the GENERAL RADIO Experimenter

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TO

GENERAL RADIO
EXPERIMENTER

Volumes XXIV and XXV

JUNE, 1949 to JUNE, 1951

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CAMBRIDGE **MASSACHUSETTS**
U. S. A.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A VERSATILE POWER AMPLIFIER

Also

IN THIS ISSUE

● **AN APERIODIC POWER AMPLIFIER** of wide frequency range and substantial output finds many applications in the laboratory and in general testing. Such amplifiers, when needed, can be built up in the laboratory, but the development work necessary to get adequate performance usually proves to be excessively expensive, and considerable time is consumed that could be more profitably used for other and more important projects.

To make this type of amplifier generally available, the General Radio Company has designed the Type 1233-A Power Amplifier.

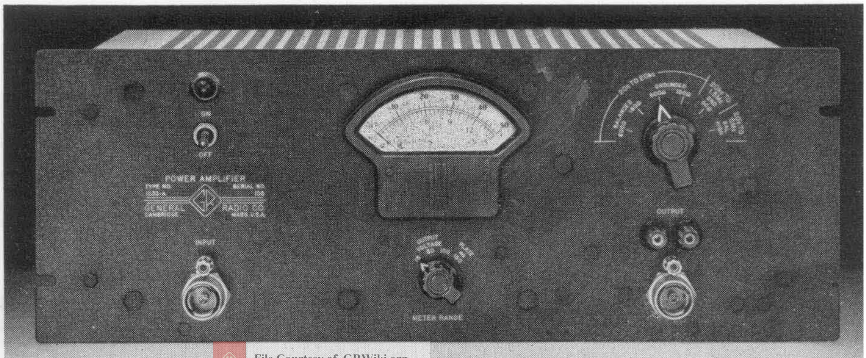
Three output combinations are provided:

(1) 20 cycles to 20 kilocycles, into 150 or 600 ohms balanced or grounded. On this range, an output of 15 watts is available between 50 and 15,000 cycles.

(2) 20 kilocycles to 1.5 megacycles into 50 ohms, balanced or grounded. Maximum output is 15 watts from 20 kilocycles to 0.5 megacycle; 8 watts at 1.5 megacycles.

(3) 20 cycles to 3 megacycles. Output is 150 volts peak-to-peak, for a

Figure 1. Panel view of the Type 1233-A Power Amplifier.



high impedance load with a gain of 60 db. With grounded output, voltage is limited to 50 volts, peak-to-peak, with a gain of 54 db. Rise time is approximately 0.1 microsecond, with negligible overshoot.

Maximum output is obtained in all cases with an input of 0.2 volt. Distortion is below 3% at maximum output over most of the frequency range, and noise is between 60 and 70 db below 15 watts.

A diode voltmeter, with full-scale ranges of 150, 50, and 15 volts, indicates the magnitude of the output voltage.

APPLICATIONS

The Type 1233-A Power Amplifier is useful in the testing and development of audio-frequency equipment, and in driving supersonic generators. At standard broadcast frequencies, it can be used to excite antennas for measurements with deflection-type instruments. When used with an antenna and tuned input, it can drive a Type 1931-A Modulation Monitor to monitor remote transmitters. On the 20 c-to-3 Mc range, the amplifier has sufficient output for use as an oscilloscope deflection amplifier.

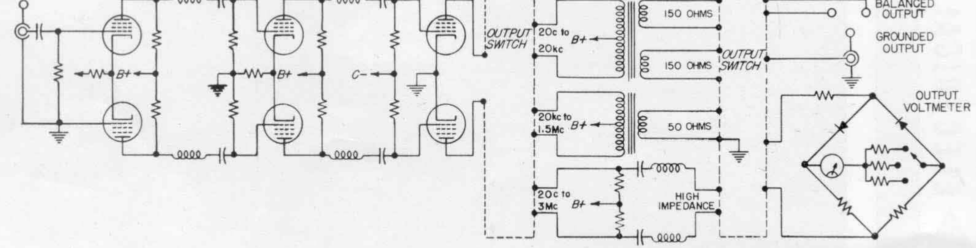
CIRCUIT

Basically, the amplifier consists of three push-pull broad-band stages and three possible output circuits, selectable by a range switch. Figure 2 is a simplified schematic. The interstage couplings are of the series-peaked type, designed for constant gain up to 5 megacycles. The input stage functions as a phase inverter by virtue of a high common cathode resistor.

OUTPUT SYSTEM

Separate output transformers are used for the 20 c-to-20 kc and the 20 kc-to-1.5 Mc ranges. Both transformers are of toroidal construction. The low frequency transformer is arranged with two secondaries so that a parallel or series connection can be selected by the output switch to provide for 150 or 600 ohm loads. The output switch also selects a grounded or ungrounded output by connecting the secondaries of this transformer to the grounded or balanced output terminals. The high frequency transformer is arranged with one secondary for 50-ohm grounded loads. This transformer is wound on a small high-permeability strip-wound toroidal core. Special care in the design and the construction of this transformer were necessary to achieve satisfactory performance at the relatively high frequency at which it operates. Both the leakage reactance between the primary and secondary windings and the distributed capacitance of the primary are limiting factors in determining the high-frequency performance. These conflicting factors in the transformer design require a compromise spacing between the grounded secondary and the primary to achieve maximum performance. Polystyrene cups are used as the interwinding insulation

Figure 2. Elementary schematic circuit diagram of the amplifier.



to keep the capacitance due to dielectric constant of the insulation to a minimum. Single-layer spaced windings are used for both the primary and secondary, and reversed windings are used on the two halves of the toroid circumference to minimize the distributed capacitance.

For the 20 c-to-3 Mc range, push-pull output is supplied through a series-peaked video network.

Type 874 Coaxial Connectors are provided at the input and output. Grounded binding posts spaced ¾-inch from the center conductor of these connectors permit connection to be made also by means of Type 274-MB Double Plugs if desired. Two insulated binding posts are provided at the output which are used when balanced output is selected.

TUNED OUTPUT

The available power output drops rapidly above 1.5 megacycles on the 20 kc-to-1.5 Mc range. However, if desired, full output can be obtained, up to 5 megacycles, by disconnecting existing leads and connecting a suitable external tuned circuit from plate cap to plate cap on the output tubes and connecting the center tap of this circuit to the high voltage plate supply.

VOLTMETER

An output voltmeter is provided which indicates the output terminal voltage on the 20 to 20,000-cycle range and the 20 kc-to-1.5 Mc range. On the 20 c-to-3 Mc range, the output voltmeter is connected to the grounded output terminals, which are not used for this range, making the voltmeter available for external use or permitting an external jumper to be used to connect it to either of the balanced output terminals. The voltmeter is provided with full-scale ranges of 150, 50, and 15 volts, and has an impedance of approximately 15,000 ohms. The voltmeter is compensated to 5 megacycles and functions as a full-wave-average type. The meter can also be switched to indicate the plate current of the output amplifier tubes.

The voltmeter uses crystal diode rectifiers in a bridge circuit.

POWER SUPPLY

The high voltage power supply uses selenium rectifiers in a full-wave voltage-doubling circuit and a two-section LC filter. A bias supply also using selenium rectifiers provides fixed bias for the output stage.

— W. F. Byers

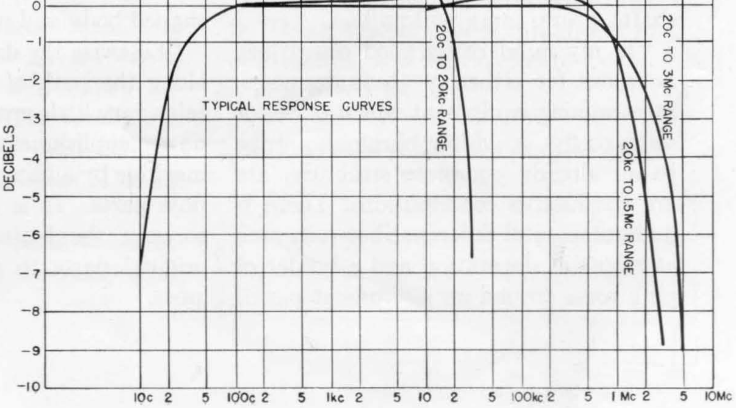


Figure 3. Typical response curves for the three amplifier ranges. The 20 c-to-3 Mc range is given a smooth roll-off at the high end to assure good transient response.

SPECIFICATIONS

Frequency Range: Three ranges are provided:
20 cycles to 20 kilocycles
20 kilocycles to 1.5 Mc
20 cycles to 3 Mc

Power Output:

20 c-to-20 kc range — 15 watts from 50 c to 15 kc; 8 watts at 20 c and 20 kc.

20 kc-to-1.5 Mc range — 15 watts from 20 kc to 0.5 Mc; 8 watts at 1.5 Mc.

Maximum available power output at low distortion depends upon power-line voltage. Rated output is obtainable at 105 line volts. At higher line voltages, output is greater.

Voltage Output: 20 c-to-3 Mc range — 150 volts, peak-to-peak.

Load Impedance:

20 c-to-20 kc range — 600 or 150 ohms, balanced or grounded.

20 kc-to-1.5 Mc range — 50 ohms, grounded.

20 c-to-3 Mc range — deflection-plate terminals of cathode-ray oscilloscope, connected with 36-inch leads and with an effective input resistance of at least one megohm.

Transient Response: 20 c-to-3 Mc range — approximately 0.1 microsecond rise time, with negligible overshoot.

Input Voltage: Less than 0.2 volt for full output.

Input Impedance: 100,000 ohms in parallel with 37 μμf (grounded).

Distortion: Less than 3% at rated output on all ranges.

Noise Output:

20 c-to-20 kc range, 60 db below 15 watts output.

20 kc-to-1.5 Mc range, 70 db below 15 watts output.

20 c-to-3 Mc range, less than 0.3 volt peak-to-peak balanced.

Frequency Response: See typical curves.

Power Supply: 105 to 125 (or 210 to 250) volts, 40 to 60 cycles a-c.

Power Consumption: Approximately 140 watts at 15 watts output; approximately 120 watts at zero output.

Voltmeter:
Ranges, 150, 50, and 15 volts full scale.
Accuracy, ±5% of full scale.

Mounting: The panel is designed for mounting in a 19-inch relay rack, but removable end frames are supplied so that it may be used equally well on a table.

Tubes: 2 — 6AC7   2 — 6AG7
2 — 807   1 — 6J6

Terminals: Type 874 Coaxial Terminals at input and output. Adjacent ground posts for connecting by Type 274-MB Plugs are provided.

Two insulated binding posts for balanced output.

Accessories Supplied: Seven-foot power cord; two Type 274-MB Double Plugs; two spare line fuses; two Type 874-C Cable Connectors.

Accessories Available: Type 874-R10 Patch Cords; Type 874 Connectors and Adaptors.

Dimensions: 19⅜ x 14¼ x 7½ inches, overall.

Net Weight: 45 pounds.

Type		*Code Word*	*Price*
1233-A	**Power Amplifier**	ANGER	**$525.00**

U. S. Patent 2,125,816, also Patent Applied For.

MECHANICAL DESIGN

"The term 'mechanical design' creates different pictures in individual minds. To some people it means styling or dressing up a product, while to others it conjures up a mechanized nightmare of shafts, gears, cams, and pulleys.

"In my mind really good design has no room for either of these extremes. Streamlining equipment which does not swim or fly, or adding chromium strips to an already complete structure, are not productive contributions. There is no fundamental difference between such attempts at decoration and a border of pink roses around an instrument panel; it is only a matter of degree. There is inherent beauty, however, in a smooth functional shape with an honest seam or bump here and there. Look at a woman! Would she be improved with a torpedo-shaped body and white side walls?

"Likewise the design which just grew along the path of least resistance contains very little creative head work. It is no accomplishment to add a feature to a machine by adding a mess of single-purpose parts. It is real accomplishment to gain the feature by designing the original parts to serve the extra purpose.

"A good design is one which combines the requisite features into the simplest possible whole with each part easy to make and each part performing as many functions as possible. This automatically results in fewer parts, clean-cut shape, and low cost, which I consider synonymous with good performance, good appearance, and good salability.

"This kind of design solution is seldom the obvious one and requires more effort than an elaborate answer. The only approach to it is to apply concentrated thought from the broadest possible viewpoint, and the only useful working tools are knowledge of materials and methods plus common sense. The results are proportional to the effort expended as in any other job and cannot be attained quickly by divine inspiration or by a shot in the arm.

"Another popular idea with which I am at odds is that a modern design must use mysterious new manufacturing processes and supernatural new materials. When one reads about these things they are intriguing, but there are generally years of pioneering between their discovery and their practical commercial application. The most economic designs use down-to-earth, proven fabrication techniques which fit available equipment and know-how and materials which can be shipped from local warehouses."

— *Excerpt from a talk by* Harold M. Wilson, *of the General Radio Mechanical Design Group, outlining the functions of the group to General Radio foremen at their monthly meeting.*

VARIAC® PHASE-SHIFT CIRCUITS

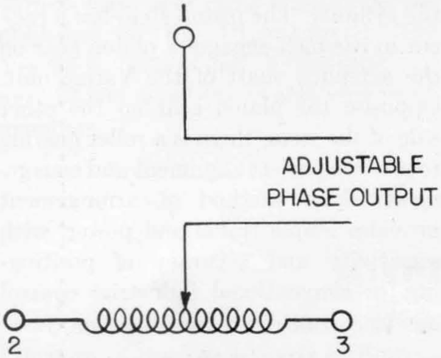


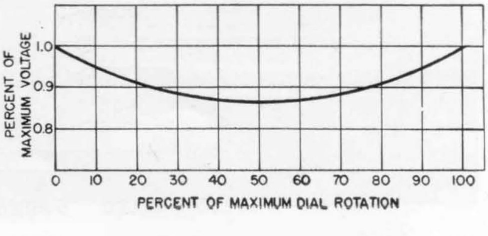
Figure 1. Simple circuit for obtaining adjustable-phase output from a 3-phase system.

In response to our recent article[1] on phase-shift circuits, we have received two letters suggesting the simpler circuit shown in Figure 1. The total phase shift obtainable is 120° and the accompanying voltage variation is small, as shown in Figure 2.

This circuit was first called to our attention by Mr. Reginald H. Rennis of the Boston Edison Company, who has been using the circuit for some years. Mr. Gordon Thompson, Chief Engineer of the Electrical Testing Laboratories, states that this circuit has been in use at E.T.L. for many years, and that tapped autotransformers were used before the introduction of the Variac. He has also used a second Variac, cam-operated from the shaft of the first, to maintain the voltage constant to 1% while phase angle is varied.

We are grateful to Mr. Rennis and Mr. Thompson for calling this circuit to our attention, and we are glad to recommend it to our readers.

Figure 2. Voltage variation as a function of dial rotation.



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[1] Gilbert Smiley. "A Variac Phase-Shift Circuit," *General Radio Experimenter*, October, 1950.

THROTTLING CONTROL USES PNEUMATICALLY OPERATED VARIAC

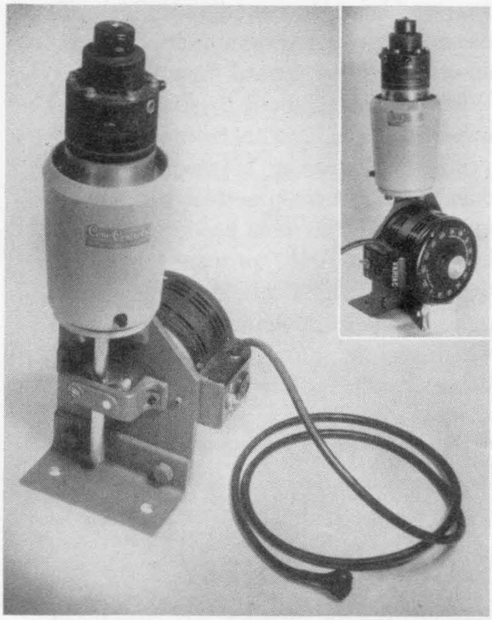
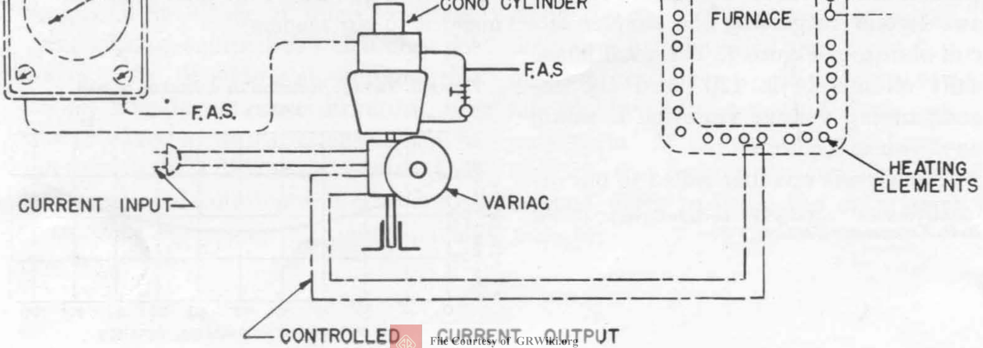


Figure 1. View of the Pneumatic Current Controller showing rock and pinion drive. Inset shows front view.

Among the modern devices for industrial control applications are the *Cono* Pneumatic Current Controllers for throttling control service, manufactured by the Conoflow Corporation, Philadelphia. Operating from the output pressure of a conventional industrial pneumatic controller, the *Cono* Model EB, shown in the photographs, Figure 1, combines the features of a *Cono* Pneumatic Cylinder and a Variac® autotransformer to provide the precise control of current input that is required in many industrial operations and processes. A typical application of such a controller is shown in Figure 3.

The *Cono* Pneumatic Cylinder permits positioning by pneumatic means to one part in 500. The unit consists of a pneumatic cylinder with a constant loading pressure on one side of the piston and the output air pressure of a built-in positioner on the other side of the piston. The positioner unit is built in to the upper end of the cylinder and the piston stem is extended through the bottom of the cylinder. The piston stem has a rack cut in it which engages a pinion gear on the extended shaft of the Variac unit. Opposite the pinion gear on the other side of the stem, there is a roller bearing to provide perfect alignment and engagement. This method of arrangement provides ample travel and power, with sensitivity and accuracy of positioning for conventional industrial control service.

Figure 2. Diagram showing the Current Controller, operating through a standard pneumatic control instrument, to regulate an electric furnace.



I.R.E. MEMBERSHIP DRIVE

The current membership drive of the Institute of Radio Engineers has as its objective the strengthening of the society in representing the interests of engineers working in the electronic and nucleonic fields.

The newly formed Professional Groups, organized to bring together specialists in various phases of these broad fields, are expanding rapidly. If your work or interest in electronic or nucleonic engineering is either general or specialized, you will find it worth while to be a member of the I.R.E.

Members receive every month a copy of the PROCEEDINGS OF THE I.R.E, the magazine which is recognized as one of the most important contributions to the engineering progress of radio. From time to time Institute Standards covering various aspects of radio engineering are published in the PROCEEDINGS. The Yearbook, containing information on over 22,000 members, is also sent to all members.

The benefits of I.R.E. membership include participation in technical meetings of the local Section and Professional Groups as well as the Regional and National Conventions. Technical Committee activities in setting standards and Professional Group activities in procuring papers and arranging meetings offer stimulating contacts with other engineers and further opportunities for direct contributions to the progress of the industry.

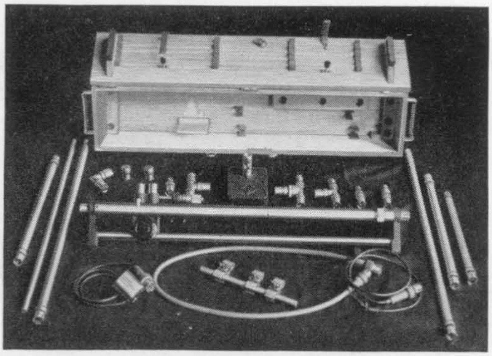
If you are not a member, now is the time to join. Membership grades are Student Associate, Member, and Senior Member and you are eligible for one of them. Application blanks and information on requirements can be obtained from your local Section officers or directly from the Institute of Radio Engineers, Inc., at 1 East 79th Street, New York 21, New York. The grade of Fellow cannot be applied for as it is conferred by action of the Board of Directors in recognition of distinguished achievement.

MISCELLANY

We are indebted to Professor H. E. Ellithorn of the Department of Electrical Engineering, Notre Dame University, for the accompanying photographs showing how TYPE 874 Coaxial Elements can be packed for convenient storage and transportation.

The box is the storage case supplied with the TYPE 874-LB Slotted Line. Mounting facilities for air lines and for the vertical shaft of the TYPE 874-Z Stand have been added to the cover, while receptacles for the smaller parts, ells, tees, and terminations, have been built into the box itself. Patch cords are stored loosely in the remaining space.

Figure 1. View of the storage box, showing the various coaxial elements that are accommodated.



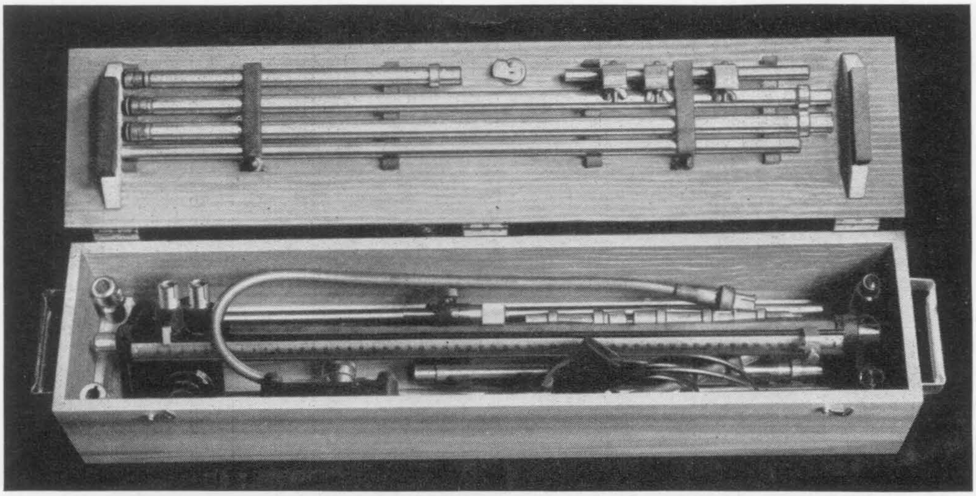


Figure 2. View of the box with elements packed in place.

The addition of handles at the ends makes the converted box a convenient, easily transported case, requiring a minimum of storage space.

RECENT VISITORS to our plant and laboratories — Dr. H. Moss, Chief Engineer, Electronic Tubes, Ltd., High Wycombe, Bucks, England; Mr. P. E. N. Towle, Mullard Electronics Products, Ltd., London, England; Mr. R. C. Auriema, of Ad. Auriema, New York, export representative for General Radio products in Latin America; and Mr. Leopoldo Brandt, of Mauricio Brandt S.R.L., Buenos Aires, Argentina, who handles General Radio products in the Argentine.

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CHICAGO 5, ILLINOIS
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THE General Radio EXPERIMENTER

VOLUME XXV No. 9 FEBRUARY, 1951

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

TYPE 1612-AL R-F CAPACITANCE METER

Also

IN THIS ISSUE

● IT IS PROBABLE that not many readers of the *General Radio Experimenter* are very keenly aware of the standardization activities of the RTMA (Radio-Television Manufacturers Association), nor of the many problems which are posed to the active committeemen as they develop these standards.

A good example of the unexpected ramifications of the standardization process can be found in the electron-tube-socket standardization work which has so far produced Standard TR-111 in the Transmitter Section and will, in the near future, produce a Receiver Section Socket Standard. Even before TR-111 actually was issued, and while it was going through the successive steps required for standardization, committee work was going forward on extensions and revisions of TR-111 to keep the standard alive and abreast of the times.

Figure 1. Panel view of the Type 1612-AL R-F Capacitance Meter, showing open capacitance scale at low end of range.

TEST EQUIPMENT NEEDED

Oftentimes in the development of a standard it will be, by common consent, deemed essential to make a certain type of test on the item being standardized. Frequently, the specification may require testing equipment which is not presently available. This was the case with the capacitance tests required by Paragraph 4.32 of TR-111. Paragraph 4.32 provides for two types of measurements: (1) direct capacitance between two specific socket contacts, all other contacts and metal parts being grounded; and (2) capacitance between a specific contact and all others (tied to all metal parts). The actual individual specification sheets for the various sockets, however, call for only the latter type of measurement.

The simple measurement was adopted because it is highly desirable that the capacitances be measurable on equipment which is inexpensive to buy and simple to operate, so that all concerned, manufacturers and users, can afford to own the testing equipment and can all have identical equipment so as to eliminate the measuring gear as a possible source of controversy in inspection. Direct-capacitance measurements are tricky to make and require expensive equipment. A simple capacitance measurement from one contact to all other metal parts, of the order of 1 μμf, is easily made with simple and inexpensive equipment. For this reason, therefore, the individual specification sheets of TR-111 contain only capacitance requirements from one contact to "all", and standardization now in process will reduce the number of these measurements from two to one.

TEST EQUIPMENT SELECTED

The capacitance values for various sockets are all of the order of 1 μμf. The search for the simple inexpensive equipment with which to measure, at a frequency of 1 Mc, a capacitance of the order of 1 μμf to an accuracy of 0.1 μμf or better was delegated to a small task group by the TR 9.8 Socket Subcommittee. Eventually it was decided to employ a modification of General Radio's TYPE 1612-A R-F Capacitance Meter[1]. The TYPE 1612-A has ranges of 80 μμf and 1200 μμf. The capacitance network in the instrument is designed to give a considerably expanded scale at the low-capacitance end of the low range. It was hoped, and later borne out by making a sample, that the expanded or quasi-logarithmic scale of a 10-μμf range would give sufficient accuracy at the 1-μμf measurement level. Experiments with the first sample carried out by several different engineers, who had had no previous experience with the instrument, indicated that it would be readily possible to repeat settings within 0.02 μμf by simply observing the maximum on the resonance-indicating meter.

As soon as these engineers had had a chance to use the experimental model of the capacitance meter at a TR 9.8 committee meeting, they immediately sensed the usefulness of the device and inquired whether a 100-μμf range could not be incorporated into the instrument. In effect, they were asking that the modified capacitance meter have roughly one-tenth the maximum ranges of the original TYPE 1612-A. This was not at all difficult to do, and a second experimental model was prepared, embodying this added feature. As in the case of the TYPE 1612-A, the shifting from one range to the other is accomplished automatically as the dial is rotated from one half of its scale over to the other, with

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[1] W. F. Byers, "A Compact Radio-Frequency, Capacitance-Measuring Instrument," *General Radio Experimenter*, November, 1948.

no extra panel switching operations. On the 10-μμf range, the first 1 μμf occupies almost one-half of the scale length, and settings can be made to 0.02 μμf.

METHOD OF MEASUREMENT

In use the capacitance meter is prepared for a series of measurements by (1) setting the main dial to one or the other of the two zero points, (2) setting the meter for maximum by use of the zero adjust (front-right-hand) dial, and (3) by setting the meter to full scale by the oscillator output (lower-left-hand) dial. If now a capacitance is to be measured, it should be attached to the unknown or *X* terminals. The main dial is retuned for maximum meter reading and the capacitance is indicated directly by the dial setting.

SOCKET MEASUREMENT METHOD

How do we go about measuring the capacitance of a *socket?* The socket, by Paragraph 4.32 of TR-111, shall be mounted on a round metal plate 1/16″ thick and 4″ in diameter. Obviously there must be some sort of an adaptor interposed between the binding posts of the Type 1612-AL instrument and the socket. This adaptor must simulate in its projecting connecting parts a tube base with which the socket is to be used. Unless adequate shielding is provided by the adaptor, two undesirable conditions will exist: (1) mainly one of inconvenience, in which hand capacity between main or zero-adjust tuning controls and the high unknown binding post will either make measurement difficult or vitiate its accuracy; and (2), the stray capacitance between the large grounded metal plate and the high unknown binding post, of an unknown magnitude, will impair the accuracy of measurement. For these reasons each adaptor is made using an aluminum shield can as a chassis, which, incidentally, provides a ready means for hiding, as well as containing, the mounting and wiring gear associated with the tube base.

An adaptor is attached to the instrument by screwing it on to the stud of the ground unknown binding post after removing the binding-post top, through the means of a female-threaded part driven from the top by a screwdriver slot. Currently there are three adaptors available, as follows:

1. 1612-P1, for 7-pin miniature sockets, to measure "No. 4 contact to all."
2. 1612-P2, for octal socket, to measure "No. 4 contact to all."
3. 1612-P3, for 9-pin miniature noval socket, to measure "No. 5 contact to all."

REDUCTION OF ERRORS

If you have been concerned, as many others working on the project were, with

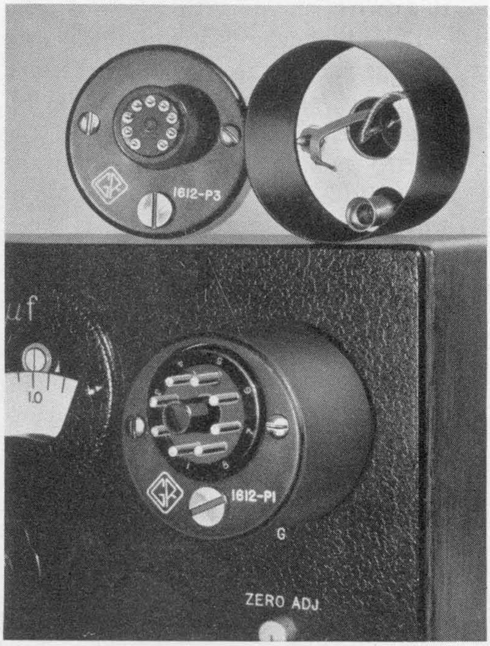


Figure 2. View showing the three socket adaptors, one attached to the X terminals of the capacitance meter. Internal view of adaptor at top right shows terminals, one of which is a lead for clamping in a binding post and the other a captive nut which replaces the binding-post cap.

the smallness of the capacitance being measured and the consequent importance of probable errors in measurement due to strays or other causes, you are probably by now ready to ask a question. How can we measure accurately the capacitance of a socket this way? The adaptor has an air capacitance between, in the case of the noval, say, pin five and all of the other eight, which capacitance is eliminated when the socket is plugged on. The socket capacitance indicated by the instrument will be less than the true socket capacitance by the amount of this air capacitance between adaptor pins. In order to measure this capacitance value experimentally, pins were progressively shortened until they just made contact with the socket springs, thus reducing as far as possible the air capacitance between pins. The difference in measurements turned out to be only one or two hundredths of a micromicrofarad, which could appropriately be neglected. Since the capacitance values listed on the individual specification sheets were determined with this factor taken into account, only variations in this correction are pertinent.

RTMA standardization will not, for obvious reasons, require the use of one particular proprietary testing device. Amendments to TR-111 now in the RTMA mill, however, state that the Type 1612-AL R-F Capacitance Meter with appropriate adaptors has been found to be a satisfactory means for making the capacitance measurements required by TR-111. And the advantages are obvious in having all inspectors, manufacturers' or users', employ the identical testing equipment.

LOSS INDICATION

The Type 1612-AL provides an additional feature not required by TR-111, namely, a rough indication of the losses in the socket dielectric.

In general, the maximum meter reading will come somewhat below full scale. The amount by which the reading fails to attain full scale depends upon the losses in the capacitance being measured. In the case of tube sockets, for instance, a little experience would indicate what deflections would be appropriate for sockets using various dielectrics. No visible departure would be observed for polyethylene-insulated sockets, only a very small amount for a ceramic socket or a glass-bonded mica one, somewhat more for a mica-filled phenolic, and several divisions for a socket of ordinary black cellulose-filled phenolic.

DIRECT CAPACITANCE MEASUREMENTS

It should be mentioned that, while direct or three-terminal capacitance measurements can be made with the capacitance meter, such measurements are not very convenient nor accurate. Three two-terminal measurements must be made and the unknown calculated from the resulting three equations.

OTHER USES

The Type 1612-AL R-F Capacitance Meter is by no means limited to measurements on sockets. Numberless other capacitance measurements can easily be made, for which the features of measurement at 1 Mc and convenience of operation, including capacitance reading on one dial, are important.

1. Many ceramic capacitors are to be found in the range of 0 to 100 $\mu\mu f$ (or in

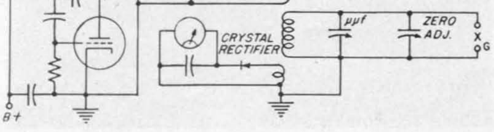


Figure 3. Simplified schematic circuit diagram of the R-F Capacitance Meter.

the range of 0 to 1000 μμf, if a Type 1612-A is available as well as a Type 1612-AL). These would include separate tubular ceramics, both insulated and uninsulated, disc-type ceramics, and the tubular ceramics included in electron-tube sockets.

2. Small molded mica fixed capacitors, of either foil-mica or silver-mica construction, can be measured at a frequency much nearer that of use than 1 kc or 60 cycles would be.

3. Small variable trimmer capacitors can be accurately measured for maximum and minimum value, or even for curve of capacitance versus rotation. This would apply to variable mica trimmers, variable plate-type air trimmers, variable multiple-cup-type air trimmers, variable ceramic trimmers, and the various piston-type variable trimmers having glass dielectric.

Precautions must be taken, of course, in providing a production-type measuring jig, to make sure that no errors in measurement are introduced by the jig itself, or as a result of its construction or shielding deficiencies. These stray capacitance errors become more important percentagewise as smaller capacitances are being measured.

Another convenient use for these instruments is in the assessment or identification of insulating materials. Samples can be measured between flat plates, and an approximate value of dielectric constant can be calculated from the measured capacitance and dimensions of the plates and the sample. The departure of the maximum reading of the resonance meter from full-scale deflection (after, of course, proper initial setting) is a good indication of the losses in the dielectric.

PROCESS SAMPLING

The R-F Capacitance Meter has also been used in sampling, for control purposes, the concentration of ingredients in chemical processing. Where dielectric properties, particularly dielectric constant, can be used as indicators of concentration, periodic comparisons of process samples with a standard sample can be made on the capacitance meter. For this application a suitable test cell can be devised by the user to meet his particular requirements.

CONCLUSION

In short, the Types 1612-A and -AL R-F Capacitance Meters are versatile and useful devices, and are extendable in their utility, almost without limit, by the imagination of their owners and users.

— P. K. McElroy

SPECIFICATIONS

Capacitance Range: Type 1612-A, 0 to 1200 μμf in two bands — 0 to 80 μμf and 0 to 1200 μμf; Type 1612-AL, 0 to 100 μμf in two bands — 0 to 10 μμf and 0 to 100 μμf. Ranges are switched automatically as capacitance dial is rotated.

Capacitance Accuracy:

Type 1612-A

Low Range — ±0.5 μμf below 10 μμf
±5% between 10 and 80 μμf

High Range — ±5 μμf below 100 μμf
±5% between 100 and 1200 μμf

Type 1612-AL

Low Range — ±0.05 μμf below 1 μμf
±5% between 1 and 10 μμf
High Range — ±0.5 μμf below 10 μμf
±5% between 10 and 100 μμf

Capacitance Scale: Scale is spread out at low end of dial and nearly linear at high end. For Type 1612-A, smallest division is 1 μμf for the low range and 10 μμf for the high range. For Type 1612-AL, smallest scale divisions are one-tenth these values. Minimum measurable capacitance is influenced by sharpness of resonance as well as scale distribution, and is about one-half the smallest division.

