THE GENERAL RADIO

Experimenter

New Audio Instrumentation

PRECISION SOUND-LEVEL METER

AUTOMATIC LEVEL REGULATOR

UNIVERSAL FILTER

AUDIOMETER CALIBRATION SET

9A-TYPE EARPHONE COUPLER

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the GR Experimenter

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CONTENTS

ABOUT THIS ISSUE

In the business of measurement, there are, broadly speaking, two kinds of advances: those that extend the accuracy or measurement range beyond what was previously available and those that give new speed or convenience to existing measurements. Both types are represented in this issue. The 1561 sound-level meter (page 3) puts a new order of accuracy and precision into acoustical measurements, exceeding the requirements of all USA and international standards for both precision and general-purpose sound-level meters. Instruments to make life in the lab easier are a high-pass/low-pass tunable filter (page 14) and a regulator that will control an audio test signal to produce a constant sound or vibration level as frequency is swept.

Two new items are directed to the attention of audiometer users: a GR earphone coupler (page 21) similar to the NBS type 9-A and an audiometer calibration set (page 20) that includes sound-level meter, calibrator, and earphone coupler, all in one tidy carrying case.

COVER—One of many systems possibilities using GR's new level regulator (second from top in relay rack). Here the regulator is combined with random-noise generator and recording wave analyzer to produce a narrow band of constant-level white noise.

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A PRECISION SOUND-LEVEL METER

Recognizing that it is unrealistic to expect one sound-level meter to be all things to all people, we have for the past two years offered two models: the 1551-C[1] and the compact, less-expensive 1565[2], both of which meet the USA standard (S1.4-1961) for general-purpose sound-level meters. The variety of demands on these instruments and the trend toward more precise measurements in some research work suggested a need for a third member of the family, with even higher performance. Thus the new TYPE 1561 Precision Sound-Level Meter joins General Radio's acoustical lineup.

The new sound-level meter meets the requirements of the standards for a precision sound-level meter as adopted by the International Electrotechnical Commission (IEC 179, 1965) and as proposed, but not yet adopted, by the United States of America Standards Institute (USASI). The instrument also satisfies the requirements of USASI and IEC standards for general-purpose sound-level meters, USASI S1.4-1961 and IEC 123, 1961.

The chief contributor to the new instrument's precision performance is a new piezoelectric ceramic microphone (TYPE 1560-P7), a descendant of the 1560-P5,[3] which benefits from a series of design improvements and from improved manufacturing techniques and careful testing. Backing up the microphone is an all-solid-state instrument designed throughout for precision work.

Description

The circuit includes a high-gain transistor amplifier with attenuator, A-, B-, and C-weighting networks (plus flat response), an indicating meter, and an electrical calibration system. A low-noise field-effect transistor in the first amplifier stage provides high input impedance and low input noise. The

[1] E. E. Gross, "TYPE 1551-C Sound-Level Meter," *General Radio Experimenter*, August 1961.
[2] W. R. Kundert, "A Compact, Inexpensive Sound-Level Meter," *General Radio Experimenter*, October-November 1964.
[3] B. A. Bonk, "The New General Radio Microphone," *General Radio Experimenter*, May–June 1967.

Figure 1. Precision sound-level meter, portable model.

Ervin E. Gross, Jr. joined General Radio in 1936, after receiving his BSEE degree from Northeastern University. As a development engineer in GR's Audio Group, he has designed many sound- and vibration-measuring instruments. He is a Senior Member of IEEE and a member of the Standards Committee of the IEEE Group on Audio and Electroacoustics.

Carlton A. Woodward, a development engineer in GR's Audio Group, received his B.Sc. degree from Northeastern University in 1935 and joined General Radio the following year. His work includes a number of instrument developments, at low and high frequencies. He is a Senior Member of IEEE.

meter circuit uses the rms response that is standard in GR acoustic instruments. Phone jacks allow insertion of an external filter in place of the standard weighting characteristics. The internal electrical calibration system allows the user to set the gain to match the sensitivity of the microphone and cable combination in use.

The 1561 comes in two versions: a portable model (1561) in a General Radio Flip-Tilt case (Figure 1) and a relay-rack model (1561-R). The expected applications of the two models lead to some differences in connections and accessories, as indicated below.

Portable Model

The portable model is equipped with a 1560-P7 Precision Microphone and a 10-foot microphone extension cable. All the connectors and all controls except two are on the front panel. A gain control and the calibrated microphone-sensitivity reference are accessible through openings in the case. Power is supplied either by standard dry cells or by rechargeable nickel-cadmium batteries. The dry cells will power the instrument for 8 to 16 hours of continuous use or about twice as long at four hours per day. The nickel-cadmium batteries will yield 14 to 22 hours of operation between charges.

When an instrument is purchased with rechargeable batteries, a battery charger is also supplied. This charger will charge one set of batteries, either in the sound-level meter or in the charger, or it will charge two sets simultaneously. Charging time is 14 to 16 hours.

Relay-Rack Model

The relay-rack instrument, Type 1561-R (Figure 2), is supplied without a microphone or microphone extension cable; both are, of course, available

Figure 2. Type 1561-R (relay-rack version) precision sound-level meter.

separately. All controls except one gain adjustment are on the front panel. Input and output connections may be made at the rear panel as well as at the front. The jacks for the external filter are at the rear only. Coaxial attenuator controls are designed to prevent overload of the input amplifier stage under all conditions.

The relay-rack instrument is ac-powered, but rechargeable batteries can be installed if desired.

Uses

The primary use for the precision sound-level meter is the measurement of noise to the degree of accuracy specified by precision-measurement standards. This instrument is in fact useful in any application involving current American or international standards for sound-level meters. In this connection it is interesting to note that one of the "general" standards, USASI S1.4-1961, actually has tighter over-all tolerance requirements for the C-weighting characteristic below 1000 Hz than has the precision-sound-level-meter standard, IEC 179, 1965.

The precision sound-level meter is also useful as a low-noise, high-gain amplifier, and the relay-rack model is particularly suitable for such use as a system component.

