the GENERAL RADIO Experimenter

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TO

GENERAL RADIO EXPERIMENTER

VOLUMES 27 and 28

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THE General Radio EXPERIMENTER

VOLUME XXVIII No. 8 JANUARY, 1954

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

NEW PRECISION CAPACITORS

TYPE 722-MD
1000 and 100 $\mu\mu f$

TYPE 722-ME
100 and 10 $\mu\mu f$

Also IN THIS ISSUE

● **AS ATTESTED** by the popularity of the Type 722-D, a two-section precision capacitor represents a practical and economical means of obtaining two ranges of adjustable capacitance at less than the cost of two capacitors. By the use of a common case, frame, panel, and indicating means, a second section is obtained at only a moderate increase in cost over that of a single unit.

Two new General Radio precision capacitors of two-section construction are now available. These new models are intended for use in substitution methods of measurement and are calibrated in terms of capacitance differences rather than terminal capacitance. For convenience in use, the scales read directly the capacitance removed from the circuit.

The new Type 722-MD Precision Capacitor replaces the Type 722-M. This new model has the 0-1000 $\mu\mu f$ ΔC range of the model it replaces but has, in addition, a 0-100 $\mu\mu f$ ΔC range. The second model, Type 722-ME, has 0-100 $\mu\mu f$ and 0-10 $\mu\mu f$ sections. The 10-$\mu\mu f$ section represents the first regular listing of this low, full-scale value. Such units have in the past been available only on special order.

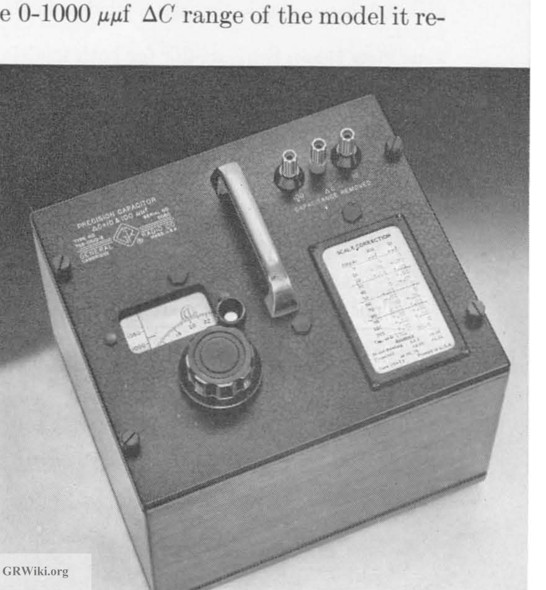

Figure 1. Panel view of the Type 722-ME Precision Capacitor.

Recently the industry requirement for accurate standards in low capacitance values has increased, largely because of the needs of manufacturers and users of ceramic-body capacitors. To meet such needs more effectively, the TYPE 722-ME is now manufactured for stock.

General Radio precision capacitors are accurate and stable standards of capacitance, carefully designed, and hand assembled and adjusted.

The entire assembly is mounted in a cast frame, which gives the unit rigidity. This frame, all spacers, the stator rods, and the rotor shaft are made of the best available alloys of aluminum, which combine the mechanical strength of brass with the weight of aluminum. The plates are also of aluminum, so that all parts have the same temperature coefficient of linear expansion.

A worm drive is used to obtain the desired high precision of setting. In order to avoid the slight eccentricity that occurs when a worm is mounted on a shaft, the shaft and the worm are one accurately machined piece. The dial end of this worm shaft runs in a self-aligning ball bearing, while the other end is supported by an adjustable spring mounting. Sealed, self-lubricating ball bearings, lightly stressed, are hand-fitted to both ends of the rotor shaft. Electrical connection to the rotor is made by means of a silver alloy brush bearing on a silver overlay drum to assure a positive electrical contact.

The preliminary assembly of the frame, shaft, and gears is motor driven to grind in the gears before final assembly.

SPECIFICATIONS

Capacitance Range:

Type	*Capacitance Range* $\mu\mu f$	*Direct-Reading Accuracy*		*Approximate Capacitance at Zero* $\mu\mu f$
722-MD	0 to 1050	±1 $\mu\mu$f	±0.1%	1140
	0 to 105	±0.2 $\mu\mu$f	±0.1%	135
722-ME	0 to 105	±0.2 $\mu\mu$f	±0.1%	145
	0 to 10.5	±0.05 $\mu\mu$f	±0.1%	35

Capacitance is indicated by the readings of the dial and drum, visible through a window in the panel.

Rotor Plate Shape: Semicircular for both models, to give a linear capacitance characteristic.

Over-all Usable Accuracy: The accuracies stated above can be attained in practice only if an acceptable standard technique is used by the operator to connect the capacitor into a measuring circuit. Otherwise, the usable accuracy at the capacitor terminals may be limited to approximately ±1 $\mu\mu$f. (See description in *General Radio Experimenter*, Vol. XXI, No. 12, May 1947, for a complete discussion of connection errors.)

Correction Chart: A correction chart is supplied giving corrections at multiples of 1, 10, or 100 $\mu\mu$f, depending on the total capacitance of the capacitor. Accuracies obtainable through the use of these charts are as follows:

		Accuracy after correction is applied	
Type	*Range,* $\mu\mu$f	*Total Capacitance* †	*Capacitance Differences*
722-MD	0 to 1050	±0.1% or ±0.4 $\mu\mu$f*	±0.1% or ±0.8 $\mu\mu$f*
	0 to 105	±0.1% or ±0.08 $\mu\mu$f*	±0.1% or ±0.16 $\mu\mu$f*
722-ME	0 to 105	±0.1% or ±0.08 $\mu\mu$f*	±0.1% or ±0.16 $\mu\mu$f*
	0 to 10.5	±0.1% or ±0.02 $\mu\mu$f*	±0.1% or ±0.04 $\mu\mu$f*

†From any zero *dial* setting. *Whichever is greater.

