OPERATING INSTRUCTIONS

TYPE 1559-B

MICROPHONE RECIPROCITY CALIBRATOR

GENERAL RADIO COMPANY

A

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TYPE 1559-B

MICROPHONE RECIPROCITY CALIBRATOR

Form 1559-0110-A
July, 1965

300

inspected by MWB

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

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SPECIFICATIONS

MICROPHONE CALIBRATOR

Range: Direct reading for microphone sensitivities between −35 dB and −75 dB re 1 V/μbar.

Frequency Range: 20 c/s to 6 kc/s direct reading, with corrections to 8 kc/s.

Accuracy: ±0.2 dB ± (0.1 db × frequency in kc) up to 2.5 kc/s. TYPE 1560-P3 and TYPE 1560-P4: ±0.7 dB above 2.5 kc/s to 7 kc/s.

TYPE 1560-P5 and TYPE 1560-P6, Western Electric 640-AA or equivalent: ±0.7 dB above 2.5 kc/s to 6 kc/s, direct reading, with corrections to 8 kc/s.

Type 1551-P1L: ±0.7 dB above 2.5 kc/s to 5 kc/s.

PRECISION ACOUSTICAL SOURCE

Frequency Range: 20 c/s to 7 kc/s.

Output: 92 dB re 0.0002 μbar for excitation of 50 V.

Accuracy: At 92 dB, ±0.1 dB + error in determining microphone sensitivity.

SOUND-LEVEL CALIBRATOR

Frequency Range: 20 c/s to 2.5 kc/s.

Output: 92 dB re 0.0002 μbar for excitation of 50 V.

Accuracy: ±0.7 dB at standard atmospheric pressure.

GENERAL

Maximum Safe Input Voltage: 50 V behind 600 Ω.

ACCESSORIES

Required: Generator and detector. Generator to supply 5 volts or more into a 2000-pF load, and 2.5 V or more into a 600-Ω load. Lower voltage can be used, with a resultant lowering of signal-to-ambient-noise ratio. The TYPE 1304-B Beat-Frequency Audio Generator, the TYPE 1210-C Unit R-C Oscillator, and the TYPE 1310-A Audio Oscillator are recommended. The TYPE 1551-B or -C Sound-Level Meter is recommended for the detector.

Supplied: TYPE 274-NP Patch Cord and an extension cable for connection to generator and detector; and adaptors for reciprocity and comparison calibration of the TYPE 1560-P5, TYPE 1560-P6, and Western Electric 640-AA or equivalent microphones.

MECHANICAL DATA: Flip-Tilt Cabinet

Model	*Width*		*Height*		*Depth*		*Net Weight*		*Shipping Weight*	
	in	*mm*	*in*	*mm*	*in*	*mm*	*lb*	*kg*	*lb*	*kg*
Portable	10	255	8	205	7½	190	13	6	22	10
Rack	19	485	10½	270	5†	130	14	6.5	29	13.5

† Behind panel.

U.S. Patent No. 2,966,257.

General Radio Experimenter reference: Vol 37, No. 4, 5, April-May 1963.

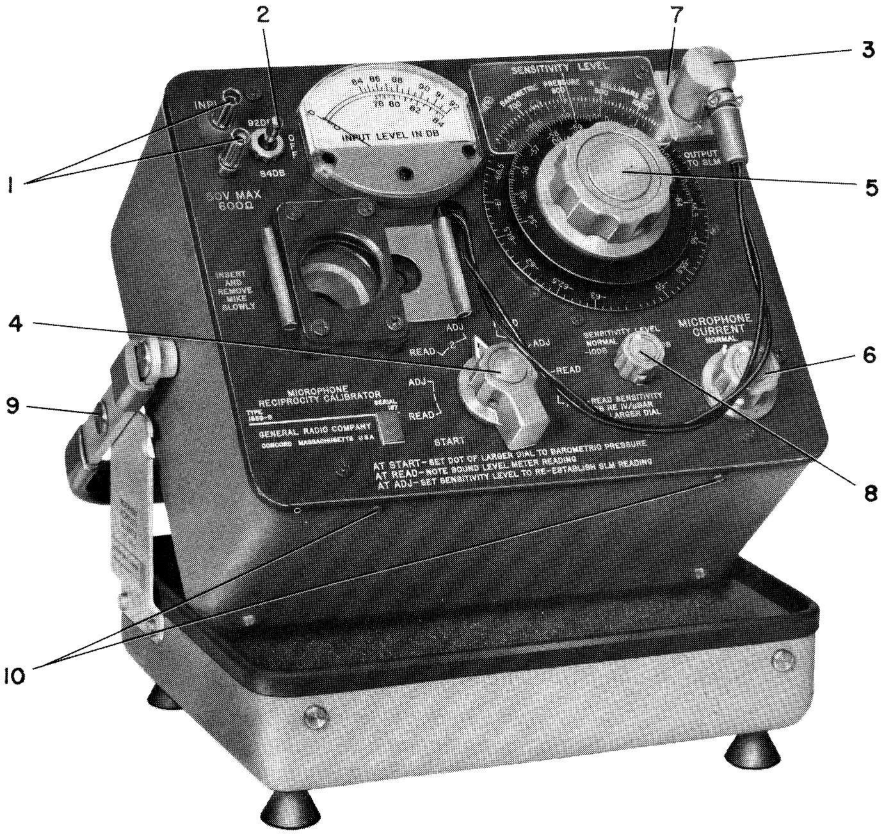

Figure 1-1. Type 1559-B Microphone Reciprocity Calibrator.

SECTION 1

INTRODUCTION

1.1 PURPOSE.

The Type 1559-B Microphone Reciprocity Calibrator (Figure 1) can be used to calibrate microphones whose sensitivity is in the range from -75 dB to -35 dB re 1 volt/μbar. This instrument will calibrate General Radio Types 1560-P1, -P3, and -P4 Microphones and, with the adaptor supplied, the Types 1560-P5 and -P6 Microphones. In addition, it includes adaptors permitting a primary calibration to be performed on W E 640AA, B & K 4131, M R 103, and other condenser microphones of this type. Because the National Bureau of Standards also uses the reciprocity method to calibrate these microphones, there is now a direct link between NBS and this new version of the GR Microphone Reciprocity Calibrator. The high accuracy of the instrument makes it suitable for standardization measurements, while its ease of operation makes it useful for daily checks on sensitivity.

The instrument can also be used as a source of constant acoustic output over a wide frequency range, to make rapid calibration checks on microphones and sound-level meters, or to set the reference level of analyzing systems.

1.2 DESCRIPTION.

1.2.1 GENERAL. The reciprocity calibrator includes the circuit and the structure required for the closed-coupler (cylindrical-cavity) reciprocity calibration procedure, which is widely recognized as the preferred method of performing the absolute calibration of laboratory standard microphones. The instrument also includes an analog computer, which performs the calculations necessary to determine microphone sensitivity. The reversible transducer necessary for the calibration procedure is the cartridge of a Type 1560-P3 PZT Microphone which is built into the coupler. The auxiliary transducer is a PZT cylinder, which forms the cylindrical wall of the coupler. The insert voltage is varied in 10-dB steps, to extend the calibration range while maintaining high resolution. The coupler has a volume of 17.74 cubic centimeters and is designed to yield the random-incidence response of the microphone over an extended range without the use of helium.

The PZT cylinder used in the reciprocity calibration also serves as a stable acoustic source when the instrument is used as a sound-level calibrator. A meter, calibrated in terms of the sound-pressure level produced, indicates the absolute value of the signal applied to the PZT cylinder.

1.2.2 CONTROLS AND CONNECTORS. Table 1 lists the controls and con-connectors on the panel of the Type 1559-B Microphone Reciprocity Calibrator.

1.2.3 ACCESSORIES SUPPLIED. Supplied with the reciprocity calibrator are a Type 274-NP Patch Cord, a 30-inch output cable for connection to the sound-level meter, and adaptors for WE 640AA-type microphones, Type 1560-P5 Microphone, and Type 1560-P6 Microphone Assembly.

TABLE 1
CONTROLS AND CONNECTORS

Fig. 1-1 Ref	*Name*	*Type*	*Function*
1	INPUT	Binding post pair	Input connection from oscillator to Type 1559-B.
2	92DB-84DB	3-position toggle switch	Selects meter range.
3	Microphone connector	3-terminal Cannon Type XLR locking connector	Receives microphone to be calibrated.
4	Transfer-function switch (READ-ADJ)	9-position selector switch	Sets necessary electrical transfers.
5	SENSITIVITY LEVEL	Continuous rotary control	Adjusts value of resistance attenuator.
6	MICROPHONE CURRENT	Continuous rotary control	Controls level of driving current of reversible transducer.
7	OUTPUT TO SLM	3-terminal Cannon Type XLR locking connector	Output connection to sound-level meter.
8	SENSITIVITY LEVEL	4-position selector switch	Sets insert voltage level.
9	Slide pins (2)	—	Lock the cabinet in the cover.
10	Phillips-head screws (4)	—	Lock the instrument in the cabinet.

1.2.4 CARRYING CASE. The Type 1559-B is mounted in a General Radio Flip-Tilt case. The captive protective cover serves as a mounting base when the instrument is in use. The friction of the rubber seal keeps the instrument at any convenient angle, from horizontal to vertical. The cables and instruction book are carried in the cover, in a protective polyurethane compartment.

1.3 ACCESSORIES REQUIRED.

1.3.1 OSCILLATOR. An audio oscillator is required to drive the Type 1559-B Microphone Reciprocity Calibrator. Ideally, this oscillator should have an output impedance of 600 ohms and should be able to deliver one watt into a 600-ohm load. The Type 1304-B Beat-Frequency Audio Generator fufills these requirements and, in addition, is readily coupled to a recorder such as the Type 1521-B Graphic Level Recorder. The Type 1310-A Oscillator is also recommended. Although the Type 1559-B Microphone Reciprocity Calibrator is designed to use a 6-dB change in output voltage when a 600-ohm source is matched and is effectively unloaded, oscillators of other impedances can be used. Two such oscillators are the Type 1311-A Audio Oscillator, which supplies 11 fixed frequencies between 50 and 10,000 c/s, and the Type 1210-C Unit R-C Oscillator, which is continuously adjustable over the audio spectrum. The Type 1311-A should be used on the 30 v output position and the Type 1210-C on the 0-7 v output position. The need for the 600-ohm generator impedance is most evident when the Type 1559-B Microphone Reciprocity Calibrator is used for sound-level calibrations. The output impedance of both the Type 1311-A Audio Oscillator and the Type 1210-C Unit R-C Oscillator can be made equal to 600 ohms by adjustment of their respective output-level controls or by the addition of series resistance.