— C. A. Woodward
— E. E. Gross

SPECIFICATIONS

Sound-Level Range (rms, dB re 20 μN/m²):

Frequency Characteristic	*With 1560-P7 Microphone and 10-ft cable*	*With 1560-P7 Microphone and 1560-P40 Preamplifier**
Flat	35 to 150 dB	31 to 130 dB
C Weighting	32 to 150 dB	27 to 130 dB
B Weighting	31 to 150 dB	26 to 130 dB
A Weighting	31 to 150 dB	27 to 130 dB

* Min obtained with ×10 preamp gain, max with ×1.

Allowance is made for a peak-to-rms ratio of 14 dB. When a sine-wave signal is applied to the 1560-P40, the range can be extended to 141 dB. The signal-to-noise ratio is at least 5 dB for the lower values given above.

Frequency Characteristics: A, B, and C weighting in accordance with USA Standard S1.4-1961, IEC Publication 123, 1961 and IEC Publication 179, 1965 for precision sound-level meters. Also provided is a flat response from 20 Hz to 20 kHz to permit measurement of sound-pressure level. Jacks are provided for insertion of an external filter.

Microphones: The GR 1560-P7 Precision Microphone is supplied with portable models with a 10-ft cable to permit microphone to be located away from instrument and observer to minimize diffraction effects (1561 gain is set to compensate for cable loss).

Sound-Level Indication: Reading is sum of meter and attenuator setting. Meter calibrated −6 to +10 dB; attenuator calibrated 30 to 140 dB in 10-dB steps.

Output (full-scale meter reading): 1.25 V behind 5500 Ω; harmonic distortion < 0.5%.

Input Impedance: > 100 MΩ, across 40 pF in portable model, across 90 pF in rack model.

Meter: Rms response; fast and slow meter speeds in accordance with above USASI and IEC standards.

Calibration: Absolute calibration of the 1561 is set acoustically at 500 Hz and a level of 114 dB re 20 μN/m². Microphone response and sensitivity are measured in a free field 20 Hz to 15 kHz by comparison with a WE 640AA Laboratory Standard microphone with calibration traceable to the National Bureau of Standards. Complete electrical frequency-response measurements are made on each instrument. Panel adjustment provided for standardizing gain with internal calibration circuit, which has adjustment to permit calibration in terms of microphone sensitivity (control is internal and accessible through case of portable models, on front panel of rack models). The 1562 Sound-Level Calibrator or 1559 Microphone Reciprocity Calibrator can be used for making periodic over-all acoustic checks.

Temperature and Humidity Effects: The instrument will operate within specifications, for meter indications above 0 dB, over a range of 10 to 50°C and 0 to 90% relative humidity, when standardized by its internal calibration circuit or an external calibrator. No damage to microphone from −30 to +60°C and 0 to 100% relative humidity.

Magnetic-Field Effects: In a 60-Hz, 1-oersted (80 A/m) magnetic field and oriented for max reading, the rack model will indicate about 42 dB, the portable model about 53 dB (C weighting).

Accessories Supplied: Portable models include Precision Microphone Type 1560-P7, 10-ft microphone cable, and either one set of dry-cell batteries or two sets of rechargeable batteries and Battery Charger Type 1560-P60. Rack model includes power cord and spare fuses.

Accessories Available: 1952 Universal Filter and 1560-P40 Preamplifier (power supplied by 1561); 1560-P5 or P7 Precision Microphone; microphone extension cables.

Power Required: The rack-mount 1561-R contains ac power supplies for operating the instrument and for recharging the batteries (not supplied) that can be used to power the instrument. This model operates from 100 to 125 or 200 to 250 V, 50 to 60 Hz, 2.5 W max.

The portable 1561 is supplied with either 3 Burgess type PM6 dry-cell batteries (or equivalent), which give about 15-h average operation, or with 2 sets of rechargeable nickel-cadmium batteries and the 1560-P60 Battery Charger. This unit will simultaneously recharge two sets of batteries (one set in the 1561, the other in the charger) from a power line of 105 to 125 or 210 to 250 V, 50 to 60 Hz, 5 W.

The nickel-cadmium batteries will provide about 20 h of operation and recharge in about 15 h; dry-cells about 15 h.

Mounting: The 1561-R is in a rack-mount cabinet, the portable model in a Flip-Tilt case; the charger in an aluminum case.

Dimensions (width x height x depth): Portable, 10¾ x 6⅛ x 5¾ in. (275 x 160 x 150 mm); rack, 19 x 3½ x 15 in. (485 x 89 x 385 mm); Battery Charger, 4¼ x 3¾ x 8 in. (110 x 95 x 205 mm).

Net Weight: Portable, 5½ lb (2.5 kg); rack, 15 lb (7.0 kg).

Shipping Weight (est): Portable, 20 lb (4.6 kg); rack, 23 lb (10.5 kg).

Catalog Number	*Description*	*Price in USA*
	1561 Precision Sound-Level Meter	
	Portable Models, incl precision microphone and 10-ft cable	
1561-9700	with dry-cell batteries	**$675.00**
	with 2 sets rechargeable batteries and recharger	
1561-9701	for 115 volts	**775.00**
1561-9702	for 230 volts	**on request**
1561-9703	**1561-R Precision Sound-Level Meter** Rack Model (no battery or microphone)	**725.00**
1560-9605	**1560-P5 Microphone**	**80.00**
1560-9607	**1560-P7 Precision Microphone.** Sold only with 1561-R	**145.00**
1560-9673	**1560-P73 Extension Cable** (25 ft)	**15.00**
1560-9977	**1560-P72B Extension Cable** (100 ft)	**29.00**
8410-3000	**Replacement Dry Cell, 3 req'd**	**1.20**
8410-1040	**Rechargeable Battery, 2 req'd**	**12.00**

SOUND-LEVEL METERS, GENERAL-PURPOSE AND PRECISION

The two sound-level-meter standards in general use in the United States today are the *USA Standard Specification for General-Purpose Sound Level Meters* (USASI S1.4 1961) and *International Electrotechnical Commission Publication 179, Precision Sound Level Meters* (IEC 179, 1965). Recently there has been an increasing call by specification-writing and code-writing committees for measurements made with precision sound-level meters. For those accustomed to thinking in terms of a single standard, this new emphasis on precision meters may cause some confusion. Whatever confusion there is is not mitigated by the fact that the general-purpose standard is actually tighter than the precision standard at frequencies below 1000 Hz. Perhaps we can clarify the situation somewhat by comparing the pertinent characteristics and tolerances allowed by the respective specifications.

