

## AIR ULTRASONIC CERAMIC TRANSDUCERS

Ultrasonic Ceramic Transducers transfer acoustical energy to mechanical energy or vice versa.

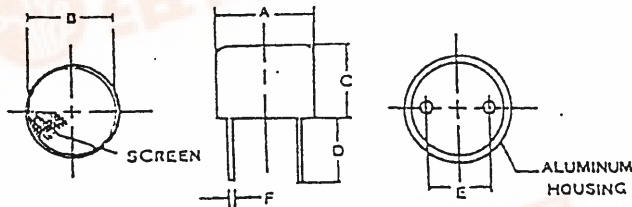
The Standard Open Type Transducer is constructed in a manner which incorporates the fundamental structure of a piezoelectric ceramic element of the monomorph type with a conical metal resonator. This special combination provides high sensitivity (over -65dB/V/ $\mu$ Bar), wider bandwidth, excellent temperature and humidity durability, stable electrical and mechanical characteristics, and small size.

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## Applications:

- Remote control devices
- Liquid & bulk sensors
- Proximity sensors
- Level controls
- Intrusion alarms
- Motion detectors
- Auto doors
- Counting devices

## Dimensions



A = 9.8 (.39)  
B = 7.7 (.30)  
C = 6.6 (.26)  
D = 8.5 (.33)  
E = 4.8 (.19)  
F = 0.5 (.020)

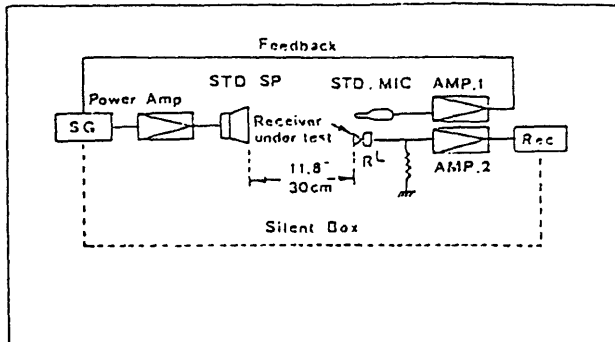
Dims in mm  
( ) in inch

ITEM	UNIT	SQ-40-T-10B	SQ-40-R-10B
Transmitting Sensitivity	SV db	110	-
Receiving Sensitivity	MV db	-	-70
Resonant Freq. Trans.	khz	40 $\pm$ 1.0	-
Resonant Freq. Rec.	khz	-	40 $\pm$ 1.0
Directional Angle	°	Approx 60°	
Max Input Volts	Vrms	10	-
Impedence		Approx 700	Approx 30k
Capacitance	pf	2000 $\pm$ 20%	
Pulse Rise Time	ms	0.7	-
Max Input Volts for Pulse Operation	Vp.p	Not recommended for Pulse Operation	
Temp Range	°C	-20 + 60	
Trans. Selectivity	Qsv	20 Min	-
Rec. Selectivity	Qmv	-	25 Min

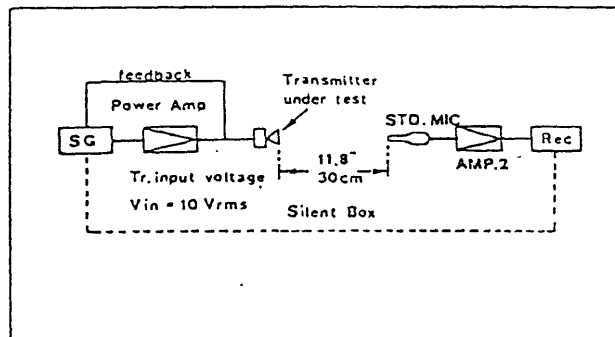


## General Information – Air Ultrasonic Ceramic Transducers

### Receiver Sensitivity Measuring Circuit



### Transmitter SPL Measuring Circuit



- Std. Mic. : Standard Condenser Microphone B&K Model 4135
- Amp : Amplifier
- CPU : IBM PC AT
- Std. Sp. : Ribbon Tweeter
- SG : Signal Generator
- Plotter : Roland Plotter
- RL : 3.9K $\Omega$