1.3.2 DETECTOR. The detector required to measure the output signals of the Type 1559-B Microphone Reciprocity Calibrator should have an input impedance of at least 5 megohms and should be capable of measuring a signal of several millivolts with a signal-to-noise ratio of at least 20 dB. In addition, the detector should have a scale suitable for observing 1-percent changes in signal level. The detector can be a Type 1551-C Sound-Level Meter, a Type 1558-A Octave-Band Noise Analyzer, or a Type 1564-A Sound and Vibration Analyzer. One of these is usually the instrument whose microphone is to be calibrated.

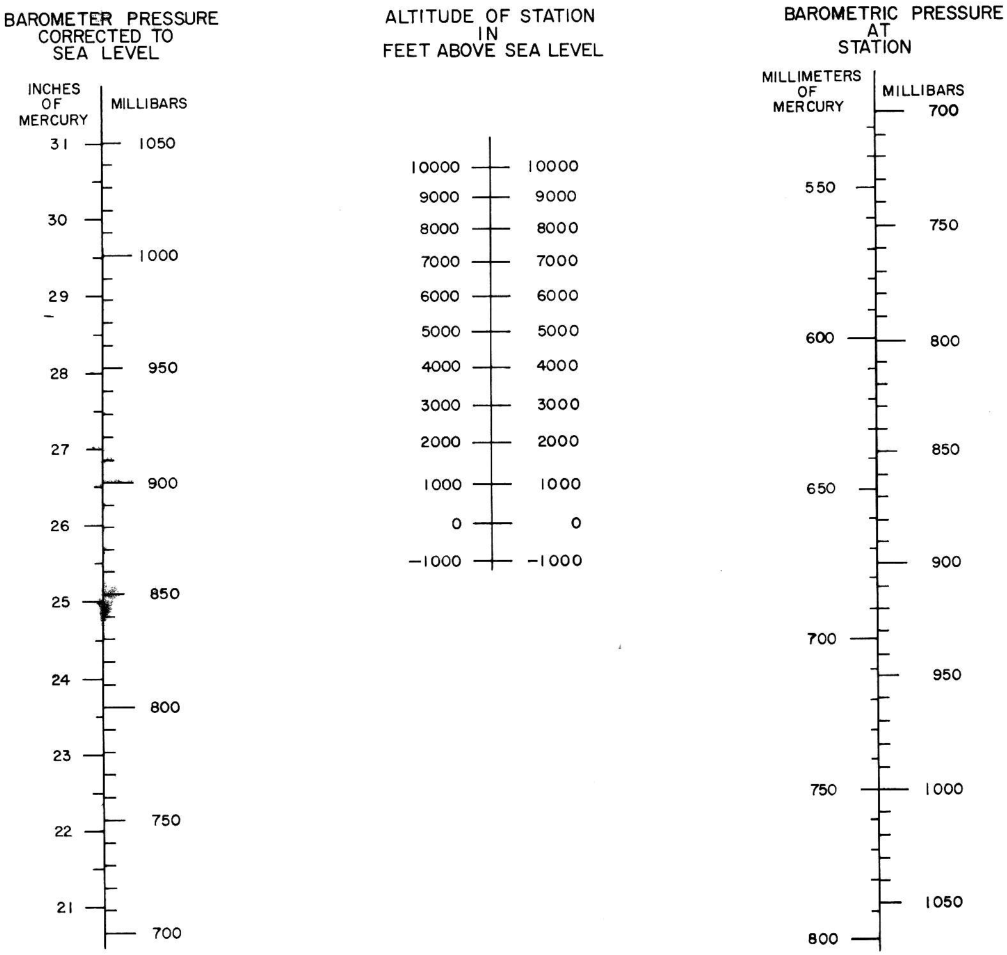

Figure 2-1. Nomograph for applying altitude correction to barometric pressure. Place straight-edge across proper points on center and left-hand scales and read actual pressure on right-hand scale. See Appendix 2 for altitudes above sea level for many cities in the U.S. and Canada.

SECTION 2

OPERATING PROCEDURE

2.1 PRELIMINARY CONTROL SETTINGS.

2.1.1 METER-ZERO CHECK. With the instrument off, set the meter pointer to zero, if necessary, by means of the screwdriver adjustment on the meter face.

2.1.2 BAROMETRIC PRESSURE COMPENSATION. For maximum accuracy, set the BAROMETRIC PRESSURE MILLIBARS control to indicate the actual barometric pressure at your location.

The pressures given by the United States Weather Bureau and by various flight facilities are corrected pressures, i.e., pressures referred to sea level. Most barometers are similarly calibrated to read pressures corrected to sea level. The actual barometric pressure can be specifically requested of your local weather station, or you can correct the published barometric reading for your own location. This correction is a function of altitude, temperature, and pressure, but the principal factor is the altitude correction of one inch of mercury per 1000 feet above sea level. Figure 2-1 includes an altitude correction chart and a conversion nomograph for inches of mercury to millibars. While the pressure set on the BAROMETRIC PRESSURE indicator should be reasonably accurate, an error of a few millibars will not greatly affect the accuracy of measurement. An error of 34 millibars (one inch of mercury) in barometric pressure will cause an error of approximately 0.15 dB in microphone calibrations and 0.3 dB in sound-level calibrations.

2.2 PIEZOELECTRIC MICROPHONE CALIBRATION.

(General Radio Types 1560-P1, -P3, and -P5 Microphones and Types 1560-P4 and -P6 Microphone Assemblies.)

NOTE

On microphones manufactured prior to January, 1961, pin No. 1 is connected to pin No. 2. This connection must be removed before the microphone is calibrated by the Type 1559-B. Remove the screw from the connector and pull out the pins. Cut the jumper between pin No. 1 and pin No. 2 and reassemble the connector.

2.2.1 CONNECTION OF GENERATOR, DETECTOR, AND MICROPHONE.

a. Connect an oscillator to the INPUT connector and a sound-level meter to the OUTPUT TO SLM connector, using the cables supplied.

b. Set the meter range switch to 92 dB.

c. Set the MICROPHONE CURRENT control to NORMAL.

d. Set the transfer function switch to ADJ 1.

e. Adjust the oscillator output control for less than full-scale deflection of the INPUT LEVEL IN DB meter.

f. Carefully place the microphone to be calibrated in the coupler (see CAUTION below) and lock it in place by moving the slider to the left. No adaptor is needed for the Types 1560-P3 & -P4 Microphones, but an Adaptor Sleeve, No. 1559-6080, is required with the Types 1560-P5 and -P6 Microphones. Then connect the microphone to the instrument, using the microphone connector attached to the panel.

CAUTION

To avoid damage to the microphone, it must be inserted into and removed from the coupler slowly enough to allow the pressure in the coupler to equalize with that of the environment.

2.2.2 SENSITIVITY-LEVEL SETTING.

The SENSITIVITY LEVEL adjusts the insert voltage applied to the unknown microphone, to permit direct calibration of microphones of various sensitivities. Set the SENSITIVITY LEVEL to -10 DB, NORMAL, +10 DB, or +20 DB, depending upon the expected microphone sensitivity. Add this setting algebraically to the reading of the large SENSITIVITY LEVEL dial to determine the microphone sensitivity. Use the NORMAL position for the General Radio Types 1560-P1, -P3, and -P5 Microphones and Types 1560-P4 and -P6 Microphone Assemblies.

2.2.3 CALIBRATION PROCEDURE.

a. Set the transfer function switch to START. Turn the SENSITIVITY LEVEL knob until the dot on the larger dial is opposite the actual barometric pressure in millibars.

b. Set the function switch to READ 1. Adjust the sound-level meter for an on-scale indication and note the reading.

c. Set the function switch to ADJ 1. Turn the SENSITIVITY LEVEL knob until the sound-level meter indicates the value noted in step b.

d. Set the function switch to READ 2. Adjust the sound-level meter for an on-scale indication and note the reading.

e. Set the function switch to ADJ 2. Turn the SENSITIVITY LEVEL knob until the sound-level meter indicates the value noted in step d.

f. Set the function switch to READ 3. Adjust the sound-level meter for an on-scale indication and note the reading.

g. Set the function switch to ADJ 3.[1] Turn the SENSITIVITY LEVEL knob until the sound-level meter indicates the value noted in step f.

h. Set the function switch to READ 4. Adjust the sound-level meter for an on-scale indication and note the reading.

i. Set the function switch to ADJ 4. Turn the SENSITIVITY LEVEL knob until the sound-level meter indicates the value noted in step h.

j. Read the microphone sensitivity[2] in dB re 1 volt/μbar on the large SENSITIVITY LEVEL dial with the added correction of the setting of the SENSITIVITY LEVEL knob (refer to paragraph 2.2.2).

2.2.4 READING THE LARGE SENSITIVITY LEVEL DIAL.

When the instructions in step i of the calibration procedure (above) are followed, the sensitivity of some microphones may cause the SENSITIVITY LEVEL dial to pass through the blank portion of the dial (a gap between -54.6 and -63.4). When this occurs, the microphone sensitivity can be correctly determined by the following straightforward procedure:

When the dial is turned through the gap in the engraving (refer to Figure 2-2) continue the calibration with the same progression of numbers as that in use before the gap was entered. Referring to the outer numbers in the figure, with a counterclockwise rotation of the dial the center of the gap becomes -54.5 and the major divisions that follow are -54.0, -53.5, -53.0, etc. With a clockwise rotation of the dial the center of the gap becomes -63.5 and the major divisions that follow are -64, -64.5, etc. Table 2 lists the microphone sensitivities involved and indicates the proper interpretation of the dial readings.

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[1] If unable to set the sound-level meter to the reading of step f, turn the MICROPHONE CURRENT control counterclockwise and repeat step f.

