the GENERAL RADIO Experimenter

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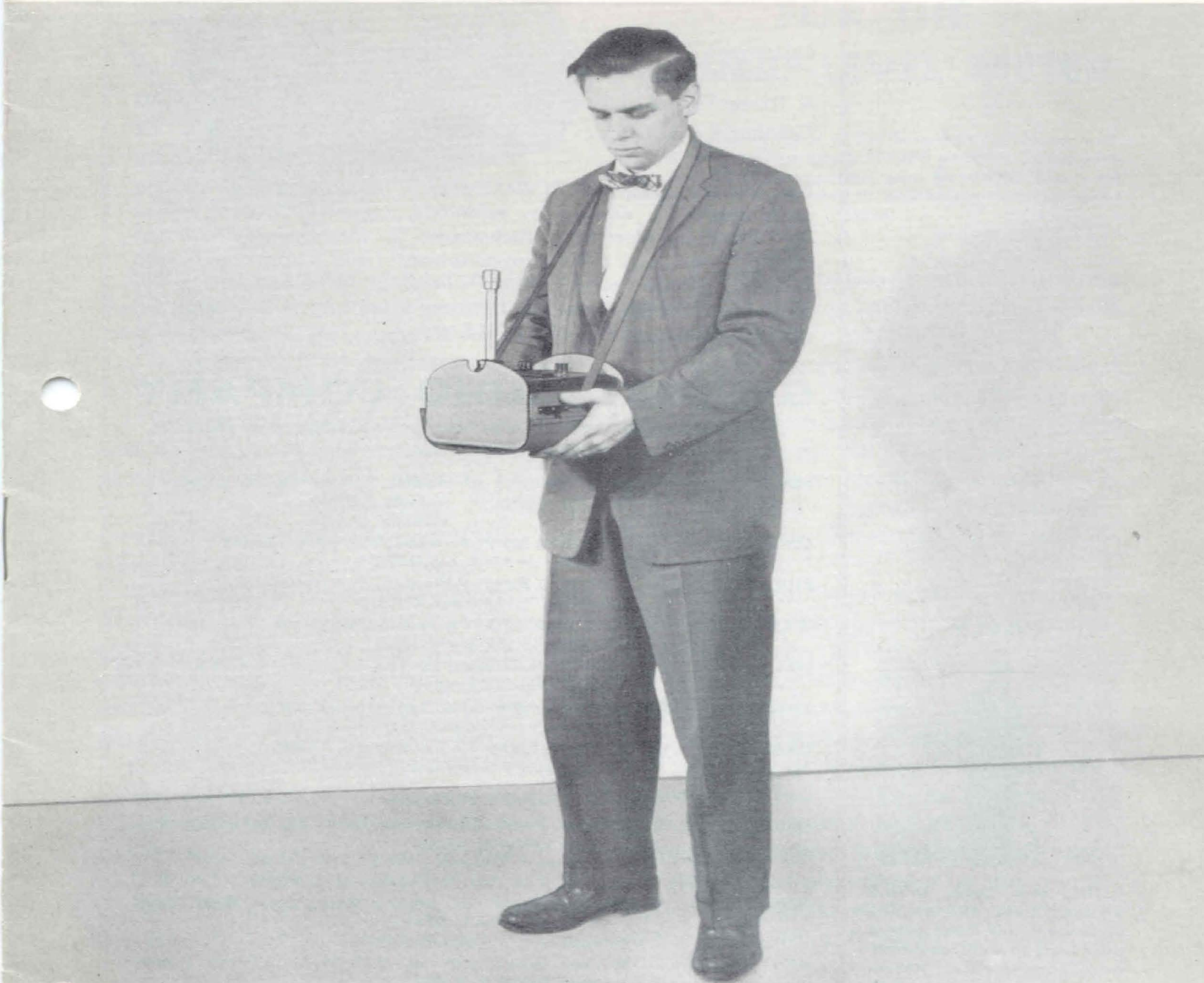

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New Sound-Level Meter

Three-Terminal Precision Capacitor

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the GENERAL RADIO Experimenter

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COVER

The new Type 1551-B Sound-Level Meter described in this issue sets a new high in both accuracy and convenience. Photograph shows instrument in carrying case, supported by shoulder strap, and ready for use.

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IMPROVED PERFORMANCE PLUS A NEW LOOK FOR THE SOUND-LEVEL METER

Figure 1. Panel view of the Sound-Level Meter, with microphone folded down in OFF position. In operating position, microphone can be either erect, as shown on front cover, or extending outward from case.