### Ratings

Temperature	Samples tested are placed for 15 min. in temperature chambers of $-20^{\circ}\text{C}$ ( $-4^{\circ}\text{F}$ ) & $60^{\circ}\text{C}$ ( $104^{\circ}\text{F}$ ) respectively. Readings are done immediately on removal from each chamber.
Humidity	Sample is stored in $40 \pm 2^{\circ}\text{C}$ ( $104 \pm 3.6^{\circ}\text{F}$ ), 90 to 95% RH atmosphere for 100 hrs. prior to subsequent 24 hrs. recuperatory period under room temperature/humidity.
Shock	Sample receives sine 100G: 6m/sec from 3 directions (X,Y,Z).
Temperature Cycle	Sample is first exposed to $120^{\circ}\text{C}$ ( $248^{\circ}\text{F}$ ) for 30 min. then to $-30^{\circ}\text{C}$ ( $-22^{\circ}\text{F}$ ) for another 30 min., for the total time length of 60 min., or a cycle. After ten (10) consecutive cycles, it is returned to and kept at room temperature for 30 min. prior to reading.
Vibration	Sample undergoes following vibration: frequency: 10 to 55 Hz Amplitude: 1.5mm Duration: 2 hrs. Sweeping period 1 min. Direction: 3 (X,Y,Z) each direction
Results	1. Temperature test: Deviation of sensitivity from $23^{\circ}\text{C}$ ( $73.4^{\circ}\text{F}$ ) environment is within allowable span of 10 dB in either case. 2. Humidity test and below: Deviation of sensitivity/SPL is within allowable span of 3dB, which meets specified value.

### Suggestions for handling

1. Characteristics vary depending on input impedance. The graph entitled "Characteristic Change Due to Load Resistance" should be consulted before designing your products, for sound pressure level and sensitivity shift.
2. Transmitter and receiver should be treated as separate considerations.
3. Terminal polarity should be properly observed when connecting, as transducers are sealed in an aluminum case after connection of ground.
4. Optimum performance is achieved if the device is covered with noise-absorbent material such as soft rubber.

### Caution

1. Transducers are designed for use in clean air. They should not be used, for example, in moist air (except enclosed type) or acid gas.
2. Transducers should not be supplied with high D.C. bias.
3. For safe operation:  
Electrically – input wattage must not exceed 200mW  
Mechanically – shield net should not be touched.

### Custom designs

This brochure lists a selection of our more standard products. We can supply ceramic transducers to fit your special needs. Our technical staffs are always at your service and they are ready to assist you with your requirements.

# Application Note – Ultrasonic Ceramic Transducers

## Selection and use of Ultrasonic Ceramic Transducers

The purpose of this application note is to aid the user in the selection and application of the SSQC's Ultrasonic ceramic transducers.

The general transducer design features a piezo ceramic disc bender that is resonant at a nominal frequency of 20 – 60KHz and radiates or receives ultrasonic energy. They are distinguished from the piezo ceramic audio transducers also offered by S. Square in that they produce sound waves above 20KHz that are inaudible to humans and the ultrasonic energy is radiated or received in a relatively narrow beam.

The "open" type ultrasonic transducer design exposes the piezo bender bonded with a metal conical cone behind a protective screen. The "enclosed" type transducer design has the piezo bender mounted directly on the underside of the top of the case which is then machined to resonant at the desired frequency.

### Comparative Characteristics

When compared to the enclosed transducer, the open type receiver will develop more electrical output at a given sound pressure level (high sensitivity) and exhibit less reduction in output as the operating frequency deviates from normal resonant frequency (greater bandwidth). The open type transmitter will produce more output for a specific drive level (more efficient).

The enclosed type transducer is designed for very dusty or outdoor applications. The face of the transducer must be kept clean and free of damage to prevent losses.

The transmitter is designed to have a low impedance at the resonant frequency to obtain high mechanical efficiency. The receiver is constructed to maximize the impedance at the specified anti-resonant frequency to provide high electrical efficiency.