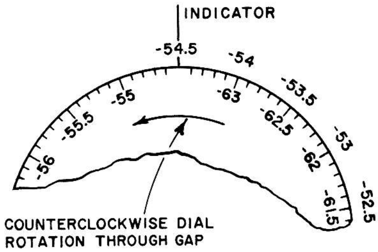
[2] Even though the calibration is a pressure calibration, the coupler has been adjusted so that the indicated sensitivity is the random-incidence (diffuse-field) sensitivity.

TABLE 2

Actual Microphone Sensitivity in dB re 1 V/μbar	*Setting of SENSITIVITY LEVEL switch*	*SENSITIVITY LEVEL DIAL*		*Microphone Sensitivity (SENSITIVITY LEVEL Dial Plus Switch Readings) in dB re 1V/μbar*
		Number Displayed	*Should be read as*	
-62.5	NORMAL	-62.5	-62.5	-62.5
-62.5	- 10 dB	*-61.5	-52.5	-62.5
-63.0	- 10 dB	*-62.0	-53.0	-63.0
-63.5	- 10 dB	*-62.5	-53.5	-63.5
-64.0	- 10 dB	*-63.0	-54.0	-64.0
-64.5	- 10 dB	**-63.5 -54.5	-54.5	-64.5
-65.0	- 10 dB	-55.0	-55.0	-65.0
-52.5	+10 dB	-62.5	-62.5	-52.5
-52.5	NORMAL	*-61.5	-52.5	-52.5
-53.0	NORMAL	*-62.0	-53.0	-53.0
-53.5	NORMAL	*-62.5	-53.5	-53.5
-54.0	NORMAL	*-63.0	-54.0	-54.0
-54.5	NORMAL	**-63.5 -54.5	-54.5	-54.5
-55.0	NORMAL	-55.0	-55.0	-55.0
-42.5	+20 dB	-62.5	-62.5	-42.5
-42.5	+10 dB	*-61.5	-52.5	-42.5
-43.0	+10 dB	*-62.0	-53.0	-43.0
-43.5	+10 dB	*-62.5	-53.5	-43.5
-44.0	+10 dB	*-63.0	-54.0	-44.0
-44.5	+10 dB	**-63.5 -54.5	-54.5	-44.5
-45.0	+10 dB	-55.0	-55.0	-45.0
-32.5	+20 dB	*-61.5	-52.5	-32.5
-33.0	+20 dB	*-62.0	-53.0	-33.0
-33.5	+20 dB	*-62.5	-53.5	-33.5
-34.0	+20 dB	*-63.0	-54.0	-34.0
-34.5	+20 dB	**-63.5 -54.5	-54.5	-34.5
-35.0	+20 dB	-55	-55.0	-35.0

*Dial passes through gap from -54.6 to -63.4 in adjustment 4.
**Dial is in center of gap from -54.6 to -63.4 after adjustment 4.

Figure 2-2. Part of the SENSITIVITY LEVEL dial, showing the progression of numbers through the gap, for counterclockwise rotation.



2.2.5 USE OF MICROPHONE SENSITIVITY.

If the measured sensitivity of the microphone is the same as its initial value, the calibration of the associated instrument (sound-level meter, octave-band analyzer, etc.) need not be changed. However, if the measured sensitivity is different, the associated instrument must be recalibrated. Refer to the appropriate paragraph in the Operating Instructions for the associated instrument: paragraph 3.8 for the Type 1551-B Sound-Level Meter, paragraph 4.8 for the Type 1551-C Sound-Level Meter, paragraph 4.4 for the Type 1558 Octave-Band Noise Analyzer, and paragraph 2.3 for the Type 1564-A Sound and Vibration Analyzer.

2.3 CALIBRATION OF WE 640AA and B & K 4131 MICROPHONES.

NOTE

> The following instructions apply for the calibration of either microphone, except that a No. DB-0111 B & K Coupler-Adaptor is required for calibration of the B & K 4131 Microphone.

A preamplifier is required to supply a polarizing voltage for condenser microphones and to give a lower impedance. The GR Type 1551-P1 Condenser Microphone System[1] is acceptable for this use.

a. Insert the Type 1559-2220 Adaptor Unit into the coupler opening on the panel of the Type 1559-B and lock it in place by sliding the clamp onto its rim.

b. Insert the banana pin of the Type 1559-2210 Adaptor Assembly into the scroll of the clamping spring on the Type 1559-B. Connect the female end of the audio connector to the output of the Type 1551-P1 Condenser Microphone System[2] and connect the male end of the audio connector to the microphone on the Type 1559-B.

[1] For precision work, the polarizing voltage must be accurately measured. An accurate, high-impedance voltmeter can be used to measure the polarizing voltage from cathode to ground of the Type 1551-P1. A correction of -2 volts, for grid to cathode bias, should be applied to the reading.

[2] Other preamplifiers can be used if they include a provision for inserting a voltage between the microphone case and the preamplifier ground.

c. Extend the center terminal of the W E 640AA Microphone by means of the adaptor contact provided[1]. Screw the plastic adaptor (supplied) into the W E 640AA Microphone, and screw the latter onto the Type 1551-P1-25 Microphone Base. Connect the base to the condenser microphone system, turn the switch to ON, and set the meter to 100; the polarizing voltage of the microphone is now 200 volts. (Refer to footnote 1, page 9.) The ground return for the microphone will be through the Type 1559-2210 Adaptor Assembly. Therefore do not attempt to use the microphone when it is not connected to the Type 1559-B Calibrator.

d. Remove the grid from the W E 640AA Microphone and *slowly* insert the microphone into the adaptor unit.

Because of the microphone polarizing voltage and capacitor leakage, it is necessary to charge the stray capacitances of the calibrator, as follows:

a. Set the Transfer Function Switch (TFS) on the Type 1559-B to START and allow the Type 1551-P1 Condenser Microphone System to charge until the meter indicates 100.

b. Set the TFS to READ 1 and again allow the Type 1551-P1 to charge to 100 on the meter.

c. Repeat this procedure with the TFS set to ADJ 1. Proceed around the switch until all positions are similarly charged.

d. Set the SENSITIVITY LEVEL switch to the +10 dB position. Proceed with the calibration of the W E 640AA Microphone by following the instructions on the panel of the Type 1559-B Microphone Reciprocity Calibrator or those given in paragraph 2.2.2.

Although the microphone is calibrated with the "grid off," the adaptor unit gives the correct "grid on" random-incidence response, for normal use of the microphone.

2.4 PRECISION ACCOUSTIC SOURCE.

In this use of the Type 1559-B, the determined sensitivity of the microphone is used to set the sound-pressure level in the coupler with an accuracy of ±(0.2 dB + the accuracy of determining the microphone sensitivity). This accurately determined sound-pressure level can then be used to calibrate a sound-level meter or a sound analyzing system. Proceed as follows:

a. Calibrate the microphone to be used as outlined in paragraph 2.2.

b. With the same connections as in paragraph 2.2, turn the function switch to ADJ 3. Set the SENSITIVITY LEVEL smaller dial to the microphone sensitivity determined in step a.

c. Adjust the oscillator output control for a full-scale deflection of the INPUT LEVEL IN DB meter. If it is not possible to set the meter to full-scale, set it for the maximum reading possible and note the reading.

d. Adjust the sound-level meter for an on-scale indication and note the reading.

[1] An adaptor contact is also provided for the B & K 4131 Microphone.

e. Set the function switch to READ 3. Adjust the MICROPHONE CURRENT knob until the sound-level meter indicates the value noted in step d. If necessary, the generator output voltage may be adjusted also.

f. Connect the microphone directly to the sound-level meter.

g. Adjust the gain of the sound-level meter so that its dB reading equals that noted on the INPUT LEVEL IN DB meter in step c.

2.5 COMPARISON WITH STANDARD MICROPHONE.

The calibrations performed with the Type 1559-B Microphone Reciprocity Calibrator can be compared to the reciprocity calibrations performed by the National Bureau of Standards on the W E 640AA Microphone. There is now a direct traceability between the NBS and General Radio reciprocity calibrations.

2.6 SOUND-LEVEL CALIBRATOR.

The PZT cylinder used as the auxiliary transducer in the reciprocity calibration procedure can be used as a stable acoustic source for rapid calibrations of microphones, sound-level meters, and analyzing systems at frequencies between 10 and 2500 c/s. The PZT cylinder produces a constant output over this frequency range. The range is limited because, when a sound source is used to produce a calibrated sound field, the sound source must have a flat and stable output. For a microphone calibration, the sound source can deviate from a flat response, and the field can vary so long as the sound pressure levels on the reciprocal microphone and the microphone being calibrated are the same. The procedure, using the PZT cylinder, is as follows:

a. Set the meter switch to 92 dB[1] and the function switch to READ 1.

b. Insert the microphone in the coupler and connect it directly to the sound-level meter.

c. Connect an oscillator (or generator) to the INPUT connector and adjust the oscillator output control for a full-scale deflection of the INPUT LEVEL IN DB meter. If it is not possible to set the meter to full scale, set it for the maximum reading possible.

d. The sound level applied to the microphone is indicated on the INPUT LEVEL IN DB meter. The value given is for atmospheric pressure; see Figure 2-3 for corrections.

If the oscillator output is constant over the frequency range, the input to the Type 1559-B can be swept for recording purposes.

2.7 CALIBRATION OF TYPE 1565-A SOUND-LEVEL METER AND TYPE 1560-P40K MICROPHONE PREAMPLIFIER.

The microphones on these instruments cannot be calibrated by the reciprocity technique without the use of a microphone base, which permits

[1] When using the Type 1310-A Oscillator, set the meter switch to 84 dB.

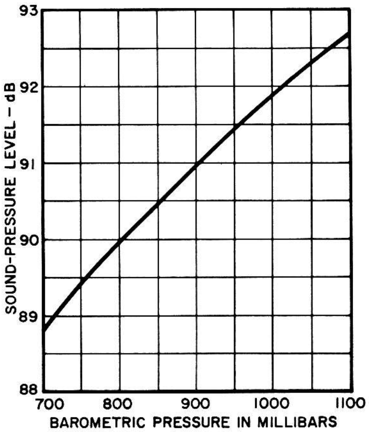


Figure 2-3. Sound-level calibration output versus atmospheric pressure.

them to be connected to the Type 1559-B. As the units are supplied, there is no provision for introducing an insert voltage for calibration. Therefore, these instruments must be calibrated by using the Type 1559-B as either an acoustic source, as outlined in paragraph 2.6, or a sound-level calibrator, as outlined in paragraph 2.4. Calibration of an auxiliary microphone is needed to use the Type 1559-B as a sound-level calibrator.