The primary function of the General Radio Sound-Level Meter is noise measurement — noise generated by machines and appliances, environmental noise, and the propagation of noise by materials and structures. With its many accessories, however, it also comprises a complete sound-measuring system, capable of accurate sound-pressure measurements, sound-spectrum analysis, and other acoustic measurements.

The latest model of this versatile instrument, TYPE 1551-B, is smaller, lighter, and easier to hold than its predecessor[1,2] and, in addition, has many worthwhile new technical features and improvements. Among these are:

1. A new microphone, for better all-round performance.
2. A new meter circuit, which more closely approximates rms response.
3. A new calibration circuit for amplifier gain standardization, which does not require a power line connection.
4. A new adjustment for microphone sensitivity, which facilitates the use of special-purpose microphones.
5. Improved signal-to-noise ratio and dynamic range. These make possible the use of spectrum analyzers over a greater amplitude range so that noises with a steeper spectrum slope can be analyzed.
6. Improved frequency response, which permits increased accuracy of measurement.
7. Improved performance at high sound levels; the upper limit of measurement has been raised and microphonics have been reduced.
8. Improved stability, requiring less frequent calibration adjustments.

These improvements, which are discussed in detail below, result from General Radio's continuous program of development in the field of acoustic measurements and also from the many constructive suggestions received from users of the TYPE 1551-A Sound-Level Meter.

MICROPHONE

Choice of the proper microphone to serve as the acoustic pickup for a high-

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[1] E. E. Gross, "TYPE 1551-A Sound-Level Meter," *General Radio Experimenter*, Vol. 26, No. 10, March, 1952.

[2] E. E. Gross, "The Sound-Level Meter as an Audio Frequency Voltmeter and Amplifier," *General Radio Experimenter*, Vol. 31, No. 8, January, 1957.

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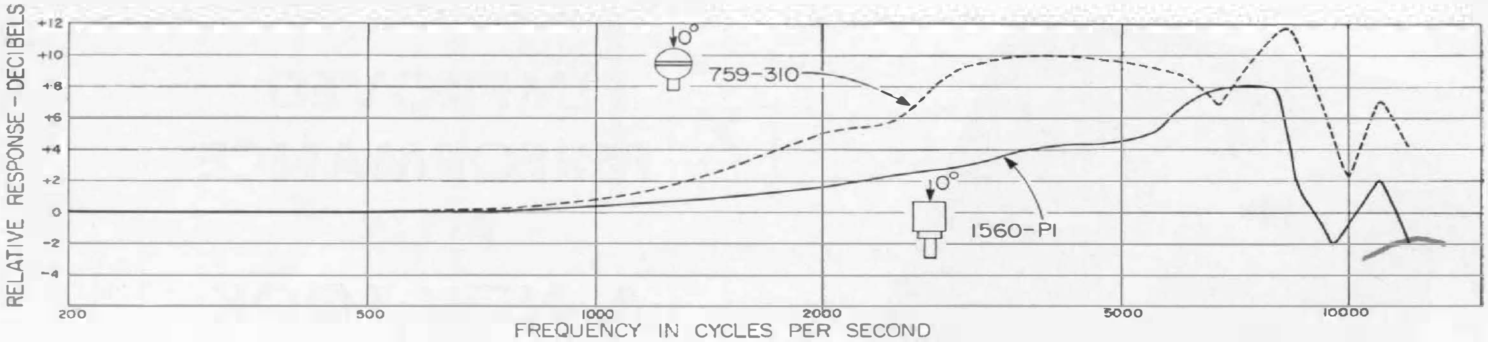


Figure 2. Free-field, perpendicular incidence (0 degrees) frequency response of Type 1560-P1 (98B99) and Type 759-310 (9898) Microphone.

quality but moderately priced sound-level meter is no easy task. Many months of testing and evaluating the many types of "hi-fidelity" microphones available must go into the process. After taking all of the factors into account, we feel that the Shure Brothers Type 98B99 microphone[3] is a "Best Buy" for this use. This microphone, which we list as the Type 1560-P1, is a small Rochelle-salt-crystal type of modern design. It has the same sensitivity as the older Type 9898, which was used on the Type 1551-A Sound-Level Meter. Its new design and small size contribute to a response that is smoother and more nearly nondirectional at high frequencies than that of the older microphone and retains the same flat response to low frequencies. Figure 2 illustrates the improvement in high-frequency response that has been obtained. The solid curve is the free-field frequency response for one of the new microphones to sounds arriving along its axis or perpendicular to the plane of its diaphraghm. The dotted curve is a similar frequency response for one of the older microphones. The new microphone response extends fairly smoothly out to 8 kc, with no major peaks or valleys. Measurements on production quantities of these microphones confirm the uniformity exhibited by the eighteen microphones that gave the results pictured in Figure 3. The solid curve starting at 0 decibel shows the C weighting, or flat, response of the Type 1551-B with the average microphone. The shaded area within the dotted lines shows the measured variation in response. The upper and lower solid curves are the current ASA[4] limits for the C weighting response of a sound-level meter.