Worm Correction Calibration: Corrections for the slight residual eccentricities of the worm drive can be supplied for all models at an extra charge indicated in the price list. Mounted charts are supplied, which give the corrections to at least one more figure than the guaranteed accuracies, which are stated below.

Type	Range, μμf	Accuracy after correction is applied: Total Capacitance	Accuracy after correction is applied: Capacitance Differences
722-MD	0 to 1050	±0.1% or ±0.1 μμf*	†±0.1% or ±0.2 μμf*
	0 to 105	±0.1% or ±0.02 μμf*	†±0.1% or ±0.04 μμf*
722-ME	0 to 105	±0.1% or ±0.02 μμf*	†±0.1% or ±0.04 μμf*
	0 to 10.5	±0.1% or ±0.005 μμf*	†±0.1% or ±0.01 μμf*

†Differences from any zero *dial* setting. *Whichever is greater.

Maximum Voltage: All models, 1000 volts, peak.

Dielectric Supports: Bars of low-loss steatite support the stator assemblies, and conical polystyrene bushings insulate the terminals from the panel. Quartz bars, coated with silicone to prevent formation of a water film, can be supplied on special order. (See price list.)

Dielectric Losses: The figure of merit, *DC* (dissipation factor times capacitance), when measured at 1 kc, is approximately 0.04 μμf for steatite insulation and 0.003 μμf for quartz.

Residual Parameters: Effective series inductance is approximately 0.06 μh for all high-capacitance sections and 0.10 for low-capacitance sections. Effective series resistance at 1 Mc is approximately 0.02Ω for high-capacitance sections and 0.03Ω for low-capacitance sections. The series resistance varies as the square root of the frequency. Its effect is negligible below 100 kc.

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

Backlash: Less than one-half division, corresponding to 0.01% of full-scale value. If the desired setting is always approached in the direction of increasing scale reading, no error from this cause will result.

Terminals: Jack-top binding posts are provided. Standard ¾-inch spacing is used. The rotor terminal is connected to the panel and shield.

Mounting: The capacitor is mounted on an aluminum panel finished in black-crackle lacquer and enclosed in a shielded walnut cabinet. A wooden storage case with lock and carrying handle is supplied.

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

Weight: 10½ pounds; 19¾ pounds with carrying case.

Type		Code Word	Price
722-MD	**Precision Capacitor**	CYNIC	**$205.00**
722-ME	**Precision Capacitor**	COUPE	**205.00**
Worm-Correction Calibration for Types 722-MD and MDQ		WORMY	**70.00**
Worm-Correction Calibration for Types 722-ME and MEQ		WORMY	**90.00**

When ordering, use compound code word, CYNICWORMY, etc.

QUARTZ INSULATION

Any TYPE 722 Precision Capacitor can be obtained with quartz insulation.

Type		Code Word	Price
722-MDQ	**Type 722-MD with Quartz Insulators**	CYNICQUATZ	**$300.00**
722-MEQ	**Type 722-ME with Quartz Insulators**	COUPEQUATZ	**300.00**

PRECISION CAPACITORS—MADE TO MEASURE

Among the lumped circuit components available to the designer who is developing measuring or operating equipment, the variable capacitor occupies a unique position by virtue of its inherent characteristics and the ease with which they can be adapted and arranged to meet the circuit designer's requirements. While not perfect, it approaches perfection as a circuit element more closely than most other components, and its many advantages make it an acknowledged boon to the designer.

One of its most useful features is that it is variable continuously, rather than in steps. The only limitation to the precision of adjustment is the excellence of the mechanical drive that can be applied to it. Over the years direct drive has given way to spur gearing and later to worm gearing for drive purposes, and sleeve or cone bearings have been succeeded by ball bearings for the shafts. Successive refinements in design and manufacture of both the worm gearing and the ball bearings have continued to enhance the smoothness and precision of adjustment.

General Radio's precision variable capacitors have, during a life span of around 35 years, gone through the continuous development alluded to above until they now constitute an essential type of precise unit employed not only in the myriad expected applications in the electronics business but also in many unexpected ones. They are necessary, for instance, to the safe operation of aircraft, since they are used to provide highly accurate checks of the calibration of aircraft fuel gauges. It is the fuel for those last few miles that really counts the most and which the pilot must be sure is actually in the tanks.

What has given such versatility and wide application to the precision variable capacitor, such as the General Radio TYPE 722? It must be the many features which can be flexibly rearranged, in nature and in combination, to meet large numbers of vastly different requirements. Some of the features of precision variable capacitors which are subject to controlled modification by the designer will be discussed one by one. The first ones are exemplified often in capacitors which are available from catalog stock, whereas the later ones are usually observed only in special capacitors made to order to meet each customer's current desires.

1. Capacitance Range

This may be almost any figure within the limits of 1 $\mu\mu$f and 1000 $\mu\mu$f. The capacitance-rotation curve is essentially a straight line except at each end where fringing causes deviations. In stock models, linearity is maintained over slightly more than 150°. Capacitors are manufactured for catalog stock having straight capacitance sections spanning nominally 10, 100, and 1000 $\mu\mu$f (actually 10.5, 105, and 1050 $\mu\mu$f). Capacitors have been built with nominal capacitance span of 1 $\mu\mu$f linear (actually 1.05 $\mu\mu$f). If