2.8 MICROPHONE RESPONSES.

The frequency response of a microphone can be expressed in several different ways:

a. Pressure Response — the ratio of the open-circuit voltage output to the value of a pressure variation applied uniformly over the surface of the diaphragm.

b. Free-Field Response — the ratio of the open-circuit voltage output to the value of the sound pressure of a plane progressive wave before the introduction of the microphone into the sound field. The direction of incidence must be specified.

(1) Free-Field Perpendicular Incidence (0°). The direction of propagation of the sound wave is perpendicular to the plane of the microphone diaphragm, and parallel (0°) to the axis of the microphone (diaphragm normal).

(2) Free-Field Grazing Incidence (90°). The direction of propagation of the sound wave is parallel to the plane of the microphone diaphragm and perpendicular (90°) to the axis of the microphone (diaphragm normal).

c. Random-Incidence (Diffuse-Field) Response — the ratio of the open-circuit rms voltage output to the rms value of the sound pressure of a diffuse field (one is which the rms sound pressure is everywhere the same and the flow of energy in all directions is equally probable) before the introduction of the microphone.

For a microphone the size of the Type 1560-P3 (about 1 inch in diameter), all of the above responses are equal from subsonic frequencies to about 1 kc/s[1]. Above 1 kc/s, diffraction effects cause a variation in the responses. See Figures 2-4 and 2-5 for the relationships between the various responses. The calibrator is adjusted to give the random response because a diffuse field closely approximates the usual environment into which a sound-level-meter microphone is placed.

2.9 AMBIENT NOISE LEVEL.

To avoid an error in the measurement, the ambient noise level in the coupler, with the microphone to be calibrated in place, should be at least 20 dB below the acoustic signal level. To check the signal-to-noise ratio, follow the procedure outlined in paragraph 2.2.1, set the function switch to READ 2, and note the reading of the sound-level meter. Then decrease the input voltage to zero and note the reading of the sound-level meter. This reading should be 20 dB below the first reading. If the noise level is too high, either increase the oscillator output (up to 50 volts) or move to a more quiet location.

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1 The usual closed coupler (pressure) calibration takes into account only pressure-equalization leaks through the diaphragm. Leaks through the case may cause a roll-off at subsonic frequencies.

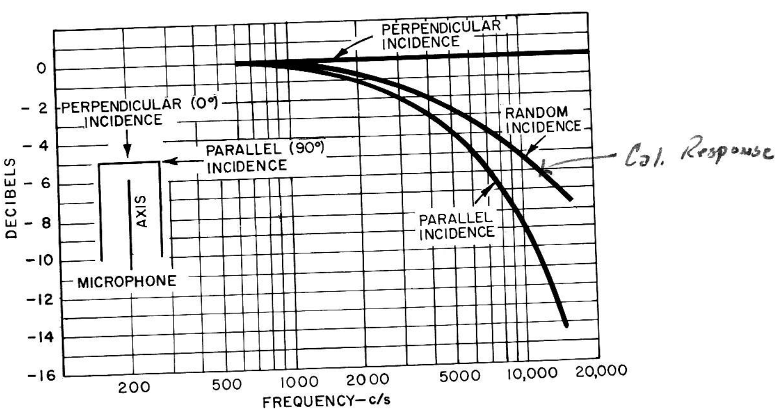


Figure 2-4. Corrections to be added to free-field perpendicular-incidence response for random- and parallel-incidence responses of W E 640AA and Type 1560-P5 Microphones and Type 1560-P6 Microphone Assembly.

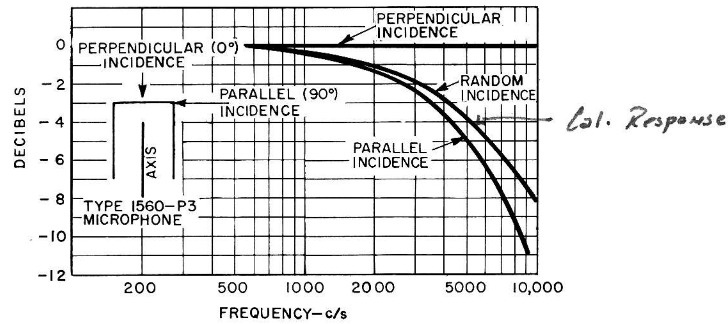


Figure 2-5. Corrections to be added to free-field perpendicular-incidence response for random- and parallel-incidence responses of Types 1560-P1 and -P3 Microphones and Type 1560-P4 Microphone Assembly.

2.10 DEVIATIONS IN MICROPHONE CALIBRATION.

At frequencies below 1 kc/s, the Type 1559-B is a primary absolute calibrator for the Type 1560-P3 PZT Microphone, with the error in determining a microphone sensitivity fixed by (1) the linearity of the potentiometer (±0.5%), (2) the accuracy of measurement of the coupler volume (±1%), and (3) the capacitance tolerance of the current-sampling capacitor (±0.25%). At frequencies above 1 kc/s, the "error" in the pressure response due to wave motion is empirically matched to the correction between the pressure and

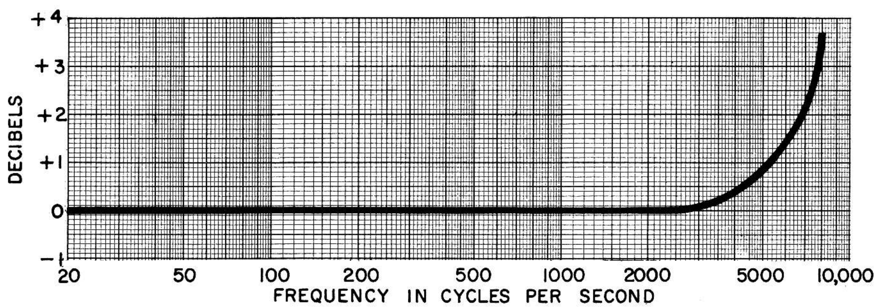


Figure 2-6. Average deviation of the calibration by the Type 1559-B Microphone Reciprocity Calibrator from the true random incidence for the General Radio Type 1560-P5 Microphone and Type 1560-P6 Microphone Assembly.

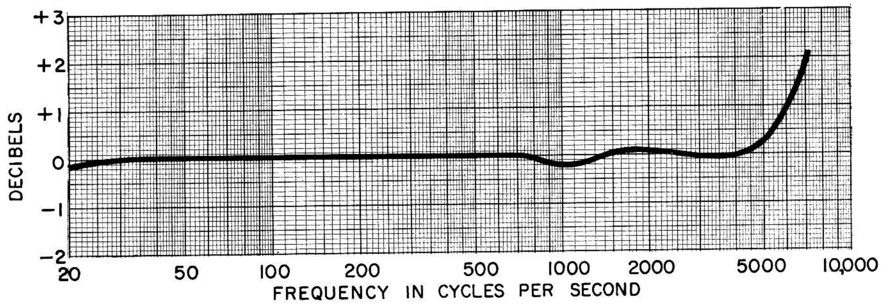


Figure 2-7. Average deviation of the calibration by the Type 1559-B Microphone Reciprocity Calibrator from the true random incidence for the W E 640AA Microphone.

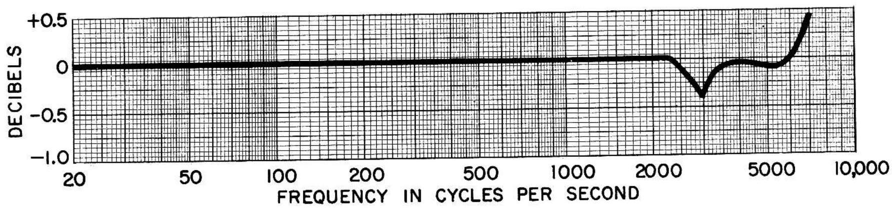


Figure 2-8. Average deviation of calibration by the Type 1559-B Microphone Reciprocity Calibrator from the true random incidence for the General Radio Types 1560-P1 and -P3 Microphones and Type 1560-P4 Microphone Assembly.

random responses of the microphone. Thus the instrument is direct reading in the random-response sensitivity of the microphone being calibrated. Figures 2-6, 2-7, and 2-8 are plots of the average deviation of the matching. These plots can be used as corrections applied to microphone calibrations by the Type 1559-B Microphone Reciprocity Calibrator to increase the accuracy.

Example: A General Radio Type 1560-P3 PZT Microphone is calibrated at 7 kc/s with the Type 1559-B. The determined sensitivity is -57.0 dB re 1 volt/μbar. Referring to Figure 2-8, the average deviation is +0.45 dB. Therefore, the corrected response of the Type 1560-P3 PZT Microphone is -57.0 dB - 0.45 dB = -57.45 dB.

SECTION 3

PRINCIPLES OF OPERATION

3.1 PRINCIPLE OF RECIPROCITY.

The Principle of Reciprocity is stated as follows: The ratio of response to excitation is unchanged if the points of excitation and observation are interchanged, provided the terminal conditions remain the same. Figure 3-1 illustrates the relationships that follow from the Principle of Reciprocity for a two-port, four-terminal electrical network. The equation on which the design of the Type 1559-B Microphone Reciprocity Calibrator is based is that the forward current transfer equals the reverse voltage transfer.

$$\left.\frac{I_2}{I_1}\right|_{V_2 = 0} = \left.\frac{V_1}{V_2}\right|_{I_1 = 0} \qquad (1)$$

In a two-port, four-terminal network,

$$V_1 = Z_{11}I_1 + Z_{12}I_2$$

$$V_2 = Z_{21}I_1 + Z_{22}I_2$$

By reciprocity,

$$Z_{12} = Z_{21} = 2$$

$$\left.\frac{I_2}{I_1}\right|_{V_2 = 0} = \left.\frac{V_1}{V_2}\right|_{I_1 = 0}$$

$$\left.\frac{I_1}{I_2}\right|_{V_1 = 0} = \left.\frac{V_2}{V_1}\right|_{I_2 = 0} = \frac{2}{3}$$

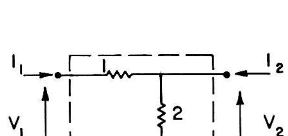


Figure 3-1.
The Principle of Reciprocity applied to a two-port, four-terminal network.

