the GENERAL RADIO Experimenter

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SOUND MEASUREMENTS AT VERY HIGH LEVELS

● **AS A RESULT** of the increasing use of jet and rocket propulsion, noise levels of 150 db and higher are becoming relatively common. Such levels are beyond the range of most sound-level meters. For the measurement of these high levels, new microphones are now available, which extend the range of the General Radio Sound-Level Meter well beyond the nominal upper limit of 140 db above the standard reference level.

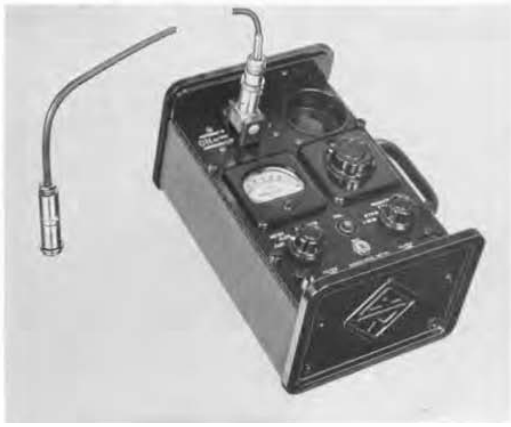
One of these, the Massa Model M-141B Standard Microphone, shown in Figure 1, can be used directly on the sound-level meter, replacing the Rochelle-salt type furnished as standard equipment. The other, the Altec 21-BR-180 Condenser Microphone, for use with the TYPE 1551-P1 Condenser Microphone System, is shown in Figure 2.

These high-level microphones are well suited for measuring sound levels in engine test cells and near high-powered airplanes, and for measuring the blast pressures of gun fire and other explosions. Furthermore, they have such good frequency-response characteristics that they are particularly useful for measuring noises characterized by strong high-frequency components, as, for example, turbine-blade noise, jet-engine noise, and textile machinery noise. The small size of these microphones makes it possible to bring the microphone near to noisy parts of a machine, a procedure which is often invaluable in tracking down sources of noise. The small size also helps in exploring sound fields with a minimum of disturbance from the microphone. In addition, the Massa microphone, because of its exceptionally rigid construction, is particularly suited to direct measurements of pressure variations in pressure chambers by mounting the microphone to form part of the chamber wall.

BEHAVIOR OF REGULAR MICROPHONES AT HIGH LEVELS

Before describing these newer microphones in detail, however, we shall re-

Figure 1. View of the Massa Model M-141B Standard Microphone with the General Radio Type 1551-A Sound-Level Meter.



view the high-pressure limitations of the other microphones available from the General Radio Company.

Rochelle-Salt Type

A Rochelle-salt crystal microphone, Shure Model 98-98, is regularly supplied with the TYPE 1551-A Sound-Level Meter. This sensitive microphone is designed to cover the usual levels encountered in sound measurements, and its use at high levels is limited by possible damage to the crystal and by possible non-linearity of the output voltage with respect to the input sound pressure.

Tests indicate that neither damage nor appreciable non-linearity occurs at levels up to 154 db. This microphone can, therefore, be used at somewhat higher levels than the normal upper limit of the sound-level meter. Levels only a few decibels above 140 db can be measured if the calibration control of the instrument is set so that the gain is lower than normal. The reading is then corrected by adding to it the number of decibels by which the gain was set low. This number of decibels can be measured by using the line-calibration system provided on the TYPE 1551-A.

To facilitate the measurement of still higher levels, a new accessory, the TYPE 1551-P11 20-db Pad, shown in Figure 3, is being made available. This pad is a resistance network connected between two phone plugs, which fit the "FILTER IN" and "FILTER OUT" jacks of the TYPE 1551-A Sound-Level Meter.

When they are thus connected, a 20-db correction is to be added to the level reading of the instrument. The nominal level range is, then, consequently, 44 to 160 db above the standard reference level of 0.0002 microbar.

Not only does this accessory extend the range of levels that can be measured by the TYPE 1551-A Sound-Level Meter, but it also helps to solve the microphonic problem, which is so serious when high levels are measured (see below, page 7). The 20-db pad also makes it easier to measure by means of an analyzer a comparatively weak high-frequency sound in the presence of a high-level low-frequency sound. This feature results from an improvement in the signal-to-noise ratio when the pad is used.