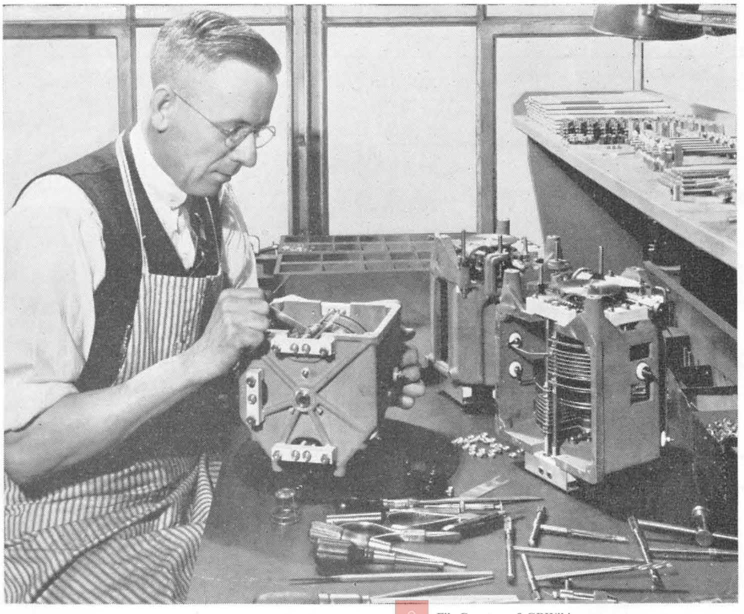

Figure 1. The accuracy and stability of a precision capacitor depend to a great degree upon the care and skill with which it is assembled and aligned. Here, a skilled machinist is assembling a group of capacitors for installation in heterodyne frequency meters.

the capacitor desired is not to be direct reading, any reasonable capacitance span can be provided. If a direct-reading scale is desired, a capacitance span over the linear portion should be chosen which can make use of available worm drive ratios. The vernier dial span must be chosen with care, since it must repeat time after time, tracking the successive marks on the drum dial.

2. Dial Markings

While there is almost no limit to the particular legends which may appear on the main and vernier dials, there are usually employed only three kinds:

a. Direct capacitance
b. ΔC, in capacitance added
c. ΔC, in capacitance removed.

3. Worm Calibrations

Enhanced accuracy in use of the capacitor can be had by providing it with a worm calibration. No worm or worm wheel, in spite of precise machining, will come out absolutely concentric, even after the grinding-in period regularly employed in capacitor manufacture. Accordingly, there will be roughly sine-wave departures from linearity, of short period (one worm revolution) and of long period (one-half worm wheel revolution). These, of course, are superposed on any departures from linearity contributed by plate shape and by failure of the axis of rotor and stator plates to coincide exactly. Most of these unwanted variations are evaluated all at once for correction purposes in the worm correction data supplied when specifically requested.

4. Quartz Insulation

While binding posts are insulated by polystyrene in most instances, there is some steatite insulation in the capacitor.

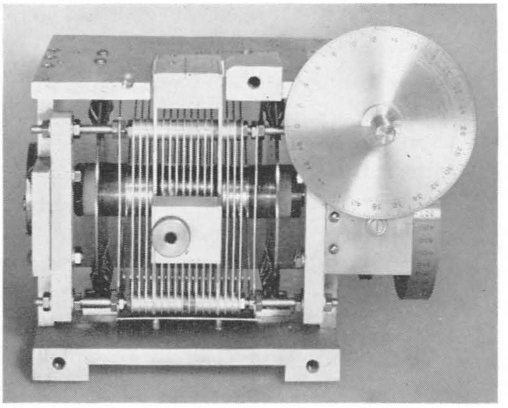

Figure 2. View of the capacitor used in the Type 821-A Twin-T Impedance Measuring Network. This capacitor is designed to have very low residual impedances.

For improved a-c dissipation factor and for improved d-c leakage resistance, silicone-treated fused-quartz insulators are available on special order. Fused quartz is in itself so expensive and so hard to machine that the fragile quartz insulation should be used only when really needed.

5. Double Scale Legends

For some purposes, such as bridge measurement, it is convenient to have two sets of scales on the main and vernier dials. Examples are:

a. Direct-reading capacitance in black characters and ΔC capacitance-removed in red.
b. ΔC capacitance-added in black and ΔC capacitance-removed in red.

6. Three-Terminal (Insulated-Rotor) Capacitors

In the usual construction, the rotor and shaft are common, and tied to the frame by a silver brush-drum takeoff short-circuiting the ball bearings. However, it is often desirable to have the rotor insulated from the frame. The reason might be that rotor and stator are both high in an oscillator circuit. Or it might be because the capacitor is to be used in a bridge or other measuring circuit with both sets of plates off ground, as for measurement of direct capacitance. It might be done to eliminate the variations of capacitance in the leads going to a remote capacitor, by using coaxial line to carry one of the two electrode leads, the shield going to the frame. The coaxial connection also inherently prevents electrostatic pickup.

Another particular advantage to be obtained from three-terminal construction is that the effects of stator-frame and rotor-frame capacitances and losses can be removed by proper circuit connections. This means that the zero capacitance of a three-terminal capacitor and the capacitance at the low end of the straight portion of the capacitance-rotation curve are both appreciably smaller (often as much as 25 $\mu\mu$f in typical TYPE 722's) than the corresponding values for a capacitor in two-terminal construction.

If noise caused by varying contact between balls and races is still too high in a critical application, a further improvement can be obtained through the use of rotor insulation, since it breaks the electrical paths through the main ball bearings.

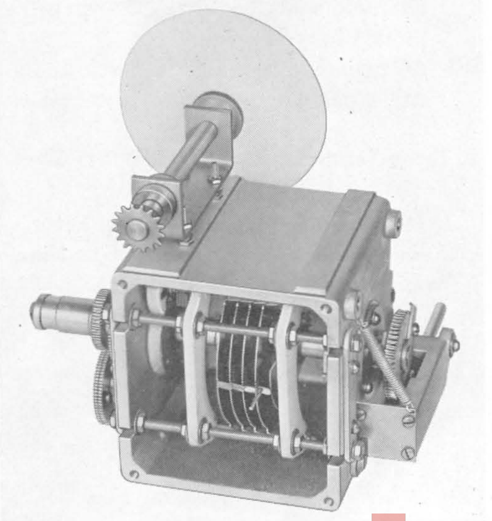

Figure 3. A special type of capacitor used in a precise heterodyne frequency meter. The cast aluminum frame provides both electrical shielding and mechanical stability.

7. Coaxial Connectors

For a large number of uses of three-terminal capacitors, replacement of the binding post terminals by coaxial connectors is indicated (see immediately above). While any type of standard coaxial connector can be supplied, use of our TYPE 874 Connectors is favored. Interconnections to other of our instruments (also using TYPE 874 Connectors) in measuring setups, for example, are easily made. Connections to almost any other type of coaxial system can readily be made with the adaptors available in the 874 line.

