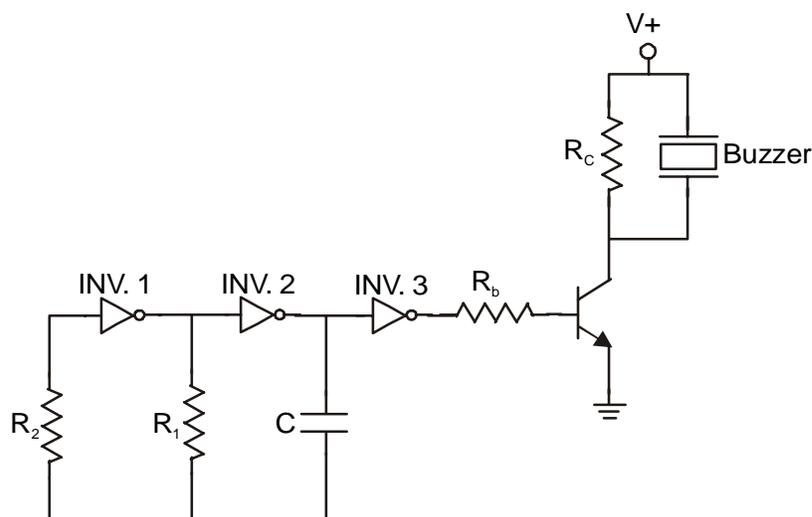


Figure 107: External Drive Circuit Using A Transistor

R_b and R_c are both generally about 1kΩ. By using a higher voltage, the diaphragm deflects more and a higher SPL can be achieved. A transistor push-pull circuit can also be made to further increase SPL (Figure 108). The transistors are biased as switches and a square wave is applied to the bases 180° out of phase. This will have the same effect as the inverter in the previous circuit, causing the element to deflect in both directions and increasing the SPL, but it can han-

die voltages that would destroy an IC.

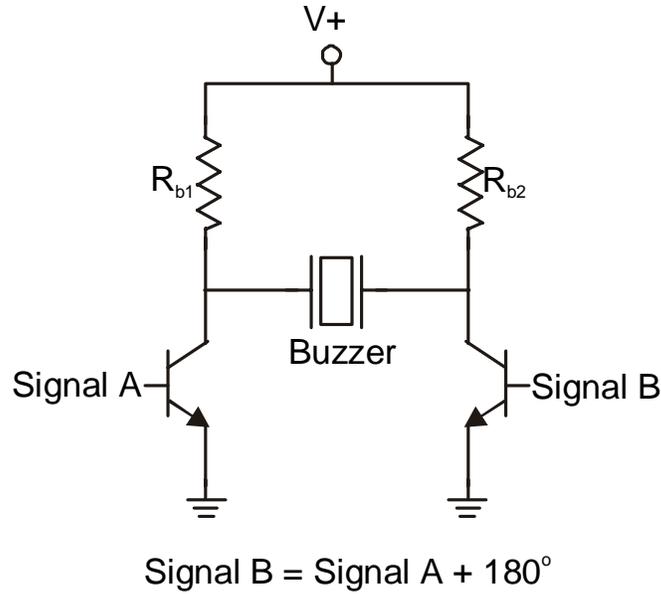


Figure 108: External Drive Push-Pull Circuit

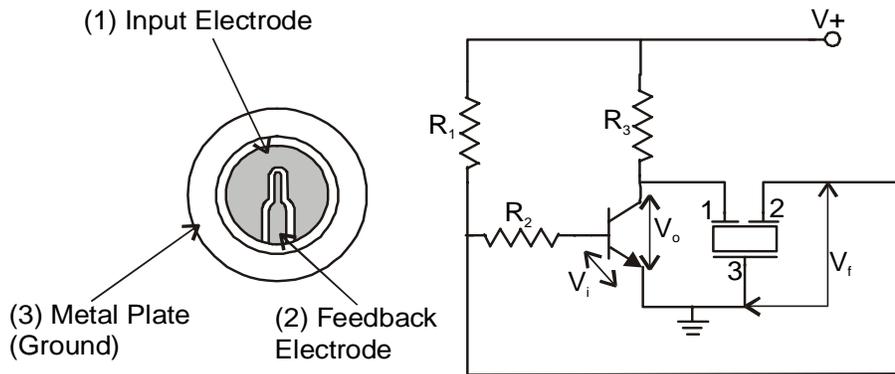


Figure 109: Example of Self-Drive Circuit

For the self drive circuit in Figure 109, R_1 is chosen so that the transistor bias point, V_{CE} , is half of the supply voltage. The following equation is used for the other resistors:

$$\frac{V_F}{V_O} = \frac{R_2 + h_{ie}}{h_{fe} \times R_3}$$

Where:

h_{ie} = input impedance of transistor

h_{fe} = current amplification

Booster Coils

It is possible to increase the SPL of a buzzer by about 3 - 6dB by replacing RC in Figure 107 and R_3 in Figure 109 with an inductor. The higher SPL is a result of the resonance between the inductor and the element, which is capacitive. The value of the inductor is determined by the following equation at the frequency of operation:

$$f_{osc} = \frac{1}{2\pi\sqrt{LC}}$$

Where:

L = value of the inductor

C = capacitance of the piezoelectric element

Generally, a suitable value is between 30mH and 60mH. When the booster coil is used with the self drive circuit in Figure 109, the other resistor values will probably need to be changed to ensure stable oscillation.