Reciprocity is not restricted to linear and passive electrical networks; it applies to any linear, bilateral, or passive network. The Type 1560-P3 PZT Microphone (Figure 3-2) is such a network.

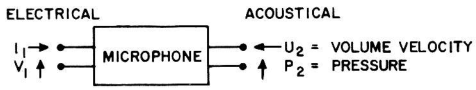


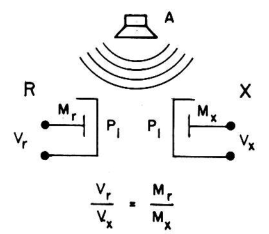
Figure 3-2. Network equivalent of Type 1560-P3 Microphone.

3.2 MICROPHONE CALIBRATION BY THE RECIPROCITY TECHNIQUE.

The Type 1559-B Microphone Reciprocity Calibrator calibrates a microphone by the closed-coupler (cylindrical-cavity) reciprocity technique, which is similar to that described in the American Standards Association Standard Z24.4-1949. The reciprocity technique of calibration is a primary method of calibration in which no acoustic standards are needed. A microphone calibration with the Type 1559-B requires four balances. The microphone sensitivity is indicated directly on a dial on the panel. The accuracy of measurement depends on the measurement of (1) resistance values of an attenuator, (2) mechanical dimensions of the coupler (cavity), and (3) the value of a current-sampling capacitor.

Three transducers and a closed-coupler (the cavity) are needed for the calibration procedure. One transducer (A, Figure 3-3) is used as a loud speaker which equally excites unknown microphone X and reciprocal microphone R with a sound pressure. The ratio of the open-circuit voltages of the two microphones R and X equals the ratio of the microphone sensitivities. The ratio of the open-circuit voltage to the exciting pressure is the definition of the microphone sensitivity $M = V/P$. The sensitivity is commonly expressed as 20 $\log_{10}$ M re 1 volt/μbar. If the two microphones are coupled

Figure 3-3. Relationships of three transducers in reciprocity calibration.



together by a known acoustical impedance (the cavity) and the reciprocal microphone (R) is driven as a loudspeaker, the ratio of the open-circuit voltage of microphone X to the driving current of the reciprocal microphone (R) can be theoretically related to the product of the microphone sensitivities. By solving two relationships, the ratio of sensitivities of microphones R and X and the product of these sensitivities, the sensitivity of either microphone can be determined.

The equivalent circuits of a ceramic microphone are shown in Figure 3-4.

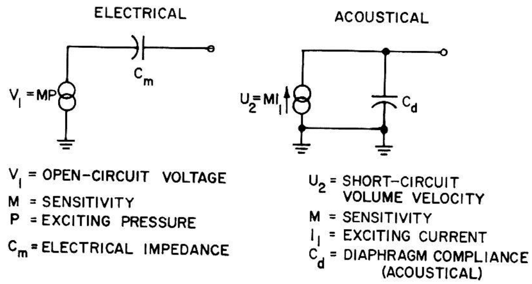


Figure 3-4. Equivalent circuits of a ceramic microphone.

3.3 THE AUXILIARY TRANSDUCER.

In the Type 1559-B Microphone Reciprocity Calibrator, transducer A is a piezoelectric ring, which produces a sound pressure in a cylindrical cavity when it is excited by a voltage. The microphone to be calibrated (transducer X) is inserted in one end of this cavity, and a similar reciprocal microphone cartridge (R) is mounted in the other end. The symmetry that results from the use of a reciprocal transducer (similar to the microphone being measured) and an auxiliary transducer in the form of an encompassing cylinder extends the usefulness of the coupler over a wide frequency range.

3.4 RATIO AND PRODUCT OF SENSITIVITIES.

Figure 3-5 illustrates the procedure by which the ratio of the microphone sensitivities is determined in the Type 1559-B Microphone Reciprocity Calibrator. Figure 3-6 illustrates the procedure for determining the product of the sensitivities of two microphones, one of which is reciprocal, that are coupled together by a known acoustical impedance (Z_a). A current (I_r) into microphone R produces a volume velocity (U) equal to the current (I_r) times the microphone sensitivity (M_r). This volume velocity (U) develops in the

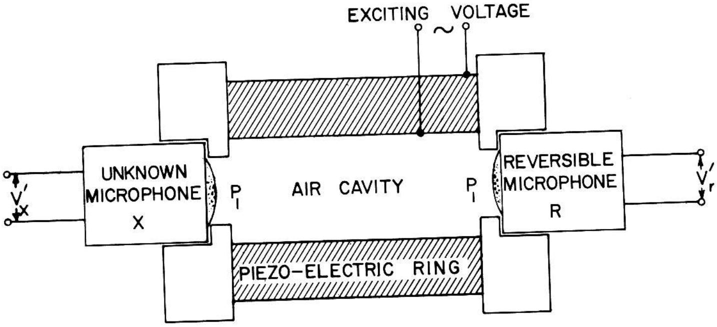


Figure 3-5. Conditions for determining the ratio of microphone sensitivities.

cavity a pressure ($P = UZ_a$) which causes an open-circuit voltage (V_x) equal to UZ_aM_x at the terminals of the second microphone. Collecting terms we have:

$$\frac{V_x}{I_r} = M_rZ_aM_x = M_rM_xZ_a \tag{2}$$

The Principle of Reciprocity, as it applies to a microphone, states that the ratio U/I_r equals M_r when the pressure (P) at the acoustical terminals is zero. Practically, this means that the impedance (ammeter) used to measure U, the short-circuit current, must be small compared with the acoustical output impedance so that the current is not changed by the measuring system. In the Type 1559-B, the impedance (Z_a) of the coupler is 1/100 of the acoustical output impedance of the microphone. This output impedance is taken into account in the determination of Z_a.

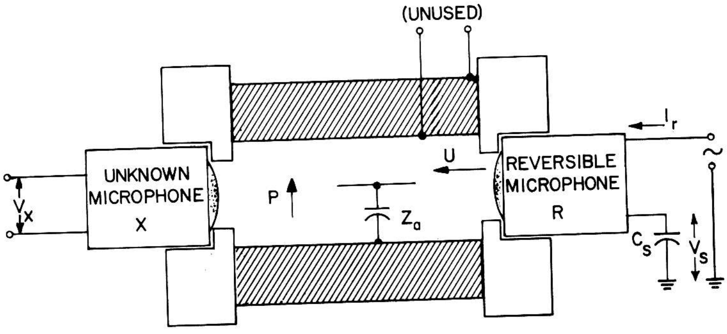


Figure 3-6. Conditions for determining the product of microphone sensitivities.

Solving the equations for the ratio and product of sensitivities yields

$$M_x = \sqrt{\frac{V_x'}{V_r'} \times \frac{V_x}{I_r} \times \frac{1}{Z_a}} \qquad (3)$$

3.5 COUPLING IMPEDANCE, Z_a.

A closed volume in an acoustical network can be represented as a capacitor in an electrical analog if the dimensions of the cavity are small compared with the wavelength at the frequency of interest. The compliance (value of the capacitor) equals:

$$C = \frac{V_{cc}}{\gamma P_o} \qquad (4)$$

where V_{cc} = the volume of the cavity in cubic centimeters
γ = the ratio of the specific heats of the gas in the cavity (1.4 for air)
P_o = the pressure of the gas in the cavity in dynes/square centimeter.

To determine the value of Z_a for use in the equation of the microphone sensitivity, the finite impedances of the diaphragms of the driving and receiving microphones must be taken into account. The compliance of each microphone diaphragm can be considered equivalent to a voulme of 0.2 cubic centimeter. These two volumes are added to the actual physical volume of the cavity in determining the value of V_{cc}. The coupler in the Type 1559-B ceases to act as a simple capacitor above 1 kc/s. However, the deviation in the impedance of the coupler is used to convert the sensitivity (M) of the microphone being calibrated from a pressure response to a random-incidence (diffuse-field) response.

$$Z_a = \frac{\gamma P_o}{j\omega V_{cc}}; \qquad \frac{1}{Z_a} = \frac{j\omega V_{cc}}{\gamma P_o} \qquad (5)$$

Substituting $\frac{1}{Z_a}$ in equation (3) for the microphone sensitivity, M_x, yields

$$M_x = \sqrt{\frac{V_x'}{V_r'} \times \frac{V_x}{I_r} \times \frac{j\omega V_{cc}}{\gamma P_o}} \qquad (6)$$

3.6 CURRENT SAMPLER.

The driving current (I_r) of the reciprocal microphone is determined by measurement of the voltage (V_s) across a capacitance current sampler (C_s) placed in series with the microphone. The current (I_r) equals the voltage (V_s) times the value of capacitive admittance (ωC_s). Because the value of the capacitor enters into the calculation of the microphone sensitivity, a stable GR polystyrene unit is used. An important advantage is gained by the use of a capacitor to measure the current of the reciprocal microphone. Substituting $V_s j\omega C_s$ for I_r in equation (6) for the microphone sensitivity (M_x) yields:

$$M_x = \sqrt{\frac{V_x'}{V_r'} \times \frac{V_x}{V_s} \times \frac{V_{cc}}{\gamma P_o C_s}} \qquad (7)$$

The equation for the microphone sensitivity (M_x) is now independent of frequency. This means that, for a microphone whose sensitivity is constant with frequency, the voltages to be measured will be constant. Also, the constant $\frac{V_{cc}}{\gamma P_o C_s}$) in the above equation need be determined only once.

3.7 RESISTIVE-INSERT TECHNIQUE.

The four voltages determined in the calibration procedure are measured by the use of the resistive-insert, or substitution, technique. The resistive-insert technique is an accurate method of determining the open-circuit voltage of a transducer by the insertion of a known voltage across a resistor connected between the low side of the transducer and ground (see Figure 3-7).

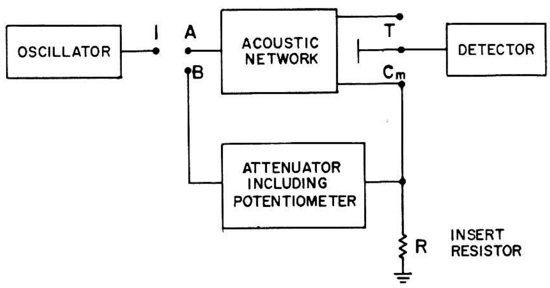


Figure 3-7. Resistive-insert technique.