8. Shaped Plates

Curves other than the usual straight-line ones representing the relationship of capacitance to rotation can be had. While either rotor or stator plate can be shaped, it is usually the rotor that is so shaped for this purpose. 180° or 90° (approx.) stators are available for, respectively, 180° and 270° (approx.) rotations. Many types of curve can be produced, such as straight-line frequency of various frequency ratios, exponential frequency (giving a logarithmic dial distribution), or even arbitrary curves.

9. Residual Parameters

Nobody wants inductance and resistance in a capacitor but likewise no one seems to know how to eliminate them completely. The real problem is to reduce them as much as is practical. The residuals (L and R) in the TYPE 722-N Precision Capacitor (for use at radio

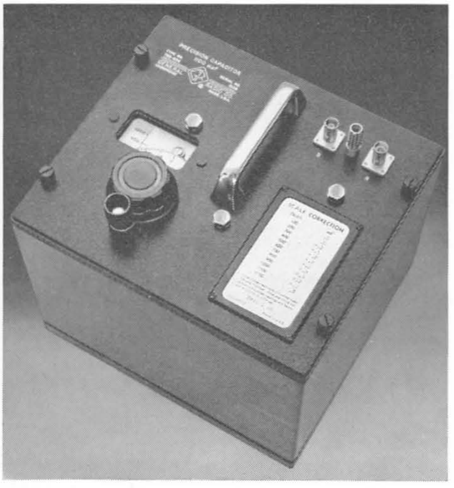

Figure 4. Panel view of a special Type 722 Precision Capacitor calibrated in direct capacitance. The coaxial terminals provide complete shielding for the leads.

frequencies) are about ⅖ of those of the large sections of other TYPE 722's. The small sections of dual capacitors have higher residuals. However, the residuals in the capacitor employed in the TYPE 821-A Twin-T are about 1/10 of those of the large sections of the usual TYPE 722, or about ¼ of those of a TYPE 722-N. This capacitor construction, shown in Figure 2, is, although available, rather expensive, since it is not regularly made for separate sale.

10. Other Designs

Occasionally particular specialized features are desired. Designs of precision variable capacitors to accomplish these results are in existence.

Some have five-sided cast bathtub frames to secure more complete shielding and greater rigidity for extremely critical locations, such as frequency-measuring equipment.

Some are arranged for equal but opposite stators, having also equal and opposite rotors. These could be used in balanced circuits, such as balanced lines or a Colpitts oscillator. The disposition of the two rotors on opposite sides of the shaft is advantageous under conditions of shock or vibration.

11. Unmounted Models

Where precision variable capacitors are to be incorporated into a customer's equipment, they will be supplied unmounted or will be mounted to panels or cabinets supplied by him.

12. Special Mechanical Features

Many special or added mechanical features have been requested and supplied for the convenience of customers. A few of these are:

a. Extra length extensions from the worm shaft. These may be from one or from both ends of the shaft.

b. Clock spring loading for the worm drive instead of the usual type where a spring presses the worm into the throat of the worm wheel.

c. Special ball bearings designed to reduce still further the backlash (which can be detected only electrically with the capacitor in a sensitive electrical circuit).

d. Extra binding posts or other special types of external connections for particular customer applications.

One anomalous fact in connection with precision variable capacitors should be clearly understood by all who use them. This fact is a direct result of the state of the art of inductance and capacitance measurements as against resistance measurements. Resistance values can be given with certainty by the National Bureau of Standards to 20 parts in a million, or less, but certifications of capacitance values under the most favorable conditions are not so good by at least an order of magnitude.* Yet it is possible to measure and intercompare capacitors with existing bridge equipment many times closer than that.

There is then the somewhat unexpected situation in which internal consistency in capacitance readings can be obtained and repeated to several times the accuracy of the capacitance standards themselves. Worm correction charts are given to more than four significant figures, indicating the internal consistency which is obtainable. However, an overriding uncertainty of capacitance value of 0.05% to 0.1% must always be borne in mind and catalog specifications are so written.

—P. K. McElroy

*For a discussion of measurement procedure and the accuracy attainable, see NBS Circular 531, entitled "Extension and Dissemination of the Electrical and Magnetic Units by the National Bureau of Standards," obtainable from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 25 cents.

WE SELL DIRECT

To develop the type of product manufactured by the General Radio Company requires a large staff of engineers, each a specialist in one or more fields of engineering and science. One of the functions of this staff is to assist the customer in the selection of instruments in order that the correct equipment may be purchased with a minimum expenditure.

There has always been close contact between our engineering staff and our customers. The technical nature and the manifold uses of our product make the maintenance of this contact essential. For this reason, the General Radio Company maintains no sales agencies in the United States, but distributes its products directly to the user on a net-price basis. The Company maintains factory branch offices in several major cities of the United States which are staffed by skilled, factory-trained engineers.

Your correspondence is welcome, and may be directed to the main office at Cambridge or to the branch office nearest you. All inquiries receive individual and immediate attention.

Our terms, if you have an account with us, are net 30 days. If not, we will prepay shipping charges to any point in the continental United States, except Alaska, if payment accompanies the order. Otherwise shipment is C.O.D.

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ELECTRONIC APPARATUS FOR SCIENCE AND INDUSTRY

COME TO THE FAIR

Also
IN THIS ISSUE

● **THE RADIO ENGINEERING SHOW** held in conjunction with the IRE National Convention moves this year to the Kingsbridge Armory, where space has been taken by 600 manufacturers for 1¼ miles of exhibits.

General Radio will be there, in Booths 251, 253, and 255, at the corner of Instruments Avenue and Radio Road. Our exhibit space has twice the back-wall of our space in past years — 40 feet in all. We are glad to have this additional space (which could not have been available had the show not moved to the Armory) because it gives us an opportunity to show you a larger part of our line of electronic instruments and associated equipment than we have been able to show in the past.