Circuit Design Considerations

- Driving Waveform

The piezo elements may be driven with sinusoidal, pulsed, or square waves. A sine wave will cause the device to operate at a frequency lower than the resonant frequency with a lower SPL. This is due to the loss of energy through the lag time between peak deflections. A square wave will produce higher sound levels because of the near instantaneous rise and fall time. Clipping of sinusoidal waveforms can result in frequency instability and pulse and square waves will cause an increase in harmonic levels. A capacitor in parallel with the diaphragm can reduce the harmonics.

- DC Precautions

Subjecting the ceramic elements to direct current can cause them to depolarize and stop working. For this reason, it is best to drive the buzzers with an A.C. signal that has a zero D.C. bias. Blocking capacitors are recommended to prevent a bias.

- High Voltage Precautions

Voltages higher than those recommended can cause permanent damage to the ceramic even if applied for short durations. Significantly higher sound pressure levels will not be achieved by higher voltages before permanent damage is caused.

- Shock

Mechanical impact on piezoelectric devices can generate high voltages that can seriously damage drive circuitry, therefore, diode protection is recommended.

- SPL Control

It is not recommended to place a resistor in series with the power source since this may cause abnormal oscillation. If a resistor is essential in order to adjust the sound pressure then place a capacitor (about 1μF) in parallel with the buzzer (Figure 110).

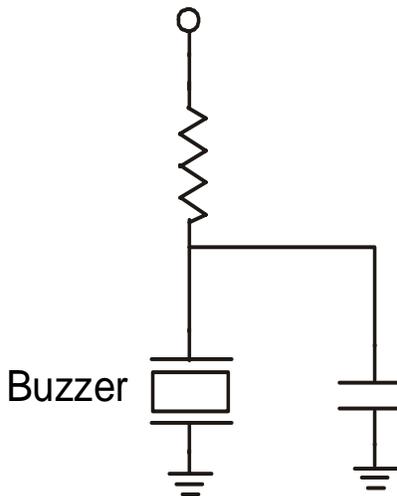


Figure 110: Capacitor Bypass of Buzzer

- Washing

Murata provides water-resistant components but will not guarantee that no water will penetrate the device. If water should get inside the component then it could cause silver migration between the terminals. This could short out the device and cause it to stop functioning. For this reason, Murata recommends that the parts not be washed. Murata can supply some components with tape covering the sound-emitting hole. This will make the component more water resistant for washing.

- Soldering

A lead wire is required to apply voltage to the piezoelectric diaphragm. This wire should be as fine as possible because it acts as a load on the diaphragm, which restricts oscillation. When using a soldering iron, the optimum temperature for soldering the lead wire to a metal plate is 300°C for a few seconds. The optimum temperature for soldering the lead wire to the ceramic silver electrode is 300°C for 0.5 second or less.

Parts

Table 14 lists the series of buzzers offered by Murata.

Buzzer Series	Description
PKMC	Surface mount external drive buzzer
PKM	Self or external drive with no internal circuitry Requires AC Drive Signal.
PKB	Internal circuitry included. Requires DC Voltage
VSB	Speaker Elements capable of reproducing speech
PKD	Electroacoustic transducer for telephones
7BB, 7NB, 7SB	Buzzer elements

Table 14. Buzzer Series Description

Figure 111 shows an example of the general part numbering system used by Murata.

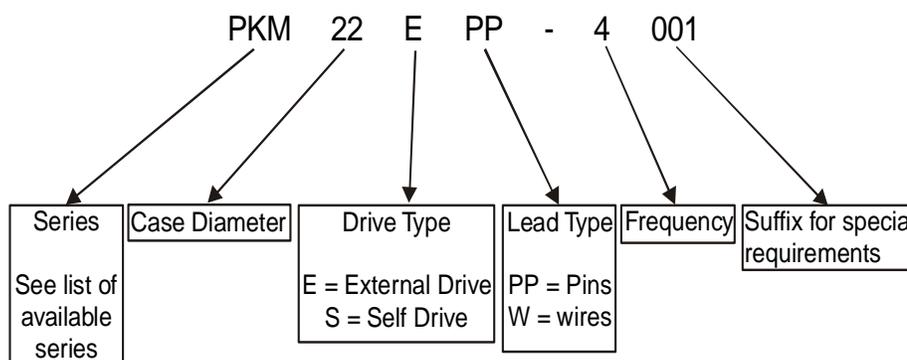


Figure 111: Buzzer Part Number System

Parts that are on tape (for automatic insertion) will have a –TF01 suffix. Currently this is only available with the PKM13EPY-4000-TF01. Parts that come with tape over the sound-emitting hole will also have a suffix. PKM series parts will have an “S” suffix. PKB series parts will have a “W” suffix. The PKB series also has epoxy around the base to help prevent water from getting into the drive circuitry. Currently only the following buzzers are available sealed for washing:

- PKM22EPP-4001S
- PKM17EPP-4001S
- PKM25SP-3701S
- PKB24SPC-3601W
- PKB30SPC-2001W
- PKB30SPC-3001W

Table 15 lists the buzzers offered by Murata.