First, the oscillator (1) is connected to terminal (A) to excite acoustically the transducer (T), and the indication of the detector is noted. Then the oscillator (1) is connected to terminal (B) and the attenuator is adjusted until the detector indication is the same as the first step. The voltage (V_i) across the insert resistor (R) now equals the open-circuit voltage (V_{oc}) of the transducer, assuming that the transducer is acoustically independent of the effects of detector loading. The voltage (V_i) is usually determined by the measurement of the oscillator voltage (E) and the attenuator setting.

3.8 THE ANALOG COMPUTER.

The calculations necessary to determine the microphone sensitivity are automatically performed during the measurement sequence by an analog computer that uses a logarithmic potentiometer in the attenuator for the resistive-insert technique. The computer mechanism is shown in Figure 3-8. The potentiometer has a linear relationship between the angle of shaft rotation and attenuation in decibels; thus the shaft position is proportional to the logarithm of the voltage measured. The voltages in the equation for the microphone sensitivity appear as ratios and products, which become substractions and additions when logarithms are used.
Equation for Microphone Sensitivity:

$$M_x = \sqrt{\frac{V_{cc}}{\gamma P_o C_s} \times \frac{V_x'}{V_r'} \times \frac{V_x}{V_s}} \tag{8}$$

$$20 \log_{10} M_x = \tfrac{1}{2}\left[20 \log_{10} \frac{V_{cc}}{\gamma P_o C_s} + (20 \log_{10} V_x' - 20 \log_{10} V_r') + (20 \log_{10} V_x - 20 \log_{10} V_s)\right] \tag{9}$$

First, the constants of the equation are set into the answer dial and the dial is clamped in place. During the first balance the shaft of the potentiometer is set to an angular position proportional to log V'_x. The answer dial is then coupled to the potentiometer shaft and, while the potentiometer shaft is set to an angular position proportional to log V_r' during the second balance, the difference between the angular positions (the difference of logarithms) is put into the answer dial. This determines the first ratio of voltages. The dB difference of the second ratio of voltages is then added to the answer dial, thereby solving the equation.

3.9 EXPLANATION OF CALIBRATION PROCEDURE.

$$20 \log_{10} M_x = \tfrac{1}{2}\left[20 \log_{10} \frac{V_{cc}}{\gamma P_o C_s} + (20 \log_{10} V_x' - 20 \log_{10} V_r') + (20 \log_{10} V_x - 20 \log_{10} V_s)\right]$$

START:

The drive voltage is disconnected and the answer dial is coupled to the potentiometer (SENSITIVITY LEVEL) shaft so that the constants of the term $(20 \log_{10} \frac{V_{cc}}{\gamma P_o C_s})$ can be set into it.

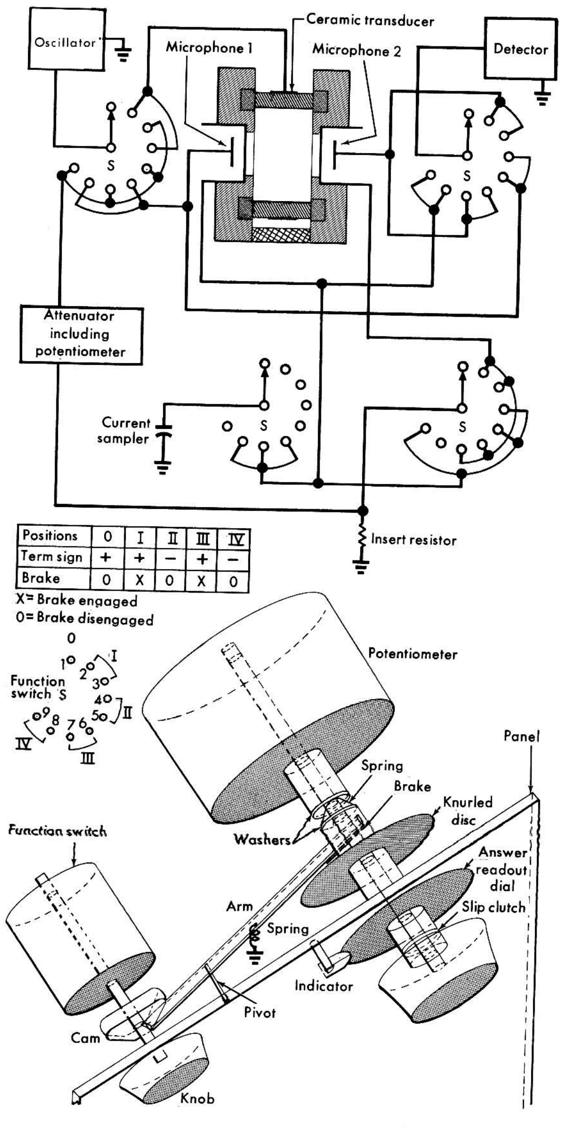


Figure 3-8. The analog-computer mechanism.

READ 1:

The answer dial is clamped, the drive voltage is connected to the PZT cylinder, and the microphone to be measured is connected to the detector, whose reading is noted. This is step A of the resistive-insert technique.

ADJ 1:

The answer dial is clamped, the drive voltage is connected to the attenuator, and the potentiometer shaft is set angularly to the logarithm of the open-circuit voltage of the microphone noted in READ 1. This is step B of the resistive-insert technique.

READ 2:

The answer dial is coupled to the potentiometer shaft, the drive voltage is connected to the PZT cylinder, and the reciprocal microphone is connected to the detector, whose reading is noted.

ADJ 2:

The answer dial is coupled to the potentiometer shaft, the drive voltage is connected to the attenuator, and the potentiometer shaft is set angularly to the logarithm of the open-circuit voltage of the reciprocal microphone noted in READ 2. The difference between logarithms

$$(20 \log_{10} V_x{}' - 20 \log_{10} V_r{}')$$

is thereby added to the constants on the answer dial.

READ 3:

The answer dial is clamped, the drive voltage is connected to the reciprocal microphone, and the microphone to be measured is connected to the detector, whose reading is noted.

ADJ 3:

The answer dial is clamped, the drive voltage is connected to the attenuator, and the potentiometer shaft is set angularly to the logarithm of the open-circuit voltage of the microphone noted in READ 3.

READ 4:

The answer dial is coupled to the potentiometer shaft, the drive voltage is connected to the reciprocal microphone, and the current-sampling capacitor is connected to the detector, whose reading is noted.

ADJ 4:

The answer dial is coupled to the potentiometer shaft, the drive voltage is connected to the attenuator, and the potentiometer shaft is set angularly to the logarithm of the voltage V_s noted in READ 4. The difference between logarithms

$$(20 \log_{10} V_x - 20 \log_{10} V_s)$$

is thereby added to the previous terms on the answer dial, thus solving the equation for the microphone sensitivity

($20 \log_{10} M_x$ re $1 \text{ v}/\mu\text{bar}$)

which is indicated directly on the answer dial.

SECTION 4

SERVICE AND MAINTENANCE

4.1 WARRANTY.

We warrant that each new instrument sold by us is free from defects in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards after examination by our factory, district office, or authorized repair agency personnel, will be repaired, or, at our option, replaced without charge, except for tubes or batteries that have given normal service.

4.2 SERVICE.

The two-year warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office, requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

4.3 REMOVAL OF INSTRUMENT FROM CABINET.

To remove the instrument from its cabinet, first open the cabinet as outlined on the side panel of the flip-tilt mechanism. Lock the cabinet in the cover by means of the slide pins (9, Figure 1-1). Remove four screws (10), and lift the instrument out of the case.

4.4 TROUBLE-SHOOTING.

Because of the passive nature of the instrument, most difficulties can be traced to either an open or short circuit. Such difficulties appear during the operation of the instrument as a failure to obtain a detector reading for a given switch position. Servicing is a matter of determining where the signal path is interrupted. For the purpose of tracing, consider the instrument divided into two electrical signal paths for each switch position — one from the generator to the transducer, and one from the transducer to the detector. To check the paths from the generator to the transducer for the READ positions, remove the microphone to be calibrated and set the generator to a frequency near 2 kc/s. The sound produced in the cavity can then be heard.

4.5 RESISTANCE MEASUREMENTS.

Table 3 gives the resistance values between various points and ground.

TABLE 3

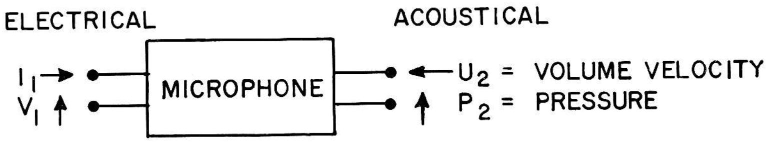
Resistance values from various points to ground.

Switch Position	*Insulated Terminal of Input Connector*	*Pin No. 1 of Microphone Connector Sensitivity Level*				*Aluminum End Cap of Cavity Assembly, Farthest from Panel*
START	∞	0	0	0	0	0
READ 1	5 kΩ	0	0	0	0	∞
ADJ 1	600 Ω	20.1Ω	63.6Ω	201.3Ω	639.5Ω	∞
READ 2	5 kΩ	20.1Ω	63.6Ω	201.3Ω	639.5Ω	0
ADJ 2	600 Ω	0	0	0	0	63.6 Ω
READ 3	∞	0	0	0	0	∞
ADJ 3	600 Ω	20.1Ω	63.6Ω	201.3Ω	639.5Ω	∞
READ 4	∞	20.1Ω	63.6Ω	201.3Ω	639.5Ω	∞
ADJ 4	600 Ω	0	0	0	0	63.6 Ω

APPENDIX 1

PRODUCT OF SENSITIVITIES

A. Reciprocal Microphone.



$$V_1 = Z_{11} I_1 + Z_{12} U_2$$

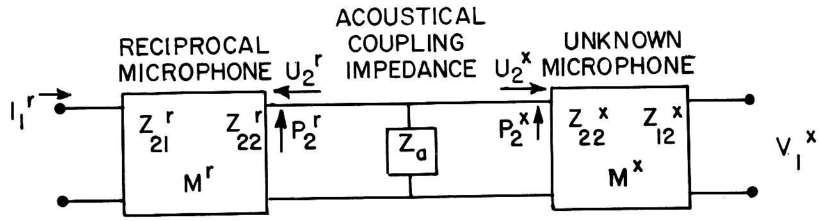
$$P_2 = Z_{21} I_1 + Z_{22} U_2$$

By reciprocity:

$$Z_{12} = Z_{21}$$

If $I_1 = 0$, define $M \equiv \left.\dfrac{V_1}{P_2}\right|_{I_1=0} = \dfrac{Z_{12}}{Z_{22}}$ = Microphone Sensitivity

B.