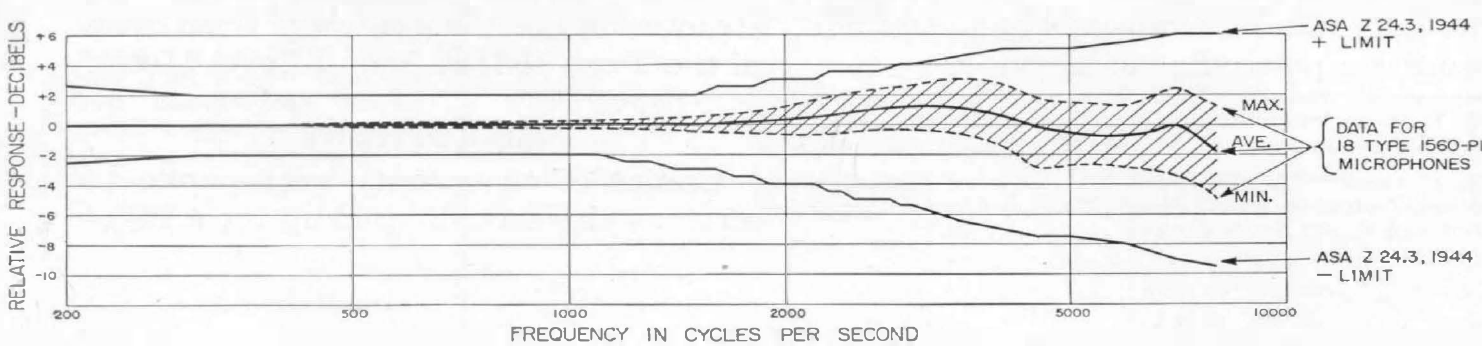
METER CIRCUIT

For many years American sound-level meters built to conform to the standard

[3] John Meddill, "A Miniature Piezo Electric Microphone," *Transactions of the IRE Professional Group on Audio*, Vol. AU 1, No. 6, November-December, 1953.

[4] American Standards Association, American Standard for Sound-Level Meters for Measurement of Noise and Other Sounds, Z24.3-1944.

Figure 3. Free-field frequency response of Type 1551-B Sound-Level Meter to sounds of random incidence (C weighting). Average and extreme values for 18 microphones are shown, together with ASA tolerances.



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referred to before have used, as indicators, full-wave rectifier meters, with rectifiers operating in the low-density region to approximate square-law operation. These meters were basically average-reading indicators and, although they met the two-tone test for rms response, their indications were much closer to average than rms on most other tests.

The new meter circuit developed for use in this sound-level meter, while it is not a true rms indicator, indicates much more closely to the rms value than did the previous meter. Simply stated, the new meter circuit shown in Figure 4 combines an average-reading circuit with a peak-reading circuit to create what we have called the "quasi-rms" indicating circuit. Since the rms value of most waveforms falls above the average value but below the peak value, it was reasoned that a portion of the peak indication added to the average value of a given waveform should result in an rms indication.[5, 6] This is true, but different waveforms require different amounts of peak indication to give the rms value. In the circuit shown in Figure 4, the ratio of R-2 to R-1 determines the amount of the peak contribution, and one set of values will give an indication on many signals that is very close to rms. Table I below shows the decibel difference between the indication of a true rms meter and the new meter circuit, an average meter, and the meter in the older TYPE 1551-A for several test signals.

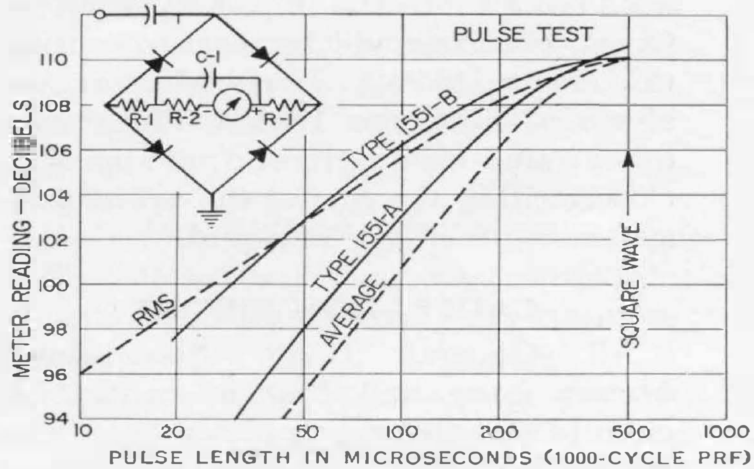

Figure 4. Quasi-rms meter circuit used in Type 1551-B, and response of meter circuits in both –B and –A models to pulses of constant amplitude and varying duration.