Dielectric Losses: Relative meter indications with different dielectric samples give a comparative measure of dielectric loss.

Oscillator Frequency: 1 megacycle ±1% adjusted at factory. Frequency can be readjusted if necessary by means of a movable dust core.

Resonance Indicator: A 1N34 crystal rectifier is used with a microammeter to indicate resonance.

Tube: A 117N7-GT tube is used in the oscillator circuit, and is supplied.

Power Supply: 115 volts, 50 to 60 cycles ac, or dc.

Power Input: 12 watts at 115 volts ac; 11 watts at 115 volts dc.

Dimensions: (Length) 12 x (height) $6\frac{5}{8}$ x (depth) $7\frac{1}{2}$ inches, overall.

Net Weight: 11 pounds, 10 ounces.

Type		*Code Word*	*Price*
1612-A	**R-F Capacitance Meter**	AFTER	**$170.00**
1612-AL	**R-F Capacitance Meter**	AGAIN	**170.00**

Licensed under patents of the Radio Corporation of America.

SOCKET ADAPTORS FOR USE WITH TYPE 1612-AL

Type		*Code Word*	*Price*
1612-P1	**Adaptor for 7-pin miniature**	HEPTA	**$9.00**
1612-P2	**Adaptor for octal**	OCTAL	**9.00**
1612-P3	**Adaptor for 9-pin miniature noval**	NOVAL	**9.00**

ROBERT F. FIELD RETIRES

On December 29, Robert F. Field formally retired from the Engineering Department of the General Radio Company after 21 years of service. Actually, he will be in and out of our laboratories for some time working on various personal investigations he has started.

To any regular reader of the *Experimenter*, Mr. Field's name is certainly a familiar one. His contacts with the engineering profession began long before his association with General Radio because, after graduating from Brown University in 1906 and receiving a Master's degree there the following year, he taught physics and electrical engineering at Brown for a number of years. Then in 1915 he left to take advanced work at Harvard University, receiving a Master's degree in 1916. From 1918 until he joined the General Radio staff, he was Assistant Professor of Applied Physics at Harvard, teaching courses in communications engineering, and specializing in electrical measurements.

Mr. Field had been with General Radio only three months when the January, 1930, *Experimenter* carried the first of a long line of his articles on bridges and associated subjects. This article,

Robert F. Field

entitled "An Equal-Arm Capacitance Bridge," analyzed substitution measurements with the now venerable TYPE 216. During the next few years several bridges were designed by Mr. Field and put into production including the bridge-type frequency meter, TYPE 434, the TYPE 716 Capacitance Bridge, the TYPE 544 Megohm Bridge, and probably the most famous of them all — the first model of the TYPE 650-A Impedance Bridge — which was soon to become a laboratory fixture along with the soldering iron and slide rule.

Work with bridge circuits soon brought him to the study of impedance standards, the measurement of all types of impedances, and the problems caused by residual impedances in standards and components. One important contribution to the art made as a result of some of this work was the paper presented jointly with D. B. Sinclair at the IRE-URSI meeting in April, 1935. It was entitled "A Method for Determining the Residual Inductance and Resistance of a Variable Air Condenser at Radio Frequencies" and was published in the "Proceedings of the I.R.E." the following year.

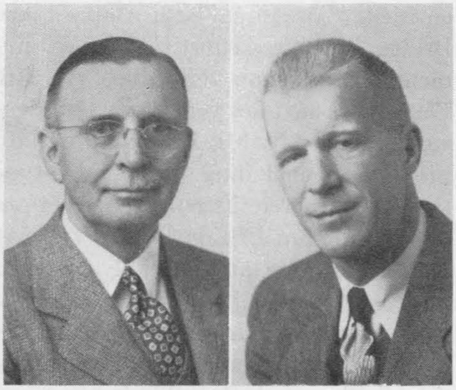
It is not necessary to mention all of the instruments developed by Mr. Field to indicate his versatility and ever-present desire to improve measuring techniques, our knowledge of impedances, and the materials from which they are constructed. Furthermore, the investigation of such details as "Connection Errors in Capacitance Measurements" (January, 1938, *Experimenter*) kept pace with his interest in circuits and instrument design. Before long anyone who didn't know about the importance of interfacial polarization to the electrical engineer just hadn't come close to Mr. Field. The results of some of his work concerning polarization and its effect on the properties of dielectrics appeared in his paper, "The Basis for the Non-Destructive Testing of Insulation," which was presented to the AIEE convention in Toronto, June, 1941, and published in the AIEE Transactions in September, 1941.

The study of insulation and dielectric materials in general subsequently occupied much of Mr. Field's time. His paper, "The Behavior of Dielectrics over Wide Ranges of Frequency, Temperature, and Humidity" (published by General Radio), was presented to many groups anxious to learn more about the mechanism of dielectrics and its relation to the testing of various existing types of insulation. The problem of humidity and its effects also was the subject of several *Experimenter* articles of much interest to those working in humid summer climates. And in the May, 1946, *Journal of Applied Physics* he presented his paper on "The Formation of Ionized Water Films on Dielectrics Under Conditions of High Humidity."

Although many of these studies indicated Mr. Field's interest in capacitors and capacitance measurements, inductors were not left out completely, and they came under his scrutiny. In March, 1942, with P. K. McElroy, Mr. Field asked in the *Experimenter*, "How Good is an Iron-Cored Coil?" His latest contribution was presented to the Symposium on Improved Quality Electronic Components at Washington, D. C., in May, 1950, on "Reduction of Losses in Air-Cored Coils."

No summary, however brief, of Mr. Field's contributions to technical literature, should omit reference to his classic paper, "An Engineering Approach to Trout Fishing," which appeared in the *Experimenter* for January, 1946.

Several of Mr. Field's colleagues are now arranging to carry on various aspects of his active engineering program. Mr. Ivan G. Easton will continue work he has done with Mr. Field in the study of electrical insulating materials and bridge measurements and will assume the over-all direction of the program, and Mr. Horatio W. Lamson, who has also done considerable work in the field of inductor design, will carry on research and development projects which Mr. Field has started, especially on air-cored inductors.



Horatio W. Lamson Ivan G. Easton

SEE US AT THE I. R. E. SHOW

Radio Engineering Show
Grand Central Palace
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BOOTHS
92 AND 93
March 19-22 1951

Plan to visit the General Radio booth at the forthcoming Radio Engineering Show, March 19-22, at Grand Central Palace, New York.

Many of the new instruments announced in the *Experimenter* during the past year will be on display—u-h-f measuring equipment, oscillators, bridges, signal generators, v-t voltmeters, decade impedance units, many others.

A complete working display of TYPE 874 Coaxial Elements will be set up. You can see how measurements of impedance, voltage, and power can be made accurately and easily with this completely integrated line of elements.

Many instruments will have their cabinets removed, to demonstrate the high-quality components and construction methods used in General Radio equipment — the features that give long life and dependable service.

Representatives of our engineering department will be on hand to answer your questions and to discuss with you the performance and applications of General Radio precision-built test equipment.

Plan now to see this display of the most complete line of high-quality test equipment available today.

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THE General Radio EXPERIMENTER

VOLUME XXV No. 10 MARCH, 1951

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

INTERMODULATION DISTORTION

● **NON-LINEAR DISTORTION** affects the reproduction of an acoustic signal by introducing components that are not present in the original. The effect of these extraneous components is one of annoyance to the listener, first, because they can interfere with, or mask, the desired signal, and, second, because they can make the reproduced signal sound unpleasant to the listener.

Both these effects are subjective. They are measurable only by psychological techniques and not by any existing objective tests with physical instruments. Such factors as annoyance, masking, and loudness are evaluated statistically from the results of a large number of tests on many listeners to give an average subjective impression of "normal" listeners. Much work has been done in this field, particularly by the Psycho-Acoustic Laboratory at Harvard University, the Bell Telephone Laboratories, some government laboratories, and numerous other university laboratories both here and abroad. Much remains to be done, particularly on the factor of annoyance, which is affected so much by past influences, by what one is trying to do at the moment,

We are finding it increasingly difficult without extending DO ratings to obtain the raw materials and precision components which are required for the manufacture of General Radio equipment.

In addition, so many priority-rated orders are being received that the delivery of material against unrated orders is becoming increasingly uncertain. We are still accepting unrated orders and are doing our utmost to fill them, but it becomes more difficult every day.

The Rating DO-98 can be obtained for the procurement of essential equipment by addressing a request to your Contracting Officer if you are a prime contractor of a military department. If you are a subcontractor, the request should be addressed to the prime contractor, who will in turn get in touch with the military department concerned.

We urgently request, therefore, that, to insure against unreasonable delay and to assist us in replacing inventory, you do everything possible to obtain and to extend to us priority on any of your unrated orders which we may now have or on any new orders which you will be placing with us.

and by the time sequence of events. In addition, there is the task of devising satisfactory physical tests for sound-reproducing equipment to evaluate factors that can be correlated with the results of the psychological tests. Some of these possible physical tests are considered here.

For many years the main test for nonlinear distortion has been the harmonic distortion test, which evaluates the harmonic components generated by nonlinear amplification and reproduction of the applied signal. It has long been recognized, however, that some systems with very low harmonic distortion still do not sound "right" to the hearer.

Because of this inadequacy of the harmonic distortion test, intermodulation tests have been developed. The first of these measures the modulation of a high-frequency tone by a low-frequency one, a method that gives satisfactory results on some systems and has been adopted by the Society of Motion Picture and Television Engineers (SMPTE).

Even this test is inadequate for some purposes, as will be shown later in this article, and a third method which measures the difference tones produced by the intermodulation of two high-frequency tones has been developed. For a single test method, this appears to be the most satisfactory.

The acceptability of this test, which is recommended by the International Telephonic Consultative Committee (CCIF), is shown by a series of distortion tests recently made on a hearing aid. These tests are discussed in terms of rating the hearing aid, and they are also used to illustrate possible effects that can cause trouble in other sound reproducing systems.

This hearing aid, a high-quality one and of excellent workmanship, was obtained through the courtesy of the Harvard University Psycho-Acoustic Laboratory, where quality ratings by subjective test had been made on it. It has a tone control that permits two settings, and the test panel rated the quality as markedly poorer with the tone control in the *A* position than in the *B* position. This is the reverse of what might be expected from the frequency response characteristics for the two positions, which show a better high-frequency re-

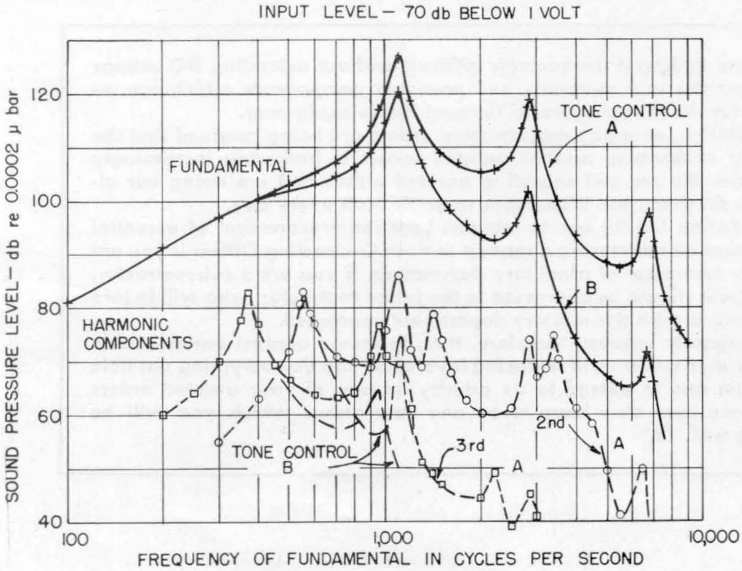

Figure 1. Sound-pressure level produced by the earphone as a function of frequency for the two positions of the tone control. Fundamental and harmonic components are plotted at the *fundamental* frequency.

sponse for the *A* position. These curves show the marked resonances that are typical of hearing aids (see Figure 1).

TEST CONDITIONS

The hearing aid was tested for non-linear distortion by supplying an electrical input at the microphone terminals from a General Radio Type 1303-A Two-Signal Audio Generator[1].

The earphone of the hearing aid unit was connected to an approximate equivalent of the standard 2-c.c. coupler[2], using an Altec Lansing 21B Microphone as the transducer. The output of the microphone was analyzed by a General Radio Type 736-A Wave Analyzer. In each figure, the levels shown are sound-pressure levels in the 2-c.c. coupler, and the operating level was selected to correspond approximately to that for which the quality ratings were made.

HARMONIC DISTORTION

The harmonic distortion results of Figure 1 show the typical resonance peaks normally found in these measurements. They do show that the distortion in the *B* position is lower than in the *A* position, which is in the right direction. However, in the region above 700 cycles, where there is a difference, the distortion components are, in either case, 40 to 50 db down from the fundamental. They are therefore almost completely masked by the fundamental. For either position of the tone control, the distortion is in the range of what is normally considered good quality.

INTERMODULATION SMPTE METHOD

The results of some measurements by the second method are shown in Figure 2 as a function of frequency. A high-frequency signal and a lower-frequency signal were simultaneously applied at the input. The output levels of these signals are shown for reference. In one case a signal of 1 kc was used as the high-frequency signal, and in another the high-frequency signal was 7 kc. In general the distortion components are 40 to 50 db below the level of the desired

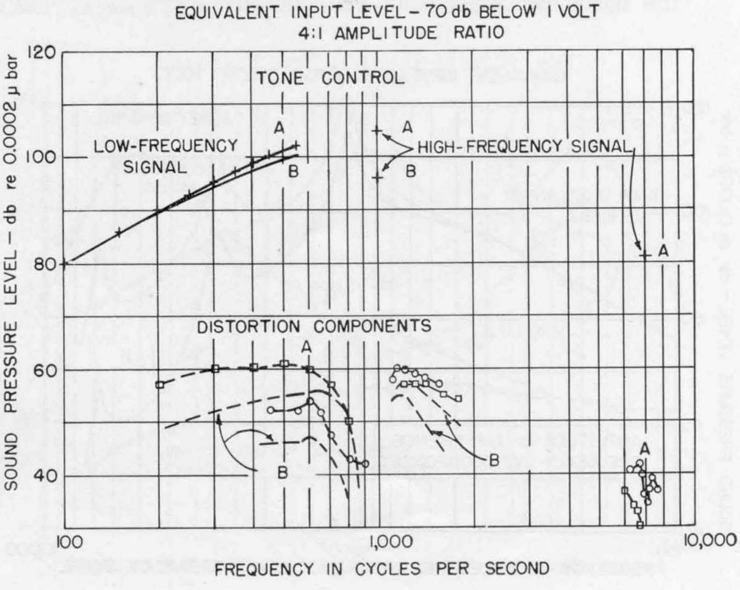

Figure 2. Sound-pressure level of intermodulation distortion components as determined by the SMPTE method. Each component is plotted at its own frequency. Upper curves show the level of the amplified input signals.

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[1] A. P. G. Peterson, "An Audio-Frequency Signal Generator for Non-Linear Distortion Tests," *General Radio Experimenter*, August, 1950.

[2] ASA Z24.9-1949, "American Standard Method for the Coupler Calibration of Earphones."

signals, so far down that they are completely masked by the desired signals. Here again we have no satisfactory indication of serious distortion.

INTERMODULATION CCIF METHOD

The final method of test is the difference-frequency intermodulation method, and some results by this method are shown in Figure 3. Two sinusoidal test signals of equal amplitude were simultaneously applied, and the difference in frequency between the two was kept at 1100 cycles. The amplitude of the undesired first-difference component at 1100 cycles is shown here as a function of the frequency of the lower-frequency signal. The amplitude of the amplified input signals is also shown for comparison.

At low frequencies the distortion is relatively low, and this part is in agreement with the harmonic test. But at frequencies above 1500 cycles, the distortion becomes very large for the tone control in the *A* position. This result is markedly different from that obtained by the harmonic test where the distortion at high frequencies was small. Thus the harmonic test would lead one to assume that the distortion problem was mainly a low-frequency one, while this test shows that the really serious distortion occurs at the high frequencies.

Considered from the viewpoint of masking effects, it is clear that this 1100-cycle component is strongly audible when input signals above 2000 cycles are used. The dissymmetrical nature of the masking curve at high levels[3] makes this form of distortion particularly noticeable, because the unwanted component is at a lower frequency than the desired components.

Another important point to notice in this figure is that the distortion for *B* position of the tone control is much less than for the *A* position. This degree of reduction is sufficient to lead one to expect a marked improvement in quality when the tone control is changed from the *A* position to the *B* position. Here is the first objective test that has shown definite confirmation of the subjective result.

The 1100-cycle difference frequency was selected because of the strong response peak at that frequency. The question then arises: Is the distortion

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[3] S. S. Stevens and H. Davis, *Hearing*, New York, John Wiley & Sons, Inc., 1938, Chapter 8.

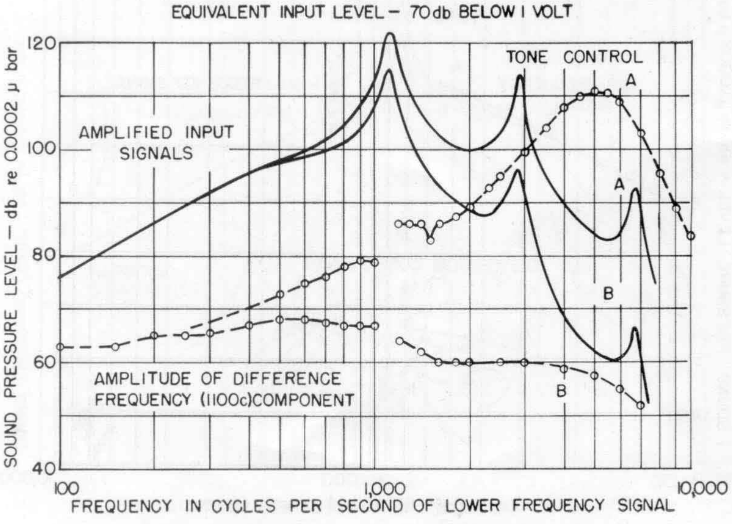


Figure 3. Sound-pressure level of first-order intermodulation component plotted as a function of the lower-frequency input signal.

for other values of difference frequency also large? Results for other values are shown in Figure 4. The 1100-cycle results are reproduced here, and in addition there are distortion characteristics for difference frequencies of 900 cycles, 1500 cycles, and 2850 cycles. The 2850-cycle value is also at a response peak, but the other two values are away from the peaks of response. All show the same general tendency of a gradual rise to high values of distortion at the higher frequencies, but the distortion components in the vicinity of peaks of response are the most important.

The results as a function of level for a particular pair of input signals are shown in Figure 5. At the left is the analyzed sound pressure for the tone control in the *A* position and on the right, for the *B* position. The levels of the desired signals at 3000 and 4100 cycles are shown by the solid lines, and the levels for the distortion components are shown by dashed lines. In both cases the level of the higher-order difference terms at 1900 and 5200 cycles are small compared to the level of the first difference of 1100 cycles. At the assumed operating input level of 70 db below 1 volt, the 1100-cycle distortion component for the *A* position is only 4 db lower in level than the stronger of the two desired components. In the *B* position the level of distortion has dropped to 28 db below the strong 3000-cycle signal. This 24 db improvement certainly would be expected to show up in a subjective test as a marked improvement in quality, which is in agreement with the subject test.

The results shown have been obtained on only one hearing unit, and, consequently, no final conclusions can be drawn. But these results are probably typical because of the usual over-all reduced power handling capacity of hearing-aid units at high frequencies, and because of the marked response peaks occurring in most hearing aids. Therefore, it is highly probable that the difference-frequency intermodulation test is generally the most significant non-linear distortion test for hearing-aid units.

The foregoing results should not be interpreted as indicating that hearing aids are low-quality devices. Both the performance requirements and the design limitation of a device to compensate for hearing loss differ considerably from those of a system to reproduce sound in

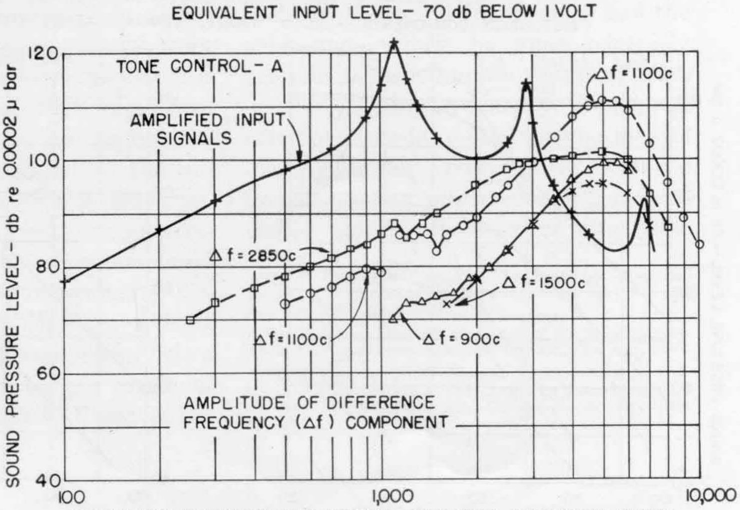


Figure 4. First-order intermodulation distortion for four values of difference frequency.

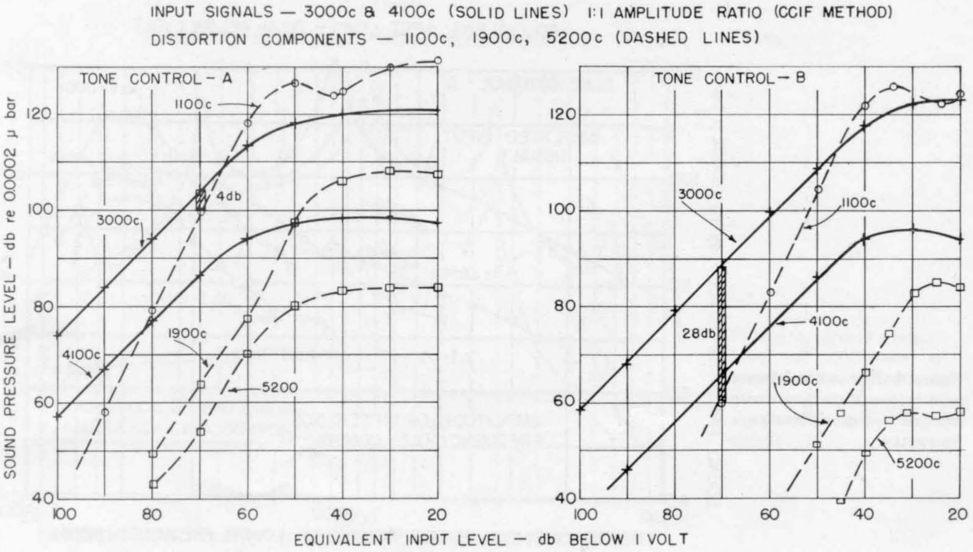
a communication system. Small size and light weight are essential, and the amplifier seems unbelievably small to the engineer accustomed to working with audio power amplifiers. The desirable frequency response characteristic is determined by subjective tests which, for this product, are the ultimate proof of consumer acceptability.

The measurements on the hearing aid were made because of the available psychological data and because the electrical setup was simple. This type of investigation should be extended, and we should like to encourage those who are interested and capable of doing so to pursue the problem for other communication elements. In order to encourage this further investigation, a few possibilities are discussed below, but it should be noted that adequate experimental proof of these possibilities is not yet available.

OTHER AUDIO SYSTEMS

Effects which are similar to those shown here for hearing aids occur in audio amplifiers, radio receivers, public address systems, and other electro-acoustic devices. One of these is the effect of resonant peaks of response. These peaks of response can exaggerate components produced by distortion to a serious degree. For example, most loud-speakers used on radio receivers do not have a smooth and uniform response characteristic as a function of frequency. The poor characteristic is mainly a result of the great difficulty, and consequently great expense, of obtaining a better characteristic. In addition, some loud-speakers are intentionally made to have markedly higher response in the moderately low-frequency range. This hump in the characteristic gives a typical boominess that is desired by some, but that quickly becomes annoying to others. With this type of response from a reproducer, one hears a boominess associated with speech and most music, even when there obviously are no strong low-frequency tones present in the original. It is easy to see that these components can be produced by non-linear distortion. The intermodulation of two higher-frequency tones produces the

Figure 5. Intermodulation distortion as a function of input level. The operating level for the subjective tests corresponds to an input level of approximately 70 db below 1 volt.



lower-frequency tone as a difference frequency. Then because of the exaggerated response at the low frequencies this tone can become relatively strong with the associated effects described above. In measuring the magnitude of this distortion, it is necessary to include the loud-speaker in the measurements, and an excellent microphone is required as a pickup. After determining an over-all response characteristic, the CCIF test can be made as a function of frequency with the difference frequency set to the various maxima in the response characteristic.

The extensive use of pre-emphasis of high frequencies in present-day communication systems has increased the power handling requirements at high frequencies. The CCIF test is the best for determining the effect of the pre-emphasis. If intermodulation occurs after pre-emphasis to produce a lower-frequency difference tone, then this component becomes more important after de-emphasis, since the higher-frequency desired components are reduced more in level than the undesired low-frequency component. The usual recording systems of today use pre-emphasis of the high frequencies. But most of them are fortunately arranged to be essentially symmetrical in action so that under normal conditions very little of this first difference component is produced. For example, the symmetrical nature of the magnetization characteristic of magnetic tape is one of the important factors in its success. However, if an unbalance occurs in the magnetization, either because of dissymmetrical biasing or residual d-c components, distortion can occur to produce a first-difference frequency component of a magnitude depending on the extent of the dissymmetry. This CCIF test for the first difference can be a sensitive check on proper biasing, and the test for the second difference can be used to show up additional distortion[4].

A few radio manufacturers have attempted to compensate for poor high-frequency response in loud-speakers by boosting or pre-emphasizing the high frequencies. This process is intended as a step toward high fidelity and increased brilliance of reproduction. However, the increased power handling ability that this requires at high frequencies is frequently not provided. The result is increased distortion. The characteristic drop in output at high frequencies in the loud-speaker then reduces the level of the high-frequency signals compared to any lower-frequency intermodulation components. The usual result is that the radio reproduction sounds better when the controls are set at a normal position rather than at this so-called "high-fidelity" position. The proper method of checking for this type of trouble is by the CCIF test with the loud-speaker included as a part of the system.

Because of non-linearity in the loud-speaker suspension and cone material, subharmonics can be generated in many loud-speakers.[5, 6] These occur at a number of distinct frequencies, and the subharmonic may be some relatively complicated fraction, for example, 5/13, of the exciting frequency. When an attempt is made to excite subharmonics directly, a high power level must be used, and the subharmonics build up rather slowly. Because of this slow

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[4] L. C. Holmes, "Techniques for Improved Magnetic Recording," *Electrical Engineering*, Vol. 68, No. 10, October, 1949, pp. 836-841.

[5] H. F. Olson, *Elements of Acoustical Engineering*, New York, D. Van Nostrand, Second Edition, 1947, pp. 167ff.

[6] H. H. Hall and H. C. Hardy, "Measurements for Aiding in the Evaluation of the Quality of Loud-speakers," Abstract, *J. Acous. Soc. Am.*, Vol. 20, No. 4, July, 1948, pp. 596f.

build-up, it has been suggested that these subharmonics cannot become a significant factor in the reproduction of music and speech. However, because these signals are complex, other factors may enter to make occasional generation of subharmonics possible of sufficient magnitude to become annoying. One tone appearing in a signal may be at a frequency for which subharmonics can occur and it may have associated with it a tone different in frequency from the first by a value approximately equal to the subharmonic. Then non-linear distortion in the driving amplifier may generate enough of this difference frequency to aid in subharmonic generation at a level much lower than normal. In addition it can produce an initial signal to cause build-up of the subharmonic to a significant level in a much shorter time than is otherwise possible.

EQUIPMENT

In general an investigation of effects of the type described requires a versatile signal source. Not only are two tones required for the intermodulation tests, but also each tone must be adjustable in frequency over a wide frequency range. The General Radio Type 1303-A Signal Generator[1] provides this versatile signal source, and the General Radio Type 736-A Wave Analyzer is a suitable, highly selective voltmeter to use as a detector for determining the extent of the non-linear distortion.

—A. P. G. Peterson

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[1] Loc. cit.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A DYNAMIC MICROPHONE FOR THE SOUND-LEVEL METER

Also IN THIS ISSUE

● **IN THE DESIGN** of a general-purpose sound-level meter, one of the important problems is the choice of a microphone. Among the many desirable microphone characteristics, there are several that are essential if the instrument is to do a creditable job of measurement. In addition to having a non-directional, wide, flat, frequency response and high sensitivity, the microphone should give a linear response over a wide range of sound pressure levels, and its output should be stable over long periods of time — not adversely affected by variations of temperature or humidity.

The National Production Authority Regulation 4 provides a uniform procedure by which any business enterprise, government agency, or public or private institution may use a priority rating to obtain "minor capital additions" as well as specified quantities of maintenance, repair and operating supplies (MRO).

Within the restrictions of the Regulation, a rating of DO-97 may be used on orders for these materials and services. Specific authorization for each order is not required. Test equipment and laboratory apparatus of the kind manufactured by General Radio are usually accounted as capital additions. The Regulation permits your use of the priority rating when the cost of one complete capital addition does not exceed $750.

In general, the amount that may be obtained under the rating is limited, with minor adjustments, to a total dollar value per quarter equal to one-fourth of the amount that was spent in 1950 for MRO.

Because so many priority-rated orders are being received, deliveries against unrated orders are becoming increasingly uncertain. We recommend that, if no other rating is available, DO-97 be used whenever it is applicable.

NPA Regulation 4 should be consulted for details. Copies are available from your nearest Department of Commerce field office.

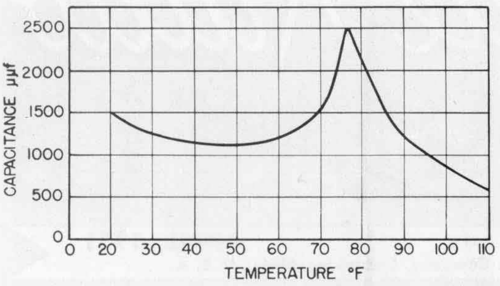


Figure 1. Capacitance variation as a function of temperature for a typical Rochelle salt crystal microphone.

THE ROCHELLE SALT CRYSTAL MICROPHONE

The Rochelle salt crystal, diaphragm-type microphone chosen for use on the General Radio Type 759-B Sound-Level Meter is a low-cost device, which fulfills all of these requirements satisfactorily so long as the microphone is connected directly to the input terminals of the sound-level meter, and so long as moderate variations of temperature and humidity are encountered.

However, when it becomes necessary to make measurements with the microphone separated from the sound-level meter by a long cable or when high temperatures and humidity are encountered, the Rochelle salt crystal microphone becomes a less satisfactory pickup. While the output voltage of the microphone changes by about .02 db per degree F., its capacitance varies considerably as the temperature changes so that loss added by a long cable is very markedly a function of temperature.

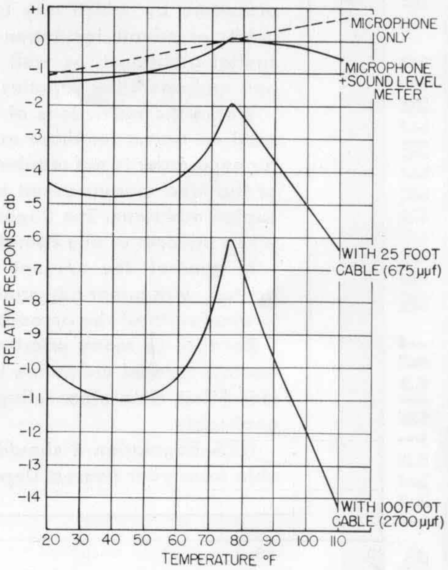
Figure 1 shows the variation in capacitance with temperature for a typical Rochelle salt crystal microphone. At the top of Figure 2 the dashed curve shows the change in output of the microphone with temperature, and the solid curve shows the change in meter reading of the Type 759-B Sound-Level Meter due to temperature changes at the microphone with the microphone mounted on the sound-level meter. The two lower curves show the large changes in meter readings that occur when 25-foot and 100-foot cables respectively are used between the microphone and the sound-level meter. The maximum safe temperature at which the Rochelle salt unit can be used is about 115° F., since it is permanently damaged at temperatures above 135° F. Although the unit is sealed, extensive use at a relative humidity below 30% or above 85% should be avoided.

THE DYNAMIC MICROPHONE

The errors arising from these effects can be avoided by the use of a dynamic, or moving coil, microphone for those applications where a long cable must be used between microphone and sound-level meter, or where extremes of temperature and humidity are encountered.

A suitable dynamic microphone for use with the Type 759-B Sound-Level Meter is now available, in combination with a transformer, a cable, and tripod.

Figure 2. Variation in response as a function of temperature for the crystal microphone alone and with various lengths of cable between microphone and sound-level meter.



This combination, the Type 759-P25 Dynamic Microphone and Accessories, is shown in Figure 3.

The dynamic microphone, the Western Electric type 633-A, now manufactured by Altec Lansing Corporation, is well established as a dependable and rugged instrument. Its output level is about −90 db re 1 volt per microbar compared to a level of −60 db for the crystal microphone, so that a transformer with a turns ratio of 30:1 is required to raise the output to the desired level. The Type 759-322 Transformer does this with no effect on the frequency response over the working range of the microphone. In addition the transformer is well shielded, so that pickup from stray magnetic fields is well below any such pickup by the microphone itself. The cable furnished is 25 feet of shielded, double conductor with vinylite sheath. A 100-foot cable is also available.

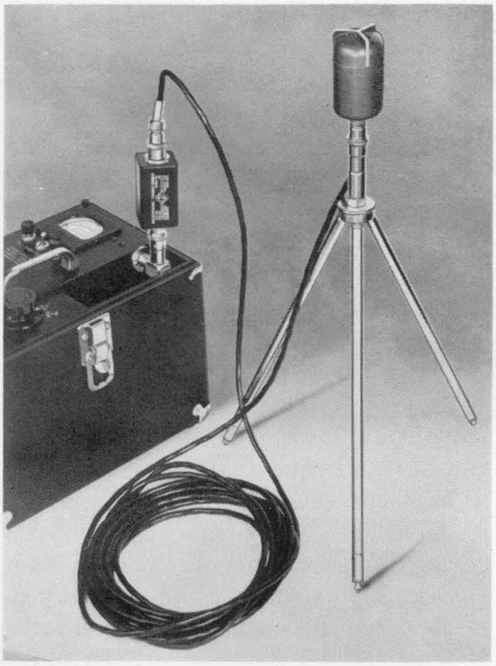
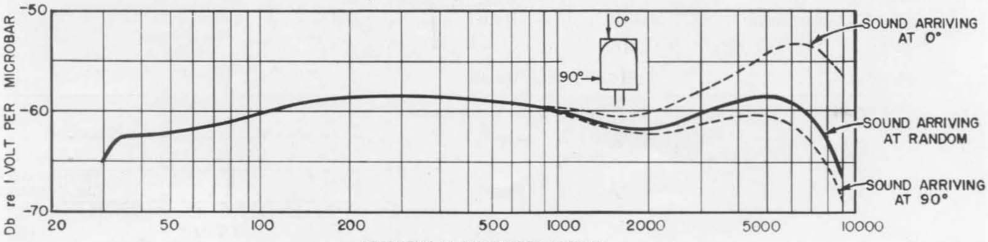


Figure 3. View of the Type 759-P25 Dynamic Microphone and Accessories connected to a Type 759-B Sound-Level Meter.