Both standards specify the same three weighting charactertistics: A, B, and C. The IEC (Precision) Publication

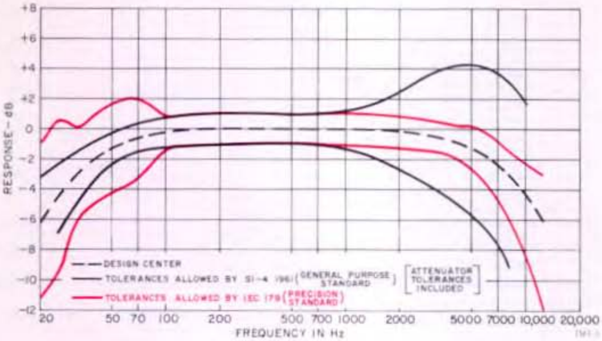


Figure 1. C-weighted response tolerances allowed by general-purpose and precision standards.

requires that an instrument include at least one of the three characteristics; the USASI (General-Purpose) Standard requires all three. As a beginning let us compare the C-weighting characteristics of the two standards.

Figure 1 shows the design-center C-weighted response, along with the tolerances allowed by the two sound-level-meter standards. Note that between 800 and 100 Hz the tolerances are identical, below 100 Hz the general-purpose specification has tighter tolerances, and above 800 Hz the precision specification has tighter tolerances. Note also that the general-purpose specification extends only to 10 kHz vs 12.5 kHz for the precision specification. One further important fact becomes evident as we study the curves and notes of Figure 1: The general-purpose tolerances apply at *any* attenuator setting, while the precision tolerances apply only at the reference setting of the attenuator or at a sound-pressure level of 80 dB. An additional tolerance is permissible at attenuator settings other than 80 dB.

In practice, it is the microphone characteristic that usually determines whether a modern sound-level meter qualifies as a precision meter or a general-purpose meter. If the microphone response uses up most of the tolerance available in the general-purpose specification, the manufacturer must then hold his attenuator tolerances much tighter than those allowed even by the precision specification. If the microphone response does not use up the available tolerances, then the manufacturer can relax tolerances on his attenuator (but no more for the general-purpose than for the precision meter).

The precision-meter specification requires that the error in over-all level introduced by a change in range (i.e., by the attenuator) be less than 0.5 dB. The general-purpose specification requires that the attenuator tolerance be no greater than ±0.5 dB between adjacent steps, nor greater than ±1.0 dB between any two attenuator steps.

As the sound level differs from the reference level or the level at which the response is determined, the indicating meter also contributes errors as its pointer moves over its operating range. Both standards place tolerance limits on the meter indication. These limits are stated differently in each standard, but the actual allowable errors are much the same over the most-used portions of the meter scale. IEC 179 (precision)

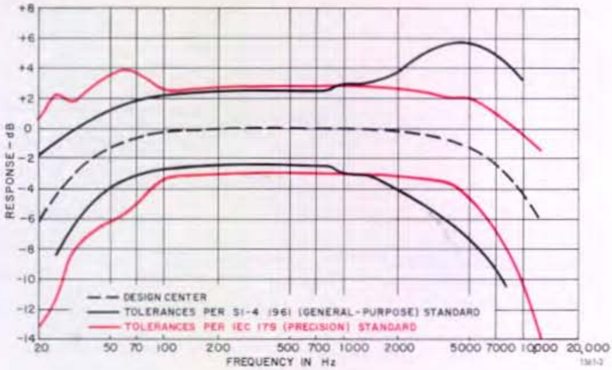


Figure 2. Tolerances imposed on over-all sound-level-meter performance (for C weighting) by general-purpose and precision standards. These tolerances include allowances for attenuators.

allows ±0.2 dB for meter scale graduations and ±0.2 dB for meter scale readability, for a total of ±0.4 dB. S1.4 (general-purpose) states that the indication shall be accurate to ±0.5 dB.

Both standards require that the absolute acoustical calibration of the instruments be ±1.0 dB at a given frequency and sound-pressure level. The precision standard (IEC 179) calls for a frequency between 200 Hz and 1000 Hz (preferably 1000 Hz) and a sound-pressure level of 80 dB. The general-purpose standard (S1.4) calls for calibration at 400 Hz or at some frequency between 320 and 500 Hz but does not specify the sound-pressure level.

Figure 2 shows the C-weighted design-center curve for sound-level meters, along with the maximum deviations (including all the tolerances discussed) from the desired curve allowed by the two sound-level-meter standards. For frequencies below 1000 Hz it can be seen that the general-purpose standard requires greater over-all control of the sound-level-meter performance than does the precision sound-level meter.

A- and B-weighting tolerances are stated differently for the two types of meter. The precision-meter standard requires the same tolerances on all three weightings (A, B, and C). These are the tolerances shown in red on Figures 1 and 2. The general-purpose standard places a close tolerance on the difference between the A or B weighting and the C-weighted response. At frequencies of 800 Hz and higher, for example, the A and B network tolerance with respect to the C weighting is ±0.5 dB. The precision specifications, while requiring closer tolerance to a design center curve, would permit the A- or B-weighted responses to differ from the C-weighted response by as much as 2 dB. The general-purpose B-weighting tolerance remains at ±0.5 dB, with respect to the C-weighting curve, down to 160 Hz and increases to ±1 dB from 125 Hz down to 25 Hz. The general-purpose A-weighting tolerances (with respect to the C response) increase to ±1 dB at 630 Hz, ±1.5 dB at 250 Hz, and to ±2 dB from 80 Hz down to 25 Hz.