In Column 2, the signal consisted of two tones, one at 1000 cps set to give a convenient indication on the meter. The other tone differs from 3000 cps by a few cycles and has 30% the amplitude of the first. A true rms meter will show no fluctuation with this type signal. Column 3 refers to the two-signal test outlined in the Sound-Level Meter Standard.[4]

The solid curves shown in Figure 4 show the response of the new meter and its predecessor to pulses of constant height but varying length. It can be seen that the new meter indicates the rms value (upper dotted curve) within ± 1 db until the pulse duration becomes as short as 1/25th that of a square wave.

[5] R. L. Frank, "Harmonic Insensitive Rectifiers for AC Measurements," *Proceedings National Electronics Conference*, Vol. 8, 1952, pp. 495-505.
[6] Arnold P. G. Peterson, "Response of Peak Voltmeters to Random Noise," *General Radio Experimenter*, Vol. 31, No. 7, December, 1956, pp. 3-8.

TABLE I

Type Meter	*db Fluctuation with Phase Changes at 30% 3rd Harmonic*	*Difference in Meter Indication and RMS Decibels* — *For Two-Signal Addition*	*For Square Waves*	*For Noise*
1551-B	0.45	+.05	+0.1	−0.25
AVE.	1.8	−1.0	+1.0	−1.0
1551-A	1.7	−0.4	+0.6	−1.0

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This is well into the impact-type waveforms, which should be measured using the Type 1556-A Impact-Noise Analyzer.[7] The Type 1551-A Meter and other sound-level meters do not approach closely either the rms or the average response for this type of signal.

CALIBRATION CIRCUIT

All General Radio Sound-Level Meters have had built-in calibration circuits for checking amplifier gain.[8] The method used in previous models required a 115-volt, 60-cycle line, which often was not convenient and sometimes not possible. The new method, like the old, equates the amplifier gain to a stable, resistive attenuator, but the method of comparison is simplified. The output of the amplifier with its internal attenuators is connected back to the input through a frequency-determining network and a preset calibrated attenuator. When the net loop gain is unity (i.e., when gain equals attenuation), the system starts to oscillate.

One might expect that the sudden start of oscillation when the critical, unity-gain condition was reached would cause the meter to slam from off down-scale to off up-scale. This is prevented by an amplitude limiter in the feedback loop, which controls the build-up of oscillation level as gain is increased. The slope of the build-up is purposely left fairly steep, however, to magnify the precision of setting. As illustrated in Figure 5, adjustment of oscillation amplitude within the 4-db span AOA′ on the meter sets the amplifier gain to its proper value within ± 0.2 db as indicated by the small triangle BOB′.

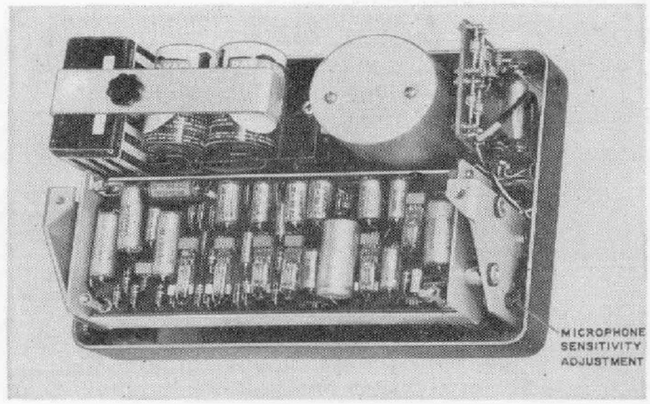

Figure 6. Location of microphone sensitivity adjustment.

MICROPHONE SENSITIVITY ADJUSTMENT

The versatility of the sound-level meter is increased greatly by the use of different types of microphones for different applications. The Rochelle-salt type supplied with the instrument is the best all-round microphone for general use; but dynamic types are useful when long cables are required, and condenser types are better when extended frequency response is required or very high sound levels are encountered.