Figure 4 shows a typical field response for the Type 759-P25 assembly used with a Type 759-B Sound-Level Meter on the *C* (flat) weighting network. For sounds arriving at random, the response falls within the tolerances allowed in the ASA Standards on sound-level meters (Z24.3 1944). It should be noted, however, that the response below 1000 cycles is not so flat as that of the crystal diaphragm-type microphone, as can be seen by comparing Figure 4 with Figure 5. The response at 400 cycles, for the dynamic microphone, is near the center of a broad maximum, so that if the gain of the sound-level meter is set to give correct readings based on the 400-cycle sensitivity of the microphone, sound-level readings of average or broad-band noises will be low. At frequencies below 30 cycles the output of the dynamic microphone falls off sharply while the output of the crystal unit is good to 20 cycles and lower.

At frequencies above about 6000 cycles the operation of the dynamic microphone is superior to the operation of the crystal microphone. For sounds arriving at random, the difference in operation is not great. As shown in Figures 4 and 5,

Figure 4. Typical response curves for the Type 759-B Sound-Level Meter with Type 759-P25 Dynamic Microphone and Accessories.



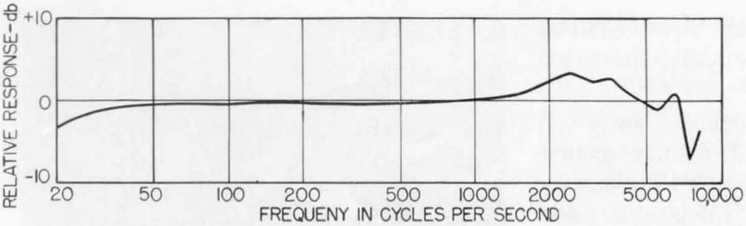


Figure 5. Typical response curve (random incidence) for sound-level meter and crystal microphone.

the response of the dynamic microphone holds up very well to 9000 cycles and the response of the crystal microphone extends out to 8000 cycles.

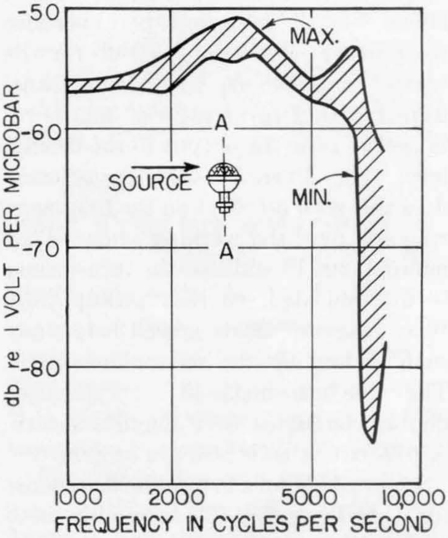


Figure 6. Variation in output of typical Rochelle salt crystal, diaphragm-type crystal microphone as a function of frequency as the microphone is rotated about axis A — A perpendicular to its diaphragm. Sound incidence is parallel to plane of diaphragm.

For sounds arriving parallel to the diaphragm, the crystal microphone does very well up to about 6000 cycles. Beyond this frequency, the dimensions and mechanical construction of the crystal microphone diaphragm cause rather large changes in the microphone output as it is rotated about an axis perpendicular to its diaphragm. These variations for a representative microphone are illustrated in Figure 6. Variations in output of the Type 633-A Dynamic Microphone under the same conditions remain within 2 db up to 9000 cycles.

CALIBRATION

A calibration tag gives the 400-cycle level, the average level of the microphone plus transformer, and the proper setting for the sound-level meter, based on the average level of the microphone when the over-all system is calibrated using the Type 1552-A Acoustic Calibrator.

For the measurement of sound levels, with components above 70 db, the dynamic microphone can be used directly at the input of the Type 760-B Sound Analyzer or the Type 1550-A Octave Band Analyzer. The absolute level can be determined by using the Type 1552-A Sound-Level Calibrator.

No corrections are necessary for cables up to 100 feet long.

SPECIFICATIONS

Sensitivity: Open-circuit output of typical microphone is 90 db below one volt per microbar, and of microphone plus transformer is 60 db below one volt per microbar.

Maximum Safe Sound Pressure Level: 140 db.

Net Weight: 4⅝ pounds.

Type		*Code Word*	*Price*
759-P25	**Dynamic Microphone and Accessories (with 25-foot cable) . . . .**	NABOR	**$150.00**
759-P22	**Extra 100-foot Cable . . . .**	NASAL	**30.00**

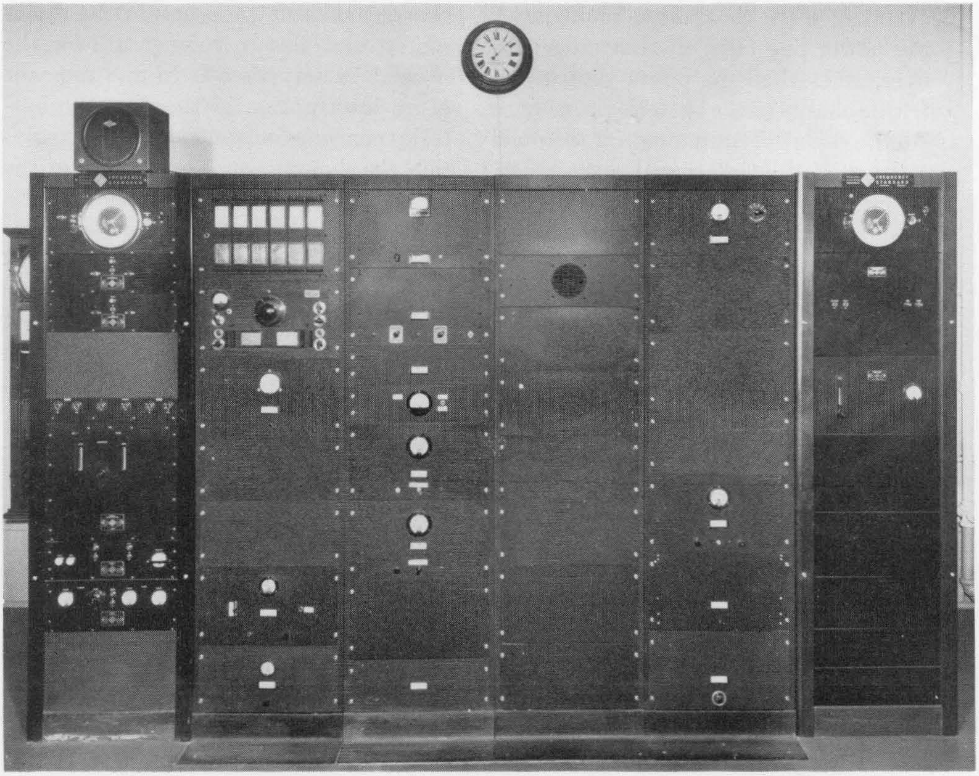
EMERGENCY POWER EQUIPMENT FOR FREQUENCY STANDARDS

Official time for all Canada is provided by the Dominion Observatory at Ottawa, whose time signals, sent by direct wire and radio, are available to the Canadian public from Halifax to Victoria, and northward to the limits of radio reception.

The crystal clock has superseded the pendulum type as the primary timekeeper at the Dominion Observatory, although here, as in most observatories, the pendulum, because of its simplicity and reliability, is still an important element in the time-determining system.

The crystal clocks at the Dominion Observatory are General Radio Primary Frequency Standards. Both are equipped with Syncronometers indicating mean time. Two additional Syncronometers, controlled by one of the crystal clocks, are used, one to compare the mean-time clocks with radio time signals from other observatories, particularly Washington and Greenwich, and the other to initiate the time signals transmitted from the Observatory. Time signals in a standard identification sequence are transmitted by a pendulum-controlled time-signal machine, upon which a signal from a crystal clock circuit is superimposed as a gate for the beginning of each second's impulse.

Figure 1. Bay of equipment in the Time Room at the Dominion Observatory. The two racks at either end contain the two General Radio Frequency Standards, or crystal clocks. The four racks in between contain a receiver, several relays and amplifiers, and the terminal blocks for the cables of wires which supply a multitude of services within the Observatory and to points outside.



POWER SUPPLY

Pendulum clocks pose no serious power supply problems, because they operate from batteries, which are continuously charged by rectifier equipment operating from the a-c power line. In the event of line failure, emergency charging equipment automatically takes over in a matter of a few seconds.

The crystal clock, however, when operated directly from the a-c line, stops operating when a power interruption of even short duration occurs. Because the crystal clock offers so much greater precision than the pendulum type, considerable effort has been expended by the Dominion Observatory in devising a satisfactory method of bridging the power-supply interruptions.

One of the original methods adopted to provide continuity of power was complete battery supply for both high voltage and low voltage. The battery bank meanwhile is kept up to strength by means of a trickle charge. Immediately the power line fails, the batteries carry over, and, when the power returns, the trickle charge to the batteries is resumed. All the essential equipment for the maintenance of the time-signal machine and its primary pendulum at the Dominion Observatory is maintained by this floating battery method.

There are, however, certain objections to the use of the floating battery. The space required by batteries for full-voltage supply becomes excessive, particularly with the modern tubes which use higher plate voltages. The fumes from such a large bank may not be inconsiderable at times and must be drawn off. When the charge is withdrawn, the voltage changes fairly abruptly by about ten per cent, providing all the cells of the bank are good. If any bad cells exist, which is quite possible, the change in voltage from charge to no charge can be still greater. It is expecting a good deal of present-day equipment to provide a smooth continuity of output with fluctuations in power supply even as great as five per cent. Furthermore, when the equipment is designed for normal 60-cycle operation, special leads must be installed to adapt it for battery operation. Against these disadvantages, of course, is the great advantage that the power available to the equipment never falls below the battery level, and usually long continuity of service may be expected.

Another type of emergency for bridging periods of power failure involves the use of batteries and a 60-cycle, 110-volt dynamotor or motor generator. During normal operation, the battery drives the dynamotor, which in turn supplies the required power to the electronic equipment. The a-c line operates through a rectifier to provide the batteries with charge sufficient to maintain the dynamotor, and also to compensate for the normal battery decay. At the moment of an interruption in the line, the batteries continue independently and maintain the dynamotor. Resumption of the line returns the charge circuit to its normal rate. A dynamotor, which operates from a 32-volt battery bank, will involve a compromise between efficiency and economy of space, and equipment designed for normal 110-volt, 60-cycle operation will require no change. Objectionable features include the fact that rotating machinery requires maintenance and involves some noise and vibration. With an interruption in the line and the charge removed from the battery, the voltage applied to the dynamotor drops quickly by one-tenth or more, and the input voltage to the equipment also drops.

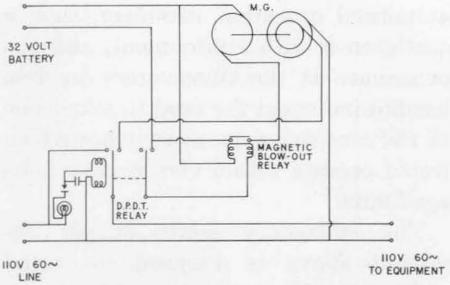


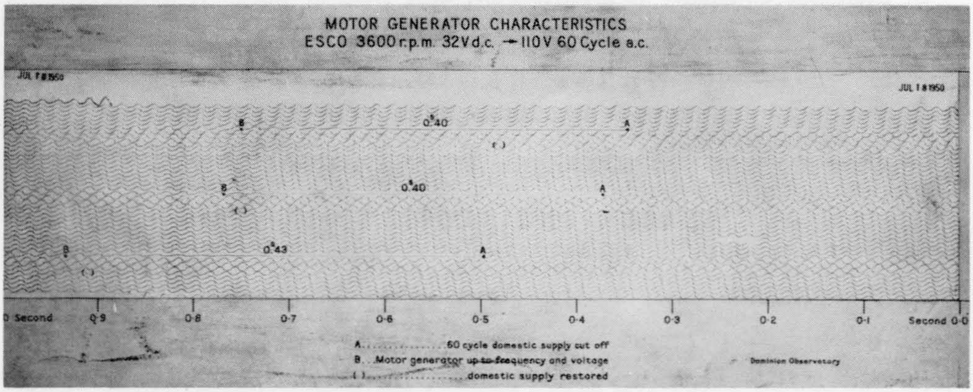
Figure 2. Schematic of the 32-volt d-c, 110-volt a-c motor generator set used in connection with each of the crystal clocks to provide emergency power with little delay. While a unit of this nature is capable of operating for a considerable time, limited only by the condition of the batteries, its main purpose is to provide a very quick source of 110 volts ac to tide over the short interval required for the gas-driven motor generator to build up.

A variation of the above method, and one which has been placed in service at the Dominion Observatory, includes the use of a 32-volt dynamotor and a bank of lead cells to provide the required 32 volts. In this system the 60-cycle, a-c line is used to provide power for the electronic equipment, and also a trickle charge to the battery. A line switch is so arranged that when the power fails the line is cut off, the battery is cut in to the dynamotor, and the a-c output of the dynamotor is cut in to the equipment.

The measured delay from the time that the a-c line is interrupted till the time that the dynamotor builds up to full frequency and voltage proves to be about 0.6 second. The normal power supply has to be provided with additional high voltage storage to bridge a time gap of this size. In the case of the frequency standards at the Dominion Observatory, seven electrolytic condensers of eighty microfarads provide adequate storage.

The initial charging of such a large condenser is beyond the normal ability of the ordinary rectifier tube without some protection. With a resistance of say three thousand ohms in series when the condenser is initially charged, the job can be handled quite well by the familiar type 80 tube. Once the charge has been made, the resistor may be shorted out because, in short intervals of a second, the condenser will suffer only a partial discharge. Tests in service indicate that it does serve effectively to maintain the high voltage during the period of switch over. No such precaution is necessary for the cathode power, since the ordinary type of heater tube suffers little change with a power cutoff of one second. On restoration of the domestic a-c supply, the line switch again closes, the dynamotor cuts off to await the next interruption, and the batteries return to their trickle charge.

Figure 3. A recording on a drum which rotates at one revolution per second shows that the build-up time of the motor generator emergency power supply is less than half a second. The instant when the domestic power supply was cut off by pulling the switch is marked by A. The interval from A to B was required for the motor generator supply to build up to full frequency and voltage.



The build-up time of 0.6 second referred to above was measured on a drum chronograph which is made to rotate synchronously at one revolution per second. The syphon pen can be made to record the 60-cycle wave from the line at the point where it is fed into the frequency standard. When a line interruption is simulated by opening the line switch, there is an immediate interruption in the a-c pattern being recorded. As the dynamotor comes up to speed, the emergency a-c supply operates the pen, showing clearly the moment when full frequency and voltage are attained, and the elapsed time proves to be about 0.6 second.

There are certain inherent faults in the use of a dynamotor and stand-by battery as an emergency source of power. The ordinary switch will maintain itself over a wide range of voltage, which means that the domestic a-c supply might drop to a low voltage due to a partial short without the switch operating. A drop to say 80 volts, which might be quite adequate to maintain a switch in the up position, would be quite inadequate to maintain a frequency standard at normal operation. However, such a condition is rather infrequent, and the experience at the Observatory to date has not indicated the need to adopt one of the sensitive type of switches which would operate within very narrow voltage limits.

The emergency power supply described above is designed for rapid pickup. It will, as a matter of fact, give continuous service for several minutes, or even hours, depending on the state of the batteries. Normally the heavy duty stand-by power plant, which is gas driven, takes over within a quarter of a minute, so that the use of the emergency supply is for short intervals only.

In the several years that this emergency system has been in operation, there has been no failure caused by power interruptions in the frequency standard which is now being used as the primary timekeeper at the Dominion Observatory.

The information on which this article is based was supplied by J. P. Henderson and M. M. Thomson of the Dominion Observatory, Ottawa, Ontario. Additional information on the time service supplied by the Observatory will be found in an article by Mr. Thomson entitled "Canada's Time Service," published in the *Journal of the Royal Astronomical Society of Canada*, XLII, 3, pp. 105-120, 1948.

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THE General Radio EXPERIMENTER

VOLUME XXV No. 12 MAY, 1951

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

AN IMPROVED VARIAC® SPEED CONTROL

Also

IN THIS ISSUE

● **THE ⅓ H.P. VARIAC SPEED CONTROLS,** Types 1700-AL and AH, have given an excellent account of themselves in a large number of applications since their introduction two years ago[1]. The combination of the Variac with a rectifier and choke has many advantages as a source of adjustable armature voltage for operating d-c shunt or compound wound motors over a wide speed range. The resistance of the armature voltage source can be made low, usually less than half the armature resistance of the motor, so that good regulation is obtained, essentially the regulation of the motor itself. The armature current is essentially ripple-free, so that torque pulsations are negligible and no derating of the motor is required. The controls are of compact single-unit construction, providing reversal and dynamic braking without auxiliary equipment.

One factor which has limited the acceptance of these controls has been that a tube rectifier is employed. The use of tubes, however rugged

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[1] For a description of these controls, see W. N. Tuttle, "Variac Motor Speed Controls," *General Radio Experimenter*, Vol. 23, April, 1949, pp. 1-8.

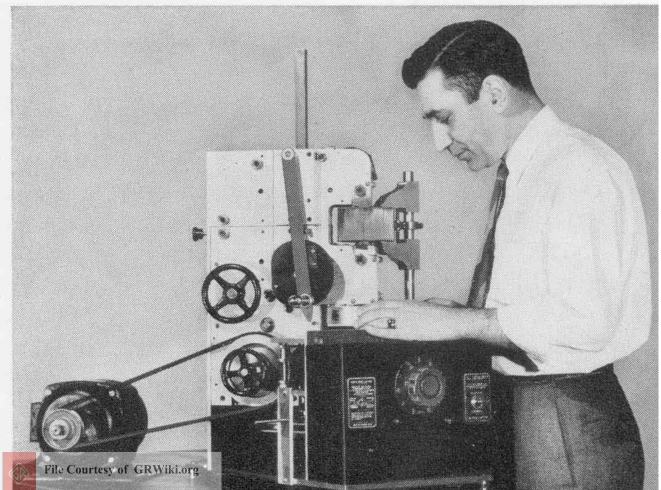


Figure 1. New Type 1700-B Variac Speed Control installed on toroidal winding machine.

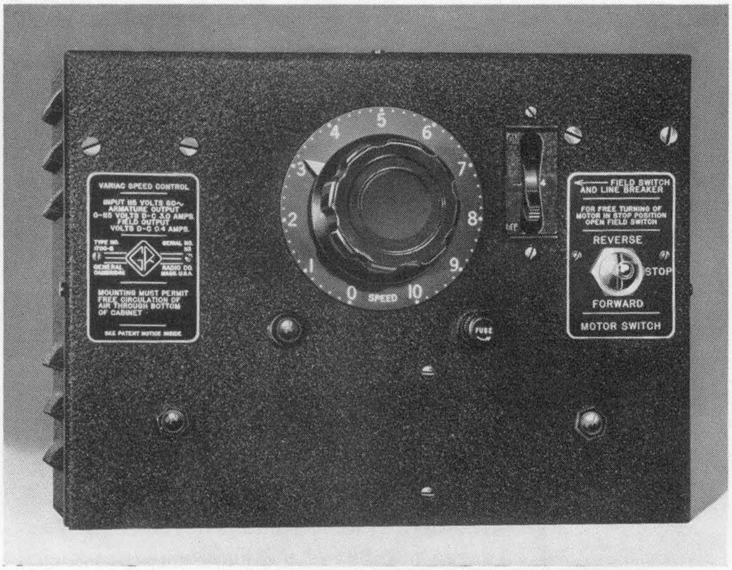


Figure 2. Panel view of the Type 1700-B Variac Speed Control.

they may be, is always a reminder to the customer that additional maintenance problems may be involved. Tube life records leave him unconvinced. (Actually we know of no tube failure whatever in the case of the Type 1700 Controls, either in equipment installed or in the course of our original experimental work.) A tube rectifier requires the use of some sort of time delay mechanism to insure proper warm-up before load is applied. This is not a handicap in shop equipment for which the power unit can be turned on at the beginning of each working day, but is a definite limitation in the case of equipment subject to occasional use, and is a reminder to the user that electronic equipment, supposedly subject to failure, is involved.

A new ⅓ h.p. control, Type 1700-B, is now offered, which is the same in size and in general appearance as the Type 1700-A design but in which a selenium rectifier is substituted for the tube rectifier with considerable simplification in construction. Figure 1 shows the new control operating a toroidal winding machine. The selenium rectifier requires no time delay device, no center-tapped step-up transformer, and no filament supply. The saving in these components results in a substantial reduction in cost without sacrifice in performance and with the advantage of instant starting.

The photograph, Figure 3, of the interior of the new control shows the simplicity of the design. At the upper corners of the cabinets are the field-supply transformer and the choke. The combination overload breaker and field switch is beside the Variac. The start-stop-reverse switch and the dynamic braking resistor are at opposite sides. The armature rectifier stacks are in the bottom corners with the field rectifier and Jones plug between them. As with the earlier Type 1700-AH and AL Controls, all components are mounted on the lid. The plug and jack arrangement simplifies installation and makes it possible to remove the unit without disturbing the wiring.

RECTIFIER LIFE

The new design has been made possible largely by improvement in available selenium rectifiers. Motor control equipment is frequently subject to operation in high ambient temperatures. To protect a rectifier from failure due to excess plate temperature, substantial derating has been necessary even when high ambient conditions were expected only occasionally. This has made both the bulk and the cost of suitable rectifiers almost prohibitive. Rectifiers recently announced not only require fewer plates for a given voltage but also are capable of withstanding sustained overloads or long periods of high ambient temperature without failure. Maximum rectifier life of 40,000 to 50,000 hours still requires derating to limit the maximum plate temperature, but occasional operation at higher-than-normal temperatures now costs only a moderate decrease in life instead of possible immediate breakdown. With the new rectifiers, it is estimated on the basis of manufacturer's tests that a life of at least 15,000 hours will be obtained on continuous duty with the control box in an ambient temperature of 40°C. This means that for ordinary applications, where operation is usually at lower temperatures, almost indefinite life is to be expected. Even where operation under extreme conditions is the rule rather than the exception, several years of rectifier life should still be obtained.

FEATURES

The Type 1700-B Control has several new features worth noting in addition to those of instant starting and freedom from tube replacement. The field supply is isolated by a transformer from the armature circuit. This means that standard compound-wound motors having five leads can be reversed by means of the switch on the control. In the Type 1700-A design, a straight shunt motor connection is required for reversing service. Operating the field supply from a separate transformer instead of from a tap on the Variac makes it possible to open the Variac input connection whenever the motor is stopped and still have field excitation available for dynamic braking. Elimination of the Variac no-load loss during standby periods results

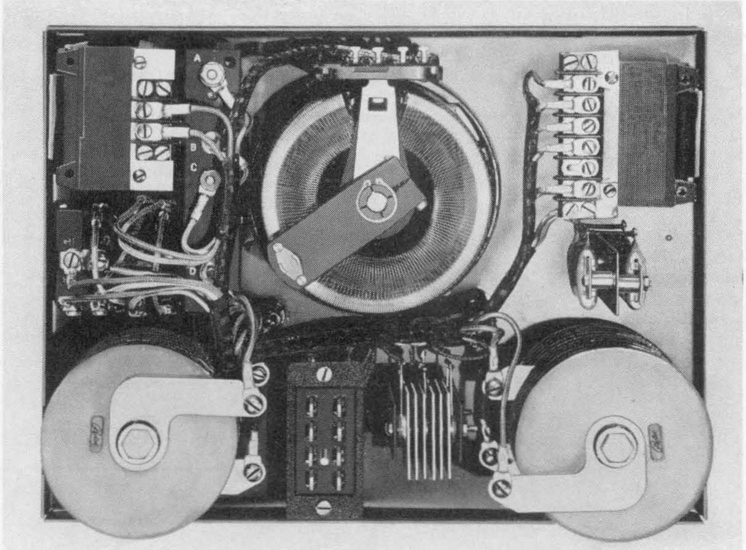


Figure 3. Interior view of the control showing simple construction resulting from use of selenium rectifiers.

in cooler operation of the control. Since there is no tube and no warm-up problem, the motor may be started or stopped by a switch in the a-c circuit, although the dynamic braking is not operative when this is done. Microswitches can be employed conveniently for limit switches in many applications because it is not necessary to interrupt the direct current in the armature circuit.

PERFORMANCE

Performance curves for the new control operating with a compound-wound motor are given in Figure 3. The regulation at base speed is about 24 per cent. With the series field disconnected, about 18 per cent regulation is obtained, but with appreciable reduction in starting torque. For most applications the compound connection is preferred because of the improved starting characteristics, although this consideration is not so important with ⅓ h.p. motors as with those of higher rating. Since the r.p.m. rise in speed between full load and no load is roughly the same at all speeds, the percentage regulation varies inversely as the speed setting. Even at the lower speed settings, however, the regulation has proved entirely satisfactory in a wide range of applications. Experience had proved that it is only the exceptional application which requires that speed be very closely held against load variations. For all ordinary applications, the inherently good regulation characteristics of the shunt motor, as provided by the Type 1700 Controls, are all that can be desired.

ONE MODEL ONLY — 115 VOLTS

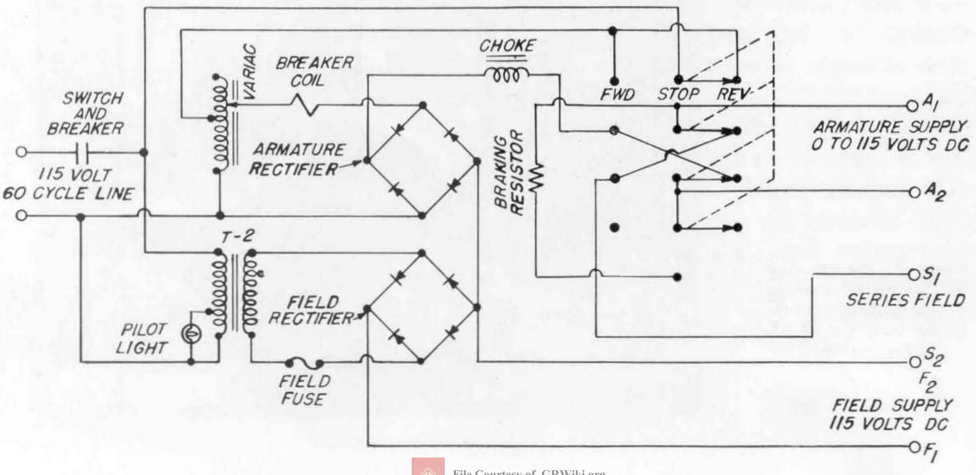
The Type 1700-B Control is available only for operation at 105-125 volts, 60 cycles. An equivalent 230-volt design is not practicable because the kva rating of the Variac is less at the higher voltage and because a more bulky and more expensive selenium rectifier would be required. Where 230-volt operation is required and the warm-up time delay is not a disadvantage, the Type 1700-AH Control is recommended. Where the instant-starting feature is desired with 230-volt operation, the Type 1700-B Control can be used with a 230-115-volt autotransformer of 600 va rating.

SUMMARY

To summarize,

(1) The new Variac control is simple and easy for shop electricians to understand.

Figure 4. Schematic circuit of the Type 1700-B Variac Speed Control.



(2) It is a rugged, long-life control that is essentially maintenance free.

(3) It is instant-starting, and adjustable speed is obtained without the complications inherent in the thyratron arrangements.

(4) It has a very large short-period overload capacity and is outstanding in its ability to start heavy loads quickly.

(5) The very low ripple in the armature circuit means that there are no torque pulsations and that standard motors can be used at their full rating.

This combination of characteristics makes these controls adaptable to a wide range of applications.

— W. N. Tuttle

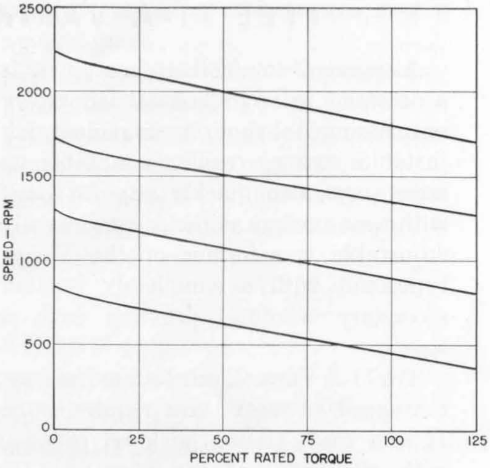


Figure 5. Speed-Torque curves of Type 1700-B Variac Speed Control operating a G.E. type BC Compound-Wound Motor rated $\frac{1}{3}$ h.p., 1725 rpm, 115 v, 3.0 a input.

SPECIFICATIONS

Supply Frequency: 60 cycles

A-C Input Voltage: 105-125

D-C Output Armature Voltage: 0-115

Continuous D-C Output Armature Current: 3.0 a

D-C Output Field Voltage: 115, 75

Maximum D-C Output Field Current: 0.4 a

Input Power: Stand-By, 38 watts
Full Load, 560 watts

Speed Range: Motor rated speed down to zero at constant torque.

Motor: 115-v D-C shunt or compound motor of $\frac{1}{3}$ h.p. rating, or other motors operating within the continuous armature current rating of 3.0 amperes, may be used with the control. A motor with a commutating pole is preferable because improved commutation is obtained over the speed range. We can supply the motor listed below. Motors of other manufacture can be used equally well.

Overload Protection: A time-delay magnetic circuit breaker permits heavy starting currents of short duration, but protects the control and motor in event of a stall. Breaker will open between 3.5 and 4.35 amperes armature current on sustained overload, but will permit a starting current inrush of 12 amperes for 3 seconds.

Reversal and Dynamic Braking: A manually operated start-stop-reverse switch and a dynamic braking resistor are included in the control. Strong braking action is obtained in the stop position.

Mounting and Wiring: Holes are provided in the back of the box for mounting on a wall or bracket. Mounting must be vertical and must permit free access of air through the bottom of the cabinet. Two holes for BX or conduit wiring are located in the center of the bottom of the box.

Domensions: Box, $9\frac{5}{16}$ x $12\frac{3}{8}$ x $4\frac{5}{8}$ inches; dimensions over knobs and louvers, $9\frac{5}{16}$ x $12\frac{3}{4}$ x 6 inches.

Net Weight: $23\frac{1}{2}$ pounds, GE motor 30 pounds.

Type		*Code Word*	*Price*
1700-B	**Variac Speed Control,* 115 v, 60 cycles.......**	AFOOT	**$165.00**
BC46AB29	**GE $\frac{1}{3}$ h.p. Semi-enclosed 1750 rpm motor, 115 v, dc, for use with Type 1700-B.................**	MOTOR†	**45.79**

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*To order speed control with motor, use compound code word, AFOOTMOTOR.

†U.S. Patent No. 2,009,013.

TYPE 71-A VARIAC® TRANSFORMER

A source of low voltage, a-c power is a necessity in any electrical laboratory or experimental shop. A convenient, adjustable source, readily adaptable to many uses, can quickly pay for itself with time savings alone. A continuously adjustable transformer of the Variac type, but with a completely isolated secondary winding, provides such a source.

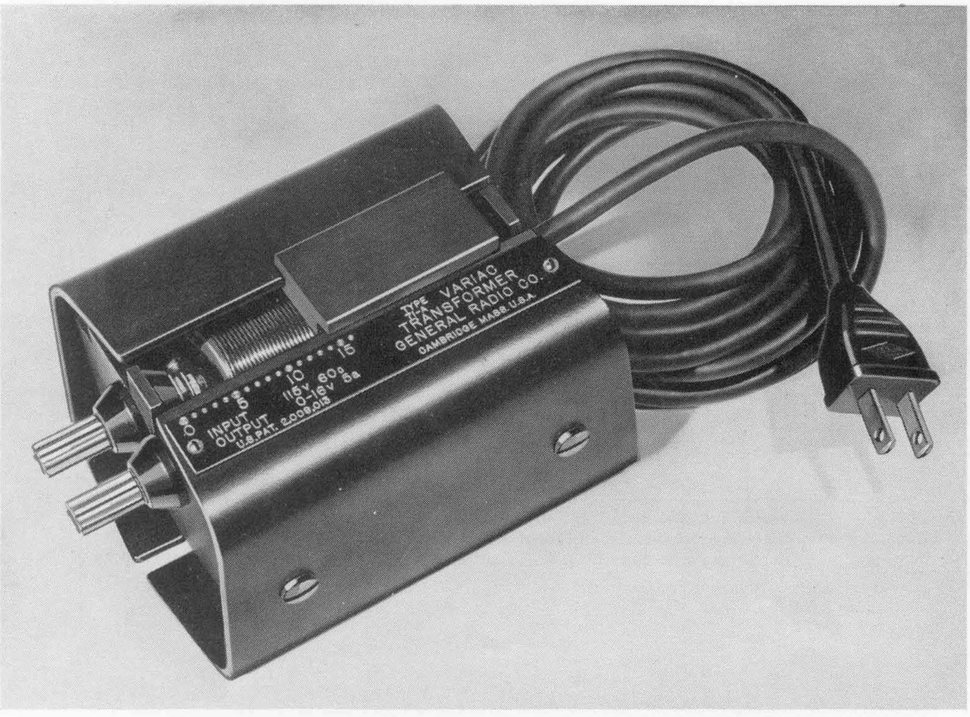
The 71-A Variac Transformer has been developed to meet these requirements. It is a ready-to-use, enclosed package with attached cord and plug for 115-volt, 60 cycle input, and a pair of versatile Type 938 Binding Posts to deliver 0 to 16 volts output.

The transformer is rated for 5 amperes continuous duty, with a conservative 50°C. internal temperature rise and an output regulation drop of less than 3 volts at full setting.

The basic unit is composed of two layer-wound primary coils on opposite legs of a conventional stack of L-type laminations plus two single-layer secondary coils wound over each of the primaries. The insulation between coils and to the core will withstand a 1250-volt breakdown test. The secondaries are tapped by a unique arrangement of two standard Variac brushes on a single aluminum radiator, which permits direct connections of the coils to both line and load without slip rings.

The simple, rugged enclosure is largely made up of two heavy aluminum U pieces, which are held so as to provide a ¼-inch mounting slot at the bottom and a guiding track for the slider carrying radiator and brushes at the top. This slider assembly is the only moving part.

The mounting slot permits securing the unit to a wall, out of working space,



or into a device as a permanent component.

The slider track is calibrated in open-circuit voltage for ready reference.

The limited voltage range makes this transformer particularly safe for experimental work, the isolated secondary permits its use in floating circuits, and the continuous adjustment is convenient in compensating for voltage fluctuation or in determining performance over a voltage range.

We have found this device extremely useful for controlling the small low-voltage soldering irons used in miniature work, as a filament supply on breadboard models, as an intensity control for microscope lamps, and in many other applications.

— H. M. Wilson

SPECIFICATIONS

Input Voltage: 115 volts

Output Current: 5 amperes maximum

Output Voltage: 0-16 volts open circuit
0-13 volts at 5 amp.

No-Load Loss: Less than 5 watts

Dimensions: (Length) 5½ x (width) 3⅝ x (height) 3¼ inches, overall.

Net Weight: 4 pounds.

Type		*Code Word*	*Price*
71-A	**Variac Transformer***	POPPY	**$18.50**

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*U. S. Patent No. 2,009,013.

MISCELLANY

PAPERS — By W. R. Thurston, of General Radio's New York Office: "U-H-F Measuring Equipment," at the April 11 Meeting of the Lancaster Subsection, I.R.E., at Lancaster, Pa.

