

## Technical Information | Piezo Transducer

### for the acoustic components

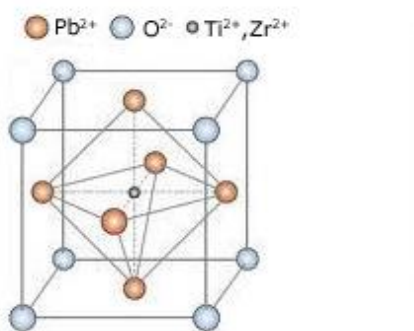
## Piezoelectricity

Piezoelectricity is a property exhibited by certain classes of crystalline materials. When mechanical stress is applied to one of these materials, the crystalline structure produces a voltage proportional to the stress. Piezoelectric is a reversible process, when an electric field is applied to one of these materials, internal mechanical stress will be generated in the crystalline structure, producing dimensional changes in the material. These materials are used as electromechanical transducers. Many man-made material or naturally occurred material exhibits piezoelectricity

## Piezoelectric Material

Quartz, Rochelle salt are the examples of piezoelectric materials. In addition to the crystals mentioned above, an important ceramic materials with crystalline structure is lead zirconate titanate (PZT), which is an oxide alloy of lead, zirconium (Zr) and titanium (Ti) with perovskite structure. It is often used in a specific composition (sometimes with additives) in order to achieve a particular crystal structure and the desired piezoelectric response. PZT is ferroelectric, which means it has spontaneous electric dipoles that can be reversed in response to electric field. Figure below shows the structure of PZT ( Fig. 1 ).

**Fig.1 Structure of PZT**



The PZT can be fashioned into components of almost any shape and size. As well as being strongly piezoelectric, PZT is hard, strong, chemically inert and completely unaffected by humid environments.

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In a ferroelectric crystal, each cell of the crystal lattice spontaneously polarizes along one of a series of allowed directions. This spontaneous polarization disappears at a critical temperature (the Curie point), above which the crystal becomes paraelectric.

If the crystal is cooled through the Curie point in the presence of an external electric field, the dipoles tend to align in the allowed direction most nearly aligned with the field. If this crystal is then stressed, the lattice will distort, leading to a change in the dipole moment of the crystal (piezoelectric effect). Within a certain stress range (which depends on the crystal concerned), this change in the dipole moment with stress is approximately linear and reversible.

A PZT component will usually have metal electrodes deposited on its surface perpendicular to its polarization axis (see Fig.2). When a voltage is applied between them, the body distorts along its poling axis. The random orientation of the crystallites, and the fact that only certain polarization directions are allowed, means that it is not possible to get perfect dipole alignment within the field.

A reasonable degree of alignment is, however, possible since there are several allowed directions within each crystal.

**Fig.2 Before Polarization & After Polarization**

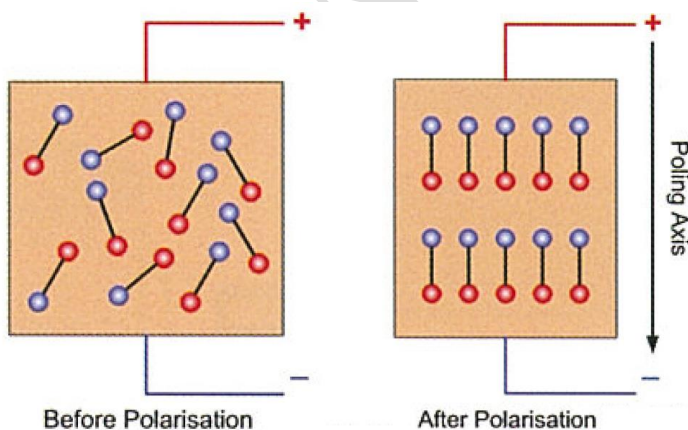
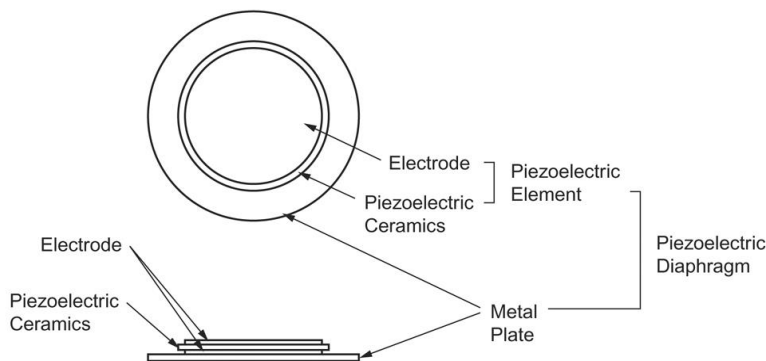