### Sound Propagation

In order to properly select a transducer for a given application, it is important to be aware of the principles of sound propagation. Since sound is a wave phenomenon, its propagation and directivity are related to its wavelength ( $\lambda$ ). A typical radiation power pattern for either a generator or receiver of waves is shown in figure 1. Due to the reciprocity of transmission and reception, the graph portrays both power radiated along a given direction (in the case of wave production), and the sensitivity along a given direction (in case of wave reception).

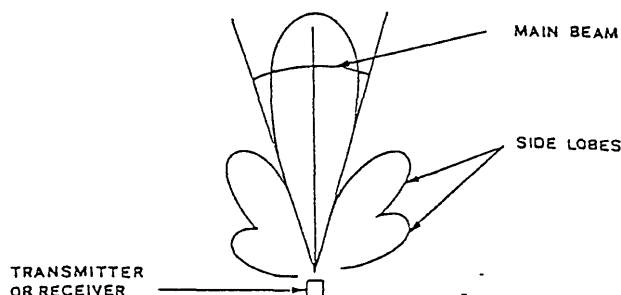


FIGURE 1 ULTRASONIC BEAM PATTERN

The angular, half-width ( $\alpha/2$ ) of the main beam is given by:

$$\sin(\alpha/2) \approx \lambda/D = V/DF$$

Where "D" is the effective diameter of the flexure diaphragm, "V" is the velocity of sound (344 meter/sec. in air at 20°C), and "F" is the operating frequency. The above relationship applies if  $\lambda < D$ . For  $\lambda \geq D$ , the power pattern tends to become spherical in form. Thus, narrow beams and high directivity are achieved by selecting "D" large in relation to  $\lambda$ .

As an example of a typical situation, a transducer with an effective diameter of 25 mm will produce a main beam with full width  $\alpha$  of 40° at a frequency of 40KHz. For open type transducer, the beam is decided by the angular and diameter of conical cone attached on the bender inside of housing and it can not be simply calculated by the diameter of housing.

The intensity of sound waves decrease with the distance from the sound source, as might be expected for any wave phenomenon. This decrease is principally a combination of two effects. The first is the inverse square law or spherical divergence in which the intensity drop 6dB per distance doubled. This rate is common to all wave phenomena regardless of frequency.

The second effect causing the intensity to decrease is in the absorption of the wave by the air. Absorption effects vary with humidity and dust content of the air and most importantly, they vary with frequency of the wave. Absorption at 20KHz is about 0.02dB/30cm. It is clear that lower frequencies are better suited for long range propagation. Of course, the selection of a lower frequency will result in less directivity (for a given diameter of source or receiver).

### Transmitter Drive Considerations

The ultrasonic transmitters can dissipate 200mW rms

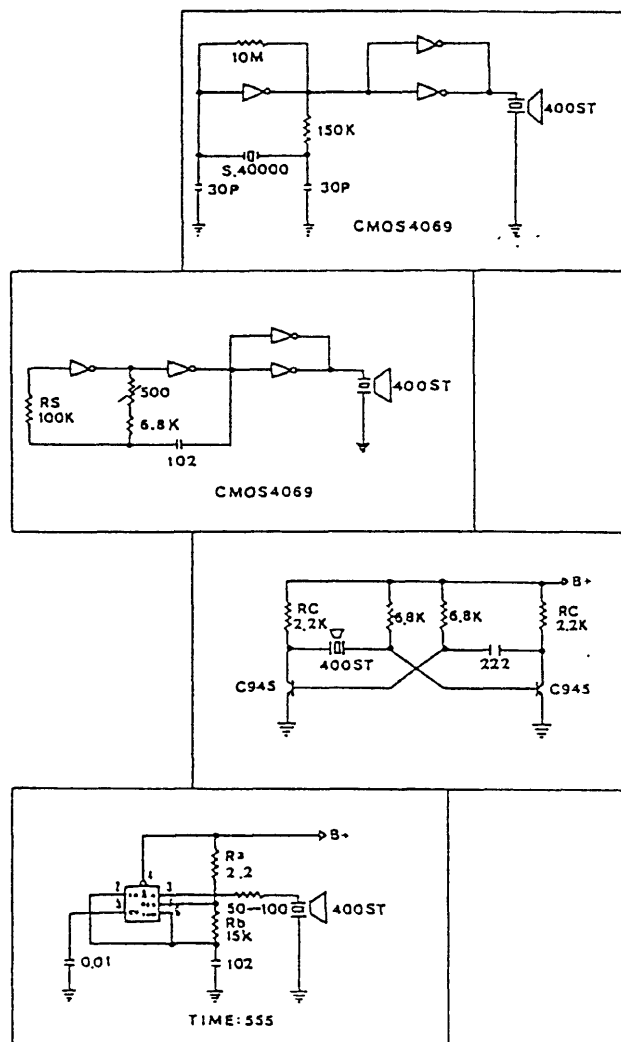
continually. Assuming a typical minimum series impedance of 500 ohms, the driver must source 20mA rms at 10Vrms.