Figure 2. View of the Type 1551-A Sound-Level Meter with the Type 1551-P1H Condenser Microphone System, which uses the Altec 21-BR-180 Microphone.

Dynamic Type

The dynamic microphone in the TYPE 759-P25 Dynamic Microphone Assembly is limited to a maximum sound-pressure level of about 140 db at low frequencies. At higher levels the microphone may be damaged.

Condenser Type

The Altec Type 21-BR-150 Condenser Microphone[1] used in the TYPE 1551-P1 Condenser Microphone System is, in contrast, not damaged by high sound levels. Its high-level limit is determined by the permissible distortion. At high sound levels, the motion of the diaphragm is great enough to result in non-linearity of the output voltage with respect to the input sound pressure. The

[1]The Altec Type 21-C Condenser Microphone was formerly used in the TYPE 1551-P1 Condenser Microphone System. That microphone has now been replaced by the newer TYPE 21-BR-150, which is an improved version for measurement applications.

distortion from this effect is generally less than 1 per cent at levels up to 135 db, increasing with level to about 10 per cent at 155 db. When a level higher than 140 db is to be measured using this microphone, the TYPE 1551-P11 20-db Pad must be used to keep the signal within the range of the TYPE 1551-A Sound-Level Meter.

Figure 3. As shown here, the Type 1551-P11 20-db Pad plugs into jacks on the sound-level-meter panel.

MICROPHONES FOR HIGH LEVELS

Altec Type 21-BR-180 Condenser Microphone

As mentioned in the introduction, another condenser microphone, the Altec Type 21-BR-180, is also available for use with the TYPE 1551-P1 System. Its sensitivity is about 15 db less than that of the Type 21-BR-150. Then the level of distortion discussed above is below 1 per cent up to about 150 db and below 10 per cent up to about 170 db. For some applications even more distortion would be permissible for a measurement of a noise of high pressure level. Above 150 db with the Type 21-BR-180, the Type 1551-P11 20-db Pad is necessary.

The Type 21-BR-180 Microphone is similar to the one regularly supplied with the TYPE 1551-P1 System. The diaphragm of the microphone is more rigid, however, so that the sensitivity is less. In addition, some acoustic damping has been introduced to reduce the resonant rise in response that is more serious with a stiffer diaphragm. As a result of these changes, the response of this high-level microphone is even better than that of the Type 21-BR-150.

A typical frequency response for this condenser microphone is shown in Figure 4. The response to 20 kc is seen to be very good, particularly for parallel incidence, that is, when the sound grazes the face of the microphone. In order to reduce the effects of unwanted disturbances in the sound field, it is often recommended that perpendicular incidence be used; and then the upper response curve of Figure 5 applies. If it is desired to reduce the peak in response that occurs, the "C"-weighting network of the TYPE 1551-A Sound-Level Meter can be used, with a result for perpendicular incidence that is essentially the same as the curve shown for parallel incidence.

The Type 21-BR-180 Microphone is not seriously affected by comparatively high temperatures, but the preamplifier of the TYPE 1551-P1 System is limited by its vacuum tube to operation at temperatures below about 100° C. (212° F.). Also, because of the high electrical impedances involved, this microphone system is not recommended for operation at high humidities, although no permanent damage results from exposure to high

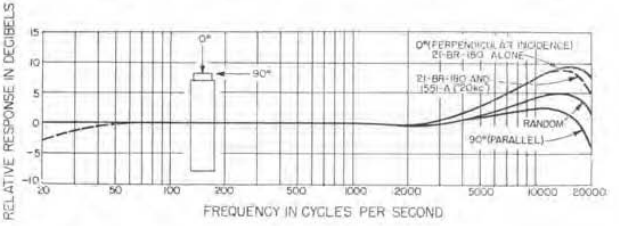


Figure 4. Typical frequency response characteristic for the Altec 21-BR-180 Microphone.

humidity. High humidity can cause enough electrical leakage so that the required bias on the microphone cannot be obtained. This condition will be obvious in operation, since one will not be able to set the indicating meter on the power supply of the TYPE 1551-P1 System to the correct level. Sometimes the effects of humidity can be reduced to an adequate degree by heating the microphone well above the ambient temperature.

