GRAS
An Axiometrix Solutions Brand

Handbook

Microphone vs Pressure Sensor

Volume 01

GRAS Sound & Vibration is a worldwide leader in the sound and vibration industry. We develop and manufacture state-of-the-art measurement microphones and related equipment for industries where acoustic measuring accuracy and repeatability are of the utmost importance. This includes applications and solutions for customers within the fields of aerospace, automotive, audiology, consumer electronics and other highly demanding industries. GRAS microphones are designed to live up to the high quality, durability and accuracy that our customers have come to expect and trust.

GRAS is represented through subsidiaries and distributors in more than 40 countries and is part of Axiometrix Solutions, a leading test solutions provider comprised of globally recognized measurement brands.

Please visit www.grasacoustics.com to find your local GRAS partner or contact us at marketing@grasacoustics.com with any questions.

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1. INTRODUCTION

The purpose of this handbook is to help you understand the differences between measurement microphones and pressure sensors. We hope this will answer common questions concerning GRAS UTP (Ultra-thin Precision) series microphones, particularly GRAS 48LA and 48LX series.

In general, pressure sensors can be grouped into three basic categories in the pressure sensor market:

- ✓ High-pressure sensors that measure above 500 psi
- ✓ Low-pressure sensors that measure between 0 – 500 psi
- ✓ Piezoresistive (PZR) microphones, or pressure sensors that measure in the typical microphone range, which is up to 16 psi, or 195 dB.

Because the noise floor of typical high- and low- pressure sensors is so high, only the PZR-type microphones can be used to measure acoustic or aeroacoustic phenomena. Therefore, all comparisons should be understood to be between surface (UTP-type) microphones and the PZR-type microphones.

This handbook begins by outlining some basic concepts, so any who already have a solid understanding of measurement microphones may begin with section 4 “Pressure Sensors”.

2. THE BASIC TERMS

2.1 Sound

What the human ear perceives as sound is dynamic pressure fluctuation with a frequency between 20 Hz and 20 kHz. Sound can propagate in gases, fluids and in solid materials (structure-borne sound).

This document focuses on sound in air, where the pressure fluctuations are superimposed on the actual atmospheric pressure, as shown in Figure 1.

2.2 Pressure

Pressure is defined as force per unit of area (Pascals per square meter (Pa/m^2)). A pressure of 101.325 kPa is defined to be equal to one International Standard Atmosphere (1 atm).

3. STANDARD LABORATORY CONDITIONS

For measurement microphones, IEC 61094-2 defines the reference environmental conditions as:

Temperature	**23°C**
Static pressure	**101.325 kPa**
Relative humidity	**50%**

Measurements are seldom performed under reference conditions, and in order to estimate the microphone's performance under other conditions, the manufacturer must specify the influence on the microphone performance due to variation in temperature (temperature coefficient), pressure (pressure coefficient) and relative humidity.

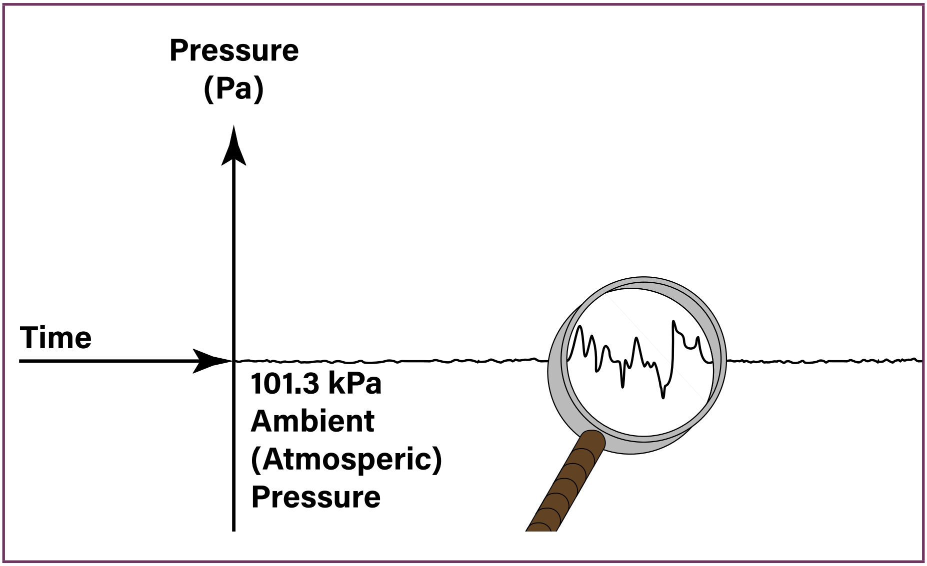

FIGURE 1.
Sound is small pressure fluctuations "riding" on top of the barometric pressure.