The attenuator in the new calibration circuit is calibrated directly in terms of microphone sensitivity from —49 to —61 db re 1 volt per μbar. This attenuator is normally preset in our laboratory to match the microphone supplied. The usual setting is in the region of —58 db.

[7] Arnold P. G. Peterson, "The Measurement of Impact Noise," *General Radio Experimenter*, Vol. 30, No. 9, February, 1956.

[8] W. R. Thurston, "The Basis for Field Checking Sound Meter Calibration," *General Radio Experimenter*, Vol. 27, No. 6, November, 1952.

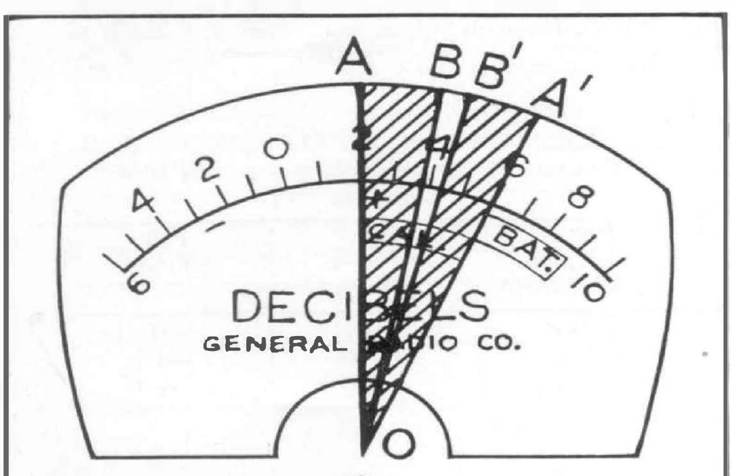

Figure 5. Showing the magnifying action of the calibration check circuit.

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To use a microphone with a —55 db sensitivity, one merely sets the microphone sensitivity adjustment (see Figure 6) to —55 and readjusts the amplifier gain until the meter needle falls in the area AOA′ of Figure 5; the sound-level meter is then direct reading with that microphone.

SIGNAL-TO-NOISE RATIO AND DYNAMIC RANGE

One of the operating characteristics of a sound-level meter which becomes important when an analyzer[9] is used is the internal noise level with respect to the desired signal. This is particularly true when the noise being analyzed has a sloping spectrum. This signal-to-noise ratio has been substantially improved in the new instrument. The attenuator controlled by the panel DECIBELS switch has been distributed throughout the amplifier to keep all tubes operating at as high a signal level as possible and hence to increase the signal-to-noise ratio. The improvement in signal-to-noise ratio and, hence, in dynamic range is apparent from the figures in Table II below.

The signal-to-noise ratio is slightly better at all higher attenuator settings than those shown below. The amplifiers will handle signal levels 10 db above full scale on the meter, so that one can say that the total dynamic range of the instrument for all attenuator settings above 60 db is greater than 70 db in the octave bands and of the order of 68 db over the frequency range of 20 to 10,000 cps.

[9] As, for instance, the General Radio TYPE 1550-A Octave-Band Analyzer and the TYPE 760-B Sound Analyzer.

FREQUENCY RESPONSE

Five design improvements contribute to a better over-all frequency-response characteristic:

A. The new microphone has a smoother high-frequency response. Manufacturer's tolerances on the allowable variation in the response of the microphone have been appreciably reduced.

B. The frequency responses of the range attenuators have been improved and these characteristics are more closely controlled.

C. Modifications in the amplifier design have resulted in a greater bandwidth. Figure 7 shows the response of the new amplifier over the frequency range of 10 cps to 50 kc.

D. New weighting networks have been designed to give *A*, *B*, and *C* responses that conform more closely to the ASA design centers. The improved frequency characteristics of the new microphone justify this effort.

E. The new indicating meter in the TYPE 1551-B has no observable frequency error in the usable range.

PERFORMANCE AT HIGH SOUND LEVELS

The maximum attenuator setting has

TABLE II
OCTAVE-BAND NOISE LEVELS DB BELOW FULL SCALE
ATTENUATOR SETTING = 70 DB (C Weighting)

BAND – CPS	*20–10,000*	*20–75*	*75–150*	*150–300*	*300–600*	*600–1200*	*1200–2400*	*2400–4800*	*4800–10,000*
Type 1551-B	58	66	71	72	71	69.5	67	65	62
Type 1551-A	37	56	56	55	52	49.5	46.5	44	40
Improvement	21	10	15	17	19	20	20.5	21	22

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been increased from 130 to 140 db, making the direct-reading range of the instrument 24 to 150 db above the reference pressure level of .0002 μbar. The numerous factors that contribute to the improved signal-to-noise ratio also improve the operation of the instrument in high sound fields. Much attention has been given to the problem of keeping the microphonic signals at a minimum in this new instrument. Microphonics due to vibrations and airborne sound are reduced by the use of low-noise cable throughout the instrument, by improvement in the shock and vibration mounting of the amplifier compartment, and by the mounting of all tubes between soft rubber pads. Measurements made in high sound fields, however, should be carried out with great care, and one should exercise the usual precautionary measures to determine that microphonics are at a safe level.