Massa Model M-141B Standard Microphone

The new Massa Model M-141B Standard Microphone, which is rated at 200 db, goes well beyond any of these microphones in the measurement of high levels. With the TYPE 1551-A Sound-Level Meter, it can be used up to 190 db.

Satisfactory operation at these extremely high levels is achieved by using a stack of ammonium-dihydrogen phosphate (ADP) crystals as the pressure-sensitive piezoelectric element. These crystals are mounted in a small, cylindrical, stainless-steel housing, having the dimensions shown in the drawing of Figure 5. This straightforward, rugged construction results in a microphone having very stable characteristics.

The front metal plate of the housing contacts the ADP crystals through a thermal isolation plate. When a sound pressure wave strikes this plate, a very small motion of the plate and a corresponding compression or expansion of the crystals results. Since the crystals are piezoelectric, the change in the dimensions of the crystals produces a voltage, without requiring any separate power supply. A 20-foot cable attached to the housing connects the microphone to the sound-level meter.

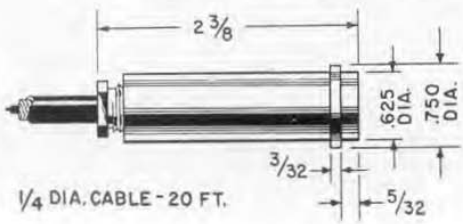


Figure 5. Dimensions of the Massa Model M-141B Standard Microphone. The 20-foot cable is terminated in an Amphenol connector, which fits the sound-level meter.

Sensitivity

The Massa Model M-141B can be purchased from the Massa Laboratories[2] with the sensitivity adjusted to be exactly 50 db less than that of the regular microphone furnished with the TYPE 1551-A Sound-Level Meter. The sensitivity of the regular microphone varies from unit to unit, and the gain of each sound-level meter is set to correspond to the sensitivity of the microphone supplied with it. Therefore, if the customer wants the Massa microphone adjusted, it is essential that he send, with his order to the Massa Laboratories, the serial number of his sound-level meter and the sensitivity figure given in the microphone well, if available. When the sensitivity of the Massa Model M-141B Microphone is set in this fashion, the measured sound-pressure level is simply 50 db higher than the pressure level indicated on the sound-level meter.

Range

The nominal range of the instrument when using the Massa Model M-141B Microphone is then 74 to 190 db. The upper limit is set by the sound-level meter, and it is still within the rating of the microphone. To illustrate how high this upper limit is, we can compare it to atmospheric pressure. For example, if there were a periodic sinusoidal variation in pressure covering a peak-to-peak range from 0.1 atmospheric pressure to 1.9 atmospheres, the corresponding

[2] 5 Fottler Road, Hingham, Mass.

sound-pressure level would be 190 db. At such high levels, of course, the variation in pressure would normally be something different from a simple sine wave.

As a consequence of the high-level use for which the microphone was designed, the minimum level at which it can be used is comparatively high. The basic limiting factor is the inherent noise level of the input circuit of the sound-level meter when the microphone, which has a capacitance with the attached cable of about 460 $\mu\mu$f, is connected across it. This noise level over the audio range is only about 4 microvolts; but, because of the low microphone sensitivity, the corresponding sound-pressure level is about 73 db. This circuit noise is negligible for levels of 80 db and higher.

Frequency Response

The frequency response of one of these microphones at perpendicular sound incidence was measured at the General Radio Company, and the smoothed result is shown in Figure 6 as the curve labeled "M-141B alone."[3]

The first resonance of this microphone is at 34 kc, well beyond the audio range. The resonant rise in response is large, because it is impractical to dampen this rigid structure to any great extent. But some of this rise in response is a diffraction effect of the sound striking the rigid cylinder. This effect is less important (for parallel incidence), where the response is essentially uniform ("flat") at high frequencies up to 20 kc as shown in Figure 7.

If the advantages of using the microphone with perpendicular incidence are desired, the "C"-weighting network of the TYPE 1551-A Sound-Level Meter can be used; and the resultant response, shown in Figure 6, is essentially uniform to about 30 kc. Such a uniform response is valuable for many measurements. It practically eliminates the need for correcting the data for the effects of variations in frequency response of the microphone. For those measurements where such correction is impossible, a response as uniform as that shown will yield as reliable data as possible. It can also simplify the application of automatic recording systems for obtaining sound-pressure levels as a function of frequency in the testing of loud-speakers and other sound sources. The uniform response to 30 kc indicates that the transient response to blast or shock waves in the audio range will be exceptionally good.