— By Frederick Ireland, of General Radio's Los Angeles Office: "Impedance Measurement Techniques at Frequencies between 50 and 1000 Mc," at the April Meeting of the Los Angeles Section, I.R.E.

— By William R. Saylor, of the Sales Engineering Department, Cambridge Office: "Some Recent Developments in the Instrument Field," at the March 27 Meeting of the Technical Group on Instruments and Measurements, Boston Section, A.I.E.E.

— By Donald B. Sinclair, Chief Engineer, and Arnold P. G. Peterson, Engineer: "A Single-Ended Push-Pull Amplifier," at the 1951 I.R.E. National Convention, New York, March 22.

— By Donald B. Sinclair, Chief Engineer: "Considerations in the Design of a Line of Inexpensive Test Equipment," at the New England Radio Engineering Meeting, Boston, April 21.

HONORS — At their 109th National Meeting, in New York on January 31, 1951, the American Meteorological Society gave its award for "outstanding services to the Society by an individual" to Henry S. Shaw of Westbrook, Maine. Mr. Shaw, now retired, was formerly Chairman of the Board of the General Radio Company.

RECENT VISITORS from ABROAD

From Sweden:

Tord Bohlin, Chief Development Engineer, A. B. Refa, Stockholm; B. G. Lindbeck, Chief, Measuring and Physical Department, SKF Laboratories, Gothenburg.

From Switzerland:

Robert Goldschmidt, Head, Research and Development Department, Cableries et Trefileries de Cossonay S. A., Cossonay; Gustave Guanella, Head, H-F Research Department, and Rene Kunzli, Assistant to Chief of H-F Construction Department, Brown-Boveri and Co. A.G., Baden.

From South Africa:

Dr. J. C. R. Heydenrych, National Physical Laboratory, South African Council for Scientific and Industrial Research, Pretoria.

From India:

S. K. Chatterjee, Lecturer, Department of Electrical Communication, Indian Institute of Science, Bangalore, India.

From Australia:

John A. Paton, Managing Director, and B. F. Israel, Sales Manager, Transmission Products Pty., Ltd., North Sydney.

From Japan:

M. Tomota, Director and Chief Engineer, Yokogama Electric Works, Ltd., Tokyo; Toshifusa Sakamoto, Department of Electrical Engineering, First Faculty of Engineering, University of Tokyo; and Dr. Takashi Isobe, Professor, Department of Electrical Measurements, Faculty of Engineering, University of Tokyo.

APPARATUS FOR NOISE MEASUREMENT

An excellent summary of the important characteristics of noise-measuring equipment is contained in a paper by Dr. Leo L. Beranek, entitled "Apparatus for Noise Measurement." Originally prepared for the National Noise Abatement Council, this paper has also been presented before medical and industrial hygiene groups. The general requirements for a sound-level meter are reviewed, and the characteristics of six types of microphones and six types of analyzers are discussed. Calibrating devices, vibration pickups, and recorders are also considered. The paper is directed to those responsible for the purchase and use of noise-measuring equipment in factories, law-enforcement agencies, business offices, medical clinics, and other organizations outside the engineering field. Copies are available on request to the *General Radio Experimenter*.

CREDIT — Author of the article in the April issue, entitled "A Dynamic Microphone for the Sound-Level Meter," was Ervin E. Gross, of our Development Engineering Group.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE NEW TYPE 1432 DECADE RESISTORS

Also

IN THIS ISSUE

● **THE PRECISION DECADE RESISTOR** is as useful and as necessary in the electrical measurement laboratory of today as is the wrench or the screwdriver on the mechanic's bench. Such everyday items reach, over the years, a certain stability of design not enjoyed by their more glamorous cousins in new and rapidly moving fields. But even monkey wrenches are redesigned and improved as new materials and processes become available.

This spring the old familiar Type 602 Decade Resistor appears in new packaging and under a new type number. Although the new cabinet is the most visible feature, far more important are the increased accuracy and stability. The basic accuracy of the resistance units is now ±.05%, better by a factor of two than that of their predecessors. Such a change is not accomplished overnight — in anticipation of this move, about 90% of GR precision resistors have been within the new tolerances for the past several years, and a large percentage of the last production runs of the Type 602 met the accuracy specifications of the Type 1432.

A Type 1432 Decade Resistor consists of a combination of Type 510

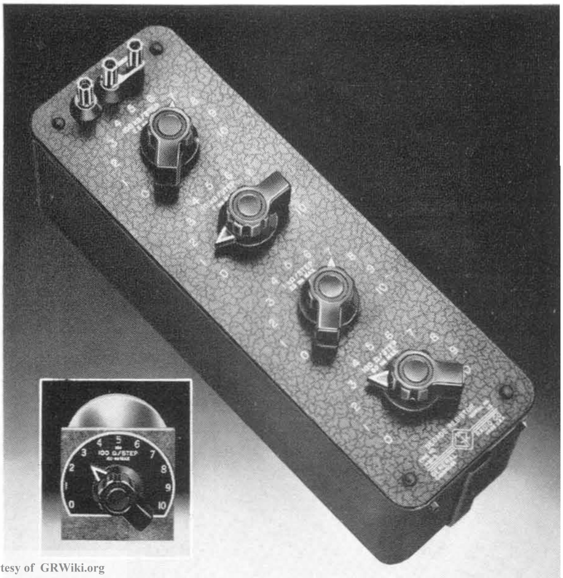

Figure 1. View of a Type 1432-A Decade Resistor. Inset at lower left shows Type 510-D Decade-Resistance Unit.

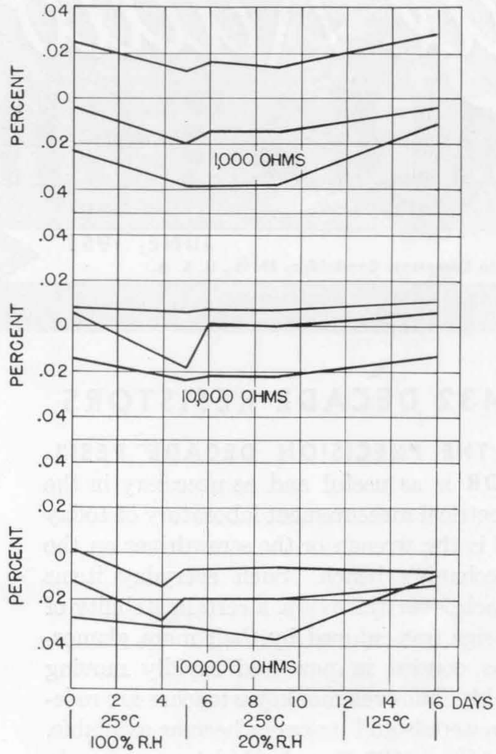

Figure 2. Measured deviations of typical resistance cards when subjected to extreme conditions of temperature and humidity. Long-term tests show a similar degree of stability.

Decade Resistance Units mounted on an aluminum panel and encased in a welded aluminum cabinet. Ample mechanical strength is assured by the use of 3/16-inch panel and 1/8-inch walls. A considerable reduction in volume is realized — 1/8-inch aluminum replacing 5/8-inch hardwood reduces both width and length by a full inch. Excellent electrostatic shielding and good thermal characteristics are also assured by this construction. A separate binding post for connection to the case is provided, thus permitting shielding of the resistors whether used grounded or ungrounded. Other time-proved features, such as engraving the current carrying capacity of each decade on the panel, are included.

Whether sold separately or assembled into "resistance boxes," the TYPE 510 Decade Units carry the new accuracy specifications, which, in the following table, are compared to the old.

Type	*Resistance per Step*	*Percent Tolerance New*	*Percent Tolerance Old*
510-A	.1 Ω	±0.5	±1.0
510-B	1. Ω	±0.15	±0.25
510-C	10. Ω	±0.05	±0.10
510-D	100. Ω	±0.05	±0.10
510-E	1000. Ω	±0.05	±0.10
510-F	10. kΩ	±0.05	±0.10
510-G	100. kΩ	±0.05	±0.10

Mere accuracy of adjustment, however, is not sufficient in a laboratory resistor. The stability of resistance value is equally important, if not more so. The resistor units used in General Radio Decades have a stability considerably better than the accuracy of adjustment and can be expected to stay within their specified tolerances well beyond the one-year warranty period.

Both the improved accuracy and greater stability result largely from the use of new resistance alloys made available during the past decade. These improved alloys have a low temperature coefficient that is substantially constant over a wide range of operating temperature, a high specific resistivity low thermal emf to copper, and a remarkable insensitivity to changes in resistance induced by mechanical strain. Furthermore, fine wire drawn of these alloys is much less susceptible to deterioration under conditions of high humidity than are the older alloys.

The new alloys are used in the 100 Ω, 1 kΩ, 10 kΩ, and 100 kΩ units. Manganin is still used in the lower-resistance units, where wire diameter is larger and atmospheric conditions are not so significant in determining long-time stability.

Figure 2 shows the performance of groups of 1 kΩ, 10 kΩ, and 100 kΩ cards

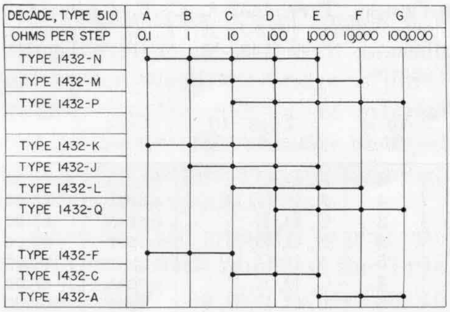

Figure 3. Chart showing the ranges of Type 1432 Decade Resistors currently available.

recently taken at random from production stock and subjected to temperature and humidity cycling. The excellent performance on these accelerated short-term tests has been duplicated by long-term tests over a period of years. Groups of these resistance units, used as working standards in our shops and laboratories, have shown a stability of better than 0.01% under constant usage over a period of years.

The 100,000-ohm unit is a new design, replacing the spool-wound resistors formerly employed for this resistance value. The winding form is a thin mica card of the type employed successfully for over twenty years in 1000-ohm and 10,000-ohm units. The high-resistivity alloy, in a wire having a diameter of one-thousandth of an inch, allows the desired resistance to be wound on a form of substantially the same size as used for lower-resistance units. These new 100,000 ohm cards result not only in improved performance but also in a reduction in the price of the TYPE 510-G Decade Resistance Unit, which uses ten of these cards.

The TYPE 1432 Decade Resistor is offered in three-, four-, and five-decade boxes in a total of ten different combinations. Included in these are four boxes containing the one-megohm decade, TYPE 510-G. With seven decades having increments per step ranging from 0.1 ohm to 100 kΩ, there are three possible 5-dial combinations, four possible 4-dial combinations, and five possible 3-dial combinations. Figure 3 indicates, by type number, the combinations available. The suffix letter formerly used is retained—thus TYPE 602-J is replaced by TYPE 1432-J.

— IVAN G. EASTON

SPECIFICATIONS

Frequency Characteristics: Identical with those of the previous design, TYPE 602. A discussion of the frequency characteristics of these resistors will be found in the *Experimenter* for December, 1940, under the title "Radio Frequency Characteristics of Decade Resistors."

Residual Impedances:

Zero Resistance (R_o): 0.002 to 0.003 ohm per dial at dc; 0.04 ohm per dial at 1 Mc; proportional to square root of frequency at all frequencies above 100 kc.

Zero Inductance (L_o): 0.10 μh per dial.

Effective Shunt Capacitance (C): This value is determined largely by the highest decade in use. With the LOW terminal connected to shield, a value of 15 to 10 $\mu\mu$f per decade may be assumed, counting decades down from the highest. Thus, if the third decade from the top is the highest resistance decade in circuit (i.e., not set at zero), the shunting terminal capacitance is 45 to 30 $\mu\mu$f. If the highest decade in the assembly is in use, the effective capacitance is 15 to 10 $\mu\mu$f, regardless of the settings of the lower-resistance decades.

Temperature Coefficient of Resistance: Less than ±0.002% per degree Centigrade at room temperatures, except for the 0.1 Ω decade, where the box wiring will increase the over-all temperature coefficient.

Accuracy of Adjustment: All cards are adjusted within ±0.05% of the stated value between card terminals, except the 1-ohm cards which are adjusted within ±0.15% and the 0.1-ohm units which are adjusted within ±0.5%.

Maximum Current: Same as for previous models, TYPE 602. Values for 40° Centigrade rise are engraved on panels directly above switch knobs.

Terminals: Jack-top binding posts set on General Radio standard ¾-inch spacing. Shield terminal is provided.

Mounting: Aluminum panel and cabinet.

Dimensions: Width, $4\frac{5}{16}$ inches; height, $4\frac{11}{16}$ inches; length, $10\frac{5}{16}$ inches for 3-dial, 13 inches for 4-dial, and $15\frac{3}{4}$ inches for 5-dial box.

Net Weight: TYPE 1432-A, C, F, 4 pounds, 2 ounces; TYPE 1432-J, K, L, Q, 5 pounds, 2 ounces; TYPE 1432-M, N, P, 6 pounds, 5 ounces.

Type	*Resistance*	*No. of Dials*	*Type 510 Decades Used*	*Code Word*	*Price*
1432-F	**111 ohms total, in steps of 0.1 ohm**	3	A, B, C	DELTA	**$ 56.00**
1432-K	**1,111 ohms total, in steps of 0.1 ohm**	4	A, B, C, D	DEFER	**75.00**
1432-C	**11,100 ohms total, in steps of 10 ohms**	3	C, D, E	DEBAR	**65.00**
1432-J	**11,110 ohms total, in steps of 1 ohm**	4	B, C, D, E	DEBIT	**83.00**
1432-N	**11,111 ohms total, in steps of 0.1 ohm**	5	A, B, C, D, E	DEMON	**99.00**
1432-L	**111,100 ohms total, in steps of 10 ohms**	4	C, D, E, F	DECAY	**87.00**
1432-M	**111,110 ohms total, in steps of 1 ohm**	5	B, C, D, E, F	DEMIT	**107.00**
1432-A	**1,110,000 ohms total, in steps of 1000 ohms**	3	E, F, G	DEMUR	**96.00**
1432-Q	**1,111,000 ohms total, in steps of 100 ohms**	4	D, E, F, G	DEPOT	**113.00**
1432-P	**1,111,100 ohms total, in steps of 10 ohms**	5	C, D, E, F, G	DETER	**133.00**

TYPE 510 DECADE-RESISTANCE UNIT

For building into the equipment, the individual resistance decades used in the TYPE 1432 Decade Resistors are available as the TYPE 510 Decade Resistance Units.

Accuracy specifications are given in the table on page 2. Other specifications remain unchanged from previous models. Units are supplied complete with dial plate, knob, and drilling template. See also photograph on page 1.

Type	*Resistance*		*Code Word*	*Price*
	Total	*Per Step*		
510-A	**1 ohm**	**0.1 ohm**	ELATE	**$12.00**
510-B	**10 ohms**	**1 ohm**	ELDER	**14.00**
510-C	**100 ohms**	**10 ohms**	ELEGY	**14.00**
510-D	**1,000 ohms**	**100 ohms**	ELBOW	**16.50**
510-E	**10,000 ohms**	**1,000 ohms**	ELECT	**18.50**
510-F	**100,000 ohms**	**10,000 ohms**	ELVAN	**21.50**
510-G	**1,000,000 ohms**	**100,000 ohms**	ENTER	**40.00**

A MULTIRANGE FILTER FOR AUDIO AND ULTRASONIC AMPLIFIERS

The TYPE 1231-B Amplifier and Null Detector has proved a useful instrument for balancing impedance bridges at audio and ultrasonic frequencies up to about 100 kc. In order to eliminate harmonics and minimize background noise, amplifier selectivity, even at the expense of some insertion loss, is almost universally desirable. Antiresonant *L-C* filters, tuned for 60 cycles (TYPE 1231-P2) and for either 400 cycles or 1 kc (TYPE 1231-P3), have been available to convert the TYPE 1231-B into a tuned amplifier at these specific frequencies.

The new TYPE 1231-P5 Filter extends the frequency range and provides tuning at eleven discrete frequencies at which impedance measurements are frequently made, namely, 50, 100, 200, and 500 cycles and 1, 2, 5, 10, 20, 50, and 100 kc. This filter is particularly useful in dielectric measurements with the TYPE

716-C Capacitance Bridge, since it provides fixed tuning at 0.1, 1, 10, and 100 kc for which the bridge is direct reading. By the addition of external capacitance, this filter can also be tuned to any other frequency within the range from 20 cycles to 100 kc.

While designed primarily to plug into the Type 1231-B Amplifier, the Type 1231-P5 Filter can also be used as an antiresonant *L-C* element in the grid circuit of *any* low-level Class A amplifier where it is not subjected to a d-c current. The resulting selectivity and insertion loss will then be a function of frequency and the parameters of the amplifier circuit.

High selectivity over such an extended frequency range, combined with reasonable insertion loss, necessitates the use of four separate inductors: *L*-1 (20 henrys) for 50 and 100 cycles, *L*-2 (2 henrys) for 200 and 500 cycles, *L*-3 (300 millihenrys) for 1, 2, and 5 kc, and *L*-4 (15 millihenrys) for 10, 20, 50, and 100 kc. Each inductor is a symmetrically wound toroid and is distinctly more astatic than the shell-type inductors used in the older Types 1231-P2 and -P3 Filters. Low-loss polystyrene or mica capacitors are used throughout.

The *L*-3 and *L*-4 inductors utilize molybdenum-permalloy dust cores having effective permeabilities of 125 (*L*-3) and 26 (*L*-4). These have negligible temperature and voltage coefficients of inductance and are ideal for the purpose. The *L*-4 inductor is wound with Litzendraht to minimize eddy current copper losses at the high frequencies used.

To achieve the desirable high *Q* at 500 cycles and below, a "solid" core is required. Accordingly, the *L*-1 and *L*-2 inductors are wound on "centricores" fabricated by spiral-winding thin tape on a mandrel with appropriate insulation and subsequent annealing. A ferromagnetic alloy having a small voltage coefficient of inductance is used.

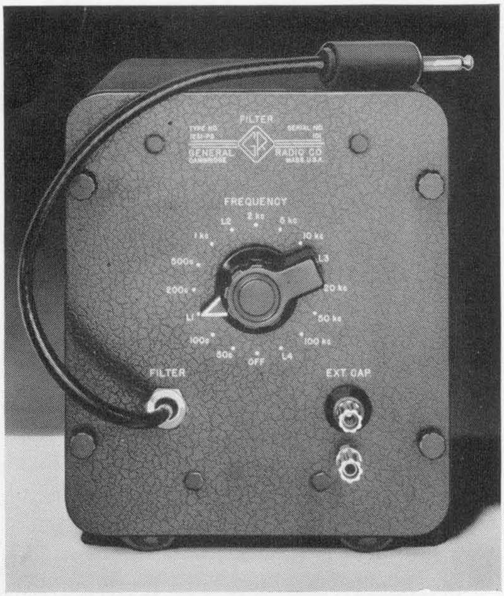

Figure 1. Panel view of the Type 1231-P5M Filter.

The filter elements and selector switch are enclosed in an aluminum chassis which, in turn, is mounted in an aluminum cabinet having an external black crackle finish and rubber feet. Good electrostatic as well as electromagnetic shielding is thereby provided. A shielded cord terminated with a standard telephone-type plug permits the selected filter circuit to be introduced into the grid circuit of the last stage of the Type 1231-B Amplifier. The filter circuits have a common terminal which is grounded to the chassis. Both terminals of the filter are available on the front panel for attaching external capacitors if desired.

The sixteen-position selector switch has an off position (giving an aperiodic amplifier), eleven positions providing, directly, the aforementioned discrete frequency values, and four positions which individually connect the four inductors across the filter terminals with only a small amount of internal capacitance.

An antiresonant filter network must be designed as a compromise between a tolerable insertion loss and a desirable discrimination against, say, the second harmonic of the operating frequency. Typical data obtained with the four inductors, precisely tuned and inserted into the TYPE 1231-B Amplifier, are shown in Figures 2 and 3. The dots indicate the eleven discrete frequency values. These data were taken at low level when the open-circuit output voltage of the amplifier was 0.2 volt. As the operating level is raised, hysteresis core loss necessarily increases the insertion loss at a given frequency and decreases the discrimination. From these data one can choose which inductor to tune for any desired operating frequency.

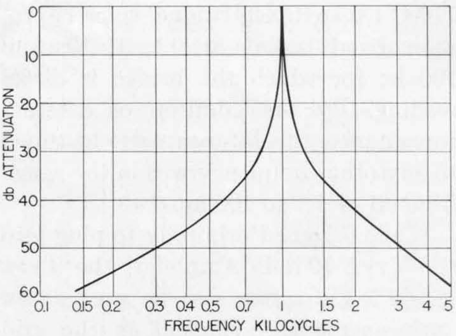

Figure 4. Selectivity curve for the 1-kc filter and Type 1231-B Amplifier. Values of second harmonic discrimination for the other filters are given in Table I, below.

Typical low-level characteristics of the TYPE 1231-P5 Filter, when used with the TYPE 1231-B Amplifier and Null Detector, are given in Table I which lists the resonant impedance in megohms, the resonant *Q*, the insertion loss (or gain) in db, and the selectivity, i.e., the discrimination in db against the second harmonic.

TABLE I

Frequency	*Inductor Used*	*Resonant* Z MΩ	*Resonant Q*	*Insertion db*	*Discrimination vs. 2nd Harmonic db*
50 c	*L*-1	0.28	45	6.4 loss	33
100 c	*L*-1	1.02	81	2.7 loss	31
200 c	*L*-2	0.21	84	7.3 loss	40
500 c	*L*-2	0.52	83	4.2 loss	35
1 kc	*L*-3	0.26	138	7.8 loss	42
2 kc	*L*-3	0.86	228	3.0 loss	40
5 kc	*L*-3	2.70	287	1.9 gain	34
10 kc	*L*-4	0.17	175	3.8 loss	46
20 kc	*L*-4	0.50	262	2.2 gain	44
50 kc	*L*-4	1.06	214	5.6 gain	37
100 kc	*L*-4	2.13	192	7.4 gain	28

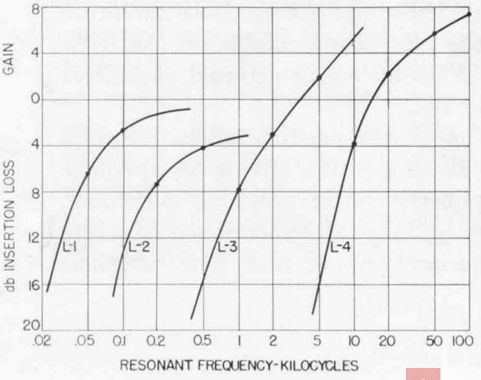

Figure 2. Low-level insertion loss versus resonant frequency for each of the four inductors.

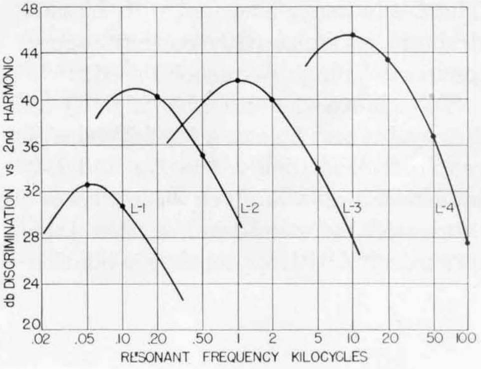

Figure 3. Low-level second harmonic discrimination versus resonant frequency for each of the four inductors.

As seen from Figures 2 and 3, a higher discrimination, at the expense of increased insertion loss, can be obtained at 100 cycles, 500 cycles, and 5 kc by tuning the *L*-2, *L*-3, and *L*-4 inductors with appropriate external capacitance. Plotted on a logarithmic scale, Figure 4, the selectivity curves (attenuation vs. frequency) are roughly symmetrical except as modified by the transmission curve of the amplifier.

The filter elements are calibrated with sufficient precision so that resonant peaks occur within ±2% of each of the eleven nominal frequency values. Within these limits, which are ordinarily close enough for the majority of bridge measurements, this filter may be used to set an adjustable non-calibrated or crudely calibrated oscillator at the desired operating frequency. On the other hand, it must be remembered that, without external capacitance, these eleven *L-C* circuits are highly resonant fixed-frequency filters, so that the operating frequency must be close to the nominal value if a minimum insertion loss (i.e., maximum amplifier gain) is to be realized.

The filter circuits are calibrated at normal room temperature and at close to zero level, which is the pertinent consideration for use as a resonant filter in a null detector. Unavoidably, the centricore inductors *L*-1 and *L*-2 (50, 100, 200, and 500 cycle filters) have noticeable positive temperature and voltage coefficients of inductance. The corresponding negative temperative coefficient of frequency is about 0.08% per degree Centigrade. The voltage coefficient, which is due to the increase of normal permeability with induction, reduces the resonant frequency by about 6% per volt impressed on the filter at 50 cycles and proportionately less at higher frequencies. These coefficients are ordinarily negligible in the dust-core inductors *L*-3 and *L*-4.

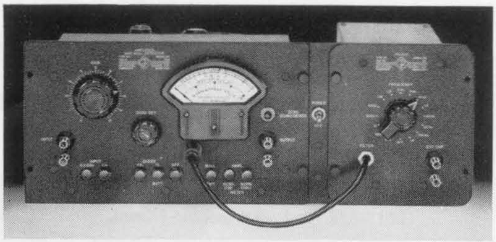

Figure 5. View of the Type 1231-P5R Filter arranged for relay-rack mounting with the Type 1231-B Amplifier and Null Detector. The filter panel attaches to the amplifier panel to make the assembly the correct width for mounting in a 19-inch relay rack. The narrow strip between the two panels carries a switch for the a-c power supply that is optional with the amplifier.

CAUTION: This TYPE 1231-P5 Filter should at no time be subjected to any d-c current. The very appreciable magnetic memory possessed by the centricore inductors would result in a residual magnetization. It would then be difficult to remove this and to restore the initial permeability at which these inductors were calibrated. A definite, more-or-less permanent, offset of the resonant frequencies from their nominal values would thereby occur. When used with the TYPE 1231-B Amplifier and Null Detector, the inductors do not carry any d-c current.

— HORATIO W. LAMSON

SPECIFICATIONS

Nominal Operating Frequencies: 50, 100, 200, 500 cycles; 1, 2, 5, 10, 20, 50, 100 kc.

Frequency Calibration: Within ±2%.

Insertion Loss: Between 6-db loss and 6-db gain, depending upon frequency.

Selectivity: Better than 30 db against the second harmonic.

Terminals: Shielded cord and plug for connection to TYPE 1231 Amplifier and Null Detector. Jack top terminals for connecting external capacitors.

Mounting: Aluminum cabinet for bench use. Also available for relay rack mounting in conjunction with TYPE 1231-B Amplifier and Null Detector. See price list below.

Dimensions: Front panel, (height) 7″ x (width) 6⅛″. Cabinet, (depth) 9¾″. Internal shield box, (height) 6¼″ x (width) 4½″ x (depth) 9″.

Net Weight: Complete 9 lb. 12 oz.

Type		*Code Word*	*Price*
1231-P5M	**Adjustable Filter (cabinet model)**	ALDER	**$215.00**
1231-P5R	**Adjustable Filter (relay-rack model)**	ADOBE	**215.00**

MISCELLANY

SPEAKERS — Harold B. Richmond, Chairman of the Board, General Radio Company, was the principal banquet speaker at the National Conference on Airborne Electronics sponsored by the Dayton Section, I.R.E., at Dayton, Ohio, May 23-25. His subject — "Diplomacy and the Changing Radio Relationships Between the United States and Europe."

Also at the Airborne Electronics Conference, Robert A. Soderman and W. M. Hague, Jr., of General Radio's Engineering Department presented a paper entitled, "Measurements to 2000 MC, with the V-H-F Admittance Meter."

HUMIDITY — Each year with the coming of warmer, more humid weather in the northern hemisphere, we remind our readers that high relative humidity sometimes has baffling and annoying effects on electrical measurements. A reprint from the *Experimenter*, entitled "The Effect of Humidity on Electrical Measurements," is helpful in identifying these effects and in preventing them. Ask for a copy.

SUMMER CLOSING

VACATION — During the weeks of July 22 and July 29 most of our employees will be vacationing. Manufacturing departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

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THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VOLUME XXVI No. 2 JULY, 1951

NEW UNIT INSTRUMENTS
POWER SUPPLIES — MODULATOR

Also

IN THIS ISSUE

Page

● **GENERAL RADIO UNIT INSTRUMENTS** are laboratory-grade instruments designed to sell at moderate prices. Their design is based on two fundamental concepts. The first of these is that functions common to several instruments, such as power supply, or modulator, should not be re-embodied in each assembly but should be isolated and packaged separately in individual units. The second is that each unit should be simple, electrically and mechanically. These units plug into one another, connect to one another, or are used with one another to form assemblies and systems for specific purposes.

Simplification of design has been a constant objective in the development, and standardized design has been adapted wherever it has seemed to offer possibilities of economy. At the same time, no concessions have been made in electrical characteristics, and the instruments offer high-grade performance as well as simple, compact, and rugged construction.

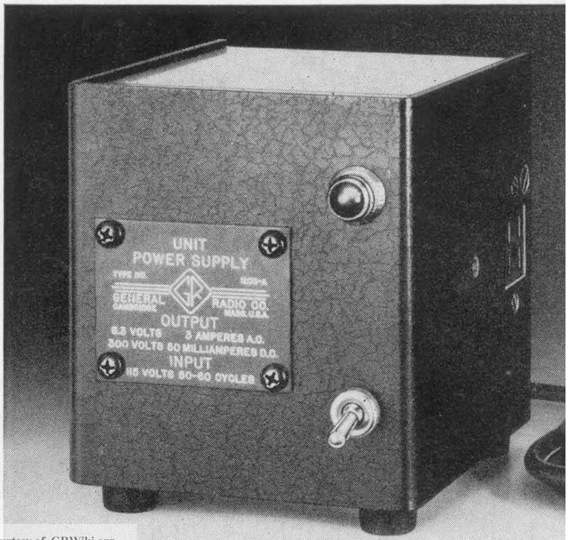

Figure 1. Panel view of the Type 1203-A Unit Power Supply.

Two unit oscillators, the Type 1208-A (50-500 Mc) and the Type 1209-A (250-920 Mc), were described in an earlier issue[1] of the *Experimenter*. This article describes two new power supplies and a simple two-frequency audio oscillator that can be used to modulate the u-h-f and v-h-f oscillators. It is planned to supplement these unit instruments with several others, which will be made available in the near future.

TYPE 1203-A UNIT POWER SUPPLY

The basic Unit Power Supply is the Type 1203-A, which supersedes the Type 1205-A. The new unit, which is designed to supply plate and cathode heater power to the unit oscillators and other unit instruments, is improved both electrically and mechanically over the older model. Supplying 50 milliamperes at 300 volts and 3 amperes at 6.3 volts, this unit is also useful as a general-purpose laboratory supply for low-power equipment. Unit instruments plug into the multipoint connector on one side of the assembly, and a mating plug is furnished for making connections to other equipment.

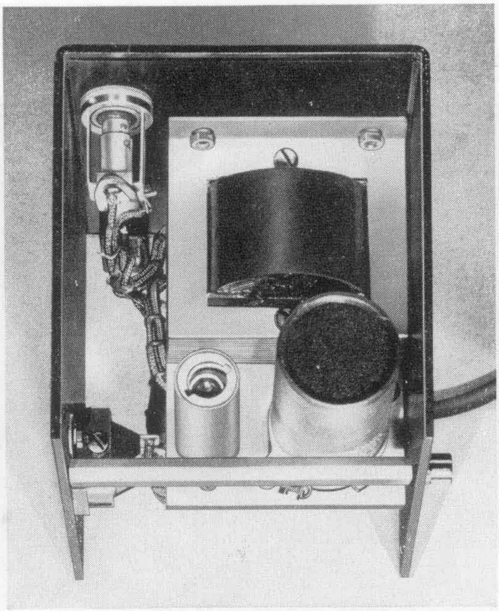

Figure 2. Top interior view of the Type 1203-A Unit Power Supply.

The mechanical design features of this power supply, which are also common to the other two instruments, have been developed to reduce the cost of construction.

The cabinet, shown in Figure 1, consists of two U-shaped aluminum pieces, one forming the front panel and the two ends, and the other the top, bottom, and back. The first piece is grooved at top and bottom to accommodate the second piece, which slides in the grooves. It is held in place by pinching the two sides of the first piece together with two screws and a tie-bar. Two sizes, the one housing the power supply illustrated, which is approximately a five-inch cube, and the other having a panel twice as wide, have been found sufficient to house the unit instruments so far developed.

Figure 2 shows the general internal construction. The clamps for the transformer have been bent up out of sheet aluminum, and the lower clamp extended to form the shelf on which are mounted the filter condensers and rectifier. The transformer terminal board carries the transformer terminals and the line fuses. The sandwich formed by the transformer assembly is complete in itself, comprising all electrical components but the pilot light, line switch, and Jones plug. It mounts on the panel with four screws.

It will be noticed from Figure 1 that a photo-etched nameplate carries all the instrument information. Since no serial number is included, there is no need for

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[1] Eduard Karplus, "V-H-F and U-H-F Unit Oscillators," *General Radio Experimenter*, Vol. XXIV, No. 12, May, 1950, pp. 7-11.

additional engraving, and substantial saving is effected at the same time that a maximum amount of information is presented. The nameplates used are made with square corners, so that they can be sheared out in various rectangular shapes without special punches, and the number of holes in them and the number of hole sizes are reduced to a minimum.

This power supply is small, convenient, and inexpensive. The construction is well adapted to get rid of heat by conduction to the panel, and the unit can supply 20 watts of heater power and 15 watts of plate power despite its small size.

SPECIFICATIONS

Output Voltages: 6.3 volts ac, nominal; 3 amperes maximum; 300 volts dc, 50 milliamperes maximum. No-load voltage is about 410 volts.

Hum Level: About 250 millivolts at 300 volts and 50 milliamperes d-c output.

Input: 115 volts, 50 to 60 cycles; 50 watts full load. A line-connector cord is permanently attached to the instrument.

Rectifier: One 6X4-type supplied.

Output Terminals: A standard multipoint connector is mounted on the side of the unit.

Accessories Supplied: A mating multipoint connector for connecting the power supply to other equipment; a 10-32 screw with wing nut for permanently attaching the power supply to other unit instruments. Also spare fuses.

Mounting: Black-crackle-finish panel and sides. Aluminum cover finished in clear lacquer.

Dimensions: (Width) 5 x (height) 5¾ x (depth) 6¼ inches, overall, not including power cord.

Net Weight: 5 pounds.

Type		*Code Word*	*Price*
1203-A	**Unit Power Supply**	ALIVE	**$47.50**

TYPE 1204-B UNIT VARIABLE POWER SUPPLY

This power supply is intended primarily for general-purpose use, where it is desirable to have a means of varying the output voltage.

As shown in Figure 3, the same general construction is used as in the TYPE 1203-A, but a meter has been added, the power output has been increased, and the high-voltage d-c output has been made continuously adjustable.

Since this power supply will be used extensively for experimental work in which convenience of attaching wires is important, binding posts on the front panel have been added in parallel with the Jones plug connections. These are grouped at the left of the panel with all controls requiring identification. The output control knob at the right needs no legend, since its setting controls the

Figure 3. Panel view of the Type 1204-B Unit Variable Power Supply.