We hear a lot of advertising claims nowadays about the "complete line" and "complete coverage." General Radio doesn't claim to make a "complete line" of electronic equipment. Furthermore, we doubt that any existing instrument manufacturer has the staff, the facilities, or the resources to do it.

But — *we make a more extensive line of instruments — more types, that do more things — than any other electronic instrument manufacturer in the world.*

When you buy a General Radio instrument, you buy a quality product, correctly designed and carefully manufactured; built to rigid specifications; built for long life; guaranteed to meet catalog specifications; and backed by 39 years of experience in electronic instrument manufacture. General Radio

instruments are outstanding values in the precision apparatus field.

Let's stroll along the General Radio booth at the Radio Engineering Show and see what's on display. On our left we see first the **Television Station Monitor,** an outstanding example of General Radio engineering and manufacturing. Over 90 per cent of the TV stations now on the air use General Radio monitors — proved in actual use. Monitoring equipment is a highly specialized field requiring the highest degree of accuracy and reliability. We've been in it for over 25 years. Almost all of the 2500 AM broadcasting stations use General Radio monitors.

Next, we see a display of **Coaxial Equipment** — instruments for measuring impedance, voltage, power, and attenuation at very-high and ultra-high frequencies, with an extensive array of coaxial connectors and elements for setting up measuring circuits — all based on the famous General Radio Type 874 Coaxial Connector — with adaptors to connect to all other commonly used coaxial systems.

Note particularly the Type 1602-B U-H-F Admittance Meter, the most convenient device on the market for impedance and standing-wave-ratio measurements at UHF and VHF; the Type 874-LB Slotted Line, an accurate, well-designed line at a very low price; and the Type 874-LK Constant-Impedance Adjustable Line, an indispensable accessory in impedance measurement.

What next? **Standard-Signal Generators.** Old timers will recall that General Radio made the first one — in 1928. Shown here are two of General Radio's most popular modern signal generators — the Type 1001-A for the range 5 kc to 50 Mc and the Type 1021-A for frequencies from 50 Mc to 920 Mc. Designed for simplicity and convenience in use, these generators met with immediate acceptance by the industry. Note the full line of accessories: voltage dividers, test loop, 50-to-300-ohm transformer, and crystal modulators. *New* is the Type 1000-P7 Balanced Modulator which makes possible pulse or 100 per cent sine-wave modulation with a 20-Mc band, at frequencies up to 2500 Mc. With the Type 1217-A Unit Pulser (in the next panel) it makes an excellent combination for pulse-modulating the Type 1021-AU Standard-Signal Generator.

Now, something special — **Unit Instruments,** a high quality, low-priced line that no laboratory should overlook. These are the basic instruments that do the everyday laboratory tasks — oscillators, amplifiers, null detectors, frequency standards, power supplies.

Brand new: the Unit Pulser and the Unit I-F Amplifier. Ask for a demonstration of the Unit Pulser. You'll be surprised that so few cubic inches can pack so much performance. You'll be more surprised that it can be done for so few dollars!

The Unit I-F Amplifier is the universal laboratory instrument. It's a U-H-F null detector, wave analyzer, and voltmeter, plus a lot of other things. Be sure to see it.

The next panel holds items for which General Radio is justly famous — **Laboratory Standards;** decades; resistive, capacitive, and inductive devices of many kinds; some in cabinets for bench use, others unmounted for building into your own equipment. You may be familiar with most of them, but there are some new items here, among them a new decade voltage divider. Better stop and have a second look.

Just ahead are **Impedance Bridges,**

another long-time General Radio specialty. What would you like to measure—resistance, capacitance, inductance, dielectric constant, dissipation factor, conductance, susceptance, standing-wave ratio? At what frequency — d-c, power, audio, ultrasonic, low, medium, high, very-high, ultra-high? Here is a representative selection from General Radio's extensive line, including the TYPE 1604-B Comparison Bridge described in this issue of the *Experimenter*. Photos and specifications of all the others.

Next, **Meters** — voltmeters, power meters, light meters, distortion meter, the audio-frequency microvolter — General Radio makes many types. Don't fail to look at General Radio's two vacuum-tube voltmeters. Incidentally, General Radio developed the first of the peak-indicating types in 1936.

The TYPE 1800-A with wide-frequency range, wide-voltage range, d-c and a-c scales, and ±2 per cent accuracy is the standard of the industry.

But don't overlook the utility model, TYPE 1803-A. For general-purpose voltage measurements up to 100 Mc, with an accuracy of ±3 per cent, it's an amazing buy — $155.00.

Everybody has heard of how a distortion meter measures distortion, but few realize what a useful laboratory instrument it can be. Read the article in the July, 1953, issue of the *Experimenter* by W. P. Buuck of our Standardizing Laboratory, and learn what the TYPE 1932-A Distortion and Noise Meter will do for you in circuit analysis. See it on display here.

Next we see the **Random Noise Generator,** an instrument of many uses, in acoustics, in circuit and meter testing, in crosstalk measurement, and in psychological and statistical studies. The demonstration here shows the truly random nature of the generator output. One generator feeds the horizontal plates, the other the vertical plates, of a cathode-ray oscilloscope. The resulting pattern has been termed a "two-dimensional Brownian movement." If you would like to learn more about random noise and about the generator, ask for a copy of the *General Radio Experimenter* for December, 1951, which contains an excellent article on the subject.

Just beyond is the General Radio **Sound-Measuring System** — sound-level meters, accessory microphones, calibrator, and spectrum analyzers. Do you have a noise problem in your plant? This equipment can help you.

These instruments are also widely used for general acoustic measurements, sound transmission and attenuation, loudspeaker characteristics, etc.

Ask to see the Sound-Survey Meter, a pocket-size instrument of a hundred uses — for noise surveys in offices, factories, stores, and vehicles; for comparisons of product noise; in classrooms, theaters, acoustic demonstrations, sound system adjustments, and many others.

See also the vibration measuring instruments — vibration meter and spectrum analyzer, for solid-borne vibrations down to two cycles per second.