Fig.2 illustrates the piezoelectric effect in a cylinder of PZT material. For clarity, the magnitude of the effect has been exaggerated.

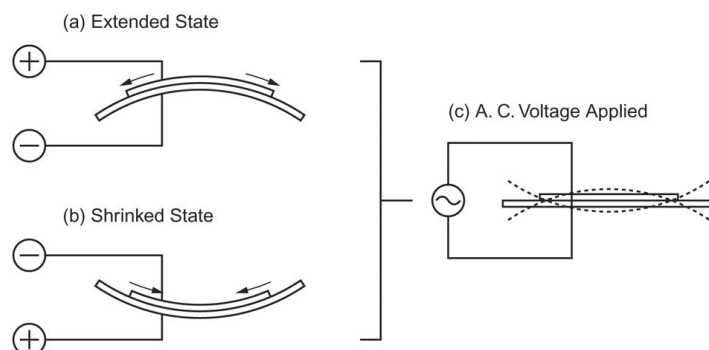
## Oscillating System

Basically, the sound source of a piezoelectric acoustic component is a piezoelectric diaphragm. A piezoelectric diaphragm consists of a piezoelectric ceramic plate which has electrodes on both sides and a metal plate (Fig.3 brass or stainless steel, etc.). A piezoelectric ceramic plate is attached to a metal plate with adhesives. Fig. 4 shows the oscillating system of a piezoelectric diaphragm. Applying D.C. voltage between electrodes of a piezoelectric diaphragm causes mechanical distortion due to the piezoelectric effect. For a misshaped piezoelectric element, the distortion of the piezoelectric element expands in a radial direction. And the piezoelectric diaphragm bends toward the direction shown in Fig. 4 (a). The metal plate bonded to the piezoelectric element does not expand. Conversely, when the piezoelectric element shrinks, the piezoelectric diaphragm bends in the direction shown in Fig. 4 (b). Thus, when AC voltage is applied across electrodes, the bending shown in Fig. 4 (a) and Fig. 4 (b) is repeated as shown in Fig. 4 (c), producing sound waves in the air.