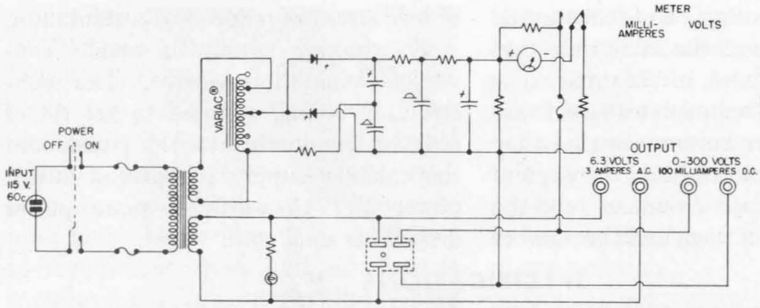

Figure 4. Circuit diagram of the Type 1204-B Unit Variable Power Supply.

meter reading, and its function is therefore obvious. The meter can be switched with the toggle switch to read either current or voltage.

A feature of the design of this power supply is the Variac®, which controls the a-c voltage to be rectified. It is used because it provides a continuous control to zero volts and because, being an autotransformer, it maintains a low source impedance at all settings. Since there is but one transformer in the instrument, and the Variac® used is a standard, 115-volt stock model, a novel circuit arrangement is used to provide a constant voltage of 6.3 volts ac and a continuously variable voltage of zero to 300 volts dc. This circuit is shown in Figure 4.

The power transformer isolates the output voltages from the line, furnishes the 6.3-volt heater supply, and provides a voltage for the Variac® augmented to about 17% above line voltage. The particular Variac® used will withstand this voltage, plus or minus 10%, at 60 cycles without excessive magnetization current, and will produce an output voltage adjustable between zero and 158 volts. A voltage-doubler rectifier circuit is used to produce the desired d-c output voltage.

SPECIFICATIONS

Output Voltages: 6.3 volts ac, nominal; 3 amperes maximum. The d-c output voltage is adjustable from zero to 300 volts with a maximum load of 100 milliamperes. No-load maximum, 400 volts.

Meter: A panel meter indicates the d-c output voltage and current.

Hum Level: About 250 millivolts at 300 volts, 100 milliamperes d-c load; about 150 millivolts at 350 volts, 50 milliamperes d-c load.

Input: 115 volts at 60 cycles; 75 watts at full output load. A line-connector cord is permanently attached to the instrument.

Rectifier: Two selenium rectifiers used in a voltage doubling circuit.

Output Terminals: Insulated binding posts on panel and a standard multipoint connector on the side of the instrument.

Accessories Supplied: Spare fuses; a mating multipoint connector.

Mounting: Black-crackle-finish panel and sides. Aluminum cover finished in clear lacquer.

Dimensions: (Width) 9⅞ x (height) 5¾ x (depth) 6¼ inches, not including power cord.

Net Weight: 9¾ pounds.

Type		*Code Word*	*Price*
1204-B	**Unit Variable Power Supply**	AGATE	**$85.00**

U. S. Patent No. 2,009,013.

TYPE 1214-A UNIT OSCILLATOR

This simple two-frequency oscillator (400 and 1000 cycles), shown in Figure 5, is useful as a modulating source for high-frequency oscillators such as the Type 1208-A and the Type 1209-A and as a general-purpose laboratory source for bridge measurements.

It will furnish approximately 0.2 watt to a balanced or unbalanced 8000-ohm load at less than 2% distortion.

Its most striking feature is that it violates the fundamental concept of the unit line by incorporating its own power supply. This was justified as an economy because an iron-coil inductor is used as the tuning inductance of a Hartley circuit, and an output coupling coil, wound on the same core, can be used to isolate the output terminals from any direct connection to the oscillator. A Type 117N7-GT Diode-Pentode tube, used as a voltage-doubler, can then be worked directly off the line without danger of cross-up of grounds on load and a-c line.

A small thyrite piece is used from grid to ground to limit the oscillator amplitude. The third-harmonic limiting resulting from the symmetrical current-voltage characteristic contributes substantially to the low distortion of the oscillator and helps to maintain stability of output as the line voltage is varied.

Figure 5. Panel view of the Type 1214-A Unit Oscillator.

SPECIFICATIONS

Frequency: 400 and 1000 cycles, accurate to ±2%.

Output: The maximum output power is over 200 milliwatts; the output impedance is about 8000 ohms with the (10 kΩ) output control at maximum. Open-circuit voltage about 80 volts.

Distortion: Less than 3% into matching load.

Output Circuit: The output can be isolated from ground for using the oscillator as a modulator in the plate circuit of a high-frequency oscillator, such as the Type 1208-A or the Type 1209-A. The output control is adequate for external d-c currents as great as 36 ma in the output circuit.

Controls: A toggle switch to select frequency, an output control, and a power switch.

Terminals: Jack-top binding posts with standard ¾-inch spacing; a ground terminal is provided.

Power Supply: 115 volts, 40-60 cycles, 16 watts.

Accessories Supplied: Spare fuses.

Tube: One 117N7-GT supplied.

Mounting: Black-crackle-finish panel and sides. Aluminum cover finished in clear lacquer.

Dimensions: (Height) 5¾ x (width) 5 x (depth) 6¼ inches, overall, not including power cord.

Net Weight: 4½ pounds.

Type		*Cord Word*	*Price*
1214-A	**Unit Oscillator** (including power supply)	ALLAY	**$60.00**

Licensed under patents of the Radio Corporation of America.

General Radio Unit Instruments are inexpensive high-quality instruments for use in laboratories operating on limited budgets. The instruments described here, in conjunction with the previously described U-H-F and V-H-F Unit Oscillators[2] and the appropriate Type 874 Coaxial Elements, make it possible to assemble many specialized setups by the building-block method. Thus, signal generators, test oscillators, heterodyne-detection systems, voltage calibrators, etc., can be made available by simply plugging together elements already available in the laboratory.

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[2] See Footnote 1.

HARMONIC GENERATION IN THE U-H-F REGION BY MEANS OF GERMANIUM CRYSTAL DIODES

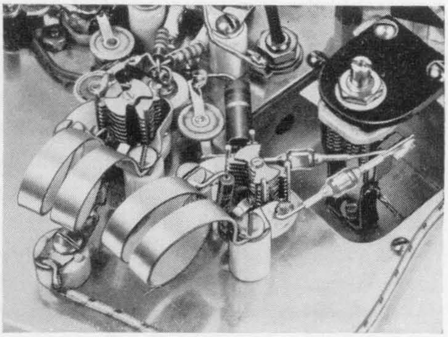
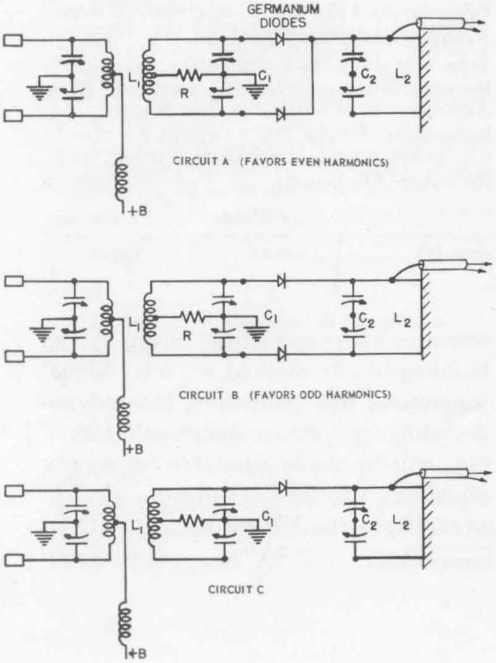


Figure 2. View of the harmonic generator incorporating the circuits of Figure 1.

In the course of the development of u-h-f monitoring equipment, it has been necessary to provide frequency multipliers to generate selected harmonics of the reference crystal oscillator. For frequencies below 300 Mc, conventional miniature receiving-type vacuum tubes work well as amplifiers or harmonic generators, and there is little temptation to explore unconventional methods of frequency multiplication. At frequencies above 300 Mc, however, difficulties arise and become increasingly important as the frequency is raised. For monitoring applications, output powers of the order of 10 to 20 milliwatts are satisfactory for use in mixer stages to convert the u-h-f signal to the desired intermediate frequency. It is somewhat surprising to find that powers far exceeding this level can be obtained from germanium crystal diodes operated as harmonic generators, as much as 60 milliwatts being available from a doubler stage at 500 Mc.

Figure 1. Circuits used for harmonic generation with germanium diodes.



The general considerations in the use of diodes as harmonic generators are similar for all frequencies. Power is fed in at the fundamental frequency and taken out at the desired harmonic. When germanium crystals are used, it has been found essential that a d-c bias be selected to produce the greatest output at the desired harmonic. The circuits should provide the proper impedances at the input and output frequencies and a means for providing bias. Either fixed d-c bias or self-bias can be used.

A form of this harmonic generating circuit is shown in the circuit diagram of Figure 1 and the photograph of Figure 2. Small butterfly-type condensers* are used, tuning a lumped-inductance circuit for the input and a capacitance-tuned parallel-wire line for the output circuit. The circuit shown covers 200-270 Mc at the input and 460-790 Mc at the output. It is connected as a push-

---

*Made by E. F. Johnson Co., Waseca, Minn.

push doubler for 460-540 Mc and as a push-pull tripler for 600-790 Mc.

The self-biasing arrangement used is shown in the photograph, the d-c resistance load being a compromise between the values which give the most output in the doubler and tripler connections. This value of bias resistor is also high enough to give some protection from burning out due to overheating caused by too high current. The available input voltage is not sufficient to cause crystal burnout from voltage alone, partly as a result of the dissipation in the crystal diodes which cuts down on circuit *Q*.

Various kinds of germanium crystal diodes were tried in order to select crystals that would be most effective for this type of application. The best crystals found were the 1N34A and 1N34, these types producing at least 20% more r-f power output than the other types tried. Crystals produced by different manufacturers show appreciable differences in power output. Types 1N21 and 1N21B silicon crystals were tried, but the maximum power output available from these is only approximately 30% of that produced by the germanium diodes in the 400-1000 Mc range.

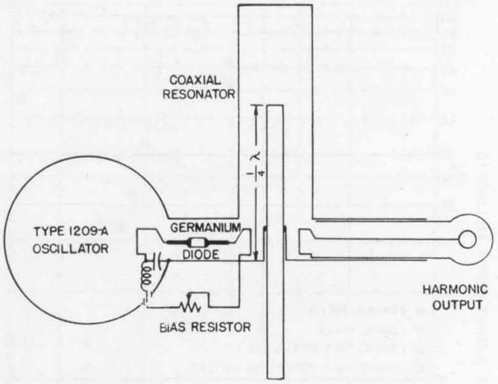


Figure 3. Circuit used in obtaining the data for Table II.

In Table I, below, is shown the maximum output power measured from various circuit arrangements with an input power of approximately 500 mw.

TABLE I

Circuit	*Input Frequency (Mc)*	*Output (Mc)*	*Output Power (mw)*
Figure A	267	534	63.0
Figure B	259	777	28.5
Figure C	259	518	50.5
Figure C	259	777	31.0

TABLE II

Single 1N34A Frequency Multiplier Driven from 1209-A Oscillator

Input Freq. (Mc)	*Harmonic*	*Output Freq. (Mc)*	*Output Power (Milliwatts)*	*Crystal Current (Ma)*	*D-C Load Resistance*
400	2nd	800	37	0.75	25 kilohms
400	3rd	1200	16.5	0.3	100 kilohms
400	4th	1600	5.5	0.3	100 kilohms
400	5th	2000	2.2	0.5	40 kilohms
500	2nd	1000	33	0.7	20 kilohms
500	3rd	1500	10.4	0.2	100 kilohms
500	4th	2000	2.2	0.2	100 kilohms
600	2nd	1200	22	0.45	20 kilohms
600	3rd	1800	4.4	0.3	40 kilohms
700	2nd	1400	17.6	0.4	20 kilohms
700	3rd	2100	2.2	0.15	100 kilohms
800	2nd	1600	6.6	0.5	12 kilohms
900	2nd	1800	2.4	0.3	12 kilohms

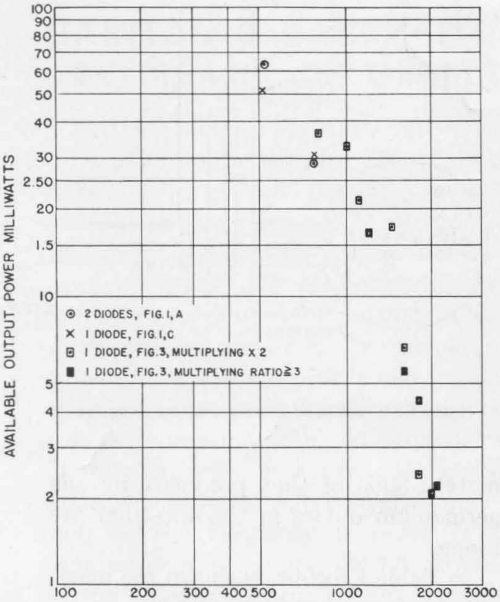


Figure 4. Maximum harmonic power output available from 1N34-A germanium diodes at various frequencies.

Further investigation of the power output capabilities of one type of germanium crystal as a function of frequency produced the data given in Table II. Input power was obtained from a General Radio Type 1209-A Unit Oscillator. The circuit, shown in Figure 3, used a coaxial-line resonator to select the output signal frequency, and the d-c load resistance was adjusted for maximum r-f output power. The maximum output power available at various output frequencies from 1N34A germanium diodes is summarized on the graph of Figure 4. The available input power was not accurately measured, but was probably a maximum of 500 mw at 400 to 500 Mc, falling off to near 100 mw at 900 Mc. Since germanium crystals are not very efficient rectifiers at frequencies above 100 Mc, the d-c crystal current is not an accurate indication of the input power.

The generally desirable features of the germanium-diode harmonic-generator circuit include (1) such items as lack of any tendency to oscillate, (2) small capacitances and inductances contributing less loading to the necessary tuned circuits, and (3) a power-handling capacity of the proper magnitude to take care of the local-oscillator signal level for a large variety of applications.

— Frank D. Lewis

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THE General Radio EXPERIMENTER

VOLUME XXVI No. 3 AUGUST, 1951

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A SAMPLE HOLDER FOR SOLID DIELECTRIC MATERIALS

Also

IN THIS ISSUE

● **A KNOWLEDGE** of the dielectric properties of insulating materials is important not only to the designer who utilizes such materials for insulation structures but also to the physicist and chemist who is concerned with the internal structure of the material. From either point of view, it is important to be able to make measurements over a wide range of frequencies. If the material is to be used as insulation, it is obviously desirable to obtain data at the frequency of use, while, if the fundamental structure of the material is of interest, the variations of dielectric constant and loss factor with frequency are clues to the chemical structure.

In the accepted method of evaluating the dielectric constant and dissipation factor, a capacitor is formed by placing the material between metallic electrodes. If the configuration of the electrodes is such that the distribution of the electric field is accurately known, the

Under the recent Order M-71 of the National Production Authority, assistance is provided to technical and scientific laboratories for the procurement of needed supplies and materials.

In accordance with the order, a laboratory may apply a new rating, DO-X1, to obtain delivery of products and materials needed to carry on scientific or technological investigations, testing or development or experimentation, provided that the total amount expended does not exceed $3,000 during any one quarter.

No further authorization is needed from the National Production Authority to use this rating, but all prospective users should consult the NPA Order M-71, which may be obtained from the nearest field office of the Department of Commerce, before applying the rating, as its use is necessarily restricted.

The order also provides a means for laboratories to obtain certain amounts of controlled materials under the Controlled Materials Plan.

constants of the material can be determined from the electrical measurements. Among structures readily calculable are parallel plates and concentric cylinders. At power, audio, and radio frequencies to 100 megacycles and more, parallel plates are used whenever possible because of the relative ease of preparing a specimen. In a two-electrode plane system, a circular electrode is most widely used because the field configuration is symmetrical and most readily calculated.

At frequencies in the megacycle range, the inductance and resistance of leads connecting the electrode system to the measuring circuit can introduce error and must be considered. In a classical paper, Hartshorn and Ward* described a method of essentially eliminating lead impedance by combining the measuring capacitor and the electrode system and using a substitution method of measurement. This type of holder is generally recognized as the most satisfactory for measurements at radio frequencies. It is recognized in ASTM Specification D-150 for use in the frequency range from 0.1 Mc to 100 Mc.

The Type 1690-A Dielectric Sample Holder, shown in Figure 1, is a micrometer-type holder of the Hartshorn type with several important refinements in design.

DESIGN DESCRIPTION

A cross-section view of the sample holder is shown in Figure 2. The main micrometer capacitor is formed by the two electrodes (H) and (L). The surfaces of these electrodes are optically ground to be plane within a few wavelengths. A precision-ground micrometer screw drives the movable grounded electrode with respect to the fixed insulated electrode. The screw adjustment is a convenient-size instrument-type knob, in contrast to the small thimble employed in the usual machinist's micrometer commonly employed for this purpose. The spacing of the electrodes is indicated by the large legible calibration on the drum as shown in Figure 1. The smallest division is one-half mil, with 1/10th mil easily readable. The micrometer screw is electrically shunted by a flexible copper bellows to assure low and constant resistance and inductance in the current path to the movable electrode. The lower electrode is supported in position by Vycor insulators which are well away from the field between the electrodes.

A unique feature of the design is the method of driving the movable electrode. A spring-loaded drive is used so arranged that, when the movable electrode comes into full contact with the specimen (or the bottom electrode), the drive disengages. Two important results are achieved by this design feature: (1) the movable electrode assumes the plane of the top surface of the specimen, thus

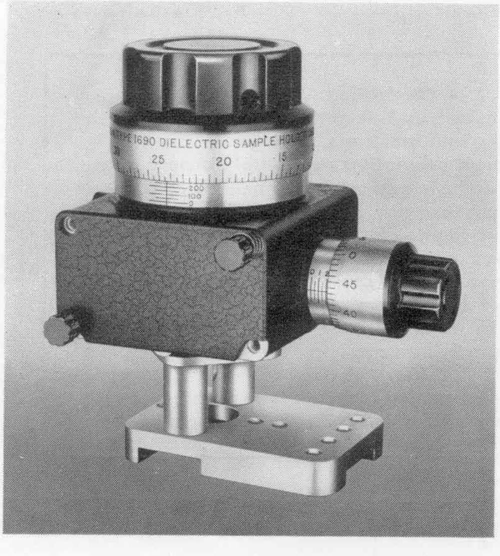

Figure 1. View of the Type 1690-A Dielectric Sample Holder.

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*L. Hartshorn and H. Ward, *Proceedings*, I.E.E. (London), Vol. 79, pages 597 to 609.

assuring best possible contact even if the faces of the specimen are not rigorously parallel, and (2) straining of the micrometer screw is avoided since the drive disengages at a predetermined pressure.

A vernier capacitor with a capacitance range of 5 μμf is also provided, for use in determining the width of resonance curves in the susceptance variation method. This capacitor is of the cylindrical type, the movable cylinder being a precision micrometer screw. Ten turns of the screw cover the range of 5 μμf, and the drum attached to the screw is accurately divided into 50 divisions, each corresponding to 0.01 μμf.

Facilities for connecting to the electrodes and for mounting the holder are extremely flexible. Pin-type connectors on standard ¾″ spacing may be used, or completely shielded connections may be made with Type 874 Universal Coaxial Connectors. Terminal facilities and mounting bosses are provided both at bottom and side of the housing. This permits the holder to be mounted with the electrodes horizontal whether the panel of the bridge or other measuring circuit is horizontal or vertical.

The electrode assembly is mounted in a rugged aluminum casting, which shields the assembly on four sides. The shielding is completed by two aluminum side panels which can be swung out of the way to insert and remove the specimen.

LOW-FREQUENCY CONSIDERATIONS

Although the micrometer type of holder was originally conceived for use at frequencies from 1 to 100 Mc, the Type 1690-A was designed in the conviction that it will be as useful at audio and power frequencies as at radio frequencies. The use of this type of holder, properly calibrated, virtually eliminates the errors from edge capacitance and stray capacitance without resort to the complication of guarded specimens and measuring circuits. The validity of this statement is demonstrated by the following outline of the methods of calibration and use.

The total capacitance at the terminals for any spacing t of the electrodes can be considered as the sum of the following components:

C_a — the direct geometric capacitance between the electrodes.

C_e — the fringing capacitance, or "edge" capacitance, contributed by the lines of force passing directly from electrode to electrode but outside the edges.

C_g — the stray capacitance of the insulated electrode and lead to the grounded enclosure.

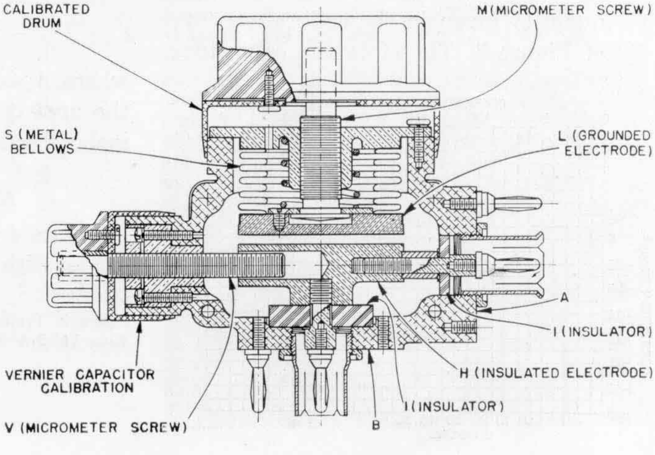

Figure 2. Cross section of the dielectric sample holder showing details of construction.

C_m — an error component caused by any mechanical imperfections in the screw thread and by any slight lack of parallelism of the electrodes.

The *difference* in capacitance between any two settings t_1 and t_2 is then the sum of the differences of the individual components

$$\triangle C = \triangle C_a + \triangle C_e + \triangle C_g + \triangle C_m$$

The direct capacitance C_a can be calculated accurately for any setting, but the error terms cannot. The calibration is made by measuring the actual $\triangle C$, taking arbitrarily a spacing of 100 mils as the reference point. The differences between the observed $\triangle C$ and the calculated $\triangle C_a$ are plotted in the form of a calibration curve as shown in Figure 3. From this curve the difference in error terms between any two settings can be determined.

In the normal method of use, an observation of the measuring circuit is made with the sample in place, at a setting t_1. The total capacitance is then

$$C_x + C_{e1} + C_{g1} + C_{m1}$$

With the sample removed, the electrode spacing is reduced until the total capacitance is restored to its original value, which then can be expressed as

$$C_{a2} + C_{e2} + C_{g2} + C_{m2}$$

Equating the two expressions, we have

$$C_x = C_{a2} + \sum \triangle C_{error}$$

But the summation of the differences in the error terms is precisely the quantity given in the calibration curve of Figure 3. Therefore the capacitance of the sample is the air capacitance at the setting t_2 after correction from the calibration data. For convenience, tables of the calculated air capacitance for 2″ electrodes are provided.

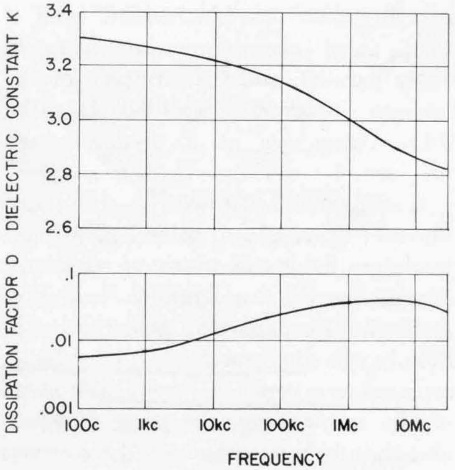

Figure 4. Dielectric constant and dissipation factor of a sample of polyvinyl butyral as measured with the Type 1690-A Dielectric Sample Holder, the Type 716-C Capacitance Bridge, and the Type 821-A Twin-T Impedance-Measuring Network.

The only assumption involved in this method is that the fringing capacitance at the setting t_1 is the same regardless of the dielectric constant of the medium between the plates. While this is not rigorously true, the error involved appears to be very small.

If the specimen is smaller in diameter than the electrodes, the expression for its capacitance is

$$C_x = C_{a2} - C_{a1}\left(1 - \frac{A_x}{A_e}\right) + \text{corrections},$$

where A_x is the area of the sample, A_e the area of the electrodes (3.14 square inches for 2″ electrodes).

MEASUREMENTS

Figure 4 shows typical measurements made with the new holder over the

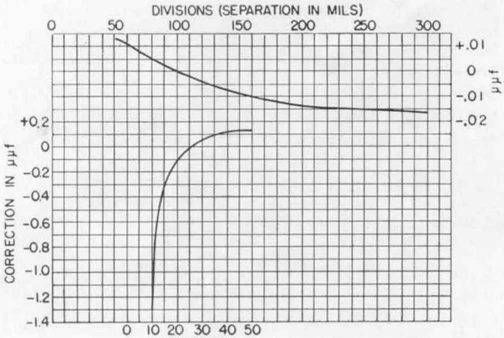

Figure 3. Typical calibration curve for the Type 1690-A Dielectric Sample Holder.

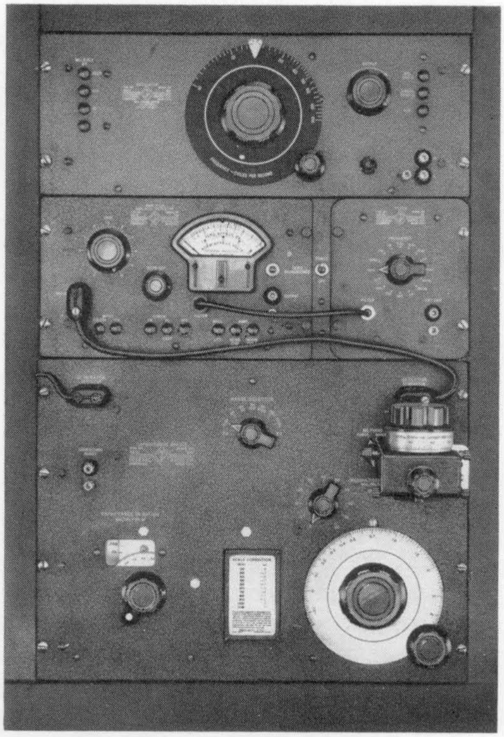

Figure 5. An assembly of equipment for dielectric measurements at frequencies between 50 cycles and 100 kilocycles, consisting of the Type 1302-A Oscillator, the Type 1231-BR Amplifier and Null Detector with Type 1231-P5R Filter, and the Type 716-C Capacitance Bridge, with the Type 1690-A Dielectric Sample Holder.

frequency range from 100 cycles to 30 Mc with the Type 716-C Capacitance Bridge and the Type 821-A Twin-T. The excellent continuity in the curves obtained with the two different measuring circuits emphasizes the advantage of using the same holder for measurements over a wide frequency range.

Sufficient measurements have been made at v-h-f and u-h-f frequencies, using the Type 874-LB Slotted Line and the Type 1602-A Admittance Meter, to establish that accurate measurement of *dielectric constant* can be made with this holder to at least 500 megacycles. Evaluation of the results for dissipation factor measurements has not been carried sufficiently far to establish performance specifications. An analysis of the high frequency performance will be presented in a later issue of the *Experimenter*.

— Ivan G. Easton

SPECIFICATIONS

Electrodes: Diameter, 2.000 inches ±0.0025. Surfaces are ground optically flat within a few wavelengths.

Electrode Spacing: Adjustable from zero to 0.3-inch maximum. The spacing is indicated directly by the micrometer reading.

Vernier: Incremental capacitance is 5 μμf nominal.

Calibration: For the main capacitor a chart is provided giving the calculated air capacitance as a function of spacing. A correction chart is also provided with each holder, giving the measured deviations from calculated values over the range from 300 mils to 10 mils spacing. In accordance with recommended ASTM practice, this calibration is referred to the calculated geometric value at a spacing of 100 mils.

For the vernier capacitor a correction chart is provided, from which capacitance differences can be determined to an accuracy of ±0.004 μμf.

Zero Capacitance: Approximately 11 μμf.

Frequency: This type of specimen holder introduces no significant error at frequencies below 100 Mc. At higher frequencies the technique of its use has not been firmly established, but satisfactory results can be obtained for many types of measurements.

Accessories Supplied: Type 1690-P1 Adaptor Assembly for mounting to the Types 716-C Capacitance Bridge and the Type 821-A Twin-T.

Accessories Available: Type 1690-P2 Adaptor Assembly for connecting for Type 874-LB Slotted Line or Type 1602-A Admittance Meter.

Mounting: Supplied with a wooden carrying case. A drawer in the case provides storage for hardware, and a spring clip holds the calibration charts, which are mounted in aluminum holders.

Dimensions: Overall, mounted on adaptor, 6¼ x 5¾ x 4½ inches.

Net Weight: 3¾ pounds.

Type		*Code Word*	*Price*
1690-A	**Dielectric Sample Holder*....................**	LOYAL	**$395.00**
1690-P2	**Adaptor Assembly (for Type 874-LB Slotted line)**	LOYALMOUNT	**30.00**

U. S. Patents Nos. 2,125,826 and 2,548,457.

WHY RHEOSTAT BURNOUTS?

Because of the nature of the circuits in which rheostats are generally employed, the current through the rheostat usually varies in a direction inverse to the amount of resistance inserted in the circuit. Oftentimes this fact is overlooked when choosing a wire-wound rheostat for use in a certain circuit position. The result may be that too small a rheostat is used and that the localized overload, when small values of resistance are in circuit, either burns out the rheostat in short order or, if it does not burn the rheostat out, gradually embrittles the phenolic mandrel until it breaks. Either condition, unfortunately, takes the rheostat out of service.

Probably there are other reasons than oversight for using too small a rheostat. The specifier of components may confuse the behavior of the usual low-operating-temperature wire-wound rheostats with that of the ones especially designed for high-power use. Many of these latter have insulated aluminum or other metal as a mandrel; many, in addition, have an aluminum housing. The metal tends to conduct the heat away from the section actually carrying the current, producing a so-called "end effect" which is quite large. The amount of energy that can be dissipated in a very small proportion of the rheostat is only slightly reduced from the over-all energy rating of the rheostat when all the resistance is in.

The generally encountered low-operating-temperature wire-wound rheostat has insulating parts made from phenolic materials, paper-based or cotton-cloth-based for the laminated materials, and wood-flour-based for the molded materials. The longitudinal conductivity of these phenolic materials away from a small area in which the energy is being dissipated is very small compared to the conductivity of metals. However, it isn't completely negligible. There *is* a small "end effect."

Advantage may be taken of this "end effect," if it is done with care, to enable one to use a somewhat smaller rheostat than he might otherwise use in cases where the circuit current goes up as rheostat resistance goes down with shaft rotation. Measurements have been made on one of our TYPE 214 Rheostats to discover the magnitude of the "end effect." These rheostats have rated currents which will produce a 60°C. rise at the hot spot. It was found, for instance, that if only one per cent of the resistance of a linear rheostat was in circuit, it could carry two times rated current without exceeding the allowable 60°C. rise. This and other figures for larger rotation percentages are given in the table.

Rotation	*Current for 60° C. Rise*
1%	2 × rated current
2%	1.65 × rated current
5%	1.3 × rated current
10%	1.1 × rated current
20%	1.03 × rated current

It will be noted that the allowable increase in current rating at 20 per cent rotation is essentially negligible. Even that at 10 per cent rotation is not very significant.

The information in the table has been plotted up in two ways and displayed in Figure 1. The variation of allowable current with percentage rotation is shown on the lower curve. The upper curve shows the amount of energy which can actually be dissipated (I^2R) as a function of rotation. If there were no "end effect," this latter curve would follow the course of the dotted 45°

line. The departures above the 45° line are the beneficial results of the "end effect."

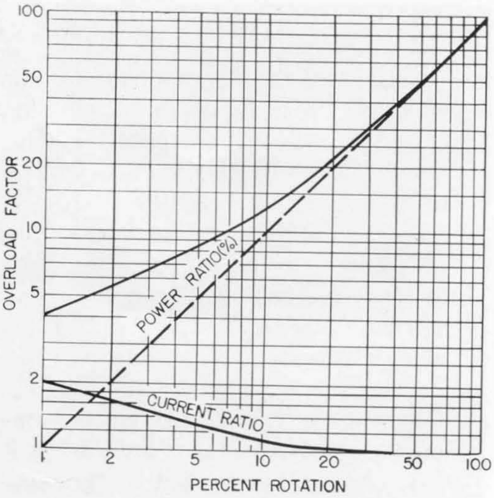

Figure 1. Plot of the allowable overload factor for Type 214 Rheostats, resulting from the "end effect" at small angles of rotation.

Some discretion should be exercised in making use of these figures. It should be remembered that they represent data actually taken on a particular design of rheostat. Change of geometric proportions, materials, and so on will change the values of the current-multiplying factors for small rotations. Change in resistance value should have negligible effect. The real criterion should, of course, be a direct and not a derived one. If one wishes to get all one possibly can out of a rheostat, he should do it by actually measuring the temperature rise under his own proposed current conditions to be sure that the safe operating temperature of the unit isn't exceeded under any conditions. There is no substitute as good as a test under actual conditions of use.

Of course there are ways to improve the current-carrying capacity of a rheostat at low rotation angles, but so far this article has dealt with the performance capabilities of a standard linear rheostat. One way to increase low-rotation current-carrying capacity is to wind the low end with lower resistance per unit angle (larger wire, lower resistivity alloy, or both). Another way would be to include between the phenolic mandrel and the winding one or two thin pieces of copper or aluminum to conduct the heat away from the overloaded section. The conducting pieces need not necessarily be the full length of the mandrel. Beyond the complication of manufacture, this expedient does not degrade the performance of the rheostat on d.c. However, it would seriously limit the usefulness of the rheostat at audio frequencies through the capacitance which the metal conducting piece would introduce across all or part of the rheostat winding.

It is hoped that this information may be found useful in some marginal applications of rheostats, to enable one to reduce the rheostat size without losing the advantages of specifying a standard rheostat normally carried in stock.

— P. K. McElroy

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

View of the General Radio booth at the 1950 Pacific Electronic Exhibit.

SEE US AT THE PACIFIC ELECTRONICS EXHIBIT

Be sure to see the General Radio booth at the Pacific Electronic Exhibit, August 22, 23, and 24, at the Civic Auditorium in San Francisco, California. In booths 418 and 419 the General Radio Company will have on display a number of new instruments, some of which have already been described in the *Experimenter* and others that will be described in forthcoming issues. Among the new instruments exhibited will be the following:

Type 1021-A U-H-F – V-H-F Standard-Signal Generator
Type 1602-A U-H-F Admittance Meter
Type 1330-A Bridge Oscillator
Type 1390-A Random Noise Generator
Type 1862-A Megohmmeter
Type 1652-A D-C Limit Bridge
Type 1550-A Octave-Band Noise Analyzer
Type 71-A Variac® Transformer
Type 874 Coaxial Elements
New Unit Instruments,
and standards of resistance, capacitance, and inductance.

The Pacific Electronic Exhibit is sponsored by the West Coast Electronic Manufacturers' Association and is held jointly with the Western Convention of the Institute of Radio Engineers. In conjunction with the Exhibit, two business conferences will be held, one on "Government Procurement Procedure," Wednesday, August 22, and another on "Where the Electronic Industry Stands in the National Preparedness Program," Thursday, August 23.

