# Application Note

## Periodic Verification of Measurement Microphones

G.R.A.S.
SOUND & VIBRATION

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# Periodic Verification of Measurement Microphones

Per Rasmussen

*A comprehensive calibration system like the one shown below may be necessary when quality assurance policies or legal requirements demand a full high accuracy calibration. However, even a simple regular calibration may cost in the range from 20 % to 50 % of the price of the microphone. It is therefore important to consider what the requirements for calibration actually are. In some cases specific quality assurance policies or legal requirements demand a regular full-scale calibration of all equipment by a certified laboratory. In other situations it is more a question of having confidence in the measurements and a check that the microphone has not changed or been damaged will be sufficient.*

***Fig. 1.*** *The G.R.A.S. 90CA Calibration System.*

## Introduction

Calibration of microphones consists of basically two parts: a level calibration and a frequency response calibration. The level calibration, most often done at 250 Hz, determines the absolute sensitivity of the microphone and gives the relationship between an input sound pressure signal and the output voltage signal. The frequency response calibration gives the deviation at other frequencies from the response at 250 Hz. This response is normally established using the electrostatic actuator method. This gives the microphones pressure response and the free field response is then calculated by adding the predetermined free field correction values to the pressure response.

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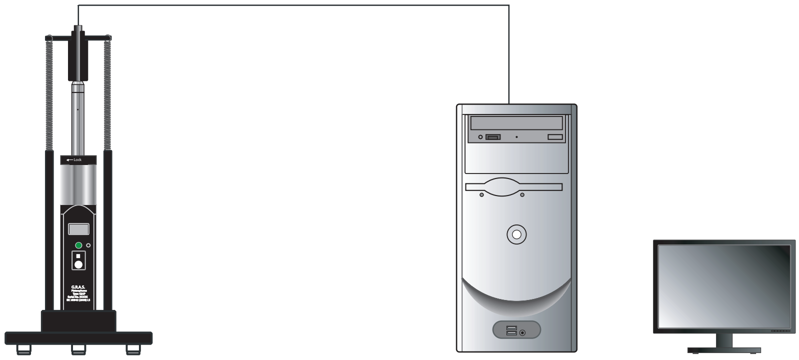


***Fig. 1.*** *Set-up for level calibration with pistonphone.*

## Level Calibration Techniques

The level calibration of microphones can be done in a variety of different ways: reciprocity calibration, comparison calibration or pistonphone calibration. The reciprocity calibration technique is normally considered as the most accurate method, but is very elaborate and expensive to perform. The comparison method where the sensitivity of the microphone under test (DUT) is compared with the known sensitivity of a reference microphone is simple and can be established with widely available equipment with only minor investments. Combined with a precision pistonphone, Fig. 1, and a precision barometer the comparison method will give a highly reliable and robust calibration method. The pistonphone and barometer for static pressure correction will give a highly reliable absolute sound pressure level. By using this set-up to check the sensitivity of the reference microphone, the preamplifier and subsequent equipment can be checked. For example, the output from the reference microphone will be directly proportional to the polarization voltage. It would therefore be necessary to check the polarization voltage directly on the microphone output terminal to ensure correct readings. If however the output of the microphone is checked with the absolute level from the pistonphone any variations in the polarization voltage can be detected.

The pistonphone is a very stable sound source, which produces a well-defined sound pressure level inside a closed coupler. It works by volume displacements with a well-defined velocity, usually at 250 Hz. As the piston is moving in and out, the volume of the closed coupler is changed and this will result in pressure variations. The actual pressure level obtained in the pistonphone depends on the volume of the coupler, the volume displacement of the pistons, the barometric pressure, and – to a lesser degree – on other factors such as humidity, heat dissipation, etc.

As the pistonphone is based on a relatively simple mechanical system, it is very reliable and easy to use in practice, with an accuracy around 0.1 dB. Also, the pistonphone is often used as the stable sound source for calibrations using comparisons or substitution methods. The 250 Hz calibration frequency is chosen so that it is well above the low-frequency cut-off frequency of the microphone and at the same time below frequencies where the pressure frequency response of free-field microphones starts to drop off. Also the long wavelength of a 250 Hz acoustical signal ensures that the sound pressure level inside the pistonphone coupler volume is uniform.