General Radio has for many years been manufacturing sound-level meters to meet the requirements of the USA and international standards for general-purpose sound-level meters. Acoustically these meters have always been well within the requirements of the

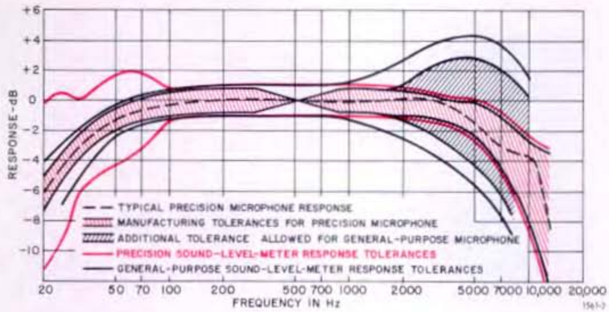


Figure 3. Curves showing data of Figure 1 plus performance of GR precision microphone.

standards, and the electrical characteristics have even met the requirements of the precision-meter standard, IEC 179, 1965. As microphone technology has improved, the over-all characteristics of our meters have come closer and closer to meeting the precision requirements. Careful control of our ceramic microphone response has made this advance possible. Figure 3 illustrates the improvement that has taken place. The broken curve shows a typical C-weighted response of the precision sound-level-meter microphone to sounds of random incidence. The area cross-hatched in red shows the manufacturing tolerances on microphone response. The area cross-hatched in black shows the additional tolerances allowed in the manufacture of microphones for general-purpose sound-level meters. The solid red and black curves duplicate those in Figure 1 and show the response tolerances permitted by the pertinent standards. It can be readily seen that below 2 kHz both kinds of microphones are held to the same close tolerances. Above 2 kHz much tighter control is maintained on the response of the precision microphone than on that of the general-purpose microphone.

While both standards require that the instruments be set to indicate sound-pressure level correctly within ±1 dB at one frequency, all General Radio sound-level meters must indicate sound-pressure level correctly within ±0.5 dB at 500 Hz when compared with a Western Electric type 640AA laboratory standard microphone maintained in calibration by reciprocity techniques and by comparison with other 640AA microphones that have been calibrated at NBS.

One very important fact must be remembered when one is considering whether to choose a precision sound-level meter or a general-purpose unit: For a sound-level meter to meet the stringent high-frequency-response requirements of IEC Publication 179, 1965, the associated microphone must be removed from the instrument and placed at the end of a cable so that the instrument and operator do not disturb the sound field that the microphone is intended to measure. The effects of the operator and of typical instruments on the response of the microphone have been explored and reported by R. W. Young, "Can Accurate Measurements be Made with a Sound-Level Meter Held in the Hand?", *Sound*, Vol. 1, No. 1, January-February 1962.

— E. E. Gross

A VERSATILE LEVEL REGULATOR FOR SWEPT-FREQUENCY SOUND AND VIBRATION TESTING

Swept-frequency sound and vibration tests can be made more quickly and simply if a control device is used to keep the test signal at a constant level as frequency is varied. With the exceptions of some rather expensive special-purpose instruments, no such control unit has been commercially available, and many people have been forced to build their own, often with only limited success.

The new TYPE 1569 Automatic Level Regulator is such a control unit, designed for use in sound or vibration test systems of the type shown in Figure 1. This setup includes an oscillator or a source of swept band-limited noise, a power amplifier and transducer, and a control transducer. As the oscillator is swept, variations in test-chamber sound pressure due to the nonuniformity of the loudspeaker response are sensed by the control microphone and fed to the regulator. This control signal causes the regulator output level to change as necessary to correct for the loudspeaker variations and thus to maintain constant sound pressure.

The control transducer may be a microphone, hydrophone, or vibration pickup. The combination of a high (25-MΩ) input impedance at the regulator's control-signal input and an adjustable high-gain amplifier makes the 1569 compatible with almost any transducer. In effect, the transducer preamplifier is built in, and control signals anywhere in the range from 5 mV to 4 V are acceptable. Sensitivity can be extended to 500 μV with an inexpensive preamplifier (TYPE 1560-P40) powered by the regulator.

The 1569 operates at frequencies from 2 Hz to 100 kHz, satisfying nearly all vibration applications, all airborne sound applications (including high-frequency modeling studies), and most underwater sound applications. The test signal can be a sine wave, a band of random noise, or any signal having components in the 2-Hz to 100-kHz frequency range.

A panel meter indicates the output-signal voltage and the relative level in decibels to show the user where in its 50-dB control range the instrument is

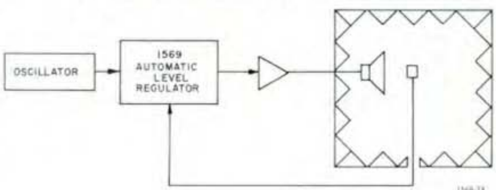


Figure 1. A typical test setup using the level regulator. A microphone in the test chamber serves as a control transducer, sensing variations in sound pressure and sending a control signal to the regulator, which adjusts its output level to correct for loudspeaker variations.

operating. A green band on the meter indicates the operating range that gives greatest signal-to-noise ratio and least distortion. Meter calibration is uniform in decibels.

The control rate (the rate at which the regulator corrects errors in the control loop) is adjustable in 1-3-10 steps from 3 to 1000 dB/second. The rate is adjusted to suit the operating frequency range and the magnitude-phase conditions in the control loop. The regulator can be stabilized for time delays as long as one second and can tolerate a narrow filter or a sharp transducer resonance in its loop.

Because the 1569 will normally be used in a system with other instruments, input and output connectors are on both front and rear panels. The 600-ohm output can be connected to any load without affecting the linear operation of the circuit. The output varies from 10 mV to 3 V in normal operation, a range compatible with most power amplifiers.