Intended primarily in calibrating sound-level meters, but also useful as a general purpose test-tone source, is the *new* TYPE 1307-A Transistor Oscillator, producing two volts across 600 ohms at 400 and 1000 cycles. Uses a P-N-P junction-type transistor and is complete with batteries in a pocket-size case.

Next, a *brand new* device, the TYPE 1570-A **Automatic Line-Voltage Regulator** — 6 KVA capacity — ±0.25 per cent regulation — rapid response — no waveform error — a must for the laboratory and for those measurements in the field at the end of a power line. The secret of its superior performance is the sensing and control system — a servomechanism, rather than the relays that most other types use.

Variac® Autotransformers occupy our next panel — you can buy variable autotransformers from several manufacturers, but only Variac® has *Duratrak*, the stabilized brush-track surface. *Duratrak* is the most significant advance since the original variable autotransformer was invented by General Radio in 1933. It truly makes the variable autotransformer as durable as a fixed-ratio transformer.

We have operated *Duratrak*-treated models side by side with untreated brush-track types (our own as well as other makes) on severe short-period overload tests, with output currents many times their normal ratings. *In every case,* Duratrak models are unharmed when untreated types burn out.

Next, **parts** — General Radio quality parts are justly famous — knobs, dials, potentiometers, air capacitors, transformers, connectors, binding posts, and chokes — all are designed for instrument use; all are used in our own instruments.

And, speaking of dials, don't miss the motor drive for precision dials shown on the *new* TYPE 1304-B **Beat-Frequency Oscillator** on the table at the front of our booth. The TYPE 1304-B is the latest model of the popular General Radio beat-frequency oscillator. New features: an output voltmeter; additional 20 kc to 40 kc range; new output amplifier using the single-ended, push-pull circuit.

Many General Radio instruments not actually displayed are illustrated in our exhibit by color transparencies. Ask our engineers about them. Bring us your measurement problems; we shall do our best to help you solve them.

THE COMPARISON BRIDGE
A VERSATILE PRODUCTION-TEST INSTRUMENT

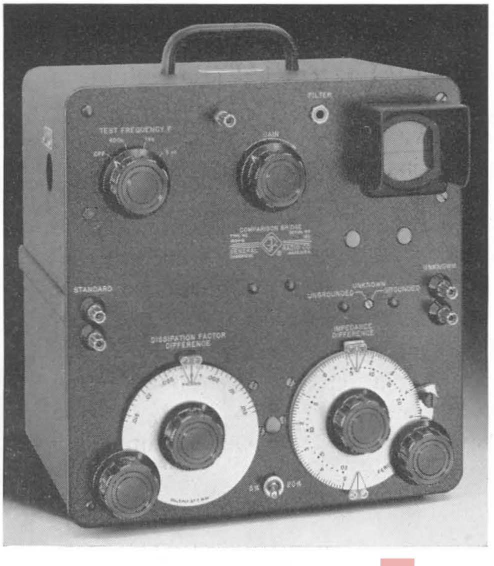


Figure 1. Panel view of the Type 1604-B Comparison Bridge.

The inclusion of a 400-cycle test frequency makes the new TYPE 1604-B Comparison Bridge even more useful than its predecessor.[1] This versatile instrument, which combines the accuracy of a laboratory bridge with the speed required for production testing, has met with ready acceptance in the electrical and electronics industries, as well as in a number of other fields where its immediate application is not so evident.

[1] M. C. Holtje, "A New Comparison Bridge for the Rapid Testing of Components," *General Radio Experimenter*, Vol. XXVII, p. 7, December, 1952.

The TYPE 1604-B Comparison Bridge uses a precision potentiometer in the ratio arms for changing the bridge ratio by ±20 per cent from unity, and a differential capacitor for balancing the dissipation factor difference. A range switch shunts the precision potentiometer to provide a ±5 per cent range for the most precise comparisons. Figure 2 is an elementary schematic diagram of the circuit.

Careful design and manufacture have made possible a superior degree of performance, in accuracy, sensitivity, stability, and range. The basic accuracy of 0.1 per cent is maintained over an impedance range of 2 ohms to 20 megohms.

The design and manufacturing features that contribute to this performance have been discussed in a previous article.[1]

THREE TEST FREQUENCIES

The two test frequencies, 1 kc and 5 kc, on the original bridge, made possible somewhat greater ranges of measurement than would be possible with a single frequency, and, in addition, the 5 kc frequency is useful in showing up the effect of differences in distributed capacitance of coils. The 400-cycle test frequency now available in the new model is useful in measuring high-inductance coils whose apparent inductance, even at 1000 cycles, might be affected by the distributed capacitance. It is also useful for those measurements which must be made in accordance with test codes that specify 400 cycles.

Measurement at these frequencies avoids the possibility of errors resulting from 60-cycle hum pickup, which can be serious when the measurement frequency is 60 cycles, particularly in the measurement of coils and small capacitors.

[1] Loc. cit.

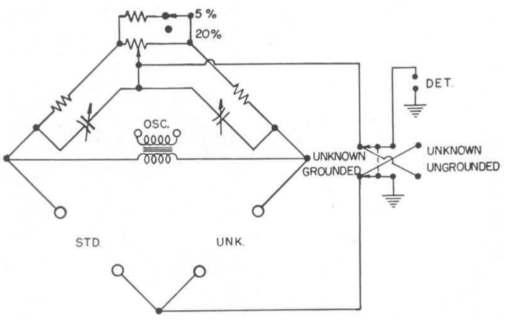


Figure 2. Elementary schematic circuit diagram of the bridge.

TWO METHODS OF USE

An outstanding feature of the Comparison Bridge is its adaptability to either direct measurement or high-speed sorting. In direct measurement, the unknown is compared against a suitable standard, the bridge dials being rotated until the cathode-ray tube indicates a null. The difference between standard and unknown is then indicated by the dial settings. For high-speed sorting, the cathode-ray tube can be calibrated at the desired sorting tolerance and used to give a continuous "go, no-go" indication.