A sound pressure calibrator is basically a small self-contained comparison calibration device. The test microphone is inserted into a small, closed volume and a small loudspeaker produces a single frequency signal, usually 1 kHz. The output level of the loudspeaker is controlled by a feedback system with a signal from a reference microphone. Provided that the reference microphone and the feedback gain are stable, the sound level at the test microphone will be well-defined and the sensitivity can be determined.

The sound level calibrators are normally not used to make accurate microphone calibrations, but rather to make field checks of the integrity of a complete measurement system. The 1 kHz calibration frequency is convenient for calibrating sound level meters including A-weighting filters as the attenuation of the filter is 0 dB at 1 kHz. It does however pose a problem for accurate calibration of typical 1/2" free field microphones as the pressure frequency response of the microphone may have dropped by 0.2 dB.

A normal microphone calibration involves the determination of the Open Circuit Sensitivity. This gives the output from the microphone for a given input signal when there is no electrical load on the microphone's output terminal. The Closed Circuit Sensitivity is however dependant on the specific type of preamplifier and can vary from one preamplifier type to the next. The loading from the preamplifier will reduce the output signal from the microphone and the Closed Circuit sensitivity will therefore be lower than the Open Circuit Sensitivity.

The Open Circuit Sensitivity is determined with the Insert Voltage technique using a special preamplifier, where a test signal can be injected directly on the preamplifier input terminal. The Open Circuit Sensitivity is important when the microphone may be used with different measurement set ups and hence the loading conditions are not known. In larger organizations having several measurement microphones it may be necessary to establish the open circuit sensitivity.

It is common practice for the measurement microphone to always be used in connection with a known preamplifier and hence the loading of the microphone is known. In these conditions the Closed Circuit Sensitivity can be determined from the Pistonphone calibration value, by simply measuring the output from the preamplifier with the pistonphone signal applied to the microphone input. If the pistonphone calibration value, corrected for the barometric pressure, is for example 113.8 dB re. $2*10^{-5}$Pa and the output from the preamplifier is for example 456 mV then the Closed circuit sensitivity of the microphone is:

$$S_{Closed} = \frac{456mV}{2*10^{-5}Pa*10^{(113.8/20)}} = \frac{456mV}{9.795Pa} = 46.55mV/Pa$$

[1]

This Closed Circuit Sensitivity is in principle only valid for this particular combination of preamplifier and microphone, and includes the loading of the microphone by the preamplifier as well as the gain in the preamplifier.

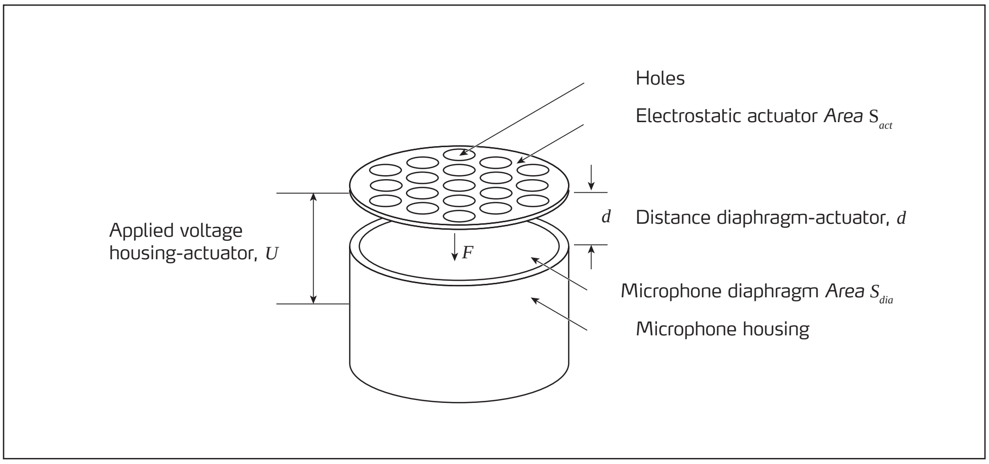


***Fig. 2.*** *Principle of microphone excitation with electrostatic actuator.*

## Frequency Response Measurements

The frequency response of measurement microphones can be presented in different ways i.e. pressure response, free field response and diffuse field (random incidence) response. As these three values are directly related the general procedure is to measure only the pressure response and then corresponding free field and diffuse field responses are calculated by adding corrections to it. The correction factors are established for a type of microphone and are assumed identical for all individual microphones of that type.

