CTRL WHITE PAPER

WHY 40 kHz?

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Regarding the Selection of 40 kHz Piezoelectric Transducer

The 40 kHz transducer was selected for the UL101 and most other airborne ultrasonic sensors because it is ideal for detecting gas leaks from a reasonable distance and for diagnosing mechanical components for early signs of wear or defects. If a sensor were designed specifically for the detection of mechanical defects, a transducer with a higher center of frequency might be used, provided the intensive attenuation of ultrasound throughout the mechanical would not affect the sensitivity of the instrument. It is important to consider the suitable distance by which an ultrasound detecting device may detect with respect to the rate of a high frequency chosen.

Airborne Ultrasound

As sound travels through air, its energy attenuates more rapidly as the frequency increases. The maximum theoretical rate of attenuation for ultrasonic sound up to 200 kHz is given by:

$$a_{\max} = f \times .01$$

where: $a_{\max}$ = maximum attenuation in dB/ft
f = frequency in kHz

Therefore, sound energy from a 200 kHz transducer would be attenuated a maximum of 2 dB/ft. But at 40 kHz, the sound energy would be attenuated a maximum of just 0.40 dB/ft. Knowing this, the attenuation of a 200 kHz sound producing a 100 dB noise at its source would attenuate completely at 50 feet. However, the attenuation of a 40 kHz sound of the same initial intensity would attenuate completely at 250 feet.

Other factors affecting the rate of attenuation include temperature, humidity, and atmospheric pressure.

Temperature

The speed of sound in air varies as a function of temperature by the relationship:

$$c(T) = 13,044\sqrt{1+\frac{T}{273}}$$

where: c(T) is the speed of sound in air as a function of temperature in inches/sec.
T is the temperature of air in ºC

Humidity

The attenuation of ultrasonic sound in air is a function of frequency and humidity:

As sound travels, the amplitude of the sound pressure is reduced due to friction losses in the transmission medium. The value of humidity that produces the maximum attenuation is not the same for all frequencies. (ie. 125 kHz – maximum attenuation occurs at 100% relative humidity; 40 kHz – maximum attenuation occurs at 50% relative humidity) Since ultrasonic sensors are required to operate at various humidity levels, the selected frequency should have the largest value of attenuation.

For frequencies up to 50 kHz a good estimate for the maximum attenuation at room temperature over all humidities is given by:

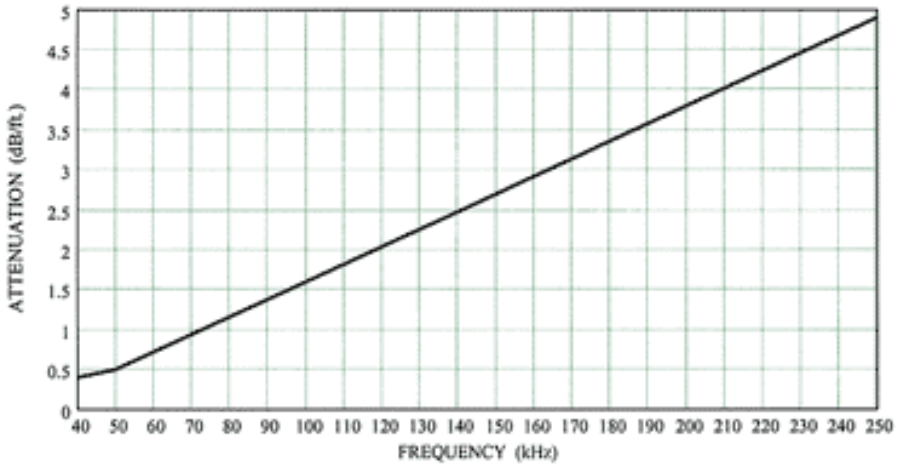
$$a(f) = .10\ f$$

where: a(f) is the maximum attenuation in dB/ft.
f is the frequency of sound in kHz

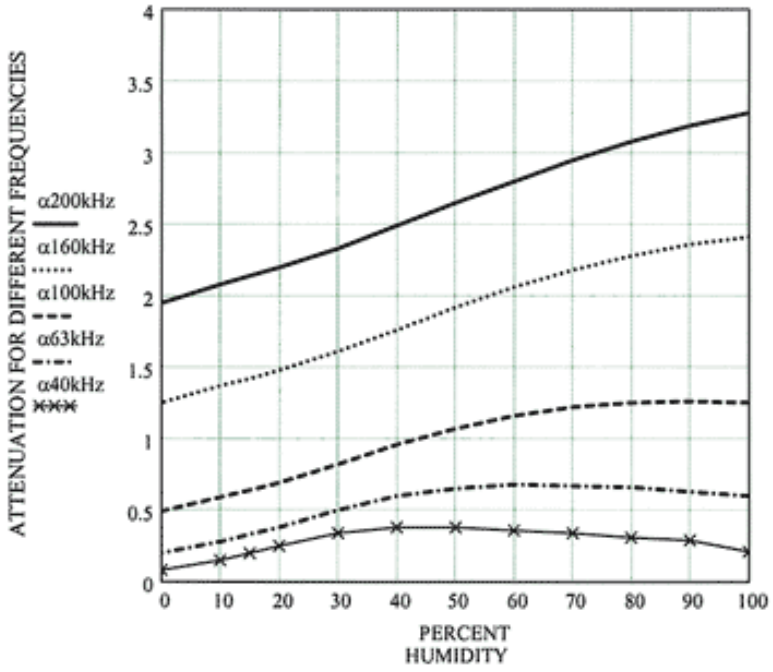
For frequencies between 50 kHz and 300 kHz, the maximum attenuation is:

$$a(f) = .022f - 0.6$$

The following figure shows the maximum attenuation of sound as a function of frequency in air at room temperature over all humidities for frequencies between 40 kHz and 250 kHz. Note the increase in rate of attenuation at 50 kHz.



The following figure shows a family of curves that plot the variations in the attenuation of sound in air at room temperature as a function of humidity for various frequencies between 40 kHz and 200 kHz. Please note the relatively small attenuation rate changes and low attenuation at 40 kHz over the range of percent humidity.



Sources

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