Part Number	Oscillating Frequency (kHz)	Case Diameter (mm)	Case Thickness (mm)	Pins / Wires	Pin Spacing (mm)	Available in Tape	External / Self Drive	Flange Center (mm)
PKMC16E-4000-TY	4	16	2.7	P	16	N	E	-----
PKM22EPP-4001	4	22	7	P	10	N	E	-----
PKM22EP-2001	2	22	11	P	22	N	E	-----
PKM35-4AO	4	16.8	4	W	-----	N	E	-----
PKM17EW-2001	2	16.8	7	W	-----	N	E	-----
PKM13EPY-4002	4	12.6	6.9	P	5	Y	E	-----
PKM17EPP-4001	4	17	7	P	10	N	E	-----
PKM11-4AO	4.096	24	4.5	W	-----	N	E	29
PKM25-6AO	6.8	25	7	P	4 / 8.5	N	S	-----
PKM25SP-3701	3.7	25	7	P	4 / 8.5	N	S	-----
PKM24SP-3805	3.8	24	11	P	ANGLED	N	S	-----
PKM11-6AO	6.5	24	4.5	W	-----	N	S	29
PKM29-3AO	3.4	39	20	P	8 / 10.5	N	S	-----
PKM37-2AO	2	30	10	P	ANGLED	N	S	-----
PKB24SPC-3601	3.6	24	9.7	P	15	N	E	-----
PKB30SPC-2001	2	30.3	17.7	P	15	N	E	-----
PKB30SPC-3001	2.7	30.3	17.7	P	15	N	E	-----
PKB5-3AO	2.8	42	14.5	W	-----	N	E	50
PKB6-5AO	4.7	34	13.5	W	-----	N	E	45
VSB35EW-0701B	0.6 - 20	35	1.7	-----	-----	-----	E	-----
VSB50EW-O3O1B	0.25 - 20	50	2.5	-----	-----	-----	E	-----
VSB41D25-07ARO	0.5 - 20	50	2	-----	-----	-----	E	-----
PKD17EW-01R	0.3 - 3.4	17	2	-----	-----	-----	E	-----
PKD22EW-01R	0.3 - 3.4	21.5	2	-----	-----	-----	E	-----
PKM33EP-1001	1	33	7.5	P	ANGLED	N	E	-----
PKM34EW-1101C	1.1	34.5	9	W		N	E	40
PKM44EW-1001C	1	61	14	W		N	E	52
PKM44EP-0901	1	40.5	13	P	45	N	E	-----
PKM17EPT-4001	4	20	7.5	P	10	N	E	-----
PKM22EPT-2001	2	26.5	7	P	12.5	N	E	-----
PKM30SPT-2001	2	33.25	7.7	P	7.5 / 12.5	N	S	-----
7BB-20-6C	6.3	20	0.42	W	-----	N	S	-----
7BB-27-4C	4.6	27	0.54	W	-----	N	S	-----
7BB-35-3C	2.8	35	0.53	W	-----	N	S	-----
7BB-41-2C	2.2	41	0.63	W	-----	N	S	-----
7SB-34R7-3C	3.3	34.7	0.5	W	-----	N	S	-----
7SB-34R7-3C2	3.1	37.4	0.5	W	-----	N	S	-----
7BB-20-6CAO	6.3	20	0.42	W	-----	N	S	-----
7BB-27-4CAO	4.6	27	0.54	W	-----	N	S	-----
7BB-35-3CAO	2.8	35	0.53	W	-----	N	S	-----
7BB-41-2CAO	2.2	41	0.53	W	-----	N	S	-----
7BB-12-9	9	12	0.22	W	-----	N	E	-----
7BB-15-6	6	15	0.22	W	-----	N	E	-----
7BB-20-6	6.3	20	0.42	W	-----	N	E	-----

Table 15. Murata Buzzer Products

7BB-27-4	4.6	27	0.54	W	-----	N	E	-----
7BB-35-3	2.8	35	0.53	W	-----	N	E	-----
7BB-41-2	2.2	41	0.63	W	-----	N	E	-----
7SB-20-7	7.2	20	0.42	W	-----	N	E	-----
7SB-21-7	6.6	21	0.36	W	-----	N	E	-----
7SB-27-5	4.8	27	0.47	W	-----	N	E	-----
7BB-20-6AO	6.3	20	0.42	W	-----	N	E	-----
7BB-27-4AO	4.6	27	0.54	W	-----	N	E	-----
7BB-35-3AO	2.8	35	0.54	W	-----	N	E	-----
7BB-41-2A0	2.2	41	0.64	W	-----	N	E	-----
7NB-31R2-19R7DM-1	1.3	31.2	0.27	W	-----	N	E	-----
7NB-41-25DM-1	0.85	41	0.21	W	-----	N	E	-----

Table 15. Murta Buzzer Products