Apply current $I_1{}^r$ and measure open-circuit voltage $V_1{}^x$.

Since: $I_1{}^x = 0$ $\qquad V_1{}^x = Z_{12}{}^x U_2{}^x$

$$U_2{}^x = \frac{P_2{}^x}{Z_{22}{}^x} \qquad = Z_{12}{}^x \frac{P_2{}^x}{Z_{22}{}^x}$$

$$P_2{}^r = P_2{}^x \qquad = \frac{Z_{12}{}^x}{Z_{22}{}^x} P_2{}^r$$

$$U_2{}^r = -\frac{P_2{}^r}{(Z_a \| Z_{22}{}^x)}$$

$$P_2{}^r = Z_{21}{}^r I_1{}^r + Z_{22}{}^r U_2{}^r$$

$$P_2{}^r = Z_{21}{}^r I_1{}^r - \frac{Z_{22}{}^r P_2(Z_a + Z_{22}{}^x)}{Z_a Z_{22}{}^x}$$

$$P_2{}^r \left(1 + \frac{Z_a Z_{22}{}^r + Z_{22}{}^x Z_{22}{}^r}{Z_a Z_{22}{}^x}\right) = Z_{21}{}^r I_1{}^r$$

$$P_2{}^r = I_1{}^r \left(\frac{Z_{21}{}^r \; Z_a Z_{22}{}^x}{Z_a Z_{22}{}^x + Z_a Z_{22}{}^r + Z_{22}{}^x Z_{22}{}^r}\right)$$

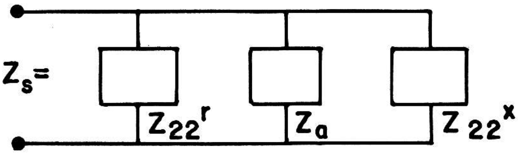
$$V_1{}^x = \frac{Z_{12}{}^x}{Z_{22}{}^x} \; P_2{}^r$$

$$= \frac{Z_{12}{}^x}{Z_{22}{}^x} \; I_1{}^r \left(\frac{Z_{21}{}^r Z_a Z_{22}{}^x}{Z_a Z_{22}{}^x + Z_a Z_{22}{}^r + Z_{22}{}^x Z_{22}{}^r}\right)$$

$$Z_{21}{}^r = Z_{12}{}^r$$

and, multiplying by $\dfrac{Z_{22}{}^{r}}{Z_{22}{}^{r}}$,

$$= I_1{}^{r}\ \frac{Z_{12}{}^{x}}{Z_{22}{}^{x}}\ \frac{Z_{12}{}^{r}}{Z_{22}{}^{r}}\left(\frac{Z_a Z_{22}{}^{x} Z_{22}{}^{r}}{Z_a Z_{22}{}^{x} + Z_a Z_{22}{}^{r} + Z_{22}{}^{x} Z_{22}{}^{r}}\right)$$

DEFINE $Z_s =$ 

$$\frac{V_1{}^{x}}{I_1{}^{r}} = \frac{Z_{12}{}^{x}}{Z_{22}{}^{x}}\ \frac{Z_{12}{}^{r}}{Z_{22}{}^{r}}\ Z_s$$

Since $\dfrac{Z_{12}}{Z_{22}} = M$, $\dfrac{V_1{}^{x}}{I_1{}^{r}} = M_x M_r Z_s$

APPENDIX 2

ALTITUDES ABOVE SEA LEVEL FOR SELECTED CITIES IN U.S. AND CANADA

CITY	FEET ABOVE SEA LEVEL
Akron, Ohio	950
Albany, New York	20
Allentown, Pennsylvania	320
Ashland, Kentucky	530
Atlanta, Georgia	1105
Augusta, Georgia	141
Baltimore, Maryland	81
Bangor, Maine	21
Bay City, Michigan	593
Binghamton, New York	865
Birmingham, Alabama	598
Boise, Idaho	2717
Boston, Massachusetts	45
Brandon, Man.	1204
Buffalo, New York	590
Burlington, Vermont	190
Bridgeport, Connecticut	12
Calgary, Alta.	3439
Cambridge, Massachusetts	80
Camden, New Jersey	30
Campbellton, N.B.	42
Charleston, South Carolina	13
Charlotte, North Carolina	734
Charlottetown, P.E.I.	8
Chicago, Illinois	604
Cleveland, Ohio	600
Colorado Springs, Colorado	6012
Columbus, Georgia	261
Columbus, Ohio	759
Council Bluffs, Iowa	989
Dallas, Texas	437

APPENDIX 2 (cont)

CITY	FEET ABOVE SEA LEVEL
Dartmouth, N.S.	14
Davenport, Iowa	571
Dayton, Ohio	743
Denver, Colorado	5227
Des Moines, Iowa	626
Duluth, Minnesota	626
Edmonton, Alta.	2183
Elizabeth, New Jersey	28
Erie, Pennsylvania	709
Evansville, Indiana	380
Flint, Michigan	716
Fort Smith, Arkansas	445
Fort Wayne, Indiana	780
Fort Worth, Texas	600
Fredericton, N.B.	32
Galveston, Texas	28
Grand Rapids, Michigan	628
Great Falls, Montana	3309
Halifax, N.S.	59
Hamilton, Ontario	300
Harrisburg, Pennsylvania	355
Hartford, Connecticut	36
Houston, Texas	48
Huntington, West Virginia	565
Indianapolis, Indiana	749
Jackson, Mississippi	286
Jacksonville, Florida	25
Jersey City, New Jersey	44
Kansas City, Missouri	750
Knoxville, Tennessee	895
Lansing, Michigan	842
Lexington, Kentucky	966
Lincoln, Nebraska	1169
Little Rock, Arkansas	286
London, Ontario	804
Los Angeles, California	292
Loisville, Kentucky	454
Manchester, New Hampshire	210
Memphis, Tennessee	238

APPENDIX 2 (cont)

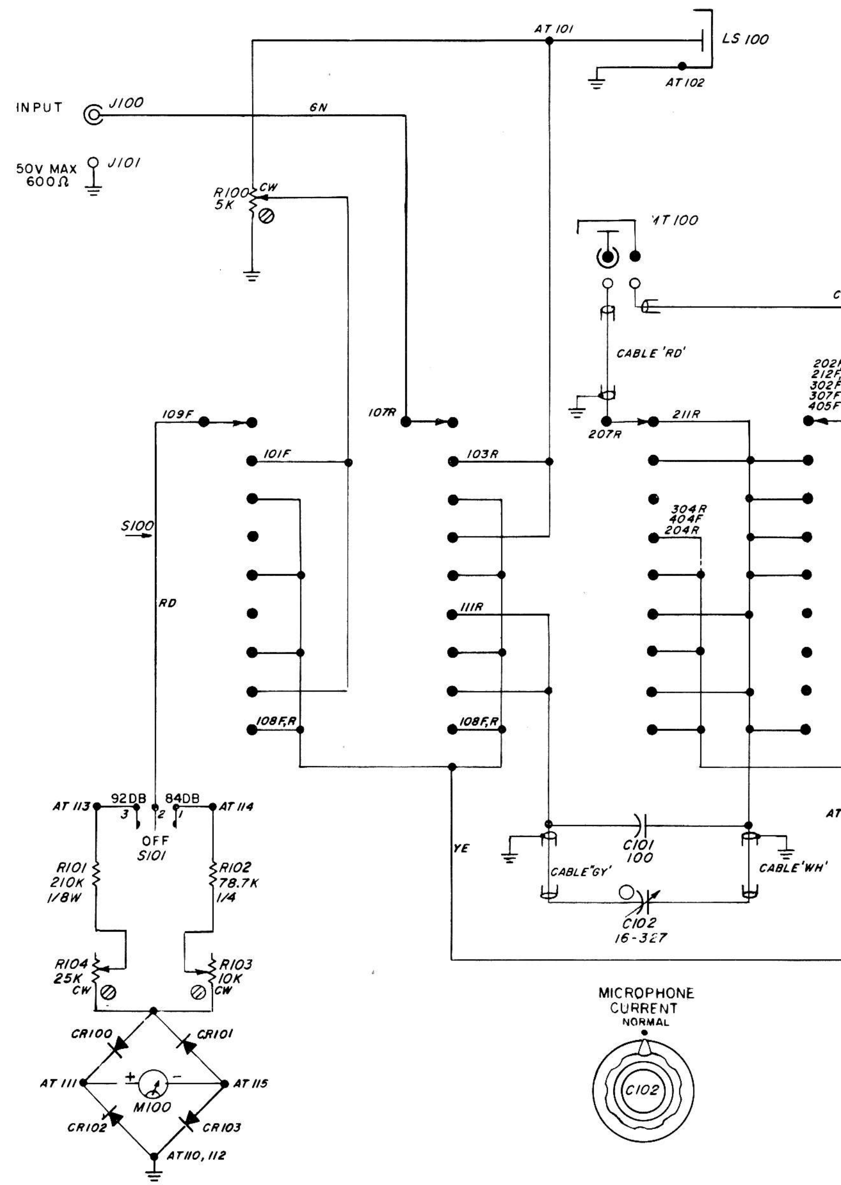
CITY	FEET ABOVE SEA LEVEL
Miami, Florida	15
Milwaukee, Wisconsin	609
Minneapolis, Minnesota	826
Mobile, Alabama	15
Moncton, N.B.	50
Montgomery, Alabama	191
Montreal, P.Q.	110
Nashville, Tennessee	498
Newark, New Jersey	43
New Haven, Connecticut	21
New London, Connecticut	27
New Orleans, Louisiana	5
New York, New York	35
Norfolk, Virginia	38
Oakland, California	18
Omaha, Nebraska	1040
Ottawa, Ontario	200
Paterson, New Jersey	117
Peoria, Illinois	465
Philadelphia, Pennsylvania	150
Phoenix, Arizona	1085
Pittsburg, Pennsylvania	742
Portland, Maine	34
Portland, Oregon	69
Providence, Rhode Island	43
Quebec, P.Q.	20
Racine, Wisconsin	619
Regina, Sask.	1414
Reno, Nevada	4487
Richmond, Virginia	84
Rochester, New York	509
Saint John, N.B.	21
Saint Louis, Missouri	460
Saint Paul, Minnesota	754
Salt Lake City, Utah	4300
Sacramento, California	30
San Antonio, Texas	657
San Francisco, California	50
Saskatoon, Sask.	1596