The rapid, no-overshoot response of the cathode-ray null indicator is particularly valuable in this kind of testing.

AUTOMATIC SORTING

An interesting application of automatic-sorting technique is shown in Figure 3 where the Comparison Bridge is used for automatic sorting of capacitors in project "Tinkertoy." Capacitors from a hopper are fed past the unknown terminals of the bridge. They are measured and sorted automatically into one of three bins according to their value, at a rate of two per second.

The large error signal available at the plates of the cathode-ray indicator can be used in many ways to operate auto-

Figure 3. PROJECT TINKERTOY is the code name assigned to a program conceived and developed by the National Bureau of Standards for the Navy Bureau of Aeronautics, which involved the Modular Design of Electronics (MDE) and the Mechanized Production of Electronics (MPE).

More than 20 machines are utilized to produce electronic subassemblies automatically. Uniformity and reliability of product is achieved by employing automatic 100 percent inspection at nearly every station in the production process. This photograph shows equipment used in automatic inspection of titanate capacitors for specific capacity value. Type 722 Precision Capacitors with a range of from 110 to 1100 micromicrofarads and a Type 1604 Comparison Bridge are incorporated in the inspector. One of the precision capacitors is set at the upper tolerance limit of the required capacity, and the other is set at the lower tolerance. As the titanate bodies exit from the vibrator feeder, all silvered surfaces are checked for continuity. The capacitor is then automatically released and falls into the inspection circuit containing the precision capacitors and comparison bridge. The output of the bridge controls three inspection circuits: one to reject those capacitors that are above the upper tolerance, another to reject those bodies below the lower tolerance, and the final circuit to accept the capacitors that fall within the required tolerances. The automatic inspection of a single capacitor can be accomplished in less than half a second.

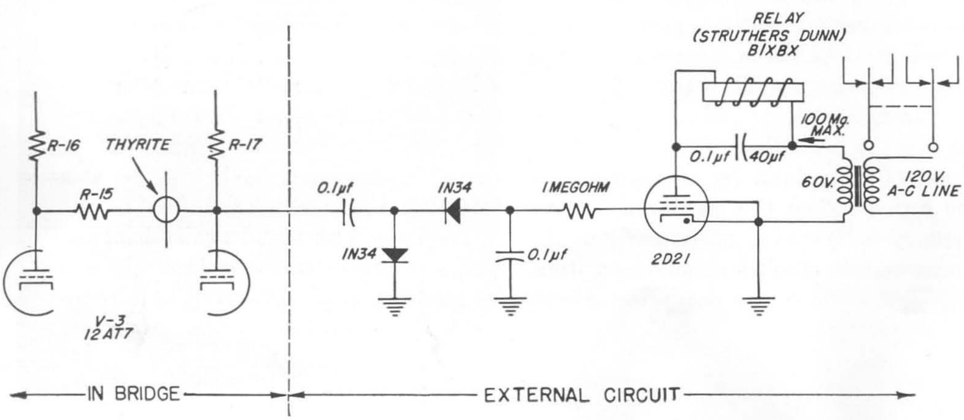
matic equipment limited only by the ingenuity of the designer.

One of the simplest methods to operate automatic equipment is shown in Figure 4. In this circuit, the error voltage is rectified and used to bias a thyratron to cut-off. If the unknown component is within tolerance, the bias will be reduced to the point where the thyratron will operate the relay. Sufficient sensitivity is available to select components within 0.02 per cent of the desired value. The gain control on the bridge can be used to decrease this sensitivity to sort to any tolerance. A simple circuit like this operates on the magnitude of the error signal and will reject components if either the impedance or dissipation factor is outside the limit set.

STANDARD

For production testing, the standard need not be a precision laboratory standard, but can be a component, similar to those being checked, which has been measured independently. A standard

Figure 4. Simple circuit for operating automatic sorting equipment.



precisely at the desired value is not necessary, since an offset zero is provided within the bridge. Thus, if ±2 per cent resistors are being sorted and the available standard is off 1.3 per cent, the bridge zero can be offset exactly 1.3 per cent and the resistors checked as if a perfect standard were available.

To select or to check matched pairs of components, no standard is necessary. The pairs are simply connected to the standard and unknown terminals, the difference between the components being indicated directly by the bridge.

OTHER TYPICAL USES

Figure 5 shows the bridge being used to adjust an air core inductor used in the TYPE 1181-A Frequency Deviation Monitor to within 0.1 per cent of the standard coil. The start of the inductor winding is connected through a slip ring on the turntable to the bridge. The other end of the inductor winding is connected directly to the bridge. After the bridge is set to the desired value, turns are removed from the coil until the cathode-ray indicator shows an exact balance.

One of the most time-saving applications of this bridge at General Radio Company is the testing for tracking of ganged potentiometers and capacitors. Figure 6 shows the four-gang condensers used in the TYPE 1302-A R-C Oscillator being checked before assembly. In a few seconds the condensers can either be adjusted to track correctly or rejected.

Other uses include checking transformer turns ratio or balance in center-tapped windings, and the measurement of capacitors as small as fractional micromicrofarads. Measurement of the changes in impedance of chemical solutions is also possible, permitting precise control of some chemical processes. The high accuracy and versatility of the TYPE 1604-B Comparison Bridge make it extremely useful for nearly all production and engineering jobs where the quantity to be measured can be reduced to a change in impedance.

— M. C. HOLTJE

SPECIFICATIONS

Deviation Range: For impedance difference, ±5% and ±20%, selected by a panel switch. For dissipation factor difference, ±.006 at 400 c, ±.015 at 1 kc, ±.075 at 5 kc.

Impedance Range and Accuracy: Impedances between 2Ω and 20 MΩ can be compared. For the 5% deviation range, the basic accuracy is ±0.1%, but at extreme values of impedance the error is somewhat greater. The range for resistors, capacitors, and inductors for which the ±0.1% accuracy applies is given in the table:

Frequency	*R*	*L*	*C*
400 c	2Ω to 20 MΩ	2 mh to 1500 h	100 μf to 50 μμf
1 kc	2Ω to 20 MΩ	1 mh to 250 h	30 μf to 50 μμf
5 kc	4Ω to 2 MΩ	200 μh to 10 h	2 μf to 50 μμf

These ranges apply for comparison of components whose dissipation factor differences do not exceed .02. On the 20% deviation range, the accuracy is ±0.5% over the same impedance ranges.