**Fig. 3 Structure of Piezoelectric Diaphragm**



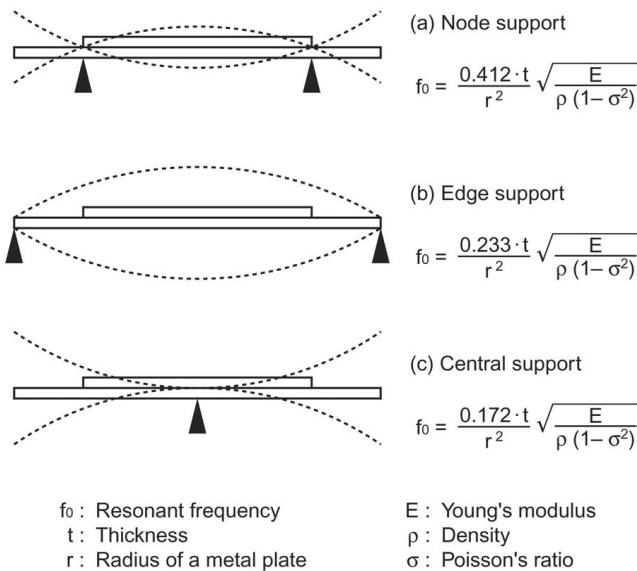
**Fig. 4 Oscillation System**



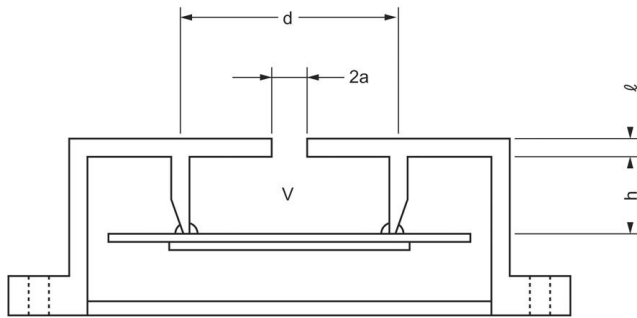
## Design Procedures

In general, man's audible frequency range is about 20 Hz to 20 kHz. Frequency ranges of 2kHz to 4kHz are most easily heard. For this reason, most piezoelectric acoustic components are used in this frequency range, and the resonant frequency ( $f_0$ ) is generally selected in the same range too. As shown in Fig. 5, the resonant frequency depends on methods used to support the piezoelectric diaphragm. If piezoelectric diaphragms are of the same shape, their values will become smaller in the order of (a), (b) and (c). In general, the piezoelectric diaphragm is installed in a cavity to produce high sound pressure (Fig. 6). The resonant frequency ( $f_{cav}$ ) of the cavity in Fig. 6 is obtained from Formula (1) (Helmholtz's Formula). Since the piezoelectric diaphragm and cavity have proper resonant frequencies ( $f_0$ ) and ( $f_{cav}$ ) respectively, sound pressure in specific frequencies can be increased and a specific bandwidth can be provided by controlling both positions.

**Fig. 5 Supporting Method**



**Fig. 6 Sectional View of a Cavity**



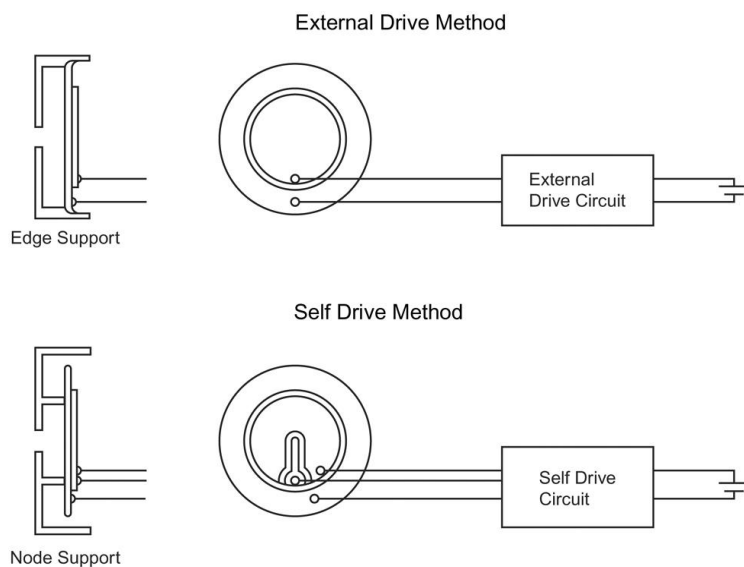
$$f_{cav} = \frac{C}{2\pi} \sqrt{\frac{\pi a^2}{V(\ell + 1.3a)}} = \frac{C}{2\pi} \sqrt{\frac{4a^2}{d^2 h(\ell + 1.3a)}} \dots\dots\dots (1)$$

$f_{cav}$  : Resonant freq. of a cavity (Hz)       $d$  : Diameter of a supporting rim (cm)  
 $c$  : The speed of sound (cm/sec)       $h$  : Depth of a cavity (cm)  
 $a$  : Radius of sound emitting hole (cm)       $\ell$  : Wall thickness of a cavity (cm)

## Drive Procedures

Drive procedures for piezoelectric sound components include external drive method and self drive method as shown in Fig. 7.