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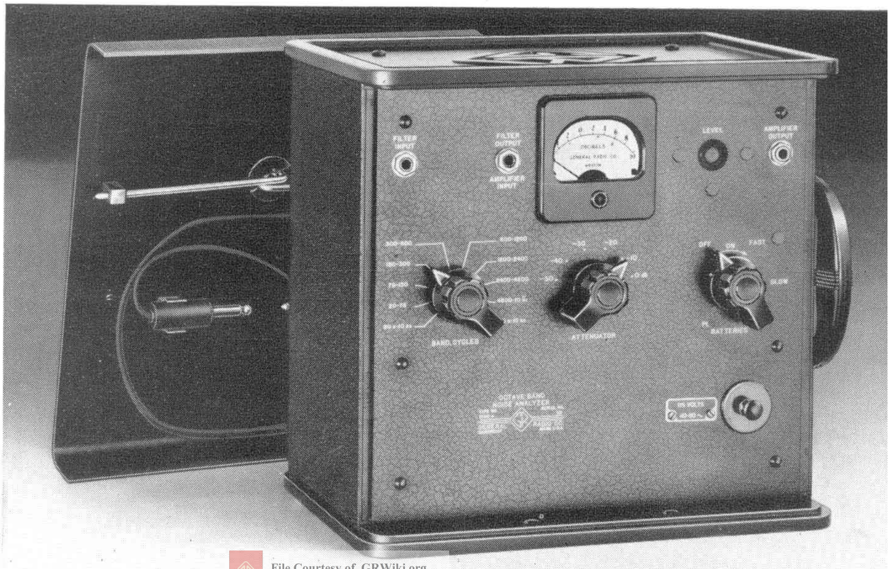
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

AN OCTAVE-BAND ANALYZER FOR NOISE MEASUREMENTS

● **MODERN INVESTIGATIONS** in the field of noise measurements have shown the need for frequency analyses of the noise spectra. Problems that require calculation of the loudness or the speech interference of noise, the determination of the effect of manufacturing variations on product noise, the use of noise measurements to detect faulty operation in machinery, or the identification of sources of noise to aid in quieting can best be solved by using analyzers with the sound-level meter.

Over-all sound levels alone are an inadequate indication of the effect of complex noise on the hearing mechanism and on the ability of people to converse. Most sounds of a complex type impress the listener as interfering with his speech and hearing only when the intensity of the noise is high in the frequency range between about 500 and 5000 cycles per second. Similarly, studies of aviators' and boilermakers' deafness reveal that sounds in that frequency range cause the most damage.

Figure 1. View of the Type 1550-A Octave-Band Noise Analyzer with cover removed to show panel.



In buildings, on the other hand, noises which have traveled through partitions are in large part shorn of their higher-frequency components. The annoying effects of these sounds must frequently be judged by the intensity in the frequency range below 1000 cycles per second.

The acoustical engineer requires more information than simply the over-all noise level if he is to select acoustical materials, or if he is to design acoustical mufflers for reducing the noise of machinery and ventilating systems. He also needs to know the spectra of noises in vehicles if he is to isolate one type of noise from another, say, to isolate wind noise from engine noise.

The examples just cited show the necessity for knowing the distribution of intensities of a complex noise as a function of frequency. For some years, the General Radio Company has supplied the Type 760-B Sound Analyzer for determining in detail the spectrum of a complex noise. Having an effective band width of slightly more than three per cent, that instrument, continuously adjustable in frequency, effectively divides the frequency spectrum between 25 and 7500 cps into 180 separate bands, in each of which the intensity of the noise may be determined. Analysis in such detail as provided by the 760-B Sound Analyzer is often necessary when resonances in a device are being sought, or when the intensities of the several harmonic components of a sound with a low-frequency fundamental are desired. For many applications, however, much less detail is desired than is given by an instrument with the equivalent of 180 bands.

In response to the demand for an analyzer with fewer bands, the General Radio Type 1550-A Octave-Band Noise Analyzer has been developed. It divides the frequency range from 20 to 10,000 cps into eight bands so that the analysis is relatively simple. Yet it is sufficient in the great majority of cases to provide the information needed to solve the problems mentioned above.

This new portable instrument, pictured in Figure 1, combines versatility with superior filter characteristics. In addition to the filter set, as shown in the simplified schematic of Figure 2, it consists of an amplifier, an indicating meter, and a portable battery supply. The complete assembly, including batteries, weighs only 27 pounds. This design makes it possible for the user to connect the instrument, without concern over the availability of 60-cycle power, to the output of a sound-level meter, a magnetic-tape recorder, or any other source of audio-frequency signal. Furthermore, for economy in laboratory or plant use, the cabinet has been made large enough so that the battery can be replaced by a Type 1261-A A-C Power Supply.

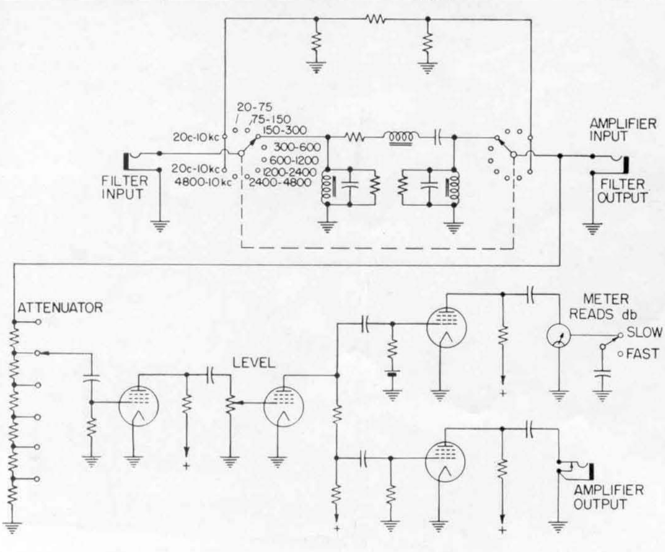


Figure 2. Elementary schematic circuit diagram of the analyzer.

FILTER DESIGN AND CHARACTERISTICS

The filter assembly itself is small and light in weight, with excellent selectivity characteristics. This combination is a result of taking advantage of design by modern filter theory. Good selectivity is not difficult to obtain by ordinary filter design, but the resulting filter is heavy, large, and expensive, because the inductors must have low losses. To avoid this excessive weight, the filter in the octave-band analyzer has been designed on an insertion-loss basis, rather than by the characteristic-impedance method.

A complete analysis of the effects of the loss in all the inductor elements showed that the desired filter could be obtained with all inductors having a Q (reactance-to-resistance ratio) less than 8, with a moderate insertion-loss in the pass band. This low Q made it possible to use small "postage-stamp" inductors, tapped for more than one range, without spoiling the filter characteristic because of high losses. Typical filter characteristics are shown in Figure 3.

The filter set has pass bands with the following nominal cut-off frequencies:

20 c — 75 c (low pass)
75 c — 150 c
150 c — 300 c
300 c — 600 c
600 c — 1200 c
1200 c — 2400 c
2400 c — 4800 c
4800 c — 10,000 c (high pass)

The six middle bands are an octave in width, and the other two are a low-pass and a high-pass filter. These eight bands has been found particularly useful for noise analysis, and they are standard in many applications. A straight-through or over-all connection is provided in addition to the eight filter bands.

The band-pass sections have an initial rate of attenuation beyond cut-off of about 50 decibels per octave of frequency. This high initial rate is important when the measured noises have energy levels that change rapidly as a function of frequency. When such a noise has appreciable energy extending over a wide-frequency range, the high level of over 50-decibels attenuation attained in this filter set at frequencies well beyond cut-off is also important. Without these features, the analysis of many noises encountered in practice would be seriously in error.

The filter is isolated by a resistance pad. This pad makes the filter characteristics essentially independent of the source used to supply the analyzer, provided the source impedance is constant over the audio-frequency range, or small compared to the 20,000-ohm input impedance of the analyzer.

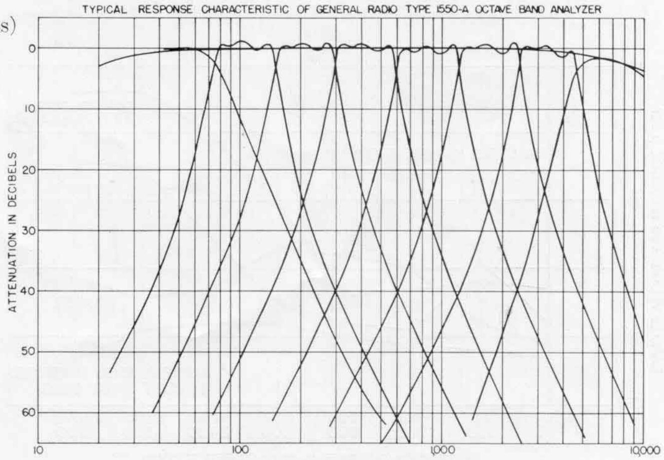


Figure 3. Typical response characteristic of the Type 1550-A Octave-Band Noise Analyzer.

MEASURING AND OUTPUT SYSTEM

The attenuator, amplifier, and indicating meter permit one to measure octave-band levels over a range of about 60 decibels. The attenuator is calibrated in 10-db steps from 0 to 50 db, and the indicating meter provides a range from −6 to +10 db. The amplifier compensates for the pass-band insertion loss of the filters and provides more than 50-db additional gain to obtain a meter reading for the 50-db range. A level control is provided to set the gain of the amplifier to the desired value.

In order to use the full range of analysis provided, an input level of about one volt is required across the 20,000-ohm input impedance of the analyzer. This level is readily supplied by the Type 1551-A[1] and Type 759-B Sound-Level Meters. Levels below one volt can be used with a correspondingly reduced range of analysis. Higher voltages can also be used, but above 10 volts the characteristics of the low-frequency filter changes with signal level and the amplifier may be overloaded.

Any amplifier or sound-level meter that is used to supply the input to the analyzer should be operated so that it introduces very little distortion, noise, or hum into the amplified signal. Any of these added effects will lead to incorrect results in analysis. The extent of the error will depend on the relative level of these added components. For example, a hum level 60 to 70 db below the total signal level is very satisfactory. Some sound-level meters have an inherently poor signal-to-noise ratio over much of the range, while others introduce appreciable distortion. The Type 1551-A[1] and Type 759-B Sound-level Meters are inherently superior in these respects, and are recommended for supplying the signal for analysis.

For the analysis of high-level sounds, the analyzer can frequently be connected directly to the output of a microphone system. The Type 759-P25 Dynamic Microphone[2] Assembly is a suitable type of microphone for the range from 70 to 140 db, and an Altec-Lansing Type M 11 Microphone System is another type suitable at levels from 60 to 135 db. A crystal microphone is not satisfactory for connection directly to the analyzer because its capacitance source impedance will lead to a response that increases with frequency over most of the audio range. For a particular microphone of known sensitivity, one can compute the level at which an analysis can be made, thus determining whether or not the simple combination of a microphone system and analyzer will be satisfactory for a given application. When the Type 759-P25 Dynamic Microphone Assembly is used, the absolute level can be set by the Type 1552-A Acoustic Calibrator.[3]

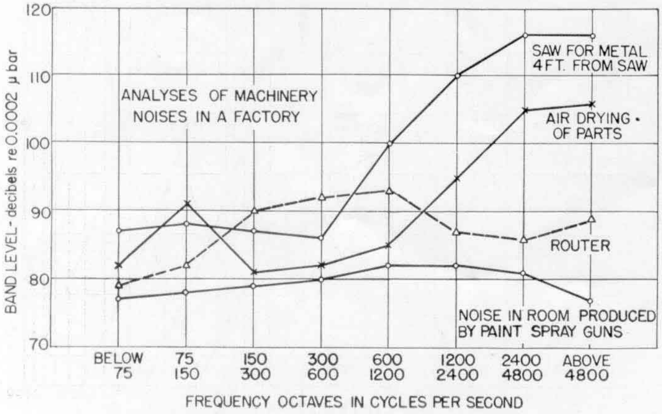


Figure 4. Octave-Band frequency analysis of noise produced by machines in a factory.

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[1] To be described in a forthcoming issue of *Experimenter*.

[2] "A Dynamic Microphone for the Sound-Level Meter," *Experimenter*, April, 1951.

[3] E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *Experimenter*, December, 1949.

A separate, low-distortion monitoring output is provided for supplying a signal to a recorder or for listening to the filtered signal. It can also be used to supply a signal to a narrow-band analyzer, such as the General Radio Type 760-B Sound Analyzer, when more complete analysis within one band is desired, and when the selectivity provided by the octave-band noise analyzer is necessary to reduce strong interfering components to a low value.

EXAMPLES OF USE

Some problems that require analysis have been mentioned briefly in the introduction. For example, a value of loudness can be calculated from the results of an octave-band analysis.[4] This value will agree, in general, with subjective estimates much better than a value calculated from the reading of a sound-level meter.

Some further typical examples of the many possible uses of this instrument are given below.

ANALYSIS OF MACHINERY NOISE AND EAR PROTECTION

The General Radio Type 1550-A Octave-Band Noise Analyzer is particularly useful in measuring the noise spectra of many types of industrial machinery. Examples of noise spectra measured in a large factory are shown in Figure 4. From these data the management concluded that ear protection was required for operators of the air drying equipment and metal saws; that ear protection was desirable for operators of routers; and that ear protection was not required for operators of paint spray guns.

A comprehensive study of the deafening effects of noise has recently been made by Kryter.[5] His study has lead to tentative limits on levels that confirm the conclusions above.

ANALYSIS OF VEHICLE NOISE

Cities are showing an increased interest in the noise made by vehicles such as elevated trains, electric and steam trains, buses, automobiles, and motorcycles. Recent studies of noise in Chicago have used the octave-band method of analyzing vehicle noise.[6] Typical results of their measurements are shown in Figure 5. The data for this figure were measured at a distance of 20 feet from the vehicles.

ANALYSIS OF OFFICE NOISE

Forward-looking corporations are becoming increasingly aware of the advantages of satisfactorily low noise en-

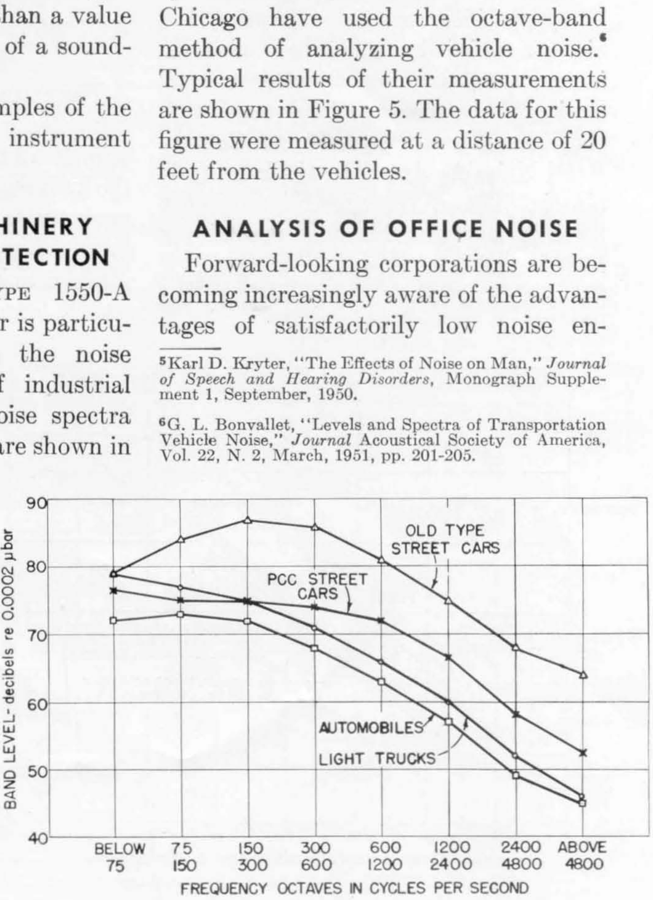

Figure 5. Results of analysis of vehicle noise made with an octave-band analyzer at a distance of 20 feet from the vehicles.

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[4] Leo L. Beranek, "Acoustic Measurements," New York, John Wiley & Sons, Inc., 1949, pp. 524-526, and Leo L. Beranek, J. L. Marshall, A. L. Cudworth, and A. P. G. Peterson, "Calculation and Measurement of the Loudness of Sounds," *Journal* Acoustical Society of America, Vol. 23, N. 3, May, 1951, pp. 261-269.

[5] Karl D. Kryter, "The Effects of Noise on Man," *Journal of Speech and Hearing Disorders*, Monograph Supplement 1, September, 1950.

[6] G. L. Bonvallet, "Levels and Spectra of Transportation Vehicle Noise," *Journal* Acoustical Society of America, Vol. 22, N. 2, March, 1951, pp. 201-205.

vironments for their employees. With charts made available recently, it is possible to measure the noise levels in offices using the General Radio TYPE 1550-A Octave-Band Noise Analyzer and to rate the office noise on an appropriate rating scale.[7] The procedure is to take a simple average of the noise levels in the 600-1200, 1200-2400, and 2400-4800-cps bands. This quantity is called the *speech-interference level*. Transformation from the speech-interference level to a rating of the noise condition in the office is possible with the aid of Figure 6.

ANALYSIS OF AIRCRAFT NOISE

The increased use of airplanes for long-distance travel by the general public has made the problem of noise in airplanes particularly important. Army-Navy specifications today require that aircraft noise be measured with an instrument possessing octave filter bands having the same cutoff frequencies as the General Radio TYPE 1550-A Octave-Band Noise Analyzer. In airplanes (and also in offices), the speech-interference level is a reasonable measure of the noisiness of the various compartments.[8] The relationship between the ability of passengers to converse at various voice levels and distances as a function of speech-interference level is shown in Table I.

TABLE I

MAXIMUM VALUES OF SPEECH-INTERFERENCE LEVELS OF NOISE FOR WHICH ENTIRELY RELIABLE SPEECH INTELLIGIBILITY WILL BE OBTAINED FOR AVERAGE VOICES AND HEARING.

	Voice Level			
Distance ft.	*Normal*	*Raised*	*Very Loud*	*Shouting*
0.5	71	77	83	89
1	65	71	77	83
2	59	65	71	77
3	55	61	67	73
4	53	59	65	71
5	51	57	63	69
6	49	55	61	67
12	43	49	55	61

DETERMINATION OF ACOUSTICAL CHARACTERISTICS OF STRUCTURES

The sound-transmission loss of building walls, partitions, and floors is determinable in the field at eight points along the frequency scale with the octave-band analyzer, a sound-level meter, and a source of sound which produces either a random noise, an explosive sound, or a warble tone.

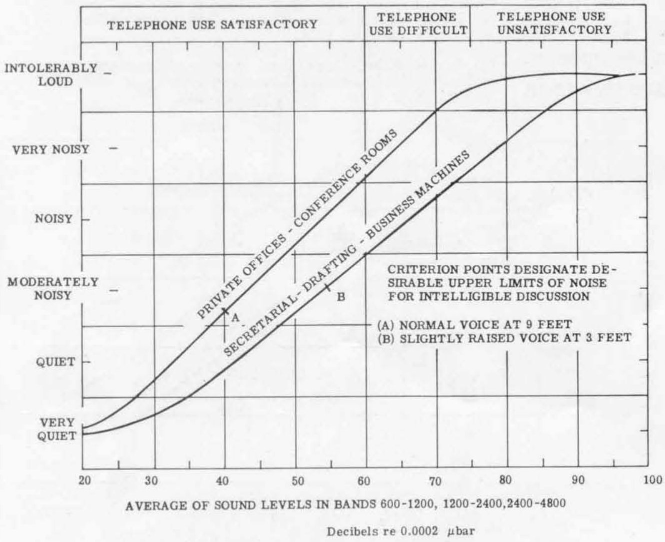

Figure 6. Rating chart for office noises. Data were determined by an octave-band analysis and correlated with subjective tests. (Courtesy *Beranek and Newman*.)

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[7] Leo L. Beranek and R. B. Newman, "Speech-Interference Levels as Criteria for Rating Background Noise in Offices," presented at June 22, 1950, Meeting of Acoustical Society of America, State College, Pa.

[8] Leo L. Beranek and H. Wayne Rudnose, "Sound Control in Airplanes," *Journal* Acoustical Society of America, Vol. 19, N. 2, March, 1947, pp. 357-364, and L. L. Beranek, "Airplane Quieting II — Specification of Acceptable Noise Levels," *Trans.* A.S.M.E., Vol. 69, February, 1947, pp. 97-100.

OTHER USES

These examples serve to show the variety of applications that can be handled in the field of noise analysis. The Type 1550-A Octave-Band Noise Analyzer, however, is not restricted to that field. It has been found useful as a selective bridge detector, particularly when used with headphones in the monitoring output. It can be used as a filter set for purposes other than analysis, for example, sound effects and speech studies. To increase further the general usefulness of the instrument, phone jacks are provided so that the amplifier or the filter can be used alone for various types of laboratory measurements.

— A. P. G. Peterson

SPECIFICATIONS

Range: 20 cycles to 10,000 cycles in 8 bands:

20 c to 75 c (low pass)
75 c to 150 c
150 c to 300 c
300 c to 600 c
600 c to 1200 c
1200 c to 2400 c
2400 c to 4800 c
4800 c to 10,000 c (high pass)

In addition, a band with a flat characteristic from 20 c to 10 kc is available at two switch positions for convenience in calibration against the sound-level meter.

Input Level: Between 1 and 10 volts for normal range. Levels below one volt reduce the range of reading; those higher than 10 volts overload the filters.

Input Impedance: 20,000 ohms. Input is isolated by a resistance pad, so that performance is independent of source if source impedance is constant over audio range or is small compared to 20,000 ohms.

Source: Sound-level meter supplying analyzer input must have low hum, low internal noise, and low distortion. The Type 1551-A or the the Type 759-B Sound-Level Meter is recommended.

Direct Use with Microphone: Type 759-P25 Dynamic Microphone is recommended if the band levels exceed 70 db.

Level Indication: Meter calibrated in decibels from −6 to +10 db; attenuator covers 50 db in 10 db steps. Level is sum of meter and attenuator readings.

Attenuation: Except for the lowest and highest bands, at least 30-db attenuation is obtained at one-half the lower nominal cutoff frequency and twice the upper nominal cutoff frequency; at least 50-db attenuation is obtained at one-fourth the lower nominal cutoff frequency and at four times the upper nominal cutoff frequency. The 75-cycle low-pass filter has at least 30-db attenuation at 200 c and 50 db at 400 cycles. The 4800-cycle high-pass filter has at least 30-db attenuation at 2400 cycles and 50 db at 1200 cycles.

Tubes: Three 1U4 and one 1T4, all furnished.

Power Supply: Battery, Burgess 6TA60. Battery is included in price. For a-c operation, Type 1261-A Power Supply fits battery compartment.

Accessories Supplied: Shielded cable and plug assembly for connecting analyzer to sound-level meter.

Dimensions: (Width) $11\frac{5}{8}$ x (height) $12\frac{9}{16}$ x (depth) 9 inches, overall.

Net Weight: 27 pounds including battery.

Type		*Code Word*	*Price*
1550-A	**Octave-Band Noise Analyzer**	ABEAM	**$535.00**
	Replacement Battery for above	ABEAMADBAT	**5.79**
1261-A	**A-C Power Supply**	NUTTY	**120.00**

SERVICE DEPARTMENT NOTES

Our Service Department is now in a position to supply information on the modification of the following instruments to accommodate newer and more satisfactory vacuum tubes. More complete details will be forwarded upon request.

TYPE 1861-A MEGOHMMETER — Currently available 85 tubes do not operate satisfactorily because of high grid current. The 6AU6 tube can be substituted, but other changes are necessary.

TYPE 561-D VACUUM-TUBE BRIDGE—This bridge can be adapted to making measurements on noval tubes. Also, more complete shielding can be installed to eliminate spurious oscillation when tubes of high transconductance are being measured.

TYPE 805-C STANDARD SIGNAL GENERATOR — Stability of the output meter can be improved by replacing the 955 tube with a 6AU6 and making certain wiring changes.

When writing always mention the type and serial numbers of the instruments for which information is requested.

MISCELLANY

NEW PLANT UNIT IN CONCORD—Construction has been started by the General Radio Company on a new plant unit in the town of Concord, Massachusetts, to provide the additional manufacturing facilities necessitated by the nation's defense and rearmament program. The new plant will be a modern three-story brick-faced structure of 72,000 square feet and will provide facilities for about two hundred employees.

The executive offices and main manufacturing plant will continue to be at 275 Massachusetts Avenue, Cambridge. Present space at the Cambridge plant is about 145,000 square feet, with approximately 500 employees.

CREDITS — The Type 1550-A Octave-Band Noise Analyzer was developed by Dr. Arnold P. G. Peterson, author of the article appearing in this issue. Credit is also due to Dr. Leo L. Beranek, of M.I.T., consultant in the development, to Mr. Corwin Crosby for the mechanical design, and to Mr. Robert J. Ruplenas, who performed much of the experimental work on the circuit development.

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A NEW PUSH-PULL AMPLIFIER CIRCUIT

AS ONE RESULT of a continuing development program on audio-frequency instruments, a new audio power-amplifier circuit[1,2] that promises to be widely useful has been devised. In addition to being suitable for regular audio power amplifiers, this new circuit is particularly well adapted to amplifiers for constant-voltage audio distribution systems, to high-power modulators, to amplifiers for electronic musical instruments, and to audio amplifiers for industrial uses.

This new circuit permits one to obtain the high efficiency of Class AB_1 operation without switching transients, and this feature is obtained without the use of special components. The circuit also has important advantages for direct-coupled power amplifiers and for amplifiers operated Class A when very low distortion is required.

Because of the widespread interest already shown in this development, three practical high-power amplifiers using this new circuit with low-cost tubes will be described and component values will be given to aid the experimenter in making an initial setup. Before discussing these, however, the basic principle of the new circuit will be outlined briefly.

The basic circuit is shown in Figure 1. The output stage consists of two tubes connected in series across the d-c plate supply, and the load connects from the midpoint of this series connection to the plate supply. The output tubes are driven in opposite phase by a phase-inverter stage. The important feature of this phase-inverter

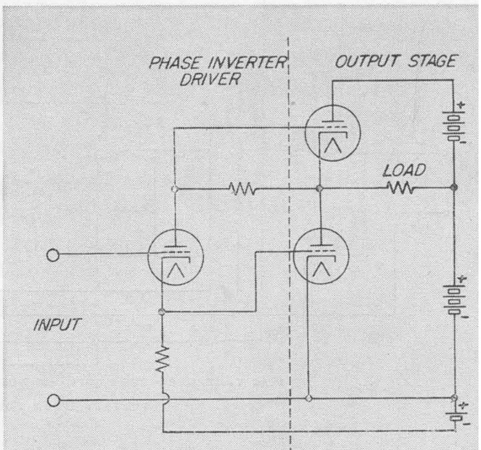

Figure 1. The basic single-ended push-pull amplifier circuit, showing the series connected output tubes supplying a common load and driven by a cathode-follower phase inverter.

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[1] Arnold Peterson and Donald B. Sinclair, "A Single-Ended Push-Pull Audio Amplifier," 1951 I.R.E. National Convention, New York, N. Y., March 22, 1951, published in News Letter of I.R.E. Professional Group on Audio.

[2] Patent applied for.

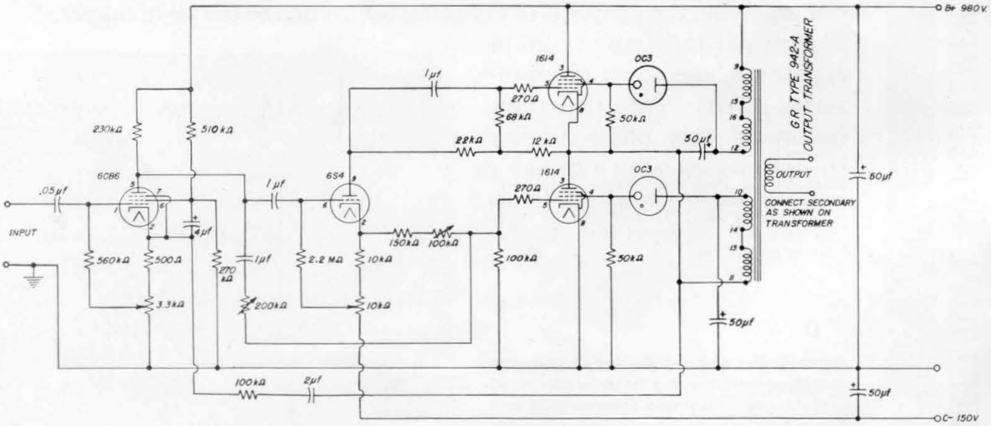
stage is that it drives each tube from its own grid to its own cathode, so that the tubes are driven in a balanced fashion. In order to achieve this type of drive, it is necessary to feed the plate impedance of the phase-inverter driver from the midpoint of the series-connected output tubes. If the plate load of this driver were connected directly to the plate supply, the upper tube would be driven with respect to ground as a cathode follower, and the balance of the two tubes would be destroyed. While the voltage driving the upper tube could be correspondingly increased to achieve a net balance of current swing in the two tubes, the operating conditions as far as distortion is concerned would be markedly different, and the push-pull cancellation of distortion would not result. The circuit shown maintains the balance in the two tubes and preserves the distortion-cancelling feature of push-pull operation.

In the usual push-pull circuit the two output tubes are in parallel for the d-c plate supply and operate effectively in series for supplying the a-c load. In a limited sense this new circuit can be considered the dual of the usual circuit since the output tubes are in series for the d-c plate supply, and they supply the a-c load in parallel. Thus the normal optimum load impedance for the new circuit is one-fourth the normal plate-to-plate load impedance for the usual push-pull connection.

This simple relationship means that some standard push-pull transformers can be readily used for the new circuit. If the two halves of the primary are separate, they can be connected in parallel, instead of in the series connection ordinarily used, to obtain this four-to-one ratio.

Because of this parallel or single-ended connection of the primary, both tubes work into the same load, and there is no deleterious effect from leakage reactance between halves of the primary. In contrast, in the conventional push-pull circuit, each tube works individually into half the primary, and leakage reactance between the windings can cause serious switching transients[3] when the tubes are operated Class AB. These switching transients, which cannot be eradicated by negative feedback, are a prime cause of high-frequency distortion, notably intermodulation, in push-

Figure 2. The circuit diagram for a 50-watt amplifier, which includes feedback to an earlier amplifier stage.



BIAS VOLTAGES - TYPE 1614, -40 VOLTS; TYPE 6S4, -42 VOLTS; TYPE 6CB6, -4.6 VOLTS

VOLTAGE INPUT FOR 50 WATTS OUTPUT: 12.8 VOLTS

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[3] A. Pen-Tung Sah, "Quasi-Transients in Class B Audio-Frequency Push-Pull Amplifiers," *Proc. I.R.E.*, Vol. 24, N. 11, November, 1936, pp. 1522–1541.

pull amplifiers. They are often responsible for the objectionable harshness in so-called high-fidelity systems.

When beam-power tubes are used in the output, the two halves of the primary of the usual push-pull transformer can serve a useful purpose in this single-ended circuit by simplifying the problem of supplying the d-c screen-grid voltages to the two output tubes. How these can be used is shown in Figure 2. The output tubes are shown connected in series, as before, for the d-c supply. The screen-grid voltage for the upper tube is supplied through one primary winding from the plate supply. This upper screen-grid is by-passed to its cathode at the midpoint where the plate and output tubes are connected together. The other screen-grid is supplied through the other primary winding from the midpoint, and this lower screen-grid is by-passed to ground. The d-c screen-grid currents flow through the windings in the opposite sense, so that there is no net d-c flux from the screen-grid currents in the windings.

The transformer connections show that the two primary windings are connected in parallel for signal voltages. The screen-grid by-pass capacitors and the plate supply output capacitor make this parallel connection. These capacitors must provide a low-impedance path at the lowest signal frequency.

The circuit of Figure 2 also includes a feedback connection from the output stage to the first stage. Since the output is single-ended, feedback to a single-ended earlier stage is relatively simple. In the circuit shown, a fraction of the output voltage is applied directly to the cathode of the first stage as a voltage feedback.

The circuit of Figure 2 is arranged to operate the final stage Class AB_1. Because this type of operation requires large driving voltages from the phase-inverter stage, the method of connection of this stage is different from that of Figure 1 in certain details. The d-c bias voltage for the upper output tube is obtained from only part of the phase-inverter plate load. The full signal voltage across the plate load, however, is applied to the upper tube through the coupling capacitor between the plate of the phase inverter and the grid of the upper tube.

The a-c plate voltage from plate to cathode of the phase inverter stage of Figure 1 is the sum of the a-c output voltage and the two a-c grid voltages produced across its load resistances. For a 50-watt amplifier using Type 1614 tubes, this a-c voltage is of the order of 500 volts peak. The d-c plate voltage required across this tube, then, must be greater than 500 volts in order to avoid serious non-linearity in the driver stage. If the experimenter has available a tube that can readily handle these voltages, the basic cathode-follower phase inverter of Figure 1 is recommended. In the particular circuit of Figure 2, a standard receiving type has been used within its rating of 500 volts by the circuit dodges shown. The resistance in the cathode is lower than necessary for full drive of the lower stage, so that the required voltage must be obtained from the previous amplifier stage. This lower resistance reduces the a-c voltage appearing from plate to cathode and makes possible the use of a Type 6S4 Triode within its 500-volt rating.

The amplifier circuit of Figure 2 can be used with two Type 1614's in the output stage to yield 50 watts output. At this level the distortion can readily be held to less than 1% (total harmonic) for frequencies in the middle audio

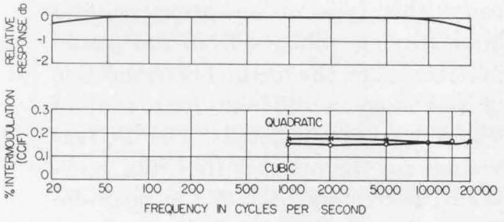

Figure 3. The upper curve shows as a function of frequency the relative output at the secondary of the output transformer, terminated in a resistance load, for constant input voltage to the amplifier of Figure 2. The lower curves show intermodulation distortion as a function of frequency. Two tones of equal amplitude differing in frequency by 400 cycles were used. The peak-to-peak swing, at the load connected to the secondary, was equal to that obtained at a 50-watt single-frequency output level, and the distortion is plotted as a function of the frequency of the lower-frequency tone.

range. By careful adjustment of balance and operating conditions, this distortion can be reduced even further.

The intermodulation results by the CCIF test[4] shown in Figure 3 demonstrate that the amplifier is operating correctly, with low distortion over the audio range. Measurements of intermodulation by the SMPTE method also showed satisfactorily low distortion. Tests at an equivalent 50-watt power level, using a low-frequency tone of 40 cps of four times the intensity of the high-frequency tone of 7000 cps, gave a total intermodulation of 1.6%, which is well below the 5% frequently used for rating high-quality systems.

Beyond the 50-watt limit, the output tubes are driven to the level where they draw grid current, which changes the operating conditions for the tubes. This change will give the results shown in the graphs, which were measured under steady state conditions. For dynamic conditions, such as occur with speech and music signals, the distortion levels above 50 watts will be somewhat higher.

This power level is obtained within the ICAS ratings of the Type 1614 and is the power available at the primary of the transformer. Because of the losses in the transformer, the power available at the secondary is reduced somewhat. When the General Radio Type 942-A Output Transformer[5] is used as specified, the reduction in available power is relatively small. The output transformer also limits the maximum low-frequency power obtainable from the amplifier. The Type 942-A Output Transformer[5] has been designed to handle a particularly high level of power, for its size, at low frequencies. The curve of Figure 4 shows its performance with the amplifier of Figure 2.