Applications

In most frequency tests where the ratio of two quantities is to be measured and plotted automatically, the 1569 is a must. Controlling one signal and measuring the other gives the ratio directly. This approach is applicable to tests on amplifiers, loudspeakers, microphones, and other transducers as well as to mechanical impedance measurements.

Warren R. Kundert received his BSEE and MSEE degrees from Northeastern University in 1958 and 1961, respectively. He came to General Radio as a development engineer in 1959, and he was appointed Audio Group Leader earlier this year. He is a member of the IEEE, Acoustical Society of America, Audio Engineering Society, and Eta Kappa Nu.

Aside from simplifying measurements, the 1569 allows tests to be made at a constant output level on devices with limited dynamic ranges. For example, the output of a loudspeaker or power amplifier can be held constant while the input voltage or power is measured.

The following paragraphs describe some test systems typical of those that can be assembled using General Radio instruments.

Transmission-Loss Tests

In transmission-loss testing it is desirable to maintain constant sound pressure on one side of a partition in order to plot transmission vs frequency directly. When such tests are made in accordance with ASTM Designation E 90-66T (*Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions*), one-third-octave bands of pink noise are used as the test signal. Figure 2 shows a system for performing this measurement. The signal

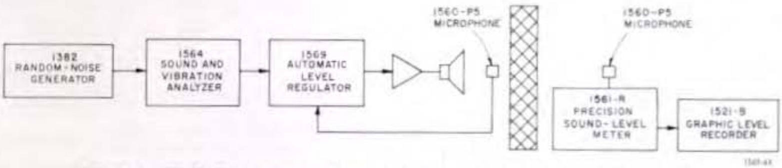


Figure 2. Block diagram of a system for performing transmission-loss tests.

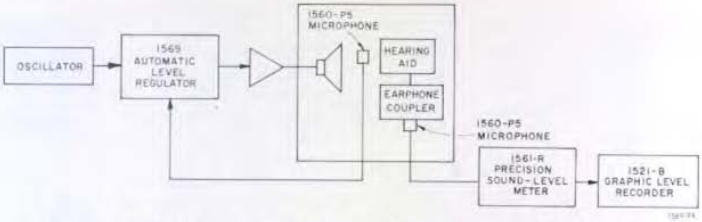


Figure 3. Block diagram of a system for plotting response of hearing aids.

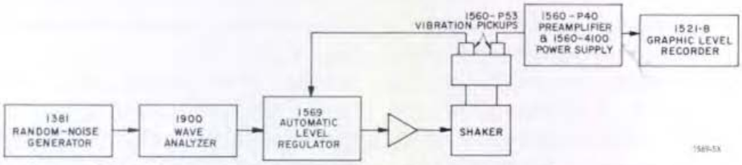


Figure 4. Block diagram of a system for making swept random-vibration tests.

in this setup is derived from the Type 1382 Random-Noise Generator driving the Type 1564-A Sound and Vibration Analyzer.

Hearing-Aid Testing

A setup for automatically plotting the frequency response of hearing aids is shown in Figure 3. The test signal is a sine wave from the Type 1304-B Beat-Frequency Audio Generator. Sound pressure is controlled in a suitable test chamber, and the output from the earphone is coupled to a sound-level meter through a standard coupler. The sound-level meter drives a Type 1521-B Graphic Level Recorder.

Swept Random-Vibration Tests

In the system of Figure 4, a narrow constant band of white noise from the Type 1900-A Wave Analyzer and Type 1382 Random-Noise Generator is fed through the level regulator and power amplifier to an electrodynamic shaker. The control transducer is a Type 1560-P53 Vibration Pickup, which maintains constant acceleration on the table.

Tracking-Analyzer System

Noise and distortion introduced in a vibration test setup can be eliminated from the control signal by means of a filter that "tracks" the test signal. The

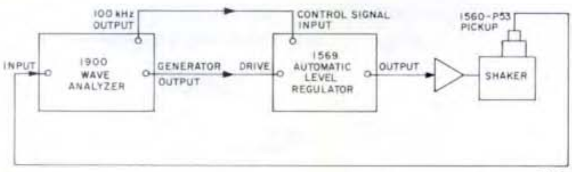


Figure 5. Block diagram showing use of the GR 1900 Wave Analyzer as a tracking filter to eliminate noise and distortion in a vibration test setup.

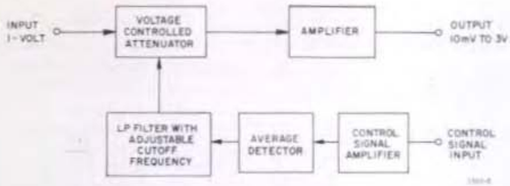


Figure 6. Block diagram of the automatic level regulator.

GR 1900-A Wave Analyzer,[1] used in its tracking mode, provides the necessary sine-wave signal and tracking filter. The setup is shown in Figure 5.

HOW IT WORKS

The 1569 Automatic Level Regulator accepts an ac signal applied to its DRIVE terminals and changes the level of this signal in accordance with a second signal applied to the CONTROL SIGNAL INPUT terminals. The adjusted signal is then fed to the OUTPUT terminals. A small change in the level of the control signal causes a large change in the output, and the result is that a potential level variation of, say, 25 dB in a system is effectively compressed to a variation of less than 1 dB.

A system corresponding to that diagrammed in Figure 5.

The block diagram, Figure 6, shows a voltage-controlled attenuator and an amplifier in the main signal path. The attenuator uses field-effect transistors as variable-resistance elements. The source-to-drain resistances of the FET's are controlled by the dc voltage from the detector and low-pass filter. The filter, whose cutoff frequency is selected by the panel RATE control, determines the speed at which the 1569 can make corrections and limits the lower operating frequency and the amount of delay or phase shift that can be introduced in the control path.

The 1569 automates and simplifies many tests that have been tedious and time consuming. Its great flexibility allows it to be used with a variety of signal sources and control transducers over a wide range of frequencies.