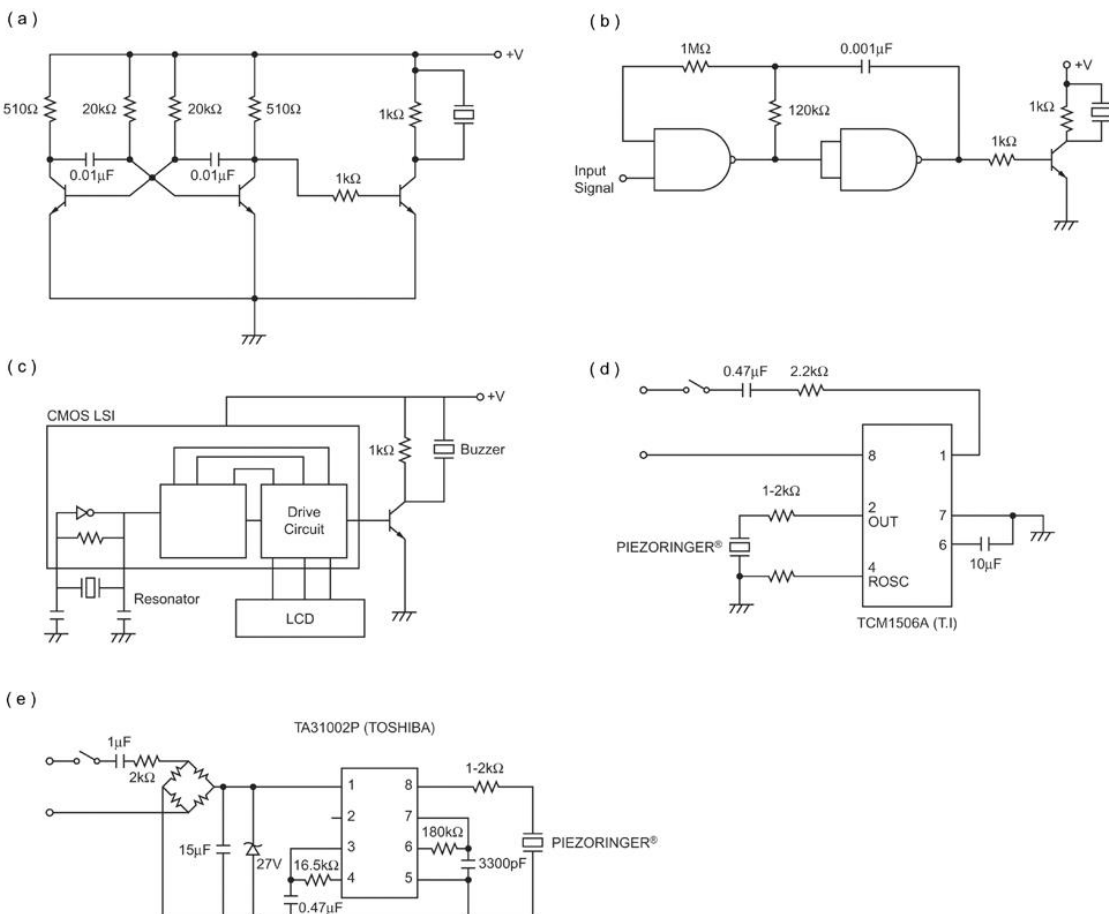
**Fig. 7 Drive Procedures**



## External Drive Method

This method produces sound by driving the piezoelectric diaphragm with electric signals supplied from an external oscillating circuit such as a multivibrator. Using this method, the piezoelectric buzzer can work as a speaker. In this method, a mechanical oscillation  $Q_m$  of the piezoelectric diaphragm is damped properly to provide a wider frequency band of the sound pressure. This is applied to a switching sounds of home electric appliances, key-in sounds of OA equipment, alarm sounds of digital watches and the multiple sounds like those used in electronic games. This method is also applied to the ringers, transmitters, receivers of telephone sets, card radios and speakers of crystal TV's. Fig. 8 shows examples of the circuit to which the external drive method is applied: (a) represents a circuit driven by output signals of the unstable multivibrator; (b) represents a circuit using 2 NAND gates, which is oscillated or stopped by ON / OFF operations of the input signal; (c) represents a circuit driven by output signals of CMOS LSI; (d) and (e) represent examples of the piezoelectric diaphragm connected to telephone tone ringer IC.