The capacitance of the Massa microphone and its associated cable is not so large as that of the Shure Model 98-98 Microphone regularly supplied with the sound-level meter, and the low-frequency response of the combination is somewhat poorer as a result of this lower capacitance, as shown in Figure 6.

[3]The relative levels shown beyond 15 kc should be regarded as approximate, since they are based on an extrapolated characteristic of a W. E. Type 640-AA Microphone, which had been calibrated at the National Bureau of Standards to 15 kc.

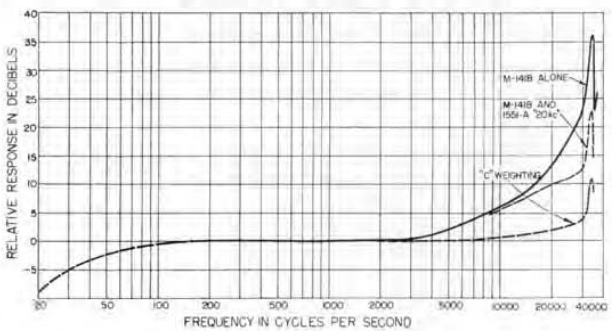


Figure 6. Frequency-response characteristics of the Massa Model M-141B Standard Microphone and Type 1551-A Sound-Level Meter for perpendicular sound incidence.

The maximum safe operating temperature of the Massa M-141B Microphone is about 75° C. (167° F.), a limit set by the cements used in the construction of the microphone. The unit is sufficiently well sealed so that exposure to normal humidity conditions will not affect the operation, but it is recommended that prolonged exposure to relative humidities in excess of 94 per cent be avoided.

SPECIAL PRECAUTIONS

When microphones of low sensitivity, such as the Massa Model M-141B and the Altec Type 21-BR-180, are used, the microphone should be mounted carefully to insure that a correct measurement is being made. In addition, when sounds of high level are being measured, any associated vacuum-tube apparatus should be kept out of the high-level sound field, if possible.

Method of Supporting Microphone

Mechanical vibration of a microphone will produce an output signal. It is necessary, then, to support a microphone so that the signal from existing vibrations is appreciably less than the desired signal from airborne sound. For microphones having high sensitivity to sound, this requirement is usually met even with fairly rigid mounting methods, but low-sensitivity microphones must be mounted carefully. These requirements can often be met by suspending the microphone by its cable, and the cable can be held in place by cords.

One way of detecting vibration errors is to note the effects on the measured levels of different microphone mounting methods.

In general, very resilient supports should be used, with a low natural period of vibration, say below 10 cps. Looping the cable before the end support

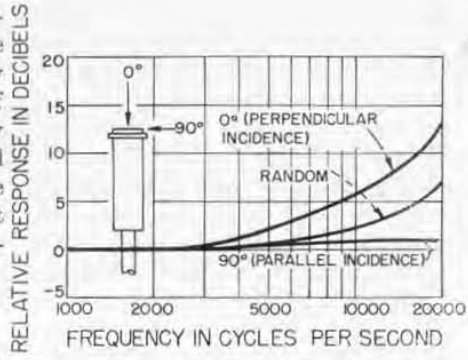


Figure 7. Frequency response characteristics of the Massa Model M-141B Standard Microphone alone.

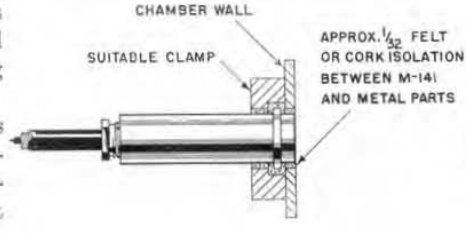
may also improve conditions, since it is particularly important to keep axial vibrations of the microphone to a very low level.

The small flange on the Massa Model M-141B Microphone simplifies the mounting of the microphone in the solid wall of a chamber. But here the isolation of the microphone from the solid-borne vibrations is particularly important, and an assembly such as that shown in Figure 9 is recommended by the Massa Laboratories for such an application.