APPENDIX 2 (cont)

CITY	FEET ABOVE SEA LEVEL
Savanah, Georgia	42
Scranton, Pennsylvania	757
Seattle, Washington	51
Shreveport, Louisiana	217
Sioux Falls, South Dakota	1405
South Bend, Indiana	718
Spokane, Washington	1905
Springfield, Massachusetts	101
Sydney, N.S.	10
Syracuse, New York	410
Tacoma, Washington	87
Toledo, Ohio	594
Toronto, Ontario	250
Topeka, Kansas	909
Tuscon, Arizona	2382
Tulsa, Oklahoma	700
Utica, New York	448
Vancouver, B.C.	18
Washington, D.C.	100
Wichita, Kansas	1285
Windsor, Ontario	580
Winnipeg, Man.	727
Youngstown, Ohio	832

PARTS LIST

Ref No.	Description	Part No.
C101	CAPACITOR, Mica, 100 pF ±10% 500v	4620-1000
C102	CAPACITOR, Air, 10-327 pF	4380-1400
C103	CAPACITOR, Plastic, 0.9 µF ±0.25%	4860-4490
C104	CAPACITOR, Plastic, 0.01 µF ±10% 100v	4860-7750
CR100	DIODE, Type 1N645	6082-1016
CR101	DIODE, Type 1N645	6082-1016
CR102	DIODE, Type 1N645	6082-1016
CR103	DIODE, Type 1N645	6082-1016
J100	JACK, Input	4060-0100
J101	JACK, Input ground	4060-1800
LS100	TRANSDUCER	1559-0401
M100	METER	5730-1373
MT100	TRANSDUCER	1560-0420
PL100	PLUG	4220-3100
R100	POTENTIOMETER, Wire-Wound, 5 kΩ ±10%	6050-1700
R101	RESISTOR, Film, 210 kΩ ±1%	6250-3210
R102	RESISTOR, Film, 78.7 kΩ ±1%	6350-2787
R103	POTENTIOMETER, Wire-Wound, 10 kΩ ±10%	6050-1800
R104	POTENTIOMETER, Wire-Wound, 25 kΩ ±10%	6050-1910
R105	POTENTIOMETER, 508.4 Ω	0433-4140
R106A	RESISTOR, 95.3 Ω ±0.1%	0510-4401
R106B	RESISTOR, 100 kΩ ±0.25%	0510-4401
R107	RESISTOR, 20.1 Ω ±0.1%	0510-4570
R108	RESISTOR, Precision, 43.49 Ω ±0.1%	6690-6043
R109	RESISTOR, Precision, 43.49 Ω ±0.1%	6690-6043
R110	RESISTOR, Precision, 181.2 Ω ±0.1%	6690-6232
R111	RESISTOR, Precision, 619.4 Ω ±0.1%	6690-6241
S100	SWITCH, Rotary wafer	7890-4220
S101	SWITCH, Toggle	7910-1605
S102	SWITCH, Rotary wafer	7890-4100
SO100	SOCKET	4230-2701



AT 101
LS 100
AT 102
INPUT
J100
6N
50V MAX
600Ω
J101
R100
5K
CW
AT 100
CABLE 'RD'
202F
212F
302F
307F
405F
109F
107R
207R
211R
101F
103R
S100
304R
404F
204R
RD
111R
108F,R
108F,R
AT 113
92DB
84DB
AT 114
3
2
1
OFF
S101
YE
R101
210K
1/8W
R102
78.7K
1/4
C101
100
CABLE"GY'
CABLE'WH'
C102
16-327
R104
25K
CW
R103
10K
CW
MICROPHONE
CURRENT
NORMAL
C102
CR100
CR101
AT 111
M100
AT 115
CR102
CR103
AT110, 112

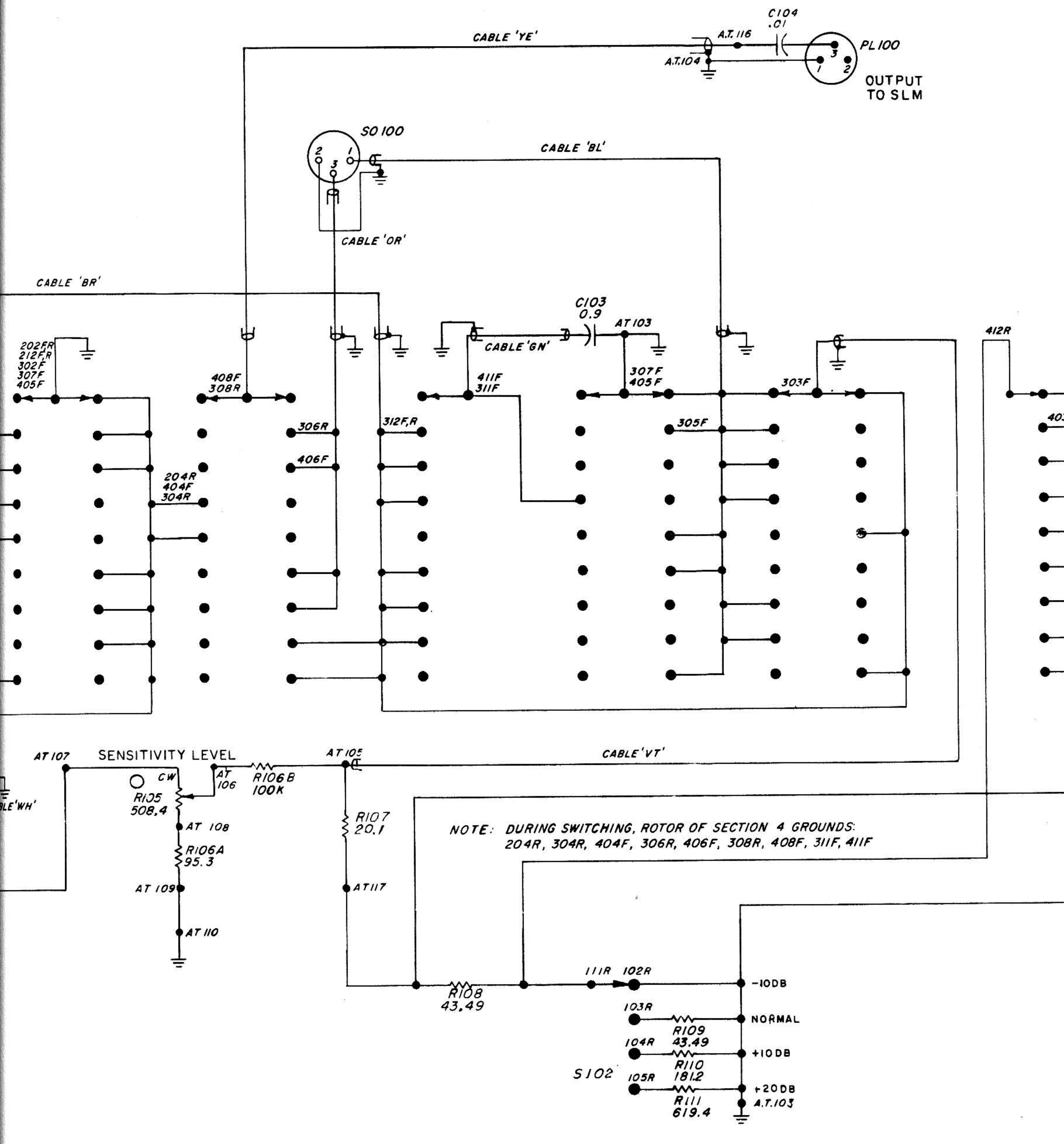
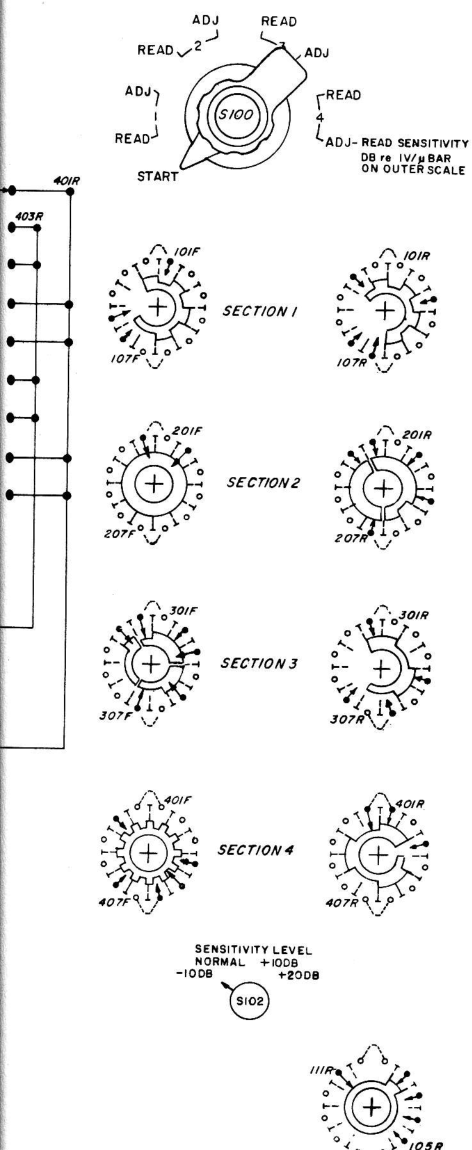


Figure 4-1. Schematic diagram of Type 1559-B.



ADJ
READ
READ
2
1
ADJ
ADJ
READ
S100
READ
4
READ
ADJ- READ SENSITIVITY
DB re 1V/µBAR
ON OUTER SCALE
START
401R
403R
101F
107F
SECTION 1
101R
107R
201F
207F
SECTION 2
201R
207R
301F
307F
SECTION 3
301R
307R
401F
407F
SECTION 4
401R
407R
SENSITIVITY LEVEL
NORMAL +10DB
-10DB
+20DB
S102
111R
105R

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