**Fig. 8 Examples of the external drive circuits**



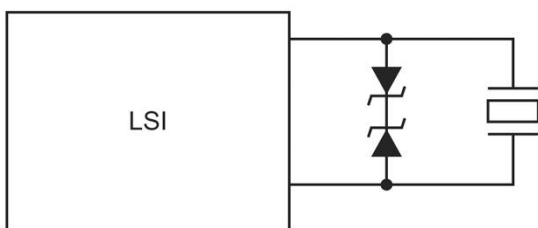
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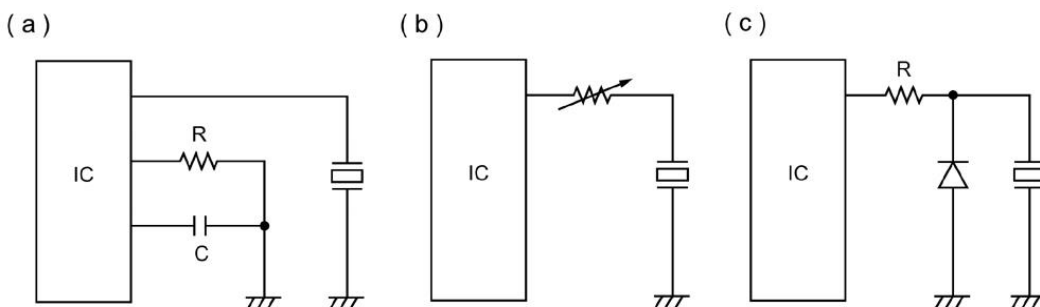
#### Notice : In Using External Drive Method

- 1) Electric charges accumulated in the piezoelectric diaphragm due to thermal and mechanical shock may cause high voltage which may destroy LSI. Use the method using a Zener diode as shown in Fig. 9 to prevent this.
- 2) Applying D.C. voltage to the piezoelectric diaphragm in the environment of high humidity causes Ag migration. Therefore, design a circuit which does not require D.C. voltage be applied for a long time.
- 3) Consider the following points in connecting a piezo ringer and tone ringer IC.
  - a) For external capacitors and resistors, especially when the ringing frequency is changed by adjusting variable resistor, tone may be distorted.
  - b) Ringer ICs; ringer ICs are produced by many manufacturers, and have different characteristics. When using a ringer IC, consult us or its manufacturer for operating procedures.
  - c) If tone is distorted as described in Fig. 10 (a), place a resistor in series to vary resistance as described in (b) and select a resistance with which the distortion can be eliminated. The recommended resistance is in a range between 1kohms to 2kohms. Alternatively, Fig. 10 (c) it is recommended to place a diode in parallel with the piezo ringer.