STABILITY

Increased stability of the amplifier was an important objective in the redesign of the sound-level meter. The change effecting the greatest part of the improved stability is the addition of a voltage-reference diode, which maintains constant plate voltage on the first two amplifier stages over the full operating range of the B+plate battery. Other contributing factors are increased negative feedback around the main amplifier, made possible by an increase in the gain of the second amplifier stage, and conversion of the output amplifier from a vacuum tube to a transistor connected as an emitter follower.

Figure 7. Frequency response of amplifier in Type 1551-B Sound-Level Meter (weighting switch set at 20 kc).

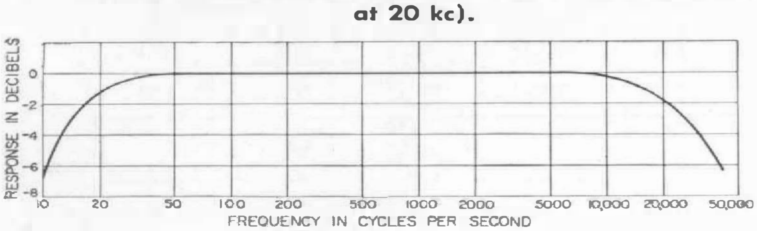

Figure 8. View of Sound-Level Meter with A-C Power Supply attached.

A-C POWER SUPPLY

Batteries are the normal power supply of the sound-level meter, as listed in the specifications. A-C power is more convenient for laboratory use, however, and the Type 1262-B A-C Power Supply is available for such applications. This small power unit mounts directly on the end of the Type 1551-B and connections are made between the two by means of a 6-terminal connector when the supply is so mounted. The supply can be operated from either a 105-125-volt, 50-60 cycle line or a 210-250-volt, 50-60-cycle line. Two well-filtered filament supplies and a plate supply are provided. Stability of the amplifiers in the Type 1551-B is such that normal line voltage variation causes negligible change in meter reading.

CARRYING CASE

The shielded aluminum cabinet, finished in dark-gray crackle, is a rugged and durable carrying case which affords adequate protection to the interior ele-

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ments. To make field use of the new meter as convenient as possible, however, an ever-ready type leather carrying case is now available. This case, the Type 1551-P2, is illustrated on the cover, protects the sound-level meter in transit, and provides a handy carrying handle. With the long strap placed over the shoulder, the instrument can easily be carried and can be operated without removal from the case.

ACCESSORIES

The full line of accessories for the A-model sound-level meter can be used equally well with the new model. These include acoustic calibrator, dynamic and condenser microphones, vibration pick-up, and spectrum analyzers. The new sound-level meter uses a different type of plug-in connector for the microphone, and an adaptor is furnished with each accessory instrument that requires it.

Much thought and effort have gone into the design of the Type 1551-B Sound-Level Meter. A new look and improved performance have resulted. Mechanical design and handling ease have been carefully considered as well as electrical and acoustical performance. The Type 1551-B is a big step forward in sound-level-meter design.

—E. E. Gross

SPECIFICATIONS

Sound-Level Range: From 24 db to 150 db (re 0.0002 microbar).

Frequency Characteristics: Any one of four response characteristics, A, B, C, and 20 kc, can be selected by a panel switch.

The A and B weighting positions approximate the response of the ear to pure tones referred to a 40-db level and a 70-db level, respectively, at 1000 cps.

The C weighting provides uniform response to all frequencies within the range of the microphone. This characteristic is used for measuring high sound levels, for measuring sound-pressure levels, or when the instrument is used with an analyzer.

The 20 kc position allows the use of the complete frequency response of the sound-level meter's amplifier, which is flat from 20 c to 20 kc, so that complete use can be made of wide-range microphones such as the General Radio Type 1551-P1 Condenser Microphone Systems.

Microphone: The microphone is a high-quality Rochelle-salt-crystal diaphragm type. Condenser and dynamic microphones are available as accessories.

Sound-Level Indication: The sound level is indicated by the sum of the readings of the meter and attenuator switch. The clearly marked, open-scale meter covers a span of 16 db with calibration from —6 to 10 db. The attenuator is calibrated in 10-db steps from 30 to 140 db above the standard reference level.