A sinewave drive should be used to minimize harmonics that may excite the transducer in an overtone mode (vibrate at a multiple of the resonant frequency).

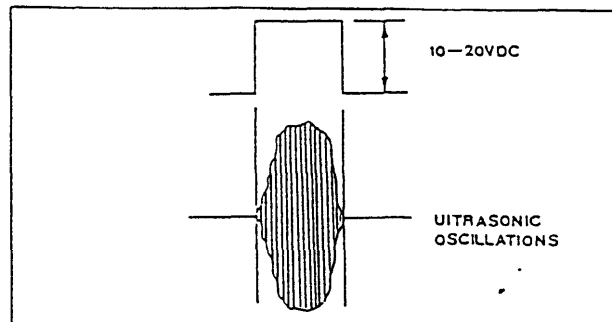
The maximum amplitude of the drive waveform should be limited to 50Vpp. The transmitter dissipation must be limited to an effective or average level of 200mW by reducing the duty cycle when the transmitter is dissipating more than 200mW.

There are several oscillator circuits suitable for driving our ultrasonic transmitter which have been widely used on security systems, remote control and other applications. Please bear in mind that the circuits we suggest sometimes need to be modified according to the different characters of impedance, phase angle and resonant frequency while driving different type of transmitters. Please refer to "Transmitter Impedance Characteristics" carefully.

#### Suggestion Oscillating Circuits:



The ultrasonic transmitters may also be driven with a pulse waveform. Application of a DC pulse of 10-20 volts will cause the transducer to "ring" at the selected resonant frequency. The ultrasonic output will be a damped ringing waveform as illustrated in the figure as follow.



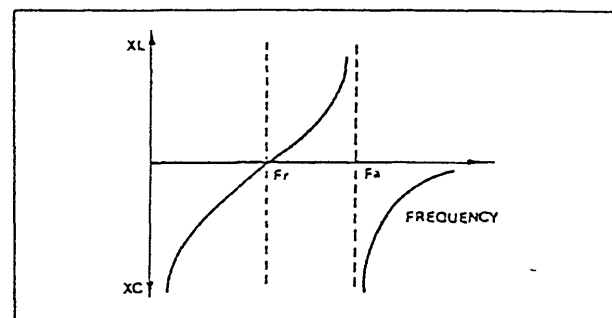
#### Transmitter Impedance Characteristics

Ultrasonic transmitter impedance characteristics vary with operating frequency and temperature in a complex manner that is different for each construction.

In general, for frequencies approximately 0.1 octave on either side of the resonant frequency, the transmitter looks like a capacitor. The current thru the transmitter will lead the voltage developed across the transmitter by 90 degrees.

As the resonant frequency is approached, the voltage drop across the transmitter will decrease to a minimum at the resonant frequency (minimum series impedance) and the current will increase proportionally. The phase lead to this current relative to the voltage will decrease to zero near the resonant frequency and the transmitter will then appear to be a pure resistance.