The pressure response is determined by the electrostatic actuator method. This method requires no special acoustic laboratory facilities and can be established with only minor investments. The method is described in IEC 61094-6 Working Draft Standard *"Measurement microphones – Part 6: Measurement of frequency response using electrostatic actuator"*. The electrostatic actuator consists of an electrically conductive, rigid plate, which is mounted close to and parallel to the microphone diaphragm, see Fig. 2.

When a voltage $U$ is applied between the microphone housing and the electrostatic actuator the microphone diaphragm will be acted upon by a force $F$ given by:

$$F = -\frac{\varepsilon_{air} \cdot S_{act}}{2 \cdot d^2} \cdot U^2 \qquad [2]$$

where $\varepsilon_{air}$ is the dielectric constant of air, $S_{act}$ is the actuator area, $d$ is the distance between the diaphragm and actuator.

This force is equivalent to a pressure $P$ acting on the diaphragm given by the relationship:

$$P_{act} = \frac{F}{S_{dia}} = -\frac{\varepsilon_{air}}{2 \cdot d^2} \cdot a \cdot U^2 \qquad [3]$$

where $a$ is the ratio between effective actuator area and active diaphragm area.

The method is normally used with a DC voltage $U_0$ and a superimposed AC signal $u$. The resulting corresponding electrostatically generated pressure signal on the microphone is:

$$p(t) = \frac{\varepsilon_{air} \cdot a}{2 \cdot d^2} \left(U_0 + u \cdot \sqrt{2} \cdot \sin(\varpi t)\right)^2 \qquad [4]$$

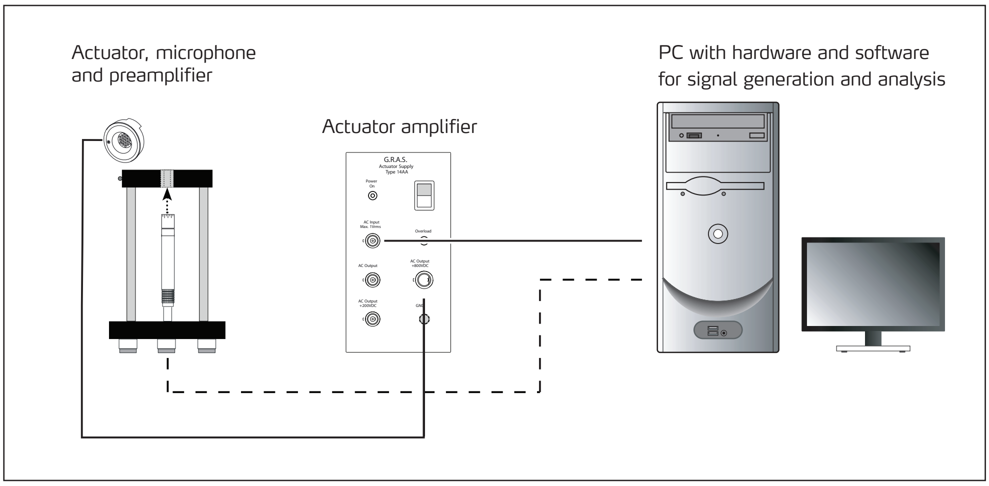


***Fig. 3.*** *Measurement set-up for frequency response calibration. An electroacoustic analyzer with signal generator can be substituded for the PC.*

This results in three components where the static component is not of interest here. The other two components are a component of interest with the frequency $\varpi$ and a second harmonic component. The fundamental frequency component is given by:

$$p = \frac{\varepsilon_{air} \cdot a}{d^2} \cdot U_0 \cdot u \cdot \sqrt{2} \qquad [5]$$