— W. R. Kundert
— C. A. Woodward

[1] A. Peterson, "New Wave Analyzer Has 3 Bandwidths, 80-dB Dynamic Range," *General Radio Experimenter*, April 1964.

SPECIFICATIONS

RANGES

Frequency Range: 2 Hz to 100 kHz.

Control Range: 50 dB.

Compression Ratio: 25 (0.04 dB per dB).

DRIVE (INPUT)

Voltage Required (for normal operation): 1 V.
Impedance: 100 kΩ.

OUTPUT

Voltage: 3 V max to 10 mV min.

Impedance: 600 Ω. Any load impedance can be connected without affecting linear operation of output circuit.

Noise: Typically better than 65 dB below 3 V in 100-kHZ band.

Harmonic Distortion: <1% total for <1-V output level.

Automatic "Shut-Down": A loss of drive (input) voltage from signal source causes the output voltage to drop to zero to protect equipment connected to output.

CONTROL-SIGNAL INPUT

Voltage: 5 mV to 4 V required.

Impedance: 25 MΩ.

Power Required: 100 to 125 or 200 to 250 V (switch selected), 50 to 60 Hz, 4 W.

Accessories Supplied: Power cord, spare fuses, bench- or rack-mount hardware.

Accessories Available: GR 1560-P40 Preamplifier (power for preamplifier available at rear-panel input connector); 1304 Beat-Frequency Audio Generator, 1521 Graphic Level Recorder; microphones and vibration pickups.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 3⅞ x 13 in. (485 x 99 x 330 mm); rack model, 19 x 3½ x 10½ in. (485 x 89 x 275 mm).

Weight: Net, 13 lb (6 kg); shipping, 30 lb (14 kg).

Control Rates and Corresponding Min Operating Frequencies:

1000 dB/s	300 dB/s	100 dB/s	30 dB/s	10 dB/s	3 dB/s
600 Hz	200 Hz	60 Hz	20 Hz	6 Hz	2 Hz

Catalog Number	*Description*	*Price in USA*
	1569 Automatic Level Regulator	
1569-9700	Bench Model	**$485.00**
1569-9701	Rack Model	**485.00**

A UNIVERSAL FILTER FOR LOW-FREQUENCY WORK

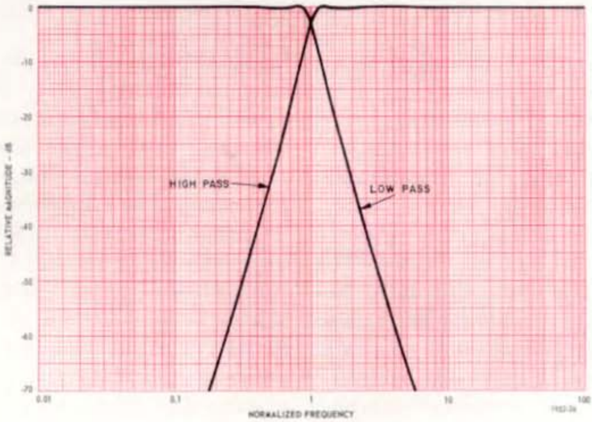
A tunable low-pass/high-pass filter is a very handy device in a variety of laboratory applications. It can, for example, be used to limit bandwidth in a measuring system in order to reduce noise or other interfering signals, to remove one frequency component of a signal in order to measure another, to produce controlled bands of noise, or to function as part of a spectrum analyzer.

The TYPE 1952 Universal Filter, whose basic magnitude and phase curves are shown in Figure 1, is a tunable high-pass/low-pass filter with some unusual features, notably including the ganged tuning of both filters to provide constant fractional bandwidth, closely controlled and well defined filter characteristics with excellent magnitude response, dc coupling, and the option of line or battery operation.

THE FILTERS

Each filter covers the frequency range from 4 Hz to 60 kHz in four bands, with a cutoff-frequency accuracy of 2% of dial indication. The designs are fourth-order Chebyshev approximations to ideal magnitude response, with negligible (±0.1 dB) pass-band ripple. The Chebyshev design is generally considered to have a magnitude-vs-frequency response superior to that of other designs for a given degree of filter complexity. Though it is an efficient design, it has not heretofore been applied to instruments of this type, probably because it is somewhat more difficult to control, requiring careful circuit design and the use of high-quality components.

The excellent filter characteristics of the 1952 allow narrow band-pass and band-reject characteristics when the filters are combined. Figure 2 shows two band-pass characteristics, of one octave and of 26% (approximately one-



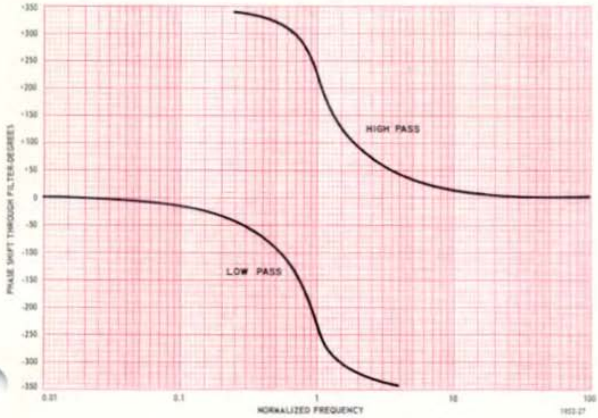


Figure 1. Basic magnitude (top) and phase (bottom) curves for the 1952 Universal Filter.

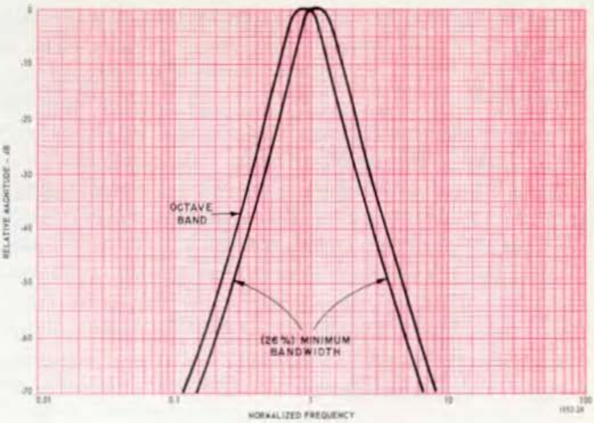


Figure 2. Band-pass characteristics for one-octave and 26% (the minimum) bandwidths.

third octave), the minimum bandwidth. Figure 3 shows a family of band-reject curves, including a narrow "null" response.