Output: An output of 1 volt across 20,000 ohms (when the panel meter is at full scale) is available at an output jack. The output can be used to drive frequency analyzers, recorders, and oscillographs.

Meter Damping: The panel meter is provided with two different damping characteristics, selected by a switch. In the fast position, the meter ballistics agree with the current ASA standards. In the slow position, the meter is heavily damped and indicates, for easy reading, the average level of rapidly fluctuating sounds.

Calibration: Internal means are provided for standardizing the sensitivity of the electrical circuits in the sound-level meter. After standardization, the accuracy of sound-level measurements, as specified in ASA standards, is within ± 1 db for average machinery noise. The Type 1552-B Sound-Level Calibrator is available for making periodic acoustic checks on the over-all calibration, including microphone.

Temperature and Humidity Effects: Readings are independent (within 1 db) of temperature and humidity over normal ranges of room conditions.

Power Supply: Two 1½-volt size D flashlight cells (Rayovac 2LP or equivalent) and one 67½-volt Burgess XX45 battery or equivalent are supplied. The Type 1262-B Power Supply for a-c operation is available.

Tube Complement: Four Raytheon CK-512-AX and two Raytheon CK 6418 tubes; one RCA 2N105 transistor.

Accessories Supplied: Telephone plug.

Cabinet: Shielded aluminum cabinet, finished in gray crackle, which serves as a convenient and rugged carrying case. A leather carrying case is available, which permits operation of the instrument without removal from the case.

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Dimensions: Sound-level meter only, (depth) 6⅛ x (length) 9¼ x (width) 7¼ inches, over-all; with a-c power supply attached, 6⅛ x 12⅜ x 7¼ inches.

Net Weight: 7 pounds, 10 ounces with batteries; 9 pounds, with a-c power supply; a-c power supply only, 2 pounds, 8 ounces; leather case, 2 pounds.

Type		*Code Word*	*Price*
1551-B	Sound-Level Meter*	MIMIC	$395.00
	Set of Replacement Batteries	MIMICADBAT	3.90
1262-B	Power Supply	MANLY	70.00
1551-P2	Leather Carrying Case	CALYX	20.00

*Licensed under patents of the American Telephone and Telegraph Company.

A THREE-TERMINAL PRECISION CAPACITOR

The normal construction of the TYPE 722 Precision Capacitor is with the rotor grounded to the frame and panel. Such construction gives what is normally referred to as a two-terminal capacitor, with one terminal connected to the ground of the unit and, in turn, to the ground of the measuring circuit.

In some measuring circuits it is necessary or desirable to have both terminals of the variable capacitor at other than ground potential. This is the so-called three-terminal construction, ground being the third terminal. We have built a great many capacitors of this type on special order in the past, and in recent years the interest in this type of construction has been increasing. The TYPE 722-CB, a three-terminal capacitor having a 1050-$\mu\mu$f range, is now offered as a stock item.

For capacitance measurement, three-terminal standards have certain definite advantages, the most obvious of which is the relative freedom from the problem of lead capacitance. In the three-terminal construction, the capacitance of leads *to ground* does not affect the direct capacitance between rotor and stator. The capacitance *between leads* can be eliminated by shielding of at least one terminal and lead. When this is done, complete freedom from lead capacitance problems is insured. Theoretically only one terminal and lead need be shielded, but in certain instances it may be advantageous to shield the low terminal as well as the high terminal. For example, in a circuit where the impedance of both terminals to ground is relatively high, electrostatic shielding to guard against pickup will be necessary on both leads. For this reason coaxial terminals (TYPE 874) are provided for both rotor and stator connections in the TYPE 722-CB.

A second equally important advantage of a three-terminal capacitor is that losses are definitely lower than in a two-terminal capacitor of similar construction. The losses in the dielectric supporting structure, which in the two-terminal construction are in parallel with the desired capacitance, appear in the terminal-to-ground capacitances in the three-terminal construction. In theory all the dielectric losses can be placed in terminal capacitance, but actually in typical construction there may be some residual fringing field between rotor and stator which passes through solid dielectric material. In the TYPE 722-CB the rotor insulation is completely shielded and the stator insulation is sufficiently removed from the main field so that residual losses from this cause are ex-

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Panel view of the Type 722-CB Precision Capacitor.

tremely small. In addition to these extremely low losses from dielectric supports, there may be some losses at the surface of the capacitor plates, and there are even detectable losses in air, both of which depend greatly upon relative humidity.