4. MICROPHONES

Generally speaking a microphones is a sensor that converts sound to an electrical signal.

There are many different kinds of microphones—most GRAS microphones are measurement microphones.

Measurement microphones are, generally speaking, microphones that meet the requirements detailed in IEC 61094-4. However, some measurement microphones may meet the performance criteria but not the mechanical dimensions specified in the "microphone standard".

GRAS surface microphones, inlcuding the UTP series are examples of this.

4.1 Microphone performance parameters

The main parameters of interest here are:

- ✓ Sensitivity often expressed in mV/Pa or in dB re 1V/Pa.

  Example: The GRAS 46AE microphone has a nominal sensitivity 50 mV/Pa corresponding to –26 dB re 1V/Pa.

- ✓ Frequency response in dB measured relative to the response at 250 Hz.
- ✓ Maximum SPL capability is the highest sound pressure level (SPL) measurable with less than 3% total harmonic distortion (THD).
- ✓ Mimimum SPL often defined as the equivalent SPL to the inherent electrical noise in the microphone output, measured in dB(A).

The difference between the two latter SPLs defines the dynamic range in decibels.

While it is commonly agreed that the "loudest sound possible" is approximately 194 dB SPL, that is both right and wrong. Above 194 dB (at reference static pressure) air molecules are pushed along rather than moving back and forth; meaning, sound waves do not propagate through air anymore, they produce shockwaves.

This extreme pressure variation is the domain of pressure sensors. However, this comes at the expense of much higher noise floors than microphones, making them unsuitable for acoustic measurement. The areas where they overlap can be seen in Figure 2.

5. PRESSURE SENSORS

As seen in Figure 2 there is an overlapping region where it is possible to use either a presure sensor or a microphone—in many cases UTP-type microphones offer unique benefits, more about that later.

Pressure sensors come in a wide variety of types, but typically pressure sensors can be designed/set up to measure one of the following:

- Gauge pressure—e.g., the pressure with reference to the ambient pressure—much like a microphone.
- Absolute pressure—e.g., the pressure relative to zero pressure.
- Differential pressure—e.g., the pressure relative to a reference port

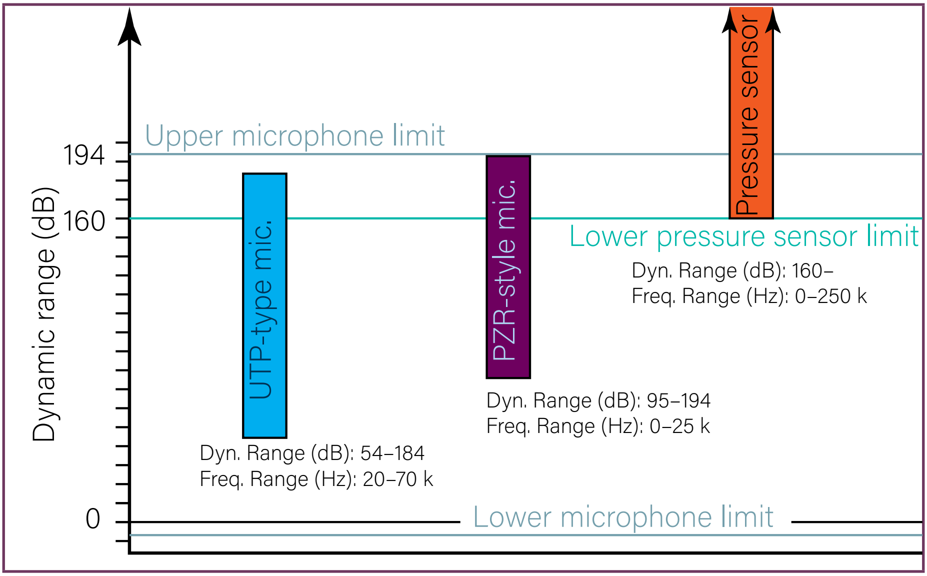

FIGURE 2.
Microphone and pressure sensor ranges based on type possibilities.

6. MICROPHONE VS PRESSURE SENSOR—THE MAJOR DIFFERENCES

NOTE: When comparing pressure sensors with microphones, it is important to keep in mind that the comparison is made using pressure sensors designed for measuring dynamic pressure fluctuations rather than pressure sensors designed, for example, to monitor the fairly static oil pressure in a car.

First of all, there is no strict standard for pressure sensors—they come in all different shapes and sizes. Also, pressure sensors are often specified for different parameters and in different units than microphones. This makes a 1:1 comparison with microphones difficult, and in some cases, impossible.