It is enlightening to compare the Chebyshev frequency response of the 1952 with the Butterworth response found in some other designs. The fourth-order low-ripple Chebyshev design used in the 1952 is far superior to the fourth-order Butterworth response. The normalized magnitude curves for these two filters, together with the magnitude curve for an eighth-order Butterworth filter, a much more costly design requiring about twice as many circuit components, are shown in Figure 4. In the pass band at 0.8 times the cutoff frequency, the Butterworth filter deviates from the desired uniform frequency response by 0.7 dB, while the error from the Chebyshev filter is only 0.1 dB. In the stop band at, say, 1.2 times the cutoff frequency, the Chebyshev filter has 10.5-dB attenuation while the attenuation of the Butterworth filter is only 7.2 dB.

Ultimate (or asymptotic) attenuation rate is often quoted when stop-band attenuation rate is specified. It should be noted that this rate is the *maximum* rate for the Butterworth design but the *minimum* rate for the Chebyshev design. Figure 4 shows that, at the cutoff frequency, the Chebyshev filter has an attenuation rate of 27 dB/octave (it has already exceeded its asymptotic rate of 24 dB/octave) while the rate for the Butterworth filter is only about 12 dB/octave. In the region near cutoff, where good performance is difficult to achieve, the Chebyshev filter used in the Type 1952 is by far the better choice. Even the eighth-order Butterworth filter, with its much greater circuit complexity, does not perform as well near cutoff as does the fourth-order Chebyshev design.

Ganging

A pulley-and-clutch arrangement operated by a front panel control allows the low-pass and high-pass sections to be ganged. This greatly enhances the usefulness of the filter for band-pass and band-reject applications. Operation is simple. The dials are set to indicate the desired upper and lower cutoff fre-

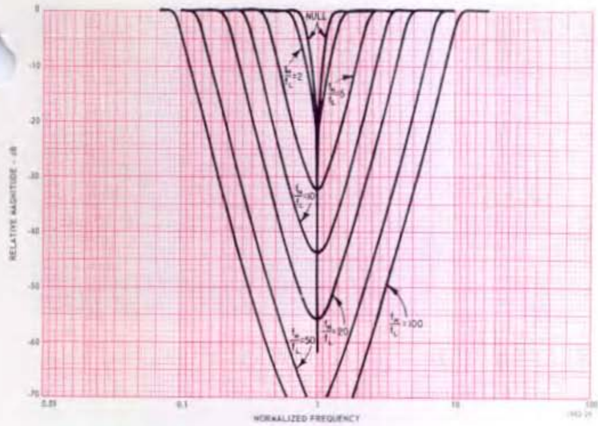


Figure 3. A family of band-reject curves from the 1952.

quencies, the ganging switch is set to GANGED, and the instrument tunes as a constant-fractional-bandwidth band-pass or band-reject filter. (Precise logarithmic dial calibration permits constant fractional bandwidth tuning.) When the dials are set to critical frequencies (indicated by dots) and the ganging clutch is engaged, the filters operate to provide a tunable notch. The narrow response of the notch is shown in Figure 3. The frequency ranges have sufficient overlap to allow tuning through successive ranges without resetting of the dials.

Input/Output Facility

The input circuit includes coupling and attenuation controls as well as a fixed passive filter to prevent frequencies outside the normal operating range of the instrument from overloading the active circuits. The instrument is normally direct-coupled, but a panel switch provides ac coupling with a lower cutoff frequency, about 0.7 Hz.

Output impedance is 600 ohms, and the output can be connected to any load impedance without affecting linear operation of the output circuit.

Input and output connectors are provided on the rear panel as well as on the front for convenience in systems installations.

Battery or Line Operation

Though the instrument is normally operated from a 115- or 230-V line, it can be battery-operated. This feature not only permits operation when line power is unavailable but is also particularly useful in applications requiring total isolation from the power line.

Other Features

The low input terminals are normally connected to the chassis by means of a ground link. In systems installation,

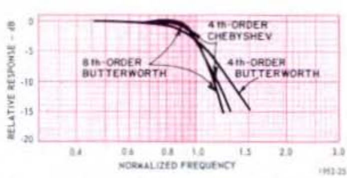


Figure 4. Fourth-order Chebyshev and 4th- and 8th-order Butterworth filter magnitude characteristics around cutoff.

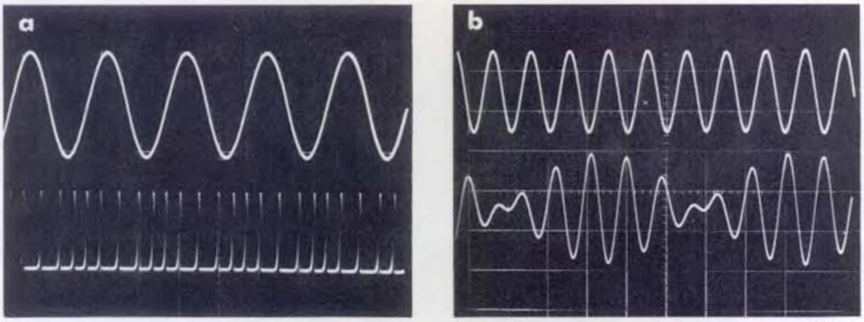


Figure 5a. Oscillogram showing results of using the 1952 to recover a 10-kHz modulating signal (upper waveform) from the output of an 1142-A Frequency Meter and Discriminator (lower trace). The signal fed to the 1142 included a 50-kHz carrier modulated at 10 kHz with a deviation of 9 kHz. Figure 5b. Oscillogram showing effect of filter "null" response to separate two equal-amplitude signals at 1 kHz and 1.2 kHz. Upper trace shows 1-kHz signal at 1952 output; lower trace shows the sum of the two sine waves as applied to the filter.

where the chassis of the filter is connected to the chassis of other instruments, it is desirable to have signal currents follow well defined paths. Removal of the ground link connects a circuit consisting of 10 ohms in parallel with 1 μF between the low signal path and the chassis. This impedance is low enough to provide good cabinet shielding with little change in the effects of internal stray capacitance but high enough to prevent low-frequency ground currents in the chassis.

