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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

TYPE 1551-A SOUND-LEVEL METER—

A Miniaturized and Improved Basic Instrument for Sound and Noise Measurements

● **THE SOUND-LEVEL METER** is the basic instrument of a sound measuring system. Born in the '30's as a result of the joint effort of several technical societies interested in standardizing[1] acoustic noise measurements, its uses have grown constantly as man's environment has become noisier. Expanding uses inevitably condition the development of a product, and so the first General Radio Sound-Level Meter, TYPE 759-A (1936) was superseded by the TYPE 759-B (1940). New tubes, new components, modern construction methods, and miniaturi-

[1]ASA, American Standard for Sound-Level Meters for measurement of noise and other sounds, Z24.3—1944.

Figure 1. Panel View Type 1551-A Sound-Level Meter.

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zation techniques have now made possible a complete redesign, resulting in a smaller, lighter, more useful instrument, the TYPE 1551-A, shown in Figure 1.

Redesign of the sound-level meter was started with certain definite objectives in mind. These objectives were dictated by users of the sound-level meter and implemented by the desire on our part to provide a sound-level meter with worthwhile improvements in utility and operating characteristics. Compared to its predecessor, the new meter should:

be considerably *smaller* and *lighter*.

be more stable.

cover a wider band of frequencies, so that, with suitable microphones, the complete audio spectrum can be measured.

be easier and simpler to operate.

The use of sub-miniature tubes and miniaturization techniques readily adapted to a system of relatively small-scale production has resulted in a new high-performance instrument, much reduced in size and weight. The amplifier circuit in the new TYPE 1551-A Sound-Level Meter uses seven sub-miniature tubes compared with the four tubes used in the older TYPE 759-B Sound-Level Meter. The added tubes make possible an extended frequency range as well as gain stabilization through the use of negative feedback.

The requirement of increased convenience and simplicity of operation was met by a rearrangement of operating controls and adjustments and by a new cabinet design.

[2]See Figure 7.

CIRCUIT

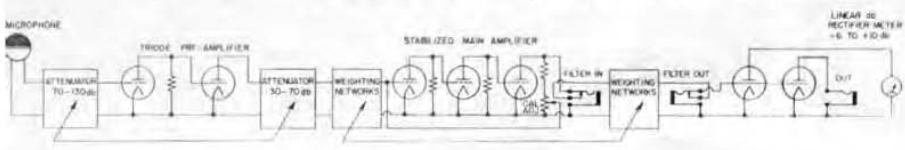
Figure 2 is a functional diagram of the new instrument. A Rochelle-salt crystal microphone is followed by an input attenuator, a two-stage triode-connected pre-amplifier, and a second attenuator. The main amplifier follows with weighting networks inserted at input and output terminals. The circuit is completed by two output amplifiers, an indicating meter, and an output jack. The two attenuators are ganged and operated by a single control, so that the second attenuator operates for dial settings of 30 to 70 db, while the input attenuator operates for settings of 70 to 130 db.

The main three-stage amplifier has a normal gain of 80 db. Under operating conditions the gain of the amplifier is reduced to less than 60 db by means of inverse feedback. Careful choice of circuit parameters and the large amount of negative feedback have made possible an extremely stable and dependable wide-band amplifier. The feedback is adjustable over a limited range to provide calibration adjustment.

The two output stages are also stabilized by negative feedback. One of these is used to drive the rectifier meter. The other supplies a separate output connection to be used for monitoring purposes or for supplying a signal to an analyzer or recorder.

The over-all frequency response of the amplifiers is flat from 20 cycles to 20 kilocycles, so that full advantage can be taken of the new high-fidelity microphones. In addition, the weighting networks provide the standard A, B, and C sound-level meter characteristics[1,2]. A single control selects the desired response.

Figure 2. Elementary Schematic (or Functional diagram) Type 1551-A Sound-Level Meter.



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Two telephone jacks labeled FILTER IN and FILTER OUT are connected ahead of the output system so that special networks or filters for altering the frequency response of the instrument may be added ahead of the indicating meter and the output jack. Simple filters for measuring loudness or speech interference level are planned as future accessories.