In the two-terminal construction, the TYPE 722 Precision Capacitor has a D_oC_o product of 0.03 $\mu\mu$f, corresponding to a dissipation factor of 30 x 10^{-6} at 1000 $\mu\mu$f and 300 x 10^{-6} at 100 $\mu\mu$f. Ideally, such a capacitor in the three-terminal construction should have losses at all settings smaller than the loss at the 1000-$\mu\mu$f setting in the two-terminal construction. Measurements show that there is actually a slight tendency for the dissipation factor to rise at low capacitance setting. The increased losses, which result when the edges of the rotor and stator plates are in close proximity, are presumably caused by the localized high voltage gradients at the relatively sharp edges of the plates.

The measurement of dissipation factors in the order of a few tens of microradians is fairly difficult, and most conventional measuring techniques have uncertainties of the same general order of magnitude. We believe, however, that under favorable conditions our measurement of dissipation factor, using a substitution technique with the TYPE 716 Bridge, has an absolute accuracy of the order of 10 microradians. Allowing for this uncertainty of measurement, the TYPE 722-CB is rated as having a dissipation factor less than 50 microradians at all settings in the linear capacitance range.

Since, in the three-terminal construction, the stator-to-ground capacitance is eliminated from the calibrated value, a lower minimum value of capacitance results, and linear calibration to a lower value is possible. The useful direct-reading linear range of the TYPE 722-CB is from 50 $\mu\mu$f to 1100 $\mu\mu$f.

—IVAN G. EASTON

SPECIFICATIONS

Capacitance Range: Direct reading on drum and dial, 50 $\mu\mu$f to 1100 $\mu\mu$f.

Accuracy: $\pm$1 $\mu\mu$f or $\pm$0.1%, whichever is the greater.

Correction Chart: A correction chart is supplied, giving corrections at multiples of 100 $\mu\mu$f. The accuracy obtained through the use of this chart is $\pm$0.1% or $\pm$0.4 $\mu\mu$f, whichever is the greater, for direct measurements. For capacitance differences, the accuracy is $\pm$0.1% or $\pm$0.8 $\mu\mu$f, whichever is the greater.

Worm Correction Calibration: A correction for the slight residual eccentricity of the worm drive can be supplied at extra charge. The accuracy after worm correction is applied is $\pm$0.1% or $\pm$0.1 $\mu\mu$f for total capacitance and $\pm$0.1% or $\pm$0.2 $\mu\mu$f for capacitance differences.

Dissipation Factor: Less than 50 x 10^{-6}.

Maximum Voltage: 1000 volts peak.

Residual Inductance: Effective series inductance is approximately 0.06 μh.

Series Resistance: Approximately 0.02 ohm at 1 Mc.

Temperature Coefficient of Capacitance: Approximately 0.002% per degree Centigrade for small temperature changes.

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Accessories Supplied: Two Type 874-C58 Cable Connectors.

Terminals: Type 874 Coaxial Panel Connectors. In addition, a jack-top binding post is provided as an alternate ground connection.

Mounting: Capacitor is mounted on an aluminum panel finished in black crackle lacquer and enclosed in a shielded hardwood cabinet. A wooden storage case with carrying handle is supplied.

Dimensions: Panel, 8 x 9⅛ inches; depth, 8⅛ inches.

Net Weight: 9 pounds, 10 ounces; 17 pounds with carrying case.

Type		*Code Word*	*Price*
722-CB	Precision Capacitor	CAROM	$205.00

COMING EXHIBITS

PATENT OFFICE SPONSORS EXHIBIT

To promote the role played by invention and the patent system in the development of the electrical and the electronics industries, the U. S. Patent Office has invited sixteen companies to participate in an exhibit to be held in the Main Lobby of the Department of Commerce Building, Washington, D. C., October 13 through November 7, 1958.

Among those exhibiting will be the General Radio Company. Our display emphasizes the invention, patenting, development and improvement, by General Radio, of the variable autotransformer, which this Company manufactures and markets under the trade name VARIAC.®

We cordially invite *EXPERIMENTER* readers to visit this and the many other interesting displays at this exhibit.

NEREM — THE NEW ENGLAND RADIO ELECTRONICS MEETING

NEREM — New England's annual electronics convention and show, sponsored by the Boston and Connecticut Valley Section of the IRE, will be held at Mechanics Building, Boston, November 19 and 20, 1958. An outstanding technical program has been arranged, and more than 100 exhibitors will show their products. You will find it worth while to attend this outstanding meeting.

General Radio, in Booths 153 and 154, will have on display the new instruments that you have read about in the pages of the *EXPERIMENTER* this year. We hope you will drop in to see us.

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