**Fig. 9 Protect Circuit**

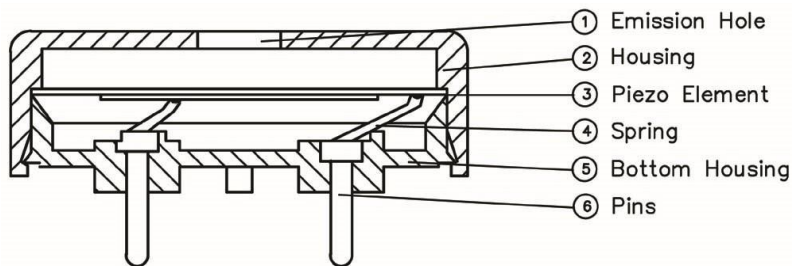


**Fig. 10 Circuits for Piezo Ringers**

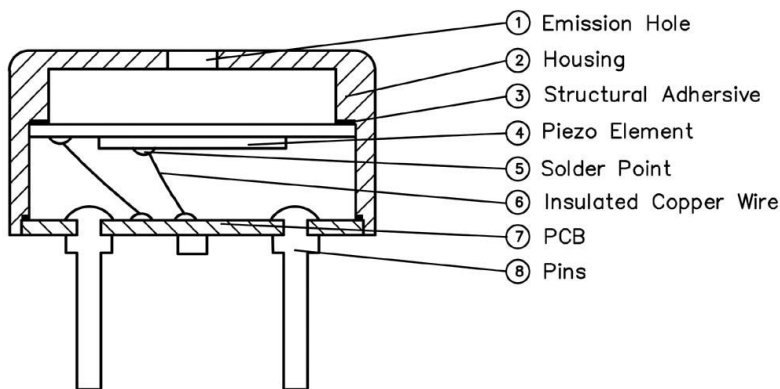


## Cross Structure of Piezo Transducer

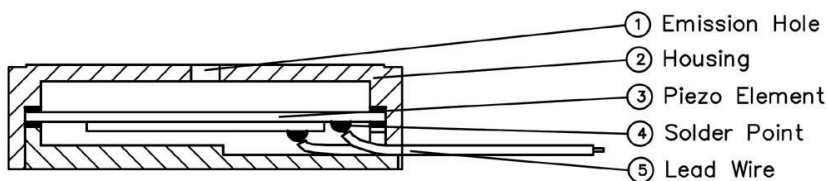
**Cross-section of External Drive Piezo Transducer (Pin Type without epoxy, internal spring contact) \*FZ-V698**



**Cross-section of External Drive Piezo Transducer (Pin Type without epoxy, internal leadwire contact) \*FZ-V478**



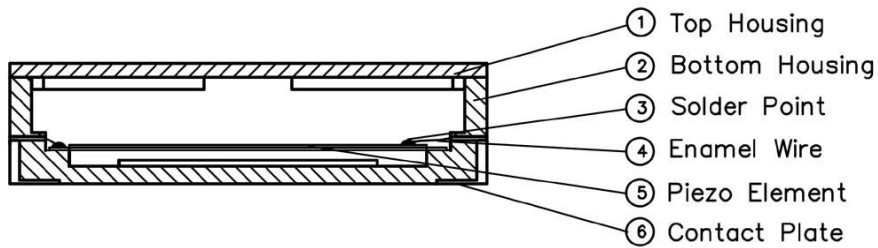
**Cross-section of External Drive Piezo Transducer (Leadwire Type) \*FZ-V678**



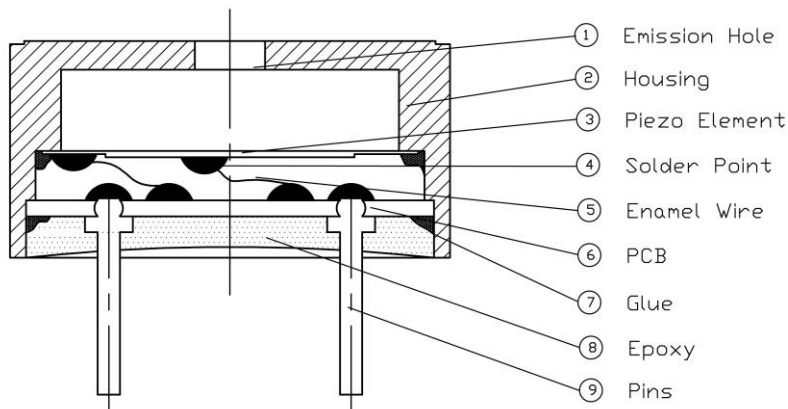


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**Cross-section of External Drive Piezo Transducer (SMD Type) \*FZ-V1898**



**Cross-section of External Drive Piezo Transducer (Pin Type with epoxy internal leadwire contact) \*FZ-V658**



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### Self Drive Method

Fig. 10 shows a typical application of the self drive method. The piezoelectric diaphragm provided with feedback electrode shown in Fig. 11 (a) is involved in the closed loop of a Hartley types oscillation circuit. When the frequency is closed to the resonant frequency, the circuit satisfies oscillating conditions, and the piezoelectric diaphragm is driven with the oscillating frequency. Fig. 11 (b) shows a simple oscillating circuit consisting of one transistor and three resistors. In general, the node support shown in Fig. 5 (a) is popular in the self drive method. Proper resonance of the piezoelectric diaphragm by the node support provides stable oscillation with high mechanical Qm of vibration but also a single high pressure tone. Basic oscillating conditions of this circuit are shown below.