INTERNAL NOISE LEVEL

Many sub-miniature tube types are being manufactured, but the Type CK512AX tube used in the pre-amplifier of this new sound-level meter has the lowest noise level of any battery type that we have yet found. In the sound-level-meter circuit, the noise output from this tube over the 20 kilocycle band is of the order of 2 microvolts. This is equivalent to the signal level from the microphone placed in a sound field of 18 db,[3] so that measurements to levels at least as low as 24 db are possible, and the overall gain in the instrument is sufficient to make such measurements. The meter scale is calibrated from −6 to +10 db, and the attenuator is calibrated from 30 to 130 db so that direct measurement of sound pressure levels can be made over a range of 24 to 140 db. (A pressure range of over 600,000 to 1 or a power range of 400 billion to 1.)

DESIGN FEATURES

Controls

Much thought and care have been exercised in determining the final location of the panel controls. While simplicity and ease of operation were dominant factors in determining control locations, electrical performance was never sacrificed. As illustrated in Figure 1, the important and most used controls have been placed at the right. The indicating meter and attenuator control have been located side by side and given equal prominence. The mask was added to the attenuator control to reduce the possibility of errors in reading the sound level, which is the sum of meter and attenuator readings. The microphone is shown in operating position. When not in use, it is folded down so that it rests in the small well at the right. The ON-OFF switch is operated by the microphone swivel post so that the instrument is automatically turned on when the microphone is raised to its operating position.

[3]Ref. level 0 db = 0.0002 μbar.

Case

The welded aluminum case designed to house this new meter is light in weight, strong, durable, and attractive. Four large rubber feet mounted on its base serve as a first stage in shock and vibration isolation for the high-gain amplifier carried within. The end frames of the case are molded from high-impact-strength bakelite and serve to protect the panel and controls when the instrument is in use. They make possible a simple U-shaped cover design, which can be attached quickly and securely, and they prevent marring and scarring surfaces when the instrument is set down in other than its operating position.

Interior Construction

Figure 3 is a view of the instrument removed from its cabinet. The amplifier cover has been removed and the amplifier shelf has been raised to show accessibility to all parts of the amplifier. The seven sub-miniature tubes are just visible along the top of the amplifier shelf. Full constructional details of the amplifier shelf are shown in Figure 4. The amplifier case is supported at three points by soft rubber bushings, which make a

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Figure 3. View of Type 1551-A removed from its case. Amplifier cover removed, and amplifier raised to show accessibility.

second stage of shock and vibration isolation. In addition, the input tubes for the pre-amplifier and main amplifier rest between pieces of light cellular rubber when the amplifier cover is in place. The attenuator switch and weighting switch are enclosed in the two cylindrical shield cans at the left of Figure 3.

Batteries

The battery complement for the new instrument is visible at the top of the photograph. It consists of two D-size flashlight cells for the filament supply and one portable radio B battery for the plate supply. Batteries used in this instrument are popular sizes manufactured by a number of battery companies and are readily available at almost any radio store or supply house. One set of A batteries will give 6 to 7 days' operation at 8 hours a day or 30 to 35 days' operation at 2 hours a day. The plate battery will give 18 to 20 days' operation at 8 hours a day or 90 to 100 days' operation at 2 hours a day. Tests to date indicate that over most of the useful life of the batteries, 8-hour stability of the instrument is within 0.5 db and 2-hour stability is within 0.2 db.

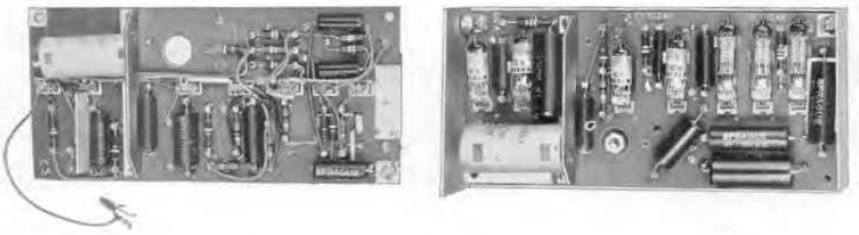
A-C Power Supply

For applications where continuous use of the TYPE 1551-A Sound-Level Meter is contemplated, a small a-c power supply has been designed. This power unit, the TYPE 1262-A Power Supply, is so constructed that it will fasten directly to the end plate of the sound-level meter case as is indicated in Figure 5. No regulation is provided in this supply, because the stability of the amplifiers in the sound-level meter is such that variations in line voltage over the range of 105 to 125 volts cause meter reading changes of the order of only 1 db, so that normal line voltage changes have little effect on the meter reading.