As the frequency is increased above the resonant point, the current may now lag the voltage by an increasing amount (maximum of 90 degrees) as the voltage across the transmitter climbs to a peak which is defined as the anti-resonant point. During this transition, the transmitter appears to have an inductive characteristic.



Increasing temperature will lower the resonant frequency and thus the point at which the phase changes will occur. The rate and magnitude of phase change is more stable than the resonant frequency.

## Ultrasonic Ranging

Ultrasonic ranging systems are used to determine the distance to an object by measuring the time required for an ultrasonic soundwave to travel to the object and return to the source. This technique is frequently referred to as "echo ranging".

The distance to the object may be related to the time it will take for an ultrasonic pulse to propagate the distance to the object and return to the source by dividing the total distance by the speed of sound which is 344 meters/second or 13.54 inches/millisecond.

Below is a block diagram that illustrates the basic design concept and functional elements in a typical ranging system.

The oscillator output is gated to the ultrasonic transmitter for a brief period that will result in the transmission of a few cycles of ultrasonic energy.

The gate signal also starts a counter which is stopped by the detected returning echo. The count is thus

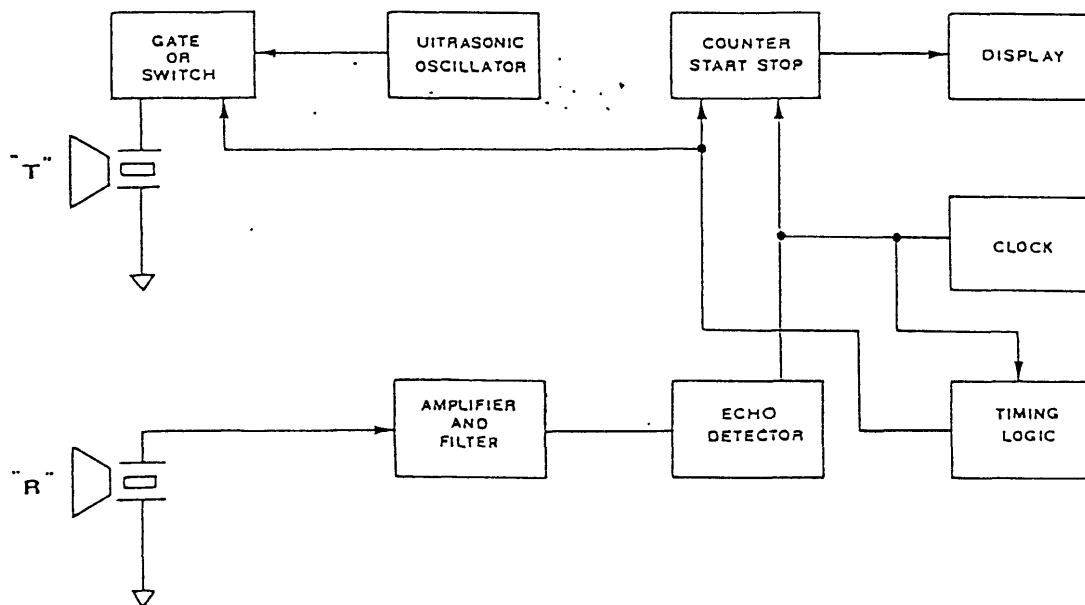
directly proportional to the propagation time of the ultrasonic sound.

The frequency of the clock that is driving the counter is selected to produce a count which represents the distance to the object in the desired engineering units.

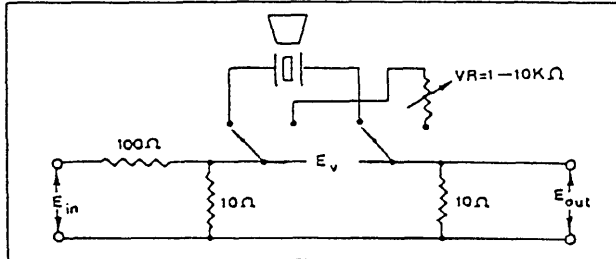
The returning ultrasonic echo is usually very weak and the key to designing a good ranging system is to utilize a high "Q" tuned frequency amplifier stage that will significantly amplify any signal at the frequency of the ultrasonic echo while rejecting all other higher or lower frequencies.