The element values given in Figure 2 have been determined to be suitable for an amplifier using four Type 1614's in

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[4] A. P. G. Peterson, "An Audio-Frequency Signal Generator for Non-Linear Distortion Tests," *General Radio Experimenter*, August, 1950.

[5] To be described in next month's *Experimenter*.

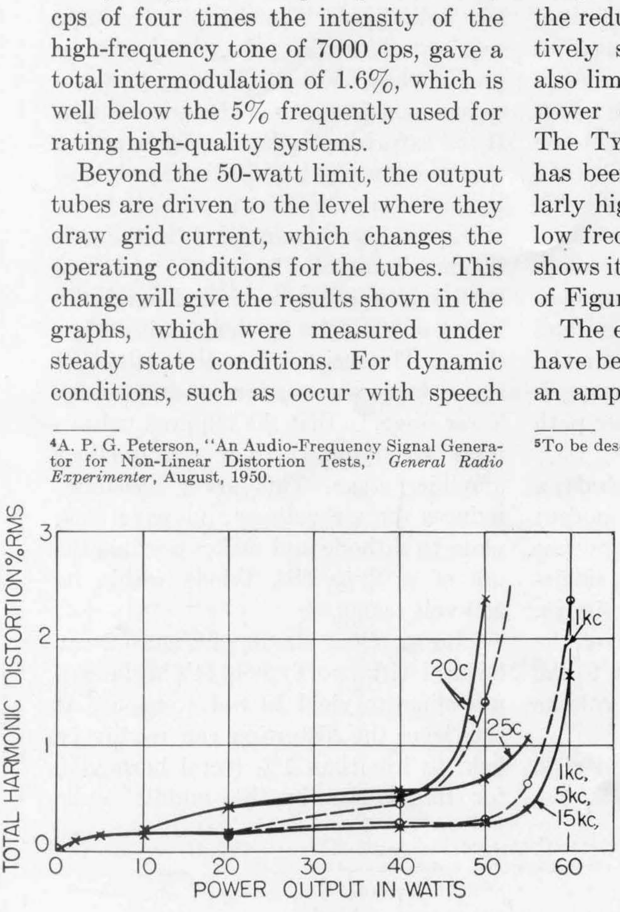
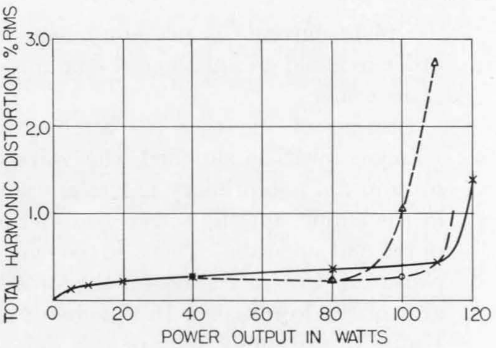


Figure 4. Harmonic distortion as a function of power delivered to the load for the circuit of Figure 2. All the curves except the dashed ones were taken with a 1500-ohm load across the primary. Since there was no essential difference in results at 1, 5, and 15 kc, only one curve is shown for these three frequencies. For frequencies above 50 cps, the results were also practically identical with the 1-kc curve. The dashed curves show the results with the load on the secondary of the transformer.

Figure 5. Harmonic distortion at 1 kc as a function of the power delivered to the load for the circuit of Figure 2, but with two Type 1614 Beam Power Tubes in parallel for the upper output tube and two in parallel for the lower tube. The solid curve was obtained with an 800-ohm load on the primary. The values given by the triangles were obtained on the secondary, using a load of about one-half the rated impedance of the transformer, and the values given by the circles, using a load of about twice the rated impedance. In each case the equivalent primary load was about 800 ohms. These latter results show the difference in copper efficiency obtainable with the different connections available on the Type 942-A Transformer.[5]

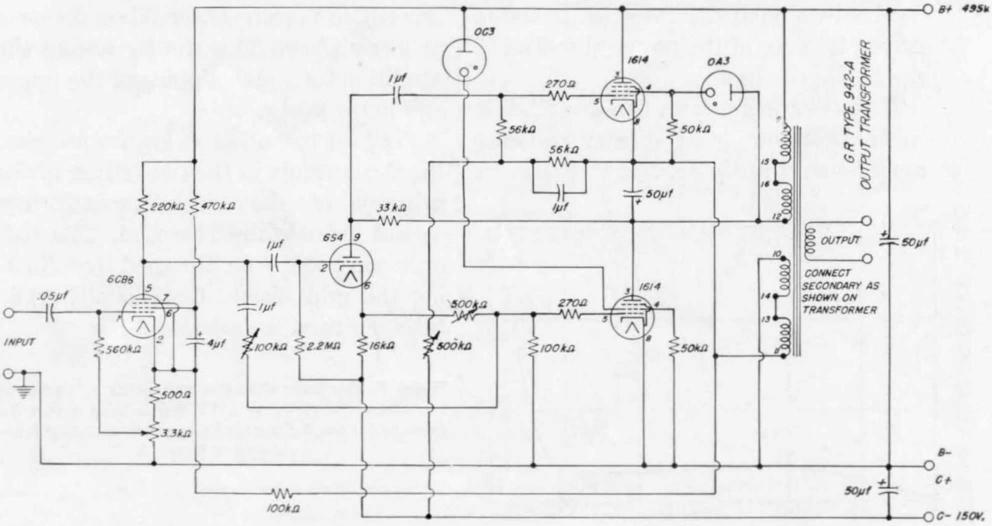


the output stage. Two tubes are used in parallel where the upper tube is shown, and two are in parallel for the lower tube. This output combination will supply 100 watts of power at the primary of the output transformer (see Figure 5), and the Type 942-A Output Transformer[5] is suitable for use at this power level over the audio range above 40 cps.

The previous circuit has the disadvantage of requiring a plate supply that operates at twice normal voltage. Of course the current taken by the output stage is correspondingly one-half that taken by the usual push-pull stage so that the total input power is normal. The high plate voltage is no longer so serious a disadvantage as it was some years ago, because of the recent development of the high-voltage selenium rectifiers. The circuit, however, is best adapted to moderate total plate voltages if the newer, low-impedance tubes such as the Type 6CD6-G or Type 6BQ6-GT are used in the output stages.

If it is desired to operate with normal plate voltages, the circuit can be modified as shown in Figure 6. Here both plate currents flow through the transformer primary windings so that there is more of a burden on the transformer, because of the d-c copper loss in the windings. More careful balancing of the

Figure 6. The circuit diagram for a 50-watt amplifier, using parallel feed for the plate voltages of the two output tubes.



BIAS VOLTAGES - TYPE 1614, -39 VOLTS; TYPE 6S4, -42 VOLTS; TYPE 6CB6, -5.2 VOLTS

VOLTAGE INPUT FOR 50 WATTS OUTPUT: 12.5 VOLTS d-c plate currents is necessary here in order to avoid an unbalanced flux in the transformer.

Because of the way the screen-grid voltages must be supplied, the voltage drop in the two primary halves appears in the supply for the screen-grid of the upper output tube. There is no compensating drop in voltage for the screen-grid of the lower tube. In the circuit of Figure 6, the major part of this difference is taken care of by the use of different voltage-regulator tubes in the two screen-grid supplies. Otherwise, this circuit is essentially the same as that of Figure 2, and the performance is comparable as shown by Figure 7.

The circuit can be appreciably simplified if the full 50-watt power level is not required. A suitable circuit for an output power of 25 watts is shown in Figure 8.

The feedback used in these circuits is about 14 db. This amount is adequate to give a source impedance of about one-fifth the optimum load impedance, which is satisfactory for most applications. This source impedance can be reduced further by increasing the feedback. With the type of feedback used here, however, an increase in feedback usually results in a small decrease in available power, because of the power absorbed in the feedback circuit.

If the distortion from this amplifier is to be kept low, good quality resistors must be used in the feedback circuit. In particular, it is recommended that the resistor from the primary of the transformer to the cathode of the first tube and the resistor to ground from the cathode of the first tube be wire-wound. Some composition resistors have an appreciable voltage coefficient, and, if they are used for the feedback circuit, they can contribute appreciable amounts of distortion.

For best operation at high audio frequencies, it is important to keep stray circuit capacitances as small as possible. Particular attention should be paid to the capacitance to ground of the circuit from the plate of the driver stage to the grid of the upper output tube. This capacitance, which shunts the phase-inverter plate-load impedance, is effectively multiplied by the gain of the output stage. For the present circuit this factor is about ten.

The circuits should be adjusted by observations using a high-resistance d-c voltmeter, a sinusoidal signal source, and a cathode-ray oscillograph. The bias adjustments should be made first to give about the values shown in the figures. Then a 1-kc signal should be applied and the signal balance adjustment should be made. Proper adjustment of this balance can be observed on the c-r-o at levels above 50 watts by noting the condition for equal clipping of the upper and lower peaks.

For best operation at low frequencies, the d-c currents in the two halves of the primary of the output transformer should be carefully balanced. This balance can usually be obtained by adjusting the grid biases. Occasionally some tube selection is desirable.

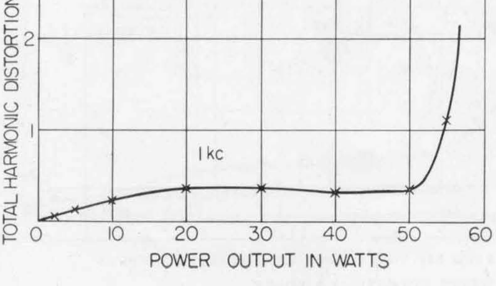


Figure 7. Harmonic distortion at 1 kc as a function of the power delivered to a 1500-ohm load across the primary for the d-c parallel connection of output tubes as shown in Figure 6.

If the amplifier is to be used for speech and music signals, it is recommended that the adjustments be trimmed to favor very low distortion at low levels. This trimming can best be done by using a very low distortion source and a wave analyzer or distortion meter.

The output tubes of these circuits operate in the Class AB region, and the plate current for the last stage varies with operating level. The main power supply should, therefore, have good regulation to maintain proper operating conditions with varying levels. The bias supply, on the other hand, can be very simple, since only a few milliamperes are needed and the load is constant.

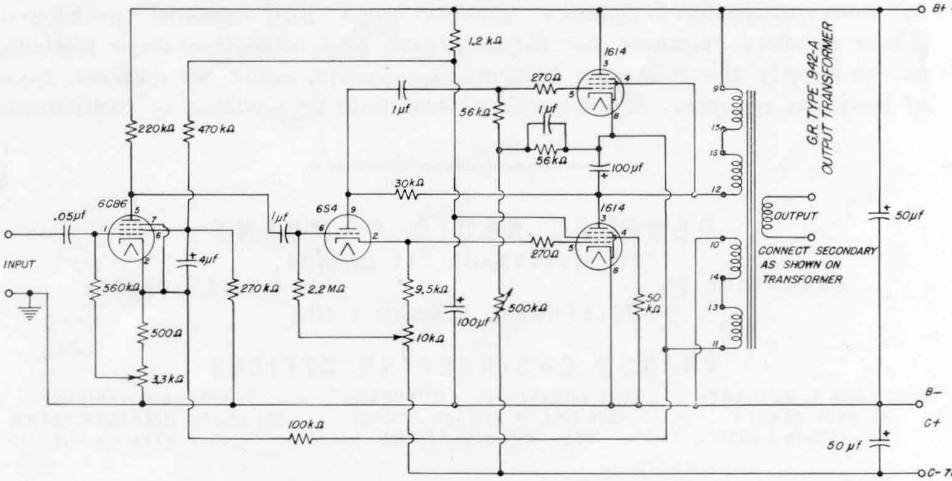
The basic circuit can, of course, be used with other output tubes. If lower plate voltages are also used, the driver voltage problems are simplified, and the straightforward cathode-follower phase inverter can be used. In some cases the load can be matched directly to the output tubes so that the impedance-matching effect of the transformer is not needed, and the efficiency is correspondingly increased.

The circuits shown here are intended only as a guide for the experienced experimenter. Numerous measurements and adjustments are usually necessary in an initial setup to make certain that the circuit is operating properly. In making those tests, the experimenter should remember that the voltages used here are dangerous, and, because of the unusual output circuit, particular care is necessary to avoid being misled by experience with standard output systems.

The power levels quoted in this article are not conservative but actual values measured on an experimental setup, so that the experimenter should not expect to find any reserve margin of power beyond the levels quoted. It is important also to notice that the vacuum tubes are not being used according to conservative instrument practice, but rather in the fashion of commercial equipment where high stability and long tube life are not important. Conservative instrument practice would dictate lower voltages than used here, and the available power would be correspondingly reduced.

— A. P. G. PETERSON

Figure 8. The circuit diagram for a 25-watt power amplifier, which uses lower supply voltages than the higher power versions and which does not operate so far into the Class AB$_1$ region.



BIAS VOLTAGES - TYPE 1614, 31 VOLTS; TYPE 6S4, 31 VOLTS; TYPE 6CB6, 3.3 VOLTS

VOLTAGE INPUT FOR 25 WATTS OUTPUT: 7.8 VOLTS

MISCELLANY

CREDITS—The single-ended push-pull amplifier described in this issue was originally developed by Dr. Donald B. Sinclair and Dr. Arnold P. G. Peterson. Credit is also due to Carlton A. Woodward, Jr., and William F. Byers for their helpful suggestions and to Mr. Woodward for his assistance in the experimental work.

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THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

VOLUME XXVI No. 6 NOVEMBER, 1951

A 500-VOLT MEGOHMMETER FOR INSULATION TESTING

Also

IN THIS ISSUE

● **THE NEW** General Radio Megohmmeter, Type 1862-A, has been specifically designed for the rapid measurement of insulation resistance, as well as general resistance testing such as the measurement of high-valued resistors. Consequently, it has a considerably wider field of application than its predecessor, the Type 1861-A.

Since insulating materials usually exhibit a marked voltage coefficient of resistance, it is necessary for purposes of standardization that measurement be made at one of the accepted standard voltage levels, and the level most commonly agreed upon by professional and industrial groups is 500 volts.[1] The new megohmmeter applies a constant 500 volts to the resistance under test and is well suited to testing the insulation of rotating electrical machinery, transformers, capacitors, cables, and household appliances in production, in the repair shop, and in the field.

Figure 1. View of the megohmmeter with cover removed to show panel.

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[1] A.S.T.M. Standards on Electrical Insulating Materials, D 257-49T.

The Type 1862-A Megohmmeter is contained in a cabinet designed for portability and ruggedness (see Figure 2) since it will be as useful in the field as in the laboratory. A cover provides a storage compartment for the power cord, test leads, and other accessories. The simplicity of the panel controls (see Figure 1) allows its use by untrained personnel. Resistance is indicated as the product of a meter reading and a multiplier setting. As seen from the photograph of Figure 3, each decade (0.5 to 5.0 on the meter) utilizes 90% of the meter scale length, and the remaining 10% provides overlap. There are six multiplier positions. The full range of the instrument is from 0.5 megohm to 2,000,000 megohms.

Other Features

This new instrument has a number of features that contribute to its speed of operation, its accuracy, and its safety from shock.

(1) In the DISCHARGE switch position, all voltage is removed from the terminals to allow connecting and disconnecting the unknown resistance with complete safety from electric shock.

(2) At this same switch position, a shunt resistor is automatically connected across the UNKNOWN terminals to remove any residual charge in the capacitive component of the unknown resistance. This feature, which is especially useful when the leakage resistance of capacitors is measured, was adopted because the relatively low resistance of the megohmmeter circuit has made the rapid measurement of capacitor leakage resistance a major application of the instrument.

Figure 3. The Type 1862-A Megohmmeter is small, compact, and easily portable.

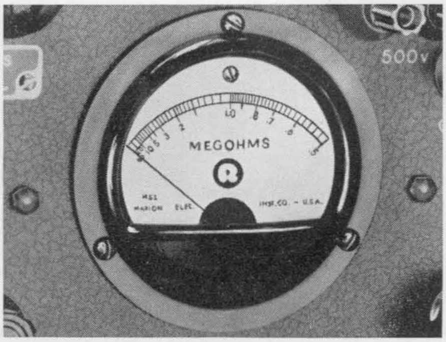

Figure 2. View of the meter scale.

(3) The circuit resistance in series with the unknown is directly proportional to the multiplier setting and at the lowest setting is so small that it has a negligible effect on the charging time for even the largest capacitors. Therefore, it is not necessary to charge the unknown as a separate operation before starting the measurement.

(4) This instrument is very convenient for observing the apparent leakage resistance after one and ten minutes of charging time as is sometimes done as a routine procedure for monitoring the condition of installations where dielectric absorption is appreciable,[1] as on large electrical machinery.

(5) Voltage-stabilized power supplies for both the 500-volt source and the vacuum-tube voltmeter circuit contribute to a high degree of calibration stability. A CHECK switch position is provided for checking the calibration and controls are provided for readjustment. This is necessary usually only when tubes are changed.

(6) In addition to the two UNKNOWN terminals, a guard and a ground binding post are provided on the

panel for making three-terminal resistance measurements; a typical application is the measurement of insulation leakage between two specific wires of a multi-conductor cable: all other wires are connected to the guard terminal. The ground terminal can be connected to either the guard terminal or to one of the UNKNOWN terminals.

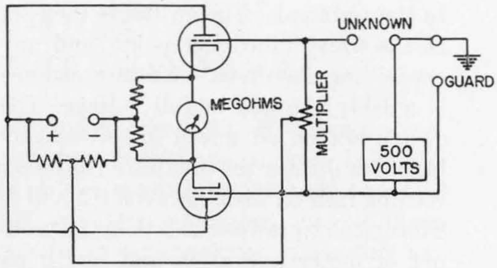

Figure 4. Elementary schematic circuit diagram of the Type 1862-A Megohmmeter.

Circuit

Schematically, the circuit is exceedingly simple: a 500-volt supply and a resistance standard are connected across the UNKNOWN terminals; a vacuum-tube voltmeter across the resistance standard is calibrated in megohms (see Figure 4). Many of the design features stem from the fact that the resistance standard is only one five-hundredth of the mid-scale resistance of the unknown. In the usual ohmmeter circuit they are equal. This large ratio is possible here because of the high-voltage of the supply (500 volts) and the high sensitivity of the meter. The vacuum-tube voltmeter sensitivity is one volt at mid-scale. The circuit comprises two balanced triodes (the 12AU7 twin triode) in a fully degenerated arrangement.

Because of the large ratio between unknown and standard, each decade covers 90% of the meter scale. In the usual ohmmeter arrangement, the central decade covers only half of the meter scale. Since the standard resistance is relatively small, a standard of high stability can be obtained, grid-current effects in the vacuum-tube voltmeter are easily controlled, and circuit leakage resistance across the standard is negligible.

Even though a balanced circuit is used, the plate supply of the vacuum-tube voltmeter is stabilized by a glow-discharge type of voltage-regulator tube (OB2) to eliminate all possible errors due to line-voltage fluctuations.

Similarly, the 500-volt supply is stabilized against line-voltage fluctuations. The degenerative series-regulator type of stabilizing circuit is used. The circuit constants are selected to maintain 500 volts across the unknown resistor for all resistance values within the range of the instrument but, if a resistance appreciably less than ½ megohm is connected, the voltage of the supply will drop rapidly to limit the current to a safe value (less than 30-ma d-c at short circuit in the worst case).

The six resistance standards are accurate to 1% or better. A check position of the control switch simplifies any readjustment of the calibration occasioned by aging or replacement of tubes. Complete degeneration in the voltmeter circuit has resulted in very small tracking error between tubes. As a consequence, the accuracy at the low-resistance end of the meter scale is 3%; it is 8% at mid-scale and 12% at the higher-resistance end of the scale ("5" on the meter). There can be an additional 2% error at the highest multiplier setting.

Operation

To measure resistance, the multiplier switch is set at DISCHARGE, and the resistance to be measured is connected to the terminals. The switch is then set at the unity multiplier point, and any capacitance associated with the resistance is quickly charged to full voltage. The switch is then advanced to successively higher multiplier settings until the meter reading falls on scale between 0.5 and 5. The unknown resistance is then the product of meter indication and multiplier switch setting.

Figure 5 shows guard-terminal connections for measuring ungrounded and grounded 3-terminal resistances.

It is possible to measure the voltage coefficient of resistors if a variable-voltage external power source is available. For this purpose the TYPE 1204-B Unit Variable Power Supply[2] is recommended. The method of connection is detailed in the instruction book supplied with the megohmmeter.

—A. G. BOUSQUET

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[2] See General Radio *Experimenter*, July, 1951.

SPECIFICATIONS

Range: 0.5 megohm to 2,000,000 megohms. There are six decade ranges, as selected by a multiplier switch.

Scale: Each resistance decade up to 500,000 megohms utilizes 90% of the meter scale. Center-scale values are 1, 10, 100, 1000, 10,000, and 100,000 megohms.

Accuracy: The accuracy in per cent of indicated value up to 50,000 megohms is ±3% at the low-resistance end of each decade, increasing to ±12% at the high-resistance end. There can be an additional ±2% error over the top decade.

Voltage on Unknown: 500 volts. Over a 105-125 volt range in supply-line voltage and over the resistance range of the instrument, the variation in voltage across the unknown resistor will be less than ±2%. At resistance values below 0.5 megohm, the applied voltage drops to limit the current to safe values.

Terminals: In addition to terminals for connecting the unknown, ground and guard terminals are provided. At two positions of the panel switch, all voltage is removed from all terminals to permit connection of the unknown in safety. In one of the positions, the UNKNOWN terminals are shunted to discharge the capacitive component of the unknown. All but the ground terminal are insulated.

Calibration Check: A switch position is provided for standardizing the calibration.

Design: Since field applications are more severe than laboratory use, the instrument, including its panel meter, was designed to be unusually rugged. The carrying case can be completely closed; accessory power cable and test leads are carried in the case. Controls are simplified for use by untrained personnel.

Tubes: Supplied with the instrument:

1 — 12AU7	1 — 2X2-A	1 — 6AU6
1 — OB2	1 — 6C4	1 — 5651
1 — 6X4		

Controls: A switch for selecting the multiplying factor, a control for standardizing the calibration, a control for setting the meter to the infinity reading, and a power switch.

Mounting: The instrument is assembled on an aluminum panel finished in black-crackle lacquer and is mounted in an aluminum cabinet with black-wrinkle finish and with black-phenolic protective sides. The aluminum-cover finish is black wrinkle. The case is provided with a carrying handle.

Power Supply: 105 to 125 (or 210 to 250) volts at 40 to 60 cycles. The power input is approximately 25 watts.

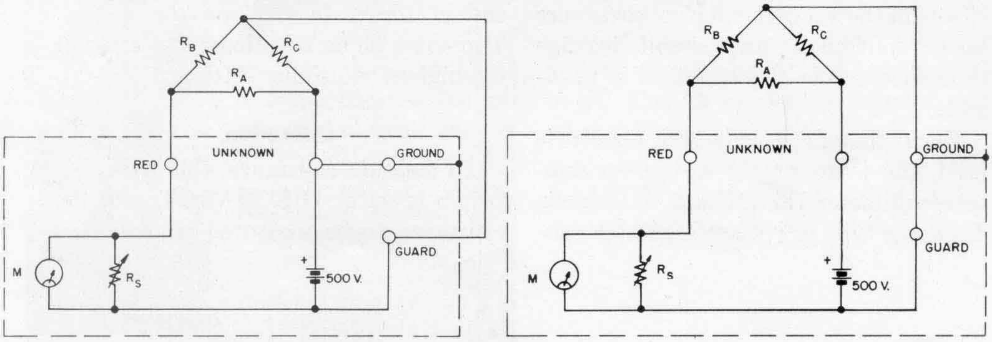
Accessories Supplied: Two color-coded test leads with phone tips, two insulated probes, two alligator clips and a TYPE 274-MB Plug.

Dimensions: (Height) 10⅛" x (width) 9⅛" x (depth) 11¾", over-all.

Net Weight: 15½ pounds.

Type		*Code Word*	*Price*
1862-A	**Megohmmeter**	JUROR	**$225.00**

Figure 5. Circuit and guard connections for (left) grounded and (right) ungrounded 3-terminal resistors.



A HIGH-POWER TOROIDAL OUTPUT TRANSFORMER

The advantages of the toroidal core transformer[1] over one using a shell-type core are becoming more generally recognized. Chief among these are the high degree of astaticism and the extremely tight coupling which can be attained between windings extending around the complete circumference of the toroid. An impedance-matching toroidal transformer, Type 941-A, was announced a year ago.[2] This article describes a high-power model, the Type 942-A Output Transformer, designed primarily for coupling push-pull output tubes to a voice coil or other low-impedance load.

This transformer combines excellent frequency response, low distortion, high power-handling capacity, and flexibility of impedance ratios in a convenient, compact unit. Leakage reactance between primary sections is very small, to give minimum distortion from switching transients in conventional push-pull amplifier circuits, and connections to individual primaries are provided for use in the single-ended push-pull amplifier described in the October *Experimenter*.[3]

The Type 942-A is wound on the same high-quality toroidal core that is used for the Type V-5 Variacs and is capable of handling peak powers up to 100 watts with a minimum of harmonic distortion. The core carries eight individual windings, four identical duplex (semi-circumferential), banked, primary windings, and two pairs of duplex, single-layer, secondary windings. These windings terminate in four sets-of-4 terminals on the upper face of the housing. Each pair of duplex windings is precisely balanced to eliminate circulating current losses when they are connected in parallel. The terminals are arranged to facilitate parallel or series connections.

Impedance Ratios

The nominal impedance values specified in the connection diagrams printed on the case of the transformer are based on a generator impedance of 6600 ohms for all four primary windings in series. This is the recommended value for a pair of 6L6's operating push-pull class AB. If these primary windings are connected in series-parallel, or all in parallel, the corresponding generator impedances should be 1650 and 413 ohms respectively.

Series and parallel combinations of secondary windings can be connected for matching loads of 4, 8, 16, 23, 32, 47, 59, and 93 ohms.

Matching generator and load impedances are not limited to the values specified above, provided that they have the

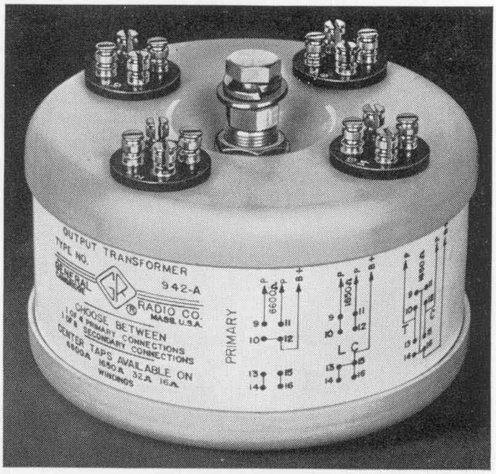


Figure 1. View of the Type 942-A Output Transformer.

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[1] Horatio W. Lamson, "Some Advantages of the Toroidal Transformer in Communication Engineering," *Tele-Tech*, May, 1950. Reprints available on request.

[2] Horatio W. Lamson, "The Type 941-A Toroidal Transformer," General Radio *Experimenter*, September, 1950.

[3] A. P. G. Peterson, "A New Push-Pull Amplifier Circuit," General Radio *Exerimenter*, October, 1951.

corresponding ratios. Eighteen impedance ratios are obtainable with this transformer, varying from 4.42 to 1650.

Primary windings can be separated as is required by the amplifier described in last month's *Experimenter* or used with a center tap in conventional push-pull operation. Center taps are also available on the 32-ohm and 16-ohm secondary windings.

Coupling Coefficient

Two different terminal connections are indicated for obtaining the 1650-ohm primary, designated respectively as TC and LC. With the TC (tight-coupled) arrangement, each half of the primary winding covers the complete circumference of the toroid, giving thereby an extremely tight coupling between the two halves of the primary. Switching transients occurring with class AB operation in conventional push-pull systems are thereby minimized, and this TC arrangement is recommended when conventional push-pull circuits are used.

With the LC (loose-coupled) connections, each half of the primary winding is on a separate semi-circumference of the toroid. Such an arrangement gives more leakage reactance between the two halves of the primary but, on the other hand, produces a lower capacitance and a more extended high frequency range than the TC connections. Choice depends upon the more important criterion. The 6600-ohm primary and all of the secondaries are tight-coupled.

The degree of coupling attained is indicated by the data in Table I.

The 6600-ohm primary has an inductance of about 24 henrys *at initial permeability* and increases with the operating level, see Figure 5. The tight coupling achieved between primary and secondary windings permits feed-back to be taken from the secondary circuit with a minimum of phase shift at high frequencies.

TABLE I

Windings	*Leakage Inductance*	*(1- r^2)**
Half Primary to Half Primary		
Tight-Coupled	2.8 mh	0.00047
Loose-Coupled	58. mh	0.0097
Full Primary to 4 or 16-ohm Secondaries	18.0 mh	0.00075
Full Primary to 8 or 32-ohm Secondaries	14.2 mh	0.00059
Full Primary to Composite Secondaries	6.4 mh	0.00027

Power Rating and Distortion

The copper efficiency is indicated by the following ratios of d-c resistance to nominal source or load impedance (Z).

Winding	$R_{d\text{-}c}/Z$
Primary	0.046
4 or 16-ohm Secondary	0.062
8 or 32-ohm Secondary	0.066
Composite Secondaries	0.034

When operating at *constant level*, the power rating of an output transformer is determined by: (1) temperature rise due to internal losses, (2) the level of distortion introduced by the transformer at low frequencies and (3), ulti-

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*The coupling coefficient, r, varies with the permeability of the core and, hence, with the operating level. r is measured at initial permeability and is greater at higher power levels. Note that leakage inductance is referred to the primary.

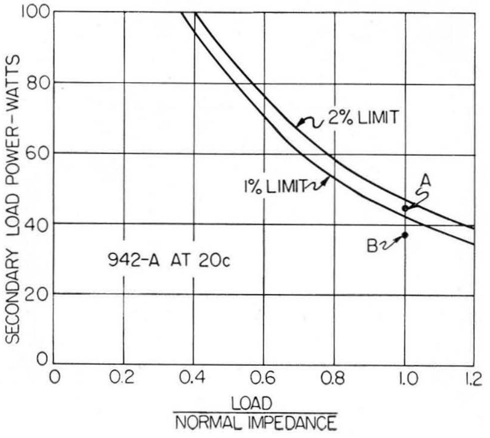

Figure 2. Showing 1% and 2% 20-cycle distortion limits as output load is varied. Taken with source impedance 0.14 × nominal primary impedance. Two-per cent limit points A and B correspond to

A — Source impedance = 0.22 nominal primary impedance

B — Source impedance = 0.65 nominal primary impedance

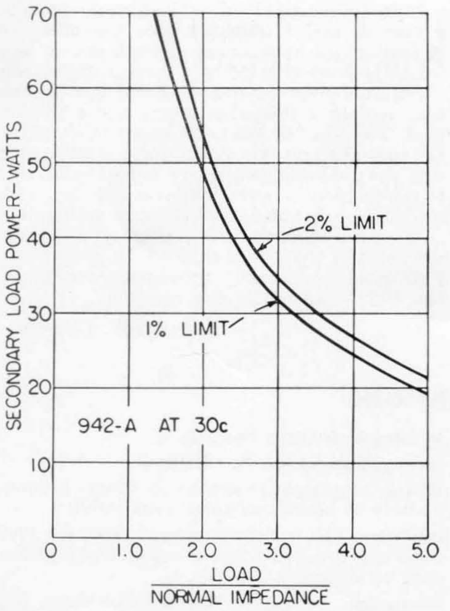

Figure 3. Showing 1% and 2% 30-cycle distortion limits as output load is varied. Taken with source impedance 0.38 × nominal primary impedance.

mately, the voltage rating of the insulation. In *speech or music* high levels occur intermittently so that the heating effect is usually not important, and the rating is determined chiefly by the distortion introduced by the non-linear magnetic characteristics of the core.

The level at which serious distortion occurs depends both upon the core material used and the peak flux density, which varies inversely with the frequency. At a specific frequency, an arbitrary value of permissible distortion may be chosen to specify the rated level.

Since transformer distortion rises abruptly above a certain voltage level, only a small change in rating occurs for a considerable range of permissible values of distortion. Likewise, the impedance of the source driving the transformer does not change the rating appreciably. Reducing the source impedance reduces the distortion values but makes little change in the level at which the abrupt rise in distortion occurs.

The data for Figures 2 and 3, illustrating a typical application of the Type 942-A, were taken on the amplifier described last month.[3] As anticipated, the *low-frequency* power rating varies, to a first approximation, inversely with the resistance load applied to the secondary. At the *nominal* impedance, the transformer can be expected, as shown in Figure 2, to handle over 40 watts at 20 cps with a distortion less than 1%. This level increases as the square of the frequency to 160 watts at 40 cps. When supplying a load which is one-half the nominal impedance, the transformer can handle 80 watts at 20 cps. However, the efficiency at higher audio frequencies is reduced by using less than the rated load.

At *higher frequencies*, above 50 cps, the power limit for continuous operation is set by copper loss, since eddy current losses in this transformer are generally negligible, and reduced flux density minimizes hysteresis losses.

The maximum allowable temperature is 65°C., which permits 8 watts internal dissipation with an ambient temperature of 35°C. Since the over-all copper efficiency is of the order of 92%, the *continuous rating* is specified as 90 watts at this ambient. The rating will then be proportional to the difference between 65°C. and the actual ambient. When an appreciable direct current is in the windings, the d-c power dissipated must also be included in determining the continuous rating for a given application.

A check of this transformer by the standard RTMA test[4] for speaker-matching transformers indicated a rating appreciably in excess of 100 watts.

Adequate secondary windings have been provided to make this output transformer suitable for supplying constant-voltage audio distribution systems.[5] For example, the standard 70-volt operating level may be obtained from the 93-ohm secondary for 50 watts or from the 47-ohm secondary for 100 watts.

The lower voltage systems or higher power levels, or both, are provided for by the lower impedance windings.

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[3] Loc. cit.

[4] RTMA Standard SE-106, Sound Systems, July, 1949, Engineering Department, Radio-Television Manufacturers Association, Section V.

[5] RTMA Standard SE-101, Amplifiers, December, 1947, Engineering Department, Radio-Television Manufacturers Association, Section III. Also, RTMA Standard SE-106, Sound Systems, July, 1949, Engineering Department, Radio-Television Manufacturers Association, Section II.

Figure 4. High-frequency characteristics of the Type 942-A Output Transformer.

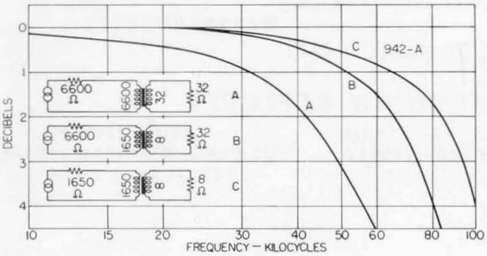
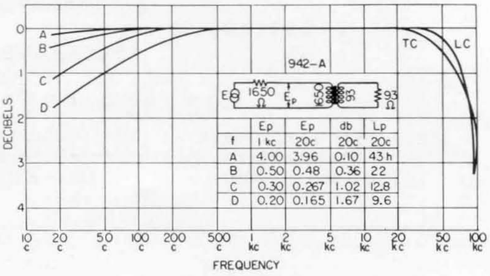


Figure 5. Over-all frequency characteristics of the transformer.