MICROPHONE CHARACTERISTICS

The diaphragm-type Rochelle-salt crystal microphone supplied with the TYPE 1551-A Sound-Level Meter is a good low-cost microphone and serves as a satisfactory pickup for most noises encountered in the home, office, or factory. It has high sensitivity, flat response to sounds of random incidence, from very low frequencies to frequencies well above 1 kilocycle, and good response up to 8

Figure 4. Detail view of panel side and bottom side of Amplifier Shelf.



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kilocycles. For sounds arriving at 90° incidence, it is essentially non-directional (in the horizontal plane) for frequencies up to 6 kilocycles. Figure 6 is a group of generalized curves showing the response of this microphone to sounds incident at 0 degrees, 90 degrees, and from random directions in the vertical plane. The upper curve in Figure 7 shows the overall response to sounds of random incidence obtained for a typical microphone used with the TYPE 1551-A Sound-Level Meter. The lower curves show the response characteristics of the electrical circuits in the sound-level meter.

Figure 5. Type 1551-A with Type 1262-A A-C Power Supply.

Temperature Effects

The open-circuit voltage of the microphone changes by about 0.02 decibel for each degree Fahrenheit change in temperature as is shown by the dotted curve of Figure 8. This relatively small change in output is accompanied by a rather large change in the capacitance of the microphone.[4] As long as the microphone is connected directly to the input of the TYPE 1551-A Sound-Level Meter, this large capacitance change is of little consequence. The response of the TYPE 1551-A as a function of temperature changes at the microphone for this condition is shown by the upper solid curve in Figure 8. The low input capacitance achieved in the new sound-level meter accounts for the close adherence of the solid curve to the dotted curve. If the input capacitance is increased as, for instance, when a long cable is used, the indicated output of the microphone will vary more widely with temperature as is shown by the middle and lower curves in Figure 8.

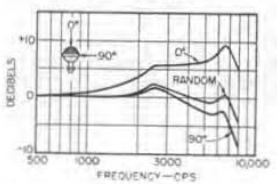
Microphone Mounting

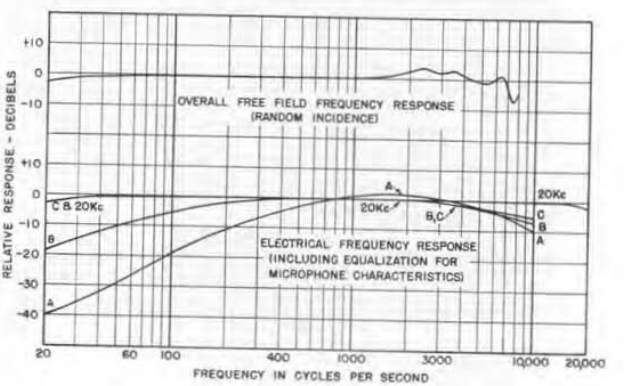
For convenience in use, storage, and transport, the microphone is mounted directly on the instrument. When sounds of random incidence are being measured, this mounting for the microphone is satisfactory, and the instrument is adjusted to conform to the ASA specifications for such sounds. For sounds of other than random incidence, this mounting can be

[4] E. E. Gross, "A Dynamic Microphone for the Sound-Level Meter," *General Radio Experimenter*, April, 1951.

Figure 6. *(Below)* Free field frequency response of microphone for sounds incident at 0 degrees, 90 degrees, and from random directions in a vertical plane.

Figure 7. *(Right)* Typical acoustical and electrical calibration curves for the Type 1551-A Sound-Level Meter.





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a source of error because the presence of any object, such as the instrument case, in the sound field of the microphone can distort the field and hence affect the meter readings. In addition, the position of the observer relative to the source of sound and the microphone becomes very important. It has been experimentally determined that when the TYPE 1551-A Sound-Level Meter is held as shown in Figure 9, these effects are negligible for frequencies up to 2 kilocycles for sounds in the horizontal direction (90° incidence, Figure 6) which arrive from the left- or right-hand side of the observer. In contrast, the observer will affect meter readings by as much as 3 db at frequencies as low as 200 cycles if he holds the instrument as in Figure 9 and faces the source of sound.