Another useful technique is to make the gain of the echo amplifier increase with time such that the amplifier gain compensates for the proportional decrease in the signal strength with distance or time.

The most common approach is to utilize the counter state outputs to drive a digital programmable amplifier such that the gain is automatically related to distance the sound travels.



The test circuit shown as below may be used to measure the resonant, anti-resonant and impedance characteristics of S. Square's ultrasonic transducers.



Adjust frequency to obtain maximum  $E_{out}$ . Switch in VR and adjust to obtain same output. VR now equals the minimum series impedance.

Adjust frequency to obtain minimum  $E_{out}$ . Switch in VR and adjust to obtain same output. VR now equals the maximum series impedance at the anti-resonant frequency.

Measure phase between voltage  $E_v$  and  $E_{out}$  to determine impedance characteristics.

#### Ultrasonic Receiver Characteristics

Ultrasonic receivers develop an electrical output in proportion to the sound pressure level at the receiver. One of the most frequently asked questions is "What output can I expect from a receiver at a specific distance?" This question can be answered by a simple calculation that is based on the published specifications in the Ultrasonic Ceramic Transducer Data Bulletin.

The basic procedure is to first determine the minimum SPL at the receiver for a specific transmitter drive voltage and distance between the transmitter and receiver. This SPL must then be converted to "Pa" (Pascal) or " $\mu\text{bar}$ " (microbar) units.

The sensitivity of the receiver must then be converted from a dB reference to an absolute millivolts/Pa or  $\mu\text{bar}$  and finally multiplied by the Pa or  $\mu\text{bar}$  level present to obtain the final output.

Assume a 400ST160 transmitter is driven at a level of 14 volts rms and a 400RT160 receiver is located 2 meters from the transmitter and loaded with a 3.9K resistor (resistor placed across the terminals of the receiver).

#### Determining SPL at the Receiver

Transmitter SPL : 119 dB at 40KHz, refer to 0dB = 0.0002 $\mu\text{bar}$  at 30cm when driven with 10Vrms.

Receiver Sensitivity : -65dB at 40KHz refer to 1 Volts/ $\mu\text{bar}$

SPL Reduction at 2 meters =  $20 \log (30\text{cm}/200\text{cm})$   
= -16.47 dB

SPL Gain for 14 Vrms Drive =  $20 \log (14\text{V}/10\text{V})$   
= 2.92 dB

The SPL at 2 meters =  $119 + 2.92 - 16.47 = 105.5\text{dB}$

#### Converting SPL to $\mu\text{bar}$

SPL = 105.5 dB  
=  $20 \log (\text{SPL in } \mu\text{bar} = "X"/0.0002\mu\text{bar @ 0dB})$   
Dividing by 20 and taking the anti-log yields:  
 $188364.9 = "X"/0.0002\mu\text{bar} = 37.67\mu\text{bar}$

#### Determining Receiver Sensitivity in Volts/ $\mu\text{bar}$

Sen. = -65dB  
=  $20 \log (\text{Output Voltage at a Specific SPL} \div 1 \text{ Volt}/\mu\text{bar})$   
=  $0.0005623 \text{ Volts}/\mu\text{bar} \times 37.67 \mu\text{bar}$   
= 0.0212 Volts = 21.2 mVolts

This is the minimum output that should be developed under the assumed conditions. The actual output may be much greater depending on operating frequency vs matching frequency between T & R, environmental conditions, and reflective or absorption characteristics of materials in or near the emanating beam.

The analysis is necessary to the fundamental understanding of the principals of soundwave propagation and detection but it is tedious. Figure as below is a graphical representation of the previous analysis which may be used once in the SPL at the receiver is determined. Enter the graph from the SPL axis and proceed upward to an intersection with -dB sensitivity level of the receiver using the 1V/ $\mu\text{bar}$  referenced data. Follow a horizontal line to the "Y" axis to obtain the receiver output in mV.