	Ep	Ep	db	Lp
f	1 kc	20c	20c	20c
A	4.00	3.96	0.10	43 h
B	0.50	0.48	0.36	22
C	0.30	0.267	1.02	12.8
D	0.20	0.165	1.67	9.6

Frequency Characteristic

The frequency characteristic of an audio transformer depends, in part, upon the source and load impedances and the turns ratio. The leakage reactance between primary and secondary, and the winding capacitances, determines the high frequency cut-off, while the low frequency characteristic is determined by the primary reactance which, in turn, is a function of both frequency and operating level.

Typical high frequency characteristics for the Type 942-A, using matching turns ratios and tight-coupled primaries, are shown in Figure 4. A comparison of Curves *A* and *B* shows the effect of changing the nominal impedance level of a transformer which is coupling a given source and load, while a comparison of curves *B* and *C* demonstrates the effect of changing the impedances of both source and load which are coupled by a given transformer.

Figure 5 gives the over-all frequency characteristic with a 1650-ohm source and a 93-ohm load. The effect of the lower capacitance of the LC primaries on the upper range is indicated, and the low-frequency range is depressed, due to a reduction in operating level and the corresponding drop in effective primary inductance.

A typical application of this transformer was discussed in the article entitled "A New Push-Pull Amplifier Circuit," appearing in the October, 1951, issue of the *Experimenter*.

—Horatio W. Lamson

SPECIFICATIONS

Impedance Ratios: See page 5.

Frequency Range: See Figures 4 and 5.

Distortion: 1% at nominal impedance and continuous power rating above 30 [illegible] les. See Figure 3.

Power Rating: 90 watts continuou[illegible] an ambient of 35°C., with no dc in wi[illegible]s. With dc in windings rating must be reduced so as not to exceed allowable power loss.

Allowable Power Loss: 8 watts for 30°C. rise over ambient.

Maximum Transformer Temperature: 65°C.

Winding Resistances: See page 6.

Leakage Inductances: See Table I.

Primary Inductance: Primaries in series, approximately 24 henries at initial permeability.

Insulation: The transformer is insulated for 2000 volts between individual windings and between each winding and the case.

Dimensions: (Height) 3¾ x (diameter) 5¼ inches, over-all.

Mounting: Above or below shelf, with single center bolt supplied.

Net Weight: 7 pounds.

Type		*Code Word*	*Price*
942-A	**Output Transformer**	TRANTORDOG	**$55.00**

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A GENERATOR OF ELECTRICAL NOISE

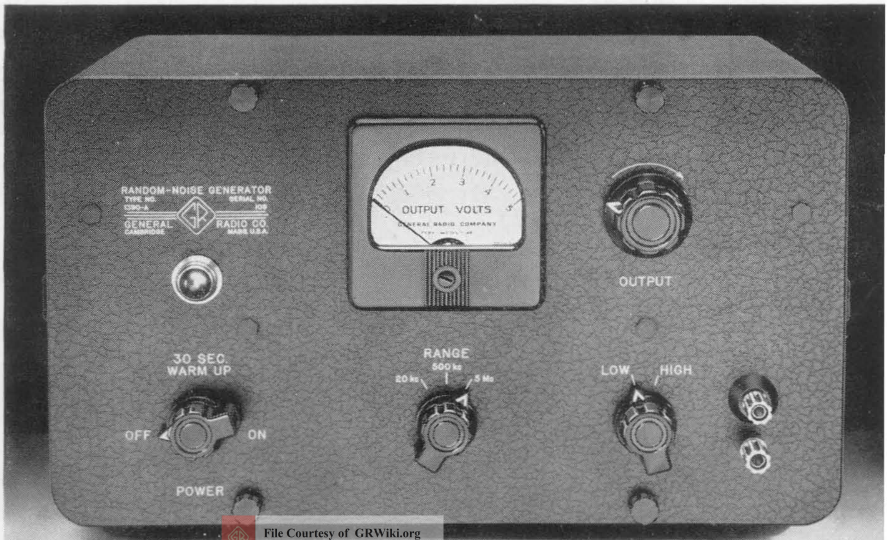
Also

IN THIS ISSUE

● **ELECTRICAL NOISE** is, by definition, an unwanted disturbance, and its reduction in communication circuits is a constant aim of the electronics engineer. When supplied by a properly controlled generator, however, noise becomes a remarkably useful signal, making possible a new approach to many measurement problems. The new General Radio Type 1390-A Random-Noise Generator, shown in Figure 1, is such a source. It provides a high level of electrical noise at its output terminals, and its many possible uses make it an indispensable item in the equipment of the modern electronics laboratory.

Typical applications are room acoustics measurements, loudspeaker and microphone tests, psychoacoustic tests, filter tests, calibration checks on recording systems, modulating signal generators and test oscillators, tests of r-m-s response of meters, observations of resonances

Figure 1. View of the Type 1390-A Random Noise Generator.



in systems, electrical averaging of resonant responses, comparisons of effective band width, and crosstalk measurements on multi-channel systems.

Furthermore, many college laboratories will find the noise generator helpful in familiarizing students with the characteristics of noise and with the measurement problems associated with noise. In the classroom it can be used for demonstrating various degrees of correlation, possible errors of random sampling, and other concepts of statistical theory.

DESCRIPTION

As shown in the elementary schematic diagram of Figure 2, the Type 1390-A Random-Noise Generator uses a gas-discharge tube as the noise source. A transverse magnetic field is applied to the tube in order to increase the noise level at high frequencies and to eliminate the oscillatory nature of the electrical discharge usually obtained in a gas tube.[1] The noise output from this gas tube is amplified in a two-stage amplifier. Between the first and second stages the noise spectrum is shaped in three different ways, depending on the setting of the range-switch control shown just below the meter in Figure 1. At the 20-kc setting, a low-pass filter is inserted, which has a gradual roll-off above 30 kc, with the audio range to 20 kc uniform in spectrum level. The 500-kc setting puts in a low-pass filter that rolls off above 500 kc. At the 5-Mc setting, a peaking network is used that approximately compensates for the drop in noise output from the gas tube at high frequencies, so that a reasonably good spectrum is obtained out to 5 Mc.

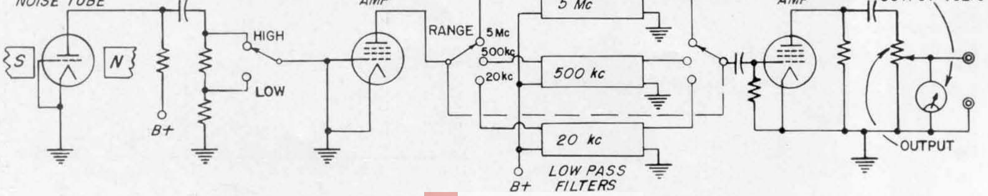
The output level is controlled by a potentiometer and a two-position switch, both these controls being located at the right as shown in Figure 1. The rectifier-type, average meter, located in the upper center of the panel, is calibrated to read the r-m-s value of the noise at the output terminals.

Easily portable and weighing only 14 pounds, the complete generator is mounted in an aluminum cabinet with rounded corners and with rubber feet. The a-c power input to the instrument is about 50 watts.

OUTPUT VOLTAGE

The maximum open-circuit output voltage on any of the three bands is one volt rms. This corresponds to a relatively high noise level, since the output impedance at maximum output is only about 800 ohms. To show how high this level is, it can be expressed in terms of the resistance noise corresponding to 800 ohms at room temperature. The r-m-s voltage in a one-cycle band that is due to thermal agitation in an 800-ohm resistor at room temperature is about 3.6 x 10^{-9} volts. The level from the Type 1390-A Random Noise Generator is about six millivolts for a one-cycle band when there is a total output voltage of one volt on the 20-kc band. This level is then about 1,600,000 times the corresponding voltage for resistance

Figure 2. Elementary schematic circuit diagram of the Type 1390-A Random Noise Generator.



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[1] J. D. Cobine and J. R. Curry, "Electrical Noise Generators," *Proc. I.R.E.*, pp. 875-879, September, 1947.

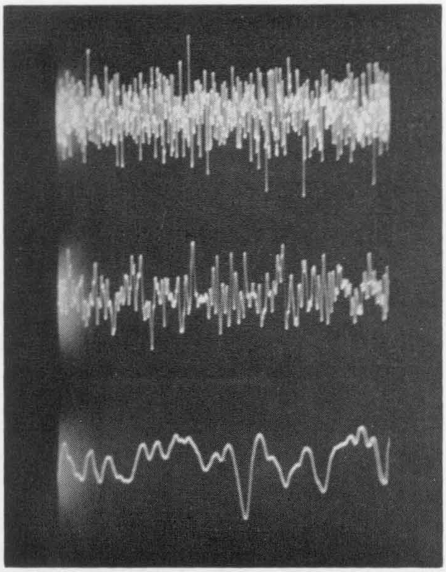


Figure 3. Oscillograms of three different samples of the output voltage wave of the noise generator. Only a single sweep and not a repetitive one was used in each case. The sweep speed for the middle trace was about four times that of the upper trace, and the wave was spread out even further in the lower trace by using a sweep speed of twenty times that of the upper trace.

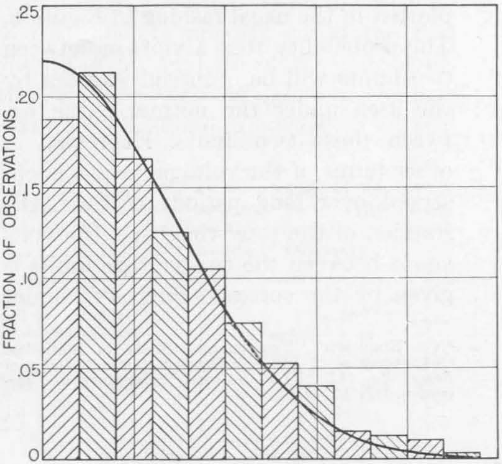
noise, or about 124 db above resistance noise at the same impedance level.

CHARACTERISTICS OF THE NOISE OUTPUT

Describing or specifying a noise signal is more difficult than specifying a sinusoidal signal. A picture of the output waveform such as that given in Figure 3 makes this evident. No regular pattern appears in this waveform; it is characterized by randomness rather than regularity. Because of this randomness, noise is usually described by statistical means,[2] and the noise is characterized by its distribution of instantaneous amplitudes and by its frequency spectrum.

A random noise is frequently defined as one that has a "normal" or "Gaussian" distribution of amplitudes. This concept can readily be understood by illustrating it in terms of the following simple experiment performed on the noise generator. The noise generator was set to the 20-kc band, and a small capacitor was connected across it. The capacitor was disconnected, and the voltage across the capacitor was measured on an electrometer. This voltage is the instantaneous amplitude of the noise voltage at the time of disconnecting the capacitor. This experiment was repeated until 400 readings had been obtained. (For convenience, only voltages of one polarity were measured.) From this set of data the chart of Figure 4 has been prepared. It shows the fraction of the observations that were in each interval of 0.2 volt. This chart shows that most of the observations were relatively low values, but some relatively high values were observed. These same re-

Figure 4. A chart of the results of a voltage sampling experiment performed on the noise generator. The continuous curve is a normal probability distribution curve adjusted according to the r-m-s value of the noise voltage and the size of the intervals used in plotting the chart.



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[2] S. O. Rice, "Mathematical Analysis of Random Noise," *Bell System Technical Journal*, Vol. 23, No. 3, July, 1944, pp. 282-332; Vol. 24, No. 1, January, 1945, pp. 46-156.

L. L. Beranek, *Acoustic Measurements*, New York, John Wiley, 1949, pp. 440-515.

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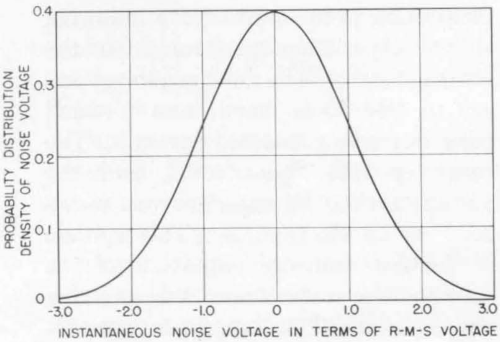

Figure 5. The normal distribution curve of a truly random noise.

sults are also shown in a qualitative way in the oscillographic picture of Figure 3.

The normal (Gaussian or Laplacian) distribution curve is also shown on the chart of Figure 4. It has been adjusted according to the computed r-m-s value of the data (the standard deviation) and the size of the interval used in plotting the data. The experimental data fit the normal curve very closely. The departures from the normal curve are almost entirely a result of having so few observations. If many more observations had been made, the result would have been even closer to the expected values.[3]

This normal curve is more precisely a probability density curve, and it is shown plotted in the usual fashion in Figure 5. The probability that a voltage between two limits will be observed is given by the area under the normal curve between those two limits. Expressed in other terms, if the voltage output is observed over long periods of time, the fraction of the total time that the voltage is between the two voltage limits is given by the corresponding area under the probability curve.[4] For example, the instantaneous voltage magnitude will be no more than one-tenth of the r-m-s value for about eight per cent of the time, and will be greater than three times the r-m-s value only about 0.26 per cent of the time.

DEPARTURES OF OUTPUT OF NOISE GENERATORS FROM TRUE RANDOMNESS

The normal curve of Figure 5 is symmetrical about the origin, and the output of the noise generator is also very closely symmetrical, with no appreciable d-c component being present. Because of the inherent amplitude limitations of vacuum tube amplifiers, however, there is some limiting of the distribution curve at high levels. The normal distribution is modified only slightly on the 20-kc range, while moderate clipping occurs on the other ranges. These limitations are of no importance for the majority of applications.

FREQUENCY SPECTRUM OF NOISE

The meaning attached to the phrase "the frequency spectrum of a noise" is also readily described in terms of an experiment. If a wave analyzer, such as the Type 736-A Wave Analyzer, is used to analyze the output of the noise generator, a fluctuating meter reading will be observed at any setting of the analyzer. If the average value of this reading is taken over a period of time very long compared to 0.2 second (the period corresponding to the five-cycle effective band width of the analyzer), this average value is the level in that five-cycle-wide band. The level determined in this way on any of the ranges of the noise generator is essentially independent of

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[3] Nic Knudtzon, "Experimental Study of Statistical Characteristics of Filtered Random Noise," *Technical Report No. 115*, M.I.T. Research Laboratory of Electronics, July 15, 1949.

[4] R. E. Neinburg and T. F. Rogers, "Amplitude Distribution Analyzer," *Radio-Electronic Engineering*, Vol. 46, No. 6, December, 1951, pp. 8-10.

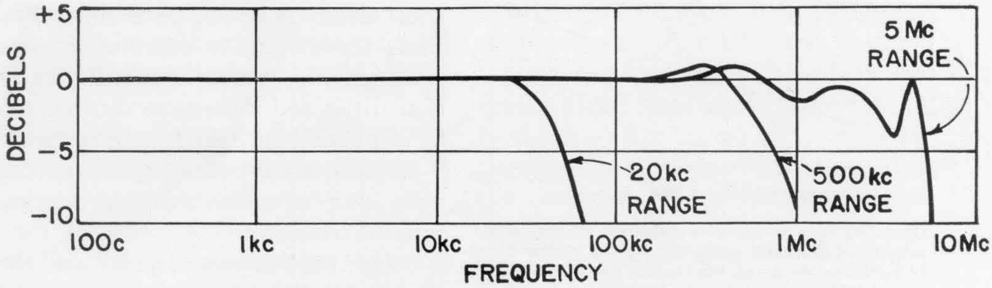


Figure 6. Typical spectrum level characteristics for Type 1390-A Random-Noise Generator.

the frequency setting of the Type 736-A Wave Analyzer. Thus the spectrum in this region is uniform. The relative spectrum of the noise can be determined by using suitable analyzers to cover the full range of the principal energy regions of the noise. A typical result of such an analysis is shown in Figure 6 for the three bands of the Type 1390-A Random Noise Generator. When the spectrum is uniform over a broad band, as shown there, it is frequently called "white noise." The "whiteness" always applies to a definite band only. For example, if the noise spectrum is uniform from 100 kc to 500 kc, the noise is referred to as white in that band.

It is customary to adjust the measured value of analyzed noise to that corresponding to an ideal filter of one-cycle band width. Since noise voltage increases as the square root of the band width, the value determined on the Type 736-A Wave Analyzer is then divided by

$$\sqrt{\frac{5 \text{ cycles}}{1 \text{ cycle}}}$$

to obtain what is called here "spectral voltage density." This value can be defined as the r-m-s voltage corresponding to the energy contained within a band one cycle per second wide.

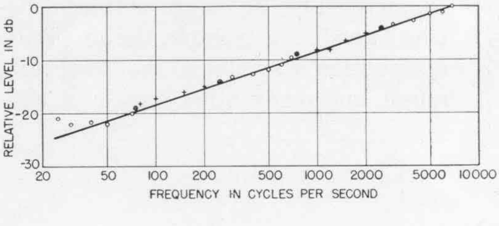
ANALYSIS OF NOISE BY CONSTANT-PERCENTAGE ANALYZERS

If the output of the Type 1390-A Random Noise Generator is analyzed by a Type 760-B Sound Analyzer, the results will be similar to that shown in Figure 7. Here the indicated level increases 10 decibels for each decade increase in frequency. This result is to be expected from the fact that this analyzer has a band width that is essentially a constant percentage of the center frequency. For example, at 5 kc the effective band width for noise is about 160 c, and at 500 c is about 16 c.

ANALYZER LIMITATIONS

Some analyzers cannot handle a noise signal satisfactorily because of the dynamic range required. As an illustration of the difficulty one can encounter, the results of an analysis of the output of the noise generator by one of our earlier Type 760-A Sound Analyzers is shown

Figure 7. The results of an analysis of the output voltage of the noise generator by a Type 760-B Sound Analyzer. The straight line is drawn at a slope of 10 db per decade of frequency.



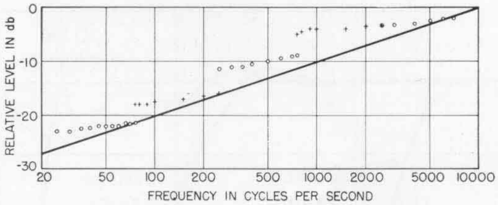


Figure 8. The results of an analysis of the output voltage of the noise generator by the earlier Type 760-A Sound Analyzer. The straight line is drawn at a slope of 10 db per decade of frequency and the departure of the observed points from this slope are a result of the inadequate dynamic range for noise signals of this earlier instrument.

in Figure 8. This analyzer was designed for periodic signal inputs, and it has ample dynamic range for that application. When an attempt is made to analyze noise, however, incorrect readings are obtained as shown. The dynamic range of the instrument is affected by the setting of the tuning control so that the levels within any one band do not follow the 10-db-per-decade slope. Furthermore, at the ends of two adjacent bands at the same frequency setting the available dynamic range is markedly different, and a discontinuity is obtained, while a check with periodic signals shows no such discontinuity. The extent of this discontinuity will vary from instrument to instrument and will depend on the condition of batteries and tubes. In any case the noise generator provides a good source for checking on this effect of dynamic range. As shown in Figure 7, our newer model of this analyzer, the Type 760-B Sound Analyzer, has adequate dynamic range for the noise signal.

APPLICATIONS

Some applications of a noise generator depend on its amplitude distribution characteristics, which are shown in Figures 4 and 5. For example, the amplitude distribution is similar to that of speech, music, and many other sounds or electrical disturbances that occur naturally,[5] while the amplitude distribution of a sine wave is entirely different. These similarities and differences can be seen by comparing the distributions of Figure 9. Because of this characteristic, random noise is an important signal for psychoacoustic tests.

Other applications depend on the various possible frequency spectra of noise. The frequency spectrum is independent of the amplitude distribution in the sense that a normal distribution of amplitudes is possible with any frequency spectrum, flat, broad, narrow, sloping, or peaked. Systems that affect one characteristic, however, may also affect the other. For example, nonlinear clipping affects both the amplitude distribution and the frequency spectrum. Linear filter networks used on purely random noise do not affect the randomness but alter the frequency characteristic and correspondingly the time scale. Linear filter networks used after clipped noise alter the frequency spectrum and also tend to make the noise more nearly random.

Interference Tests

Since noise is a common form of interfering or disturbing signal or signal that limits the threshold of detectability, the noise generator can be used to check receivers, communication systems, and detection systems for their susceptibility to interference. It can also be used as a training aid for operators who must communicate through interference. For these applications relatively low levels of noise are sometimes required, and

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[5] H. K. Dunn and S. D. White, "Statistical Measurements on Conversational Speech," *Journal of the Acoustical Society of America*, Vol. 11, No. 3, January, 1940, pp. 278-288.

W. B. Davenport, Jr., "A Study of Speech Probability Distributions," Massachusetts Institute of Technology, Research Laboratory of Electronics, *Technical Report No. 148*, August 25, 1950.

these can be obtained by using a Type 700-P1 Voltage Divider or other suitable attenuator as an accessory.

Frequency Response Measurement

For measuring the response of circuits and systems, the noise generator can be used in place of the usual sine-wave oscillator. In this application the selective characteristics of generator and detector are reversed from those ordinarily used in point-by-point measurements; the wide-band noise source and a selective detector replace the single-frequency source and wide-band detector. For speech and music circuits, this technique provides a much closer approximation to operating conditions than does the older system. This approach is particularly useful in testing recording systems.[6] The usual sweeping sinusoidal tests are sometimes inconvenient because of the problem of determining the recorded frequency when playing back. The use of a recorded noise signal that is analyzed on playback eliminates this problem.

Because of its broad frequency spectrum, noise is frequently used to avoid the marked resonance effects that can occur when measuring vibrations in mechanical structures and acoustical systems. Its use as a source in measuring the reverberation characteristics of rooms and the transmission characteristics of building structures results in a type of electrical averaging of the characteristic, provided a reasonably broad noise band is used. This averaging frequently simplifies the comparison of the characteristics of different structures.

The noise generator is useful for taking response measurements on loudspeaker systems in rooms.[7] The electrically averaged response can be taken so as to determine the optimum characteristic for equalizing networks. It can be used for setting the relative levels of woofer and tweeter units or for adjusting levels of multiple speaker units mounted in different locations in large halls.

Resonance Tests

Because of the broad frequency spectrum of noise, its use can sometimes

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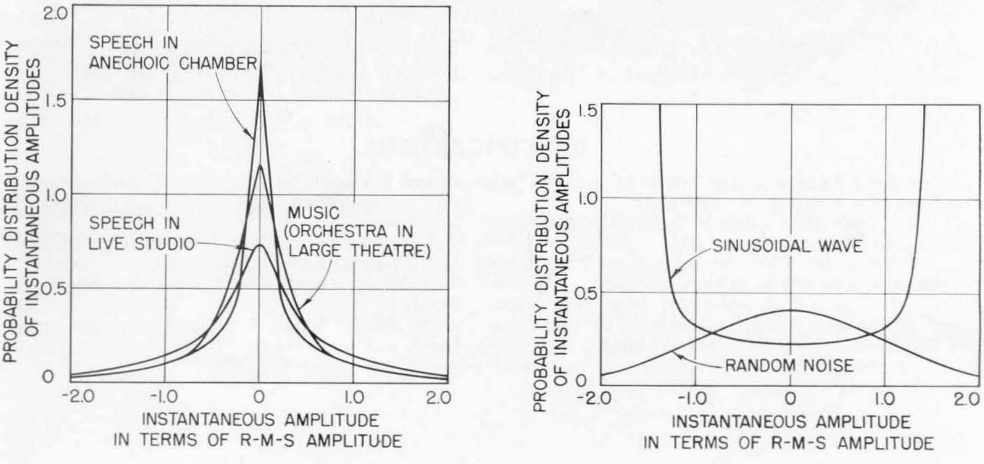
[6] S. S. Stevens, J. P. Egan, and G. A. Miller, "Methods of Measuring Speech Spectra," *Journal of the Acoustical Society of America*, Vol. 19, No. 5, September, 1947, pp. 771-780.

[7] Leo L. Beranek, op. cit., pp. 665-668 and 697-702.

Figure 9. The amplitude distribution curves obtained on various representative sounds are shown in the left-hand set of curves. The curves labeled "speech" are particular cases of the sounds produced in reading printed matter,[5] and the curve labeled "music" is an analysis of an orchestral selection made in a large theater.[5] The right-hand set of curves shows for comparison the distribution curves of a single sinusoidal wave and a random noise.



simplify the search for resonant conditions in a system.[8] The resonance produces a peak in the frequency spectrum, which can be observed in oscillographic displays.

Other Uses

Noise generators have been used for some interesting statistical demonstrations. The equipment and methods for demonstrating various degrees of correlation and possible errors of random sampling have been described by Licklider and Dzendolet.[9]

Further interesting applications of noise sources are described in the references cited at the end of this article as well as in many issues of the *Journal of the Acoustical Society of America* (for which there are two comprehensive indices available).

CONCLUSION

The wide frequency range and high level output of the TYPE 1390-A Random Noise Generator make it useful for a wide variety of applications from the audio-frequency into the radio-frequency and video-frequency ranges. The features of compactness and relatively low price also make it particularly attractive to the small laboratory, and its availability should lead to an expansion in applications for a noise source.

— ARNOLD P. G. PETERSON

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[8] Emory Cook, "White-Noise Testing Methods," *Audio Engineering*, Vol. 34, No. 3, March, 1950, pp. 13-15.

[9] J. C. R. Licklider and E. Dzendolet, "Oscillographic Scatterplots Illustrating Various Degrees of Correlation," *Science*, January 30, 1948, Vol. 107, No. 2770, pp. 121-124.

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C. R. Ammerman, "Direct Measurement of Band-width," *Electrical Engineering*, Vol. 69, No. 3, March, 1950, pp. 207-212; *Transactions, A.I.E.E.*, Vol. 69, Part 1, pp. 27-31.

H. R. Clayton and R. S. Young, "Improvements in the Design of Ultrasonic Lamination Detection Equipment," *Journal of Scientific Instruments*, Vol. 28, No. 5, May 1951, pp. 129-132.

P. H. Parkin, "Provisional Code for Field and Laboratory Measurements of Airborne and Impact Sound Insulation," Report of the 1948 Summer Symposium of the Acoustics Group, *The Physical Society, London*, 1949, pp. 36-44.

H. F. Hopkins and N. R. Stryker, "A Proposed Loudness-Efficiency Rating for Loudspeakers and the Determination of System Power Requirements for Enclosures," *Proc. I.R.E.*, Vol. 36, No. 3, March, 1948, pp. 315-334.

The experimental model of the TYPE 1390-A Noise Generator was developed by Mr. Robert Crane while he was an M. I. T. cooperative student at the General Radio Company, working under the direction of Dr. Peterson. The development has been completed by Mr. Corwin Crosby and Mr. Robert J. Ruplenas.

SPECIFICATIONS

Frequency Ranges: Three bands of noise as selected by a switch are provided:

(a) 20 kc: The spectrum level is uniform from 30 c to 20 kc within ±1 db.

(b) 500 kc: The spectrum level is uniform from 30 c to 500 kc within ±3 db.

(c) 5 Mc: The spectrum level is uniform from 30 c to 500 kc within ±3 db and from 500 kc to 5 Mc within about ±8 db.

Output Voltage: The maximum open-circuit output voltage on any of the three bands is about 1 volt rms.

The average spectrum level with 1 volt output is approximately as follows:

(a) 20-kc band: 6 millivolts for one-cycle band.

(b) 500-kc band: 1 millivolt for one-cycle band.

(c) 5-Mc band: 0.5 millivolt for one-cycle band.

The Type 700-P1 Voltage Divider can be used with this instrument to provide low output levels. It has multiplying factors of 0.1, 0.01, 0.001, and 0.0001.

Output Impedance: The source impedance for maximum output is approximately 800 ohms. The output is taken from a 2000-ohm potentiometer. One output terminal is grounded.

Waveform: The noise source is a gas tube that has a very good normal, or Gaussian, distribution of amplitudes for limited ranges of the frequency spectrum. For the 20-kc range, this distribution is modified only slightly by the unavoidable amplitude limitations of a vacuum-tube amplifier. Moderate clipping occurs on the 500-kc range and on the 5-Mc range.

Voltmeter: A rectifier-type, average meter is used for measuring the output voltage. It is calibrated to read the r-m-s value of the noise at the output terminals.

Controls: Frequency range switch, power switch, output potentiometer, and a 10:1 level attenuator.

Terminals: Jack-top binding posts with standard ¾-inch spacing. The lower terminal is grounded to the panel.

Accessories Supplied: Power cord, spare fuses.

Other Accessories Recommended: Type 700-P1 Voltage Divider, for obtaining low output levels.

Mounting: Metal cabinet.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. Total power consumption is about 50 watts.

Tubes: The following tubes are used:

1 —6D4 2 —6AQ5 1 —3-4

All tubes are supplied.

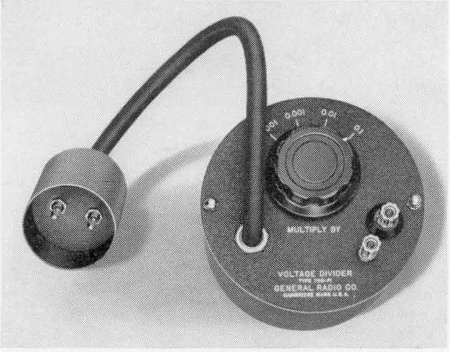
Dimensions: (Width) 12 x (height) 7½ x (depth) 9¼ inches over-all.

Net Weight: 15 pounds.

Type		*Code Word*	*Price*
1390-A	**Random-Noise Generator**	BUGLE	**$260.00**

TYPE 700-P1 VOLTAGE DIVIDER

The Type 700-P1 Voltage Divider is recommended for use with the Type 1390-A Random-Noise Generator to obtain low output levels. The voltage divider consists of a ladder-type resistive network, mounted in a metal container, which is connected to the generator output by means of a shielded plug and cable. Multiplying factors of 0.1, 0.01, 0.001, and 0.0001 can be selected.



The frequency characteristic of the divider is flat within 10%, for all settings at frequencies up to 5 megacycles.

SPECIFICATIONS

Accuracy: The accuracy of attenuation at low frequencies is ±3%.

Impedance: The input impedance is 2000 ohms; the output impedance is 200 ohms.

Dimensions: (Height) 4½ x (diameter) 4½ inches.

Net Weight: 1½ pounds.

Type		*Code Word*	*Price*
700-P1	**Voltage Divider**	OTTER	**$50.00**

MISCELLANY

CANADA

To meet the steadily increasing demand for General Radio products in Canada, which increase has been especially rapid in recent years, our distributors, Canadian Marconi Company, have added two technical sales engineers to their staff to provide additional competent technical and commercial assistance to our Canadian customers.

ERIC HICKS

Mr. Eric Hicks, after serving five years with the Technical (Signal) Branch of the Royal Air Force, has spent about three years in Canadian Marconi's development and service engineering departments, during which time he worked extensively with electronic test equipment.

Mr. Robert Declercq has been with C. M. for twelve years. The last several years were in the quality control and engineering test departments where General Radio instruments are almost exclusively used.

To bring them completely up to date with the latest General Radio products and policies, both of these men recently completed a training course of several months here at the engineering laboratories and factory in Cambridge.

Their Canadian headquarters for instrument sales are at Montreal and Toronto.

We at General Radio have always been gratified by the wide acceptance of our products in Canada, and it is our desire to serve our customers with continually improving efficiency. We believe the above arrangement will further this ambition. Communications either to us or to our distributors will receive careful and prompt attention. As always, we welcome direct correspondence with our customers.

ROBERT DECLERCQ

I.R.E. PRESIDENT

DONALD B. SINCLAIR

The Institute of Radio Engineers has announced the election of Dr. Donald B. Sinclair, Chief Engineer of the General Radio Company, as its president for 1952.

Dr. Sinclair was educated at the University of Manitoba and the Massachusetts Institute of Technology, receiving the degree of Doctor of Science from the latter institution in 1935. He was a Research Assistant and later Research Associate at M.I.T. from 1932 to 1935, and he joined the General Radio Engineering Staff in 1936. He was appointed Assistant Chief Engineer in 1944 and Chief Engineer in 1950, succeeding Dr. Melville Eastham upon his retirement.

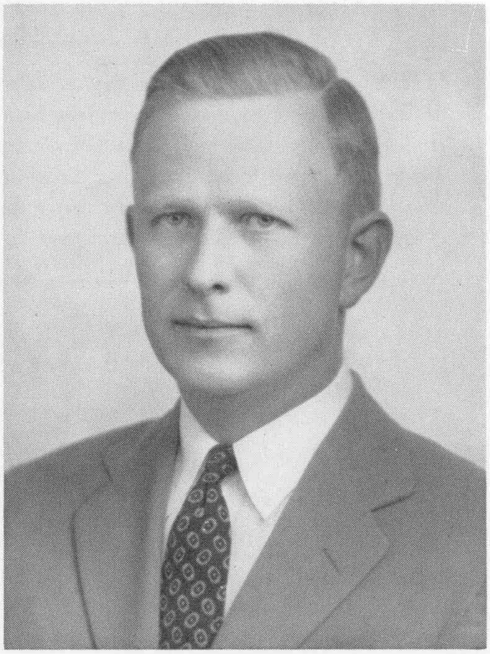
During World War II he served on the National Defense Research Committee in both the Countermeasures and Guided Missiles Divisions, receiving the President's Certificate of Merit for outstanding services.

Dr. Sinclair is a Fellow of the I.R.E., a Fellow of the A.I.E.E., and a member of Sigma Xi. He was Treasurer of the I.R.E. in 1949 and 1950 and has been on the Board of Directors of the Institute since 1945.

R. J. CALDWELL JOINS GENERAL RADIO SALES ENGINEERING STAFF

Robert J. Caldwell, formerly Manager of Sales and Application Engineering for the High-Voltage Engineering Corporation, has joined the Sales Engineering Staff of the General Radio Company.

Mr. Caldwell received his S.B. and S.M. degrees in electrical engineering from M.I.T. in 1936, after which he was employed by the General Electric Company as Student Engineer, Personnel Officer, Application Engineer, and Sales



ROBERT J. CALDWELL

Engineer. During World War II he served as Administration Officer, organizing and supervising enlisted specialists' schools, as Regimental and Battalion Radar Officer, as Executive Officer of an AAA Battalion, and as Military Government Officer in Japan.

From 1947 to 1951, Mr. Caldwell has headed the commercial and sales activities of the High-Voltage Engineering Corporation, manufacturers of high-voltage electrostatic generators.

He is a Member of the American Institute of Electrical Engineers and holds the commission of Lieutenant-Colonel in the Signal Corps Reserve.

VISITORS

RECENT VISITORS to the General Radio plant and laboratories include:

From Canada:

Prof. E. H. Gowan, Physics Department, University of Alberta, Edmonton, Alberta, Canada.

From Switzerland:

Dr. Ernst Baldinger, Professor, Physics Department, University of Basel, Basel, Switzerland.

From England:

Mr. Frederick S. Barton, Principal Director of Telecommunications Research and Development, London; Mr. J. F. Atherton, Director of the Telecommunications Research Establishment, Malvern.

From New Zeland

Prof. R. T. Pollard, Director, Industrial Development Department, Canterbury University College, Christchurch.

From Japan:

Shigezo Takao, President, Yukio Ogawa, Secretary, and Akitaro Nogami, Kobe Kogyo Corporation, Kobe; Minoru Numoto, Director, Foreign Relations, Nippon Electric Co., Ltd., Tokyo; Dr. Tadashi Sasaki, Chief Engineer, Electron Tube Department, Kobe Kogyo Corporation, Akoshi-shi, Hyago-Ken.

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