Microphonics

A vacuum tube exposed to a high-level sound field will vibrate, producing an electrical output, called microphonics, that interferes with the desired signal.

Figure 8. Diagram of recommended installation of the Massa Model M-141B Standard Microphone in the wall of a chamber.



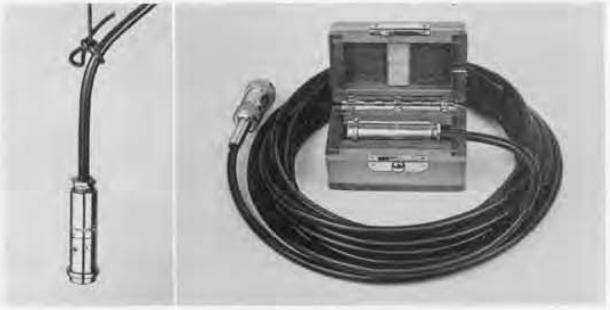


Figure 9. (Left) Microphone suspended by cord to avoid the effect of mechanical vibrations. (Right) View of the Massa M-141B Microphone in its storage box, with 20-foot cable and connector.

With the standard wide-range sound-level meter, the interference is usually unimportant until the sound level is well above 100 db. Microphonic effects can be detected by disconnecting the microphone and by then observing the reading on the instruments when exposed to the sound to be measured. When this test is made, the input terminals of the preamplifier should be shielded to prevent stray electrical pickup.

At high levels, the TYPE 1551-P11 20-db Pad can be used with the TYPE 1551-A Sound-Level Meter to reduce the effect of microphonics. This pad shifts the operating signal levels in the instrument so that the sensitive, early stages must operate with a higher signal, and the relative microphonic level is correspondingly lower.

The best solution to the microphonic problem is to keep the instruments using vacuum tubes away from vibrating surfaces and intense sound fields. But, of course, the microphone must be in the field to be measured, so that a cable must connect the microphone and the measuring instruments. The Massa Model M-141B Microphone includes a cable of about 20 feet, but a longer cable may be essential for adequately separating the microphone and the sound-level meter. Then a TYPE 759-P30 Extension Cable could be used, and 7 db should be added to the indicated level because of the cable capacitance.

When microphonics are troublesome, the most sensitive microphone that will handle the required level will usually give the most favorable signal conditions. But many other factors, for example, frequency response, size, temperature effects, are usually of so great importance that the very sensitive microphones cannot be used. The instruments should then be acoustically isolated from the sound field.

— ARNOLD PETERSON

NOTE: We are indebted to the Massa Laboratories, Inc., the Altec-Lansing Corporation, and Shure Brothers, Inc., for furnishing much of the information on which this article is based.

For complete descriptions of the instruments mentioned in the foregoing article, see the issues of the *Experimenter* listed below:

TYPE 1551-A Sound-Level Meter.....March, 1952
TYPE 1551-P1 Condenser Microphone System.....May, 1953

Condenser Microphone System.

The TYPE 1551-P1 Condenser Microphone System can be supplied with either the Altec 21-BR-150 microphone for normal levels or the 21-BR-180 for high levels. Prices are as follows:

Type		*Code Word*	*Price*
1551-P1L	**With 21-BR-150 Microphone**	NONAL	**$260.00**
1551-P1H	**With 21-BR-180 Microphone**	NATAL	**275.00**

Type 1551-P11 20-db Pad:

Type		*Code Word*	*Price*
1551-P11	20-db Pad	LABEL	$15.00

Massa Model M-141B Standard Microphone.

The Massa M-141B Microphone should be ordered directly from the Massa Laboratories, 5 Fottler Road, Hingham, Mass. When ordering, please state the serial number of your TYPE 1551-A Sound-Level Meter and the sensitivity figure marked in the microphone well.

10th NATIONAL ELECTRONICS CONFERENCE
Hotel Sherman, Chicago — October 4, 5 and 6, 1954

The General Radio Company, in Booths 87 and 88, will exhibit a representative group of instruments, including new items recently described in the *Experimenter*. Among these are the Unit Pulser, the Unit I-F Amplifier and U-H-F Detector, the Automatic Line-Voltage Regulator, and the Transistor Oscillator. In addition, a completely new line of potentiometers will be shown for the first time.

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