Because low-pass/high-pass filters are often used to remove hum and noise from signals, they should not contribute any themselves. Particular attention has been given to maintaining noise at a minimum level in the 1952.

Applications

The many applications for this versatile filter fall into three basic groups: bandwidth limiting in a measuring system, the generation of controlled bands of noise, and spectrum analysis.

The filter can be combined with the Type 1142-A Frequency Meter and Discriminator, a pulse-count discriminator whose output is a train of "equal area" pulses. Figure 5a shows the output from the 1142-A in the lower trace and the output from the filter in the upper trace. The 1952 filter has been used in its low-pass mode to remove the carrier-related frequency components, leaving the modulating signal. Figure 5b shows the effect of using the "null" response of the filter to separate two equal amplitude signals at 1 kHz and 1.2 kHz.

Controlled bands of noise are generated when the filter is driven by a source of random noise. The new GR Type 1381 and 1382 Random Noise Generators are ideal for this purpose.

In conjunction with a voltmeter or a sound-level meter or vibration meter, the 1952 functions as a spectrum analyzer. The bandwidth is selected with the frequency controls and the controls are ganged. Octave, half-octave, third-octave and other bandwidths used in sound and vibration work are readily produced.

— W. R. Kundert

SPECIFICATIONS

FREQUENCY RANGE

Cutoff Frequencies: Adjustable 4 Hz to 60 kHz in four ranges.

Pass-Band Limits: Low-frequency response to dc (approx 0.7 Hz with ac input coupling) in LOW PASS and BAND REJECT modes. High-frequency response uniform ±0.2 dB to 300 kHz in HIGH PASS and BAND REJECT modes.

Controls: Log frequency-dial calibration; accuracy ±2% of cutoff frequency (at 3-dB points).

FILTERS

Filter Characteristics: Filters are fourth-order (four-pole) Chebyshev approximations to ideal magnitude response. The nominal pass-band ripple is ±0.1 dB (±0.2 dB max); nominal attenuation at the calibrated cut-off frequency is 3 dB; initial attenuation rate is 30 dB per octave. Attenuation at twice or at one-half the selected frequency, as applicable, is at least 30 dB.

Tuning Modes: Switch selected, LOW PASS, HIGH PASS, BAND PASS, and BAND REJECT.

Ganged Tuning: The two frequency controls can be ganged in BAND PASS and BAND REJECT modes so the ratio of upper to lower cutoff frequencies remains constant as controls are adjusted. Range overlap is sufficient to permit tuning through successive ranges without the need to reset frequency controls if ratio of upper to lower cutoff frequencies is 1.5 or less.

Minimum Bandwidth: 25% (approx ⅓ octave) in BAND PASS mode.

Null Tuning: in BAND REJECT mode, setting the frequency controls for a critical ratio of upper to lower cutoff frequency (indicated on dials) gives a null characteristic (point of infinite attenuation) that can be tuned from 5 Hz to 50 kHz.

INPUT

Gain: 0 or −20 dB, switch selected. Accuracy of gain is ±1 dB, of 20-dB attenuator is ±0.2 dB.

Impedance: 100 kΩ.

Coupling: Ac or dc, switch selected. Lower cutoff frequency (3 dB down) for ac coupling is about 0.7 Hz.

Max Voltage: Max sine-wave input is 3 V rms (8.4 V pk-pk) or 30 V rms with input attenuator at 20 dB. Max peak input voltage for dc coupling is ±4.2 V. For ac coupling max peak level of ac component must not exceed ±4.2 V and dc component must not exceed 100 V. Input can tolerate peak voltages of ±100 V without damage. An LC filter at input limits bandwidth to 300 kHz, thus reducing danger of overloading active circuits at frequencies above normal operating range.

GENERAL

Output: 600-Ω impedance. Any load can be connected without affecting linear operation of output circuit. Temperature coefficient of output offset voltage is between 0 and +4 mV/°C.

Noise: <100 μV in an effective bandwidth of 50 kHz.

Distortion: Max harmonic distortion, with all components in the pass band, for a linear load, is less than 0.25% for open-circuit voltages up to 3 V and frequencies up to 50 kHz.

Power Required: 100 to 125 or 200 to 250 V (switch selected), 50 to 60 Hz, 2.5 W. Or 19.2 V, approx 20 mA from rechargeable nickel-cadmium batteries (not supplied), about 10-h operation. Connections for external battery.

Accessories Supplied: Power cord, spare fuses, bench- or rack-mount hardware.

Accessories Available: Rechargeable batteries (two required) and 1530-P30 Battery Charger.

Dimensions (width x height x depth): Bench, 19 x 3⅞ x 15 in. (485 x 99 x 385 mm); rack, 19 x 3½ x 11¾ in. (485 x 89 x 300 mm); charger, 4¼ x 3¾ x 8 in. (110 x 95 x 205 mm).

Weight: Net, 20½ lb (9.5 kg); shipping, 25 lb (11.5 kg).

Catalog Number	*Description*	*Price in USA*
	1952 Universal Filter	
1952-9801	Bench Model	$950.00
1952-9811	Rack Model	950.00
8410-1040	**Rechargeable Battery (2 req'd)**	12.00
	1560-P60 Battery Charger	
1560-9660	115 volts	95.00
1560-9661	230 volts	on request

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