- Phase difference between  $v_o$  and  $v_f$  shown in Fig. 11 must be 180 degrees.
- The following conditions must be satisfied:

$$v_f / v_o \geq \frac{R_2 + h_{ie}}{h_{fe} \cdot R_3}$$

where;

$h_{ie}$ : Input impedance of transistor

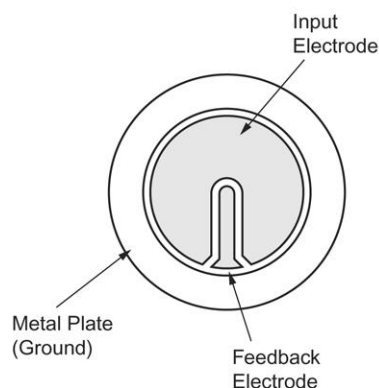
$h_{fe}$ : Current amplification

c. Set  $R_1$  so that the D.C. bias point of transistor, VCE is half of supply voltage.

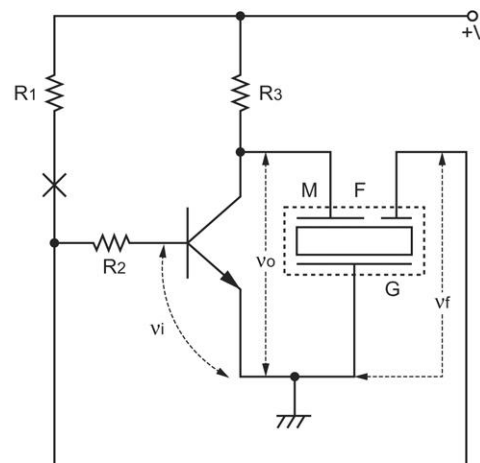
d. Adjust  $R_2$  so that spurious oscillation is not applied to oscillating waves.

**Fig. 11 Self Drive Circuit**

( a ) Piezoelectric Diaphragm  
for Self Drive



( b ) Self Drive Circuit

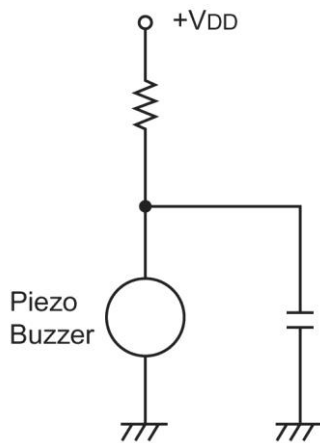


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#### Notice : In Using Self Drive Method

- 1 ) When the piezoelectric buzzer is set to produce intermittent sounds, sound may be heard continuously even when the self drive circuit is turned ON / OFF at the "X" point shown in Fig. 11. This is because of the failure of turning off the feedback voltage.
- 2 ) Build a circuit of the piezoelectric sounder exactly as per the recommended circuit shown in the catalog. hfe of the transistor and circuit constants are designed to ensure stable oscillation of the piezoelectric sounder.
- 3 ) Design switching which ensures direct power switching.
- 4 ) The self drive circuit is already contained in the piezoelectric buzzer. So there is no need to prepare another circuit to drive the piezoelectric buzzer.
- 5 ) Rated voltage (3.0 to 20.0 VDC) must be maintained. Products which can operate with voltage higher than 20.0 VDC are also available.
- 6 ) Do not place resistors in series with the power source, as this may cause abnormal oscillation. If a resistor is essential to adjust sound pressure, place a capacitor (about 1 $\mu$ F) in parallel with the piezo buzzer.



- 7 ) Do not close the sound emitting hole on the front side of casing.
- 8 ) Carefully install the piezo buzzer so that no obstacle is placed within 15mm from the sound release hole on the front side of the casing.

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### Cross Structure of Self-drive Piezo Transducer