For sounds of random incidence over the frequency range of 20 cycles to 8 kilocycles and for directive sounds from 20 cycles to 2 kilocycles, this sound-level meter with attached microphone is an excellent hand-held instrument, suitable for use in many common noise measurement problems. When directive sounds are involved and good results above 2 kilocycles are required, one should mount the microphone on a tripod and use a cable to keep the microphone well away from the observer and the sound-level meter. The TYPE 759-P25 Dynamic Microphone Assembly[4] will give better results for measurements above 2 kilocycles. For even better results at high frequencies, a Western Electric Type 640-AA Condenser Microphone or one of the recent high-fidelity microphones, such as the RCA Type BK4A[5] Pressure Ribbon Microphone or the Altec Type 21-B[6] Condenser Microphone should be used. Because good low frequency response is also important in noise measurements, a condenser type of microphone will be offered as accessory for use with the TYPE 1551-A Sound-Level Meter. The development of a battery-operated preamplifier and power supply[7] for this type of microphone will be completed soon.

Figure 9. Typical operating position for Type 1551-A Sound-Level Meter.

APPLICATIONS

The sound-level meter is a basic instrument about which a comprehensive sound measuring system can be built. Many types of measurements can be made with it directly, and its usefulness has been extended many-fold by numerous accessories, including a wide range of microphones, vibration pickups, analyzers, and recorders. The sound-level

[3] H. F. Olson and J. Preston, "Unobtrusive Pressure Microphone," *Audio Engineering*, Vol. 34, pp. 18–20 (July, 1950).

[4] J. K. Hilliard, "Miniature Condenser Microphone," *Journal of the Society of Motion Picture and Television Engineers*, Vol. 54, pp. 1–12 (March, 1950).

[7] TYPE 1551-P1 Condenser Microphone System to be described in a forthcoming issue of the *Experimenter*.

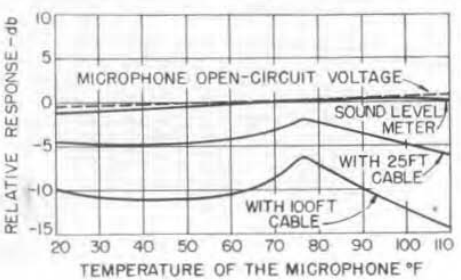

Figure 8. Variation in response as a function of temperature for the microphone alone and with various lengths of cable between microphone and sound-level meter.

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meter is commonly used in industry, in schools, and in laboratories to obtain objective measurements of a wide range of noise levels. The list of its applications for the measurement of noise or unwanted sound is growing rapidly. Many measurements are made in the process of reducing the noise in consumer products or in improving worker comfort, safety, and efficiency. With the advent of high-intensity noise makers, such as jet engines, test facilities must be carefully engineered and designed, not only for protection and comfort of test personnel, but to prevent undesirable noise conditions extending to surrounding communities.

Every effort has been made to make the TYPE 1551-A Sound-Level Meter an outstandingly useful instrument. The broad frequency-response characteristic, stability, wide dynamic range, and low noise and distortion level, resulting from careful design of the amplifier, attenuators, and output system, make it an excellent foundation on which to build a comprehensive sound-measuring system. Special microphones can be used to full advantage. The output is adequate to operate many pieces of auxiliary equipment, such as frequency analyzers, graphic level recorders, magnetic tape recorders, or cathode-ray oscillographs. In addition, this new sound-level meter is compact and light in weight, so that it is much easier to carry about than the old TYPE 759-B. Its over-all size is 470 cubic inches, compared to 1200 cubic inches, and its weight is 11 pounds, compared to the 22¼ pounds of the TYPE 759-B.

—E. E. GROSS, JR.

SPECIFICATIONS

Sound-Level Range: From 24 db to 140 db above the standard sound pressure reference level of 0.0002 microbar (a pressure of 0.0002 dyne per square centimeter) at 1000 cycles.