Another important difference is that in the world of acoustics, calibration has a very long history and there are international standards for microphone calibration, this secures traceability and higher integrity of measurements.

For instance, with pressure sensors, it is not common to determine the frequency response. In some cases the sensor's resonance frequency or rise time is specified.

Some pressure sensors have an active sensor area that is somewhat smaller than the diaphragm area of a ¼″ microphone, which gives pressure sensors the benefit of a better spatial resolution and is important in some applications. However, a pinhole cover can be used to overcome issues caused by microphone diaphragm size.

In many cases pressure sensors are used due to tradition rather than shifting to newer solutions that can provide more cost-effective results, such as UTP surface-mounted microphones.

However, it is important to note that not all pressure sensor applications can be performed with microphones.

7. HOW TO COMPARE MICROPHONES AND PRESSURE SENSORS

In order to really compare apples to apples, some parameters will need to be converted from one dimension to another.

Table 1 provides some of the most important parameters and how to express them in terms relating to microphones or pressure sensors.

TABLE 1.
Microphone-pressure sensor comparison data and comments

Parameter	Microphone	Pressure sensor	Conversion factor to pressure sensor terminology	Remark
Sensitivity (Voltage)	mV/Pa	mV/psi	mV/psi = 6895 * mV/Pa	See A.1
Sensitivity (Relative)	dB re 1V/Pa	dB re 1V/µbar	dB re 1V/µbar =	-20 dB or /10 See A.1
Full scale	dB SPL	Psi	=20e-6*10^ (dB SPL/20)/ 6895	
Burst pressure	Seldom defined	Nearly always specified		
Inherent noise/noise floor	Always specified most often as dB(A) SPL	Only seldom specified		
Resonance frequency	Sometimes specified	Most often Specified		Frequency in kHz
Frequency range	±1 dB ±3 dB	NA		See A.2
Frequency response in the full range	Specified and traceable to international standards	Seldom known		
Sensitivity to vibration	Should always be stated	Is nearly always stated		
Time constant	Seldom mentioned	Most often specified		

TABLE 1 - *Continued on next page*

TABLE 1 *- Continued*

Parameter	Microphone	Pressure sensor	Conversion factor to pressure sensor terminology	Remark
Lower limiting frequency	Most often specified at least as a range	Not always possible to specify, but some models have a specification		
Linearity	NA	Often defined in pct. of full scale		A.3
Distortion	Max. SPL often defined a 3% THD limit	Not specified		
Operating temperature range	Always defined. Best values for some types around minus 60° to 125°C.	Generally, quite wide range. Best values for some types around −55° to 250°C		
TEDS	Often yes	Not commonly available		
Output impedance	Low, good cable drive capability	Charge type output or bridge type		A.4
Need power supply	Yes, CCP (ICP) power from	Charge output no Bridge types yes		
Cable	Yes, often coaxial cable with standard connector	Often only open-ended fragile, thin wires		

APPENDIX A—NOTES TO COMPARISON TABLE

A.1 Conversion step by step

1 psi = 6894.8 Pa
1 bar = 100 kPa
1 µbar = 0.1 Pa
Factor 10 between Pascal and microbar gives -20dB
Ex = Type 48LA sensitivity:
• -78.4 rel 1V/Pa
• -94.4 rel 1V/µbar

A.2 Frequency range

In the Kulite® Transducer Handbook it is stated that their PZR sensors perform well up to 1/5 of the resonance frequency. [1] This relates to approximately 30 kHz.

±3 dB Gives 0.7×general sensitivity <real sensitivity < 1.4×general sensitivity
±2 dB Gives 0.8×general sensitivity <real sensitivity < 1.25×general sensitivity
±1 dB Gives 0.9×general sensitivity <real sensitivity < 1.12×general sensitivity

A.3 Linearity

“Non-linearity (sometimes called linearity) is defined as the maximum deviation of the calibration curve (output vs input) from a specified straight line, expressed as a percent of full-scale output, and measured on increasing measurand only.” [1]

Be aware of this; it is often stated as a certain percentage of full range, for instance 0.5% (-46 dB re full range).

A.4 Cable drive capability

Charge output is fine if you use a charge amplifier—elsewise the sensitivity will depend on cable length.

Bridge type output may have around 1000 Ω output impedance; however when used with a suited bridge amplifier, the output impedance is conditioned to around 10 Ω.

Pressure sensors use expensive bridge modules, UTP uses an industry standard CCP (ICP) interfce.

REFERENCES

1. Kulite Transducer Handbook. 2018: https://kulite.com/technology/reference-library/. Cited: Aug. 2021.

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