As can be seen, the output signal is proportional to the static voltage and inversely proportional to the square of the distance $d$. To maximise the output signal the distance $d$ should be minimized and the static voltage $U_0$ should be maximized. However, In practice one has to consider that very small distances d and very high voltages $U_0$ will result in short circuit of the polarization voltage. The ratio of the second harmonic component to the fundamental component is given by:

$$D = \frac{u\sqrt{2}}{4 \cdot U_0} \cdot 100\% \qquad [6]$$

It can be seen that as the static voltage is lowered the second harmonic contribution will increase.

## Practical Set-up for Actuator Measurements

Fig. 3 shows a practical set-up for measuring the actuator response of a microphone using a PC with hardware and software for signal generation and analysis. An analyzer with built in signal generator may also be used.

An alternative solution would be to use a sine generator for the signal generation and a Sound Level Meter to measure the result. If the Sound Level Meter has build-in filtering this may be used to improved the signal to noise ratio.

The 14AA Electrostatic Actuator Amplifier generates 800 VDC supply for the static voltage and amplifies the generator signal from the frequency analyzer by 40 dB. The amplified signal is superimposed on the 800 VDC and is fed to the electrostatic actuator mounted on the microphone. The output signal from the microphone preamplifier is connected to one channel of the frequency analyzer simultaneously with the input signal to the other.

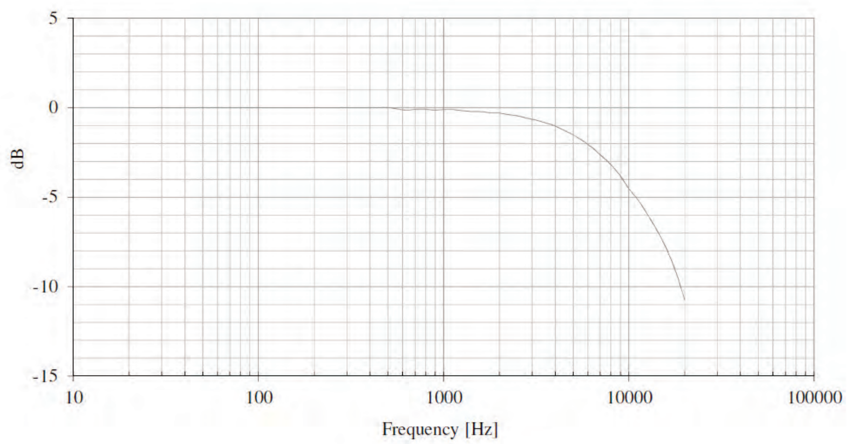


***Fig. 4.*** *Frequency response measured with electrostatic actuator.*

For an output signal from the analyzer of 1 V, the ratio of the second harmonic component to the fundamental component will be approximately 4.4 %. Using the analyzer in the sine sweep mode, the it will generate a series of sine wave signals and these will be sequentially analyzed with a discrete Fourier transformation.

As the analyzer only measures the input signal at the frequency generated by the output generator the second harmonic contribution will not be included and background noise contributions will be reduced. This means that the frequency response of microphones can be measured in normal environments and does not requires special sound insulated test chambers, as long as the back ground noise level is reasonably low.

A typical frequency response measurement involving 60 test frequencies from 100 Hz to 20 kHz can be performed in less than 30 s. Fig. 4 shows a typical pressure response for a free field microphone measured with an electrostatic actuator.

To obtain the free field response of the microphone, the free field correction factors are added to the pressure response. The free field correction factors are normally available from the microphone manufacturer and extra frequency values can be obtained by interpolation.

## Conclusion

Measurement microphones can be calibrated accurately and reliably with simple and cost effective setups. Using a standard frequency analyzer and an electrostatic actuator amplifier the frequency response of microphones can be checked and verified without the need for any special acoustic measurement facilities.

When quality assurance policies or legal requirements demand a full high accuracy calibration, a comprehensive calibration system like the G.R.A.S. 90CA is a good choice.