Frequency Characteristics: Any one of 4 response characteristics can be selected by means of a panel switch. The first and second of these are, respectively, the 40- and 70-db equal-loudness contours in accordance with the current standard specified by the American Standards Association. The third frequency response characteristic gives a substantially equal response to all frequencies within the range of the instrument and its microphone. This characteristic is used when measuring extremely high sound levels, when measuring sound pressures, or when using the instrument with the TYPE 760-B Sound Analyzer, the TYPE 736-A Wave Analyzer, or the TYPE 1550-A Octave-Band Noise Analyzer. The fourth frequency response characteristic provides an amplifier which has essentially flat response from 20 cycles to 20 kilocycles, so that full use can be made of extremely wide range microphones such as the W.E. 640-AA or the Altec 21-B Condenser Microphones.

Microphone: The microphone is of the Rochelle-salt, crystal-diaphragm type with an essentially non-directional response characteristic.

Sound-Level Indication: The sound level is indicated by the sum of the readings of the meter and an attenuator. The meter has a range of 16 db, and the attenuator has a range of 100 db in 10-db steps.

Output Terminals: A jack is provided, at which an output of 1 volt across 20,000 ohms can be obtained when the panel meter reads full scale. This output is suitable for use with the TYPE 760-B Sound Analyzer, the TYPE 736-A Wave Analyzer, the TYPE 1550-A Octave-Band Noise Analyzer, a graphic level recorder, or a magnetic tape recorder.

A SLOW-FAST switch makes available two meter speeds. With the control switch in the FAST position, the ballistic characteristics of the meter simulate those of the human ear and agree with the current standards of the American Standards Association. In the SLOW position, the meter is heavily damped for observing the average level of rapidly fluctuating sounds.

Calibration: A means is provided for standardizing the sensitivity of the instrument in terms of any a-c power line of approximately 115 volts.

The absolute level of all microphones is checked at several frequencies against a standard microphone, whose calibration is periodically checked by the National Bureau of Standards.

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TYPE 1552-A Sound-Level Calibrator* is available for making periodic checks on the over-all calibration, including microphone.

Accuracy: The frequency response curves *A*, *B*, and *C* of the TYPE 1551-A Sound-Level Meter fall within the tolerances specified by the current ASA standards. When the amplifier sensitivity is standardized, the absolute accuracy of sound-level measurements is within ±1 decibel for average machinery noises in accordance with the ASA standards.

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

Batteries: Two 1½-volt size-D flashlight cells (Eveready 950 or equivalent); one Eveready 467 B or equivalent battery. Batteries are supplied. The TYPE 1262-A Power Supply is available if a-c operation is desired.

Tubes: Four CK512AX and three CK533AX are required. A complete set is supplied with the instrument.

Accessories Supplied: Power Cord (for calibration check).

Other Accessories Available: Dynamic Microphone, Tripod, and Extension Cable, Vibration Pickup and Control Box.*

Case: Shielded carrying case of aluminum construction.

Dimensions: The over-all dimensions are approximately (height) 6⅝ x (length) 10$^{13}/_{16}$ x (width) 8⅞ inches.

Net Weight: 11 pounds, with batteries.

Type		*Code Word*	*Price*
1551-A	**Sound-Level Meter**† (with batteries)	MIMIC	$360.00
1262-A	**Power Supply**	MANLY	75.00

* Details on request.
† Licensed under patents of the American Telephone and Telegraph Co.

CREDITS

The TYPE 1551-A Sound-Level Meter was developed by Mr. Ervin E. Gross, Jr., with Dr. Arnold P. G. Peterson as project supervisor. Credit is also due Dr. Leo L. Beranek, of M.I.T., acoustic consultant in the development, to Mr. R. Corwin Crosby for the mechanical design, and to Mr. Robert J. Ruplenas for experimental work on subminiature amplifiers.

ACCESSORIES

A complete line of accessory equipment is available for use with the TYPE 1551-A Sound-Level Meter, including the following:

TYPE 760-B Sound Analyzer.
TYPE 1550-A Octave-Band Noise Analyzer.
TYPE 1552-A Acoustic Calibrator.
TYPE 759-P21 Tripod and Extension Cable.
TYPE 759-P25 Dynamic Microphone Assembly.
TYPE 759-P35 and P36 Vibration Pickup.

Complete specifications will be sent on request.

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