Dissipation Factor Accuracy: The accuracy of measurement of differences of dissipation factor is:

Frequency	*Accuracy*
400 c	±(0.0002 + 2% of the impedance difference)
1 kc	±(0.0005 + 2% of the impedance difference)
5 kc	±(0.0025 + 2% of the impedance difference)

Frequency: Frequencies of 400 c, 1 kc, and 5 kc are provided, selected by panel switch. The frequency is within ±3% of the nominal value.

Grounding: Two ground positions are provided, one of which grounds the junction of the standard and unknown impedances. With this connection, the total impedances between the high terminals and ground are compared. In the other connection, the junction of the ratio arms

Figure 5. The Comparison Bridge used in adjusting an air-core inductor to 0.1% tolerance at General Radio's West Concord (Mass.) plant.

Figure 6. Another application in our own plant: testing and adjusting four-gang capacitors for proper tracking. The bridge is also used in the adjustment of ganged potentiometers.

of the bridge is grounded, leaving both terminals of the standard and unknown ungrounded. With this connection, the direct impedance between terminals of a component is measured, and terminal impedances to ground, within certain limits, will not affect the bridge balance.

Voltage Applied to Unknown: Approximately one volt, for impedances above 500 Ω. For lower values of impedance the voltage is decreased, corresponding to a source impedance of the order of 100 Ω.

Zero Adjustment: An adjustable index mark is provided with locking means so that the zero can be offset to correspond to the deviation of the standard component from the desired nominal value.

Power Supply: 105-125 (or 210-250) volts, 50 to 60 cycles.

Accessories Supplied: Line-Connector cord.

Accessories Required: Adjustable calibrated standards such as the Type 1432 Decade Resistors, Type 219 Decade Capacitors, and Type 1490 Decade Inductors may be used. Fixed standards such as the Type 509 Standard Capacitors, Type 1481 and Type 1482 Inductors, and Type 500 Resistors may also be used whenever appropriate values are available.

For production tests, the standard is often a component of the type to be tested, that has been measured independently or otherwise selected.

Accessories Available: Types 1231-P2 and 1231-P5 Filters for providing frequency discrimination.

Mounting: Welded aluminum cabinet.

Dimensions: (Width) 12 inches, (height) 14¼ inches, (depth) 10 inches, over-all.

Net Weight: 22½ pounds.

Type		*Code Word*	*Price*
1604-B	**Comparison Bridge**	FATTY	**$390.00**

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Delivery from stock, as with 9 out of 10 General Radio products

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ELECTRONIC APPARATUS FOR SCIENCE AND INDUSTRY

PULSES IN A SMALL PACKAGE— A PULSE GENERATOR FOR THE UNIT LINE

Also

IN THIS ISSUE

● **THE TYPE 1217-A UNIT PULSER** makes available for the first time a self-contained, universal pulse generator in a small, economical package. Previously available pulse generators have been limited in usefulness by restricted ranges of adjustment for both pulse duration and repetition rate. These limitations have been overcome in the new Unit Pulser, which is a truly general-purpose instrument.

The Unit Pulser, designed as an addition to the versatile Unit-Instrument[1] line, provides, for the first time, continuously adjustable pulse durations from 0.2 μsec to 60,000 μsec, making possible generation of "flat tops" extending over a half cycle of frequencies as low as 10 cycles. A self-contained oscillator drives the output at pulse-repetition rates of 30 and 60 cycles for low-frequency tests and, in a 1-2-5 sequence, from 100 cycles to 100 kc for other tests.

[1]"New Unit Instruments," *General Radio Experimenter*, Vol. XXVI, No. 2, July, 1951, p. 1.

Figure 1. Panel view of the Type 1217-A Unit Pulser with the Type 1203-A Unit Power Supply.

GENERAL DESIGN CONSIDERATIONS

The "pulser" or the "pulse generator" is the energy source for systems which operate in the time domain (or in which time-domain techniques are the analytical tools). As such a source, the pulser is a unique device, because, unlike d-c or sinusoidal-waveform-producing devices, the idealized pulse source gives rise to an infinite number of frequencies. Just how large a segment of the resulting infinite frequency band must be produced depends upon the particular application for which the pulser is intended.

An ideal pulse source would produce three distinct types of driving waveforms. These are: (1) The unit impulse, a pulse of infinite voltage amplitude and infinitesimal duration produced once only. (2) The step function, a voltage transition of unit amplitude occurring once only. (3) Repetitive pulses of uniform amplitude, duration, and period of repetition, in which all three of these variables are arbitrarily adjustable.

In the Unit Pulser these three types of driving function are approximated as closely as the gain-bandwidth capabilities of currently available vacuum tubes will permit. The pulses of shortest duration (around 0.2 microsecond) at low repetition rates are an adequate approximation of the unit impulse for many applications. The 60,000-microsecond maximum value for pulse duration, when initiated by a single external trigger, makes a reasonable approximation of the step function. The pulse duration can be adjusted continuously between these two extremes over the entire range from 0.2 to 60,000 microseconds. The internal timing oscillator produces twelve basic repetition rates from 30 c to 100 kc, and a provision for external triggering permits continuous frequency variation from 100 kc to any arbitrarily low frequency.

The independently adjustable variables — repetition rate, pulse duration, and amplitude — make design compromises necessary in any pulse generator. For example, with the Type 1217-A Unit Pulser, one can always produce a pulse duration of a half-period or more at any frequency above 8 cycles. Although square waves are useful for testing amplifier systems, their generation places stringent demands on the output circuits if high-powered pulses (say, 1 amp. into 50 ohms) are desired. Since the choice of the ratio of pulse-time to period is unrestricted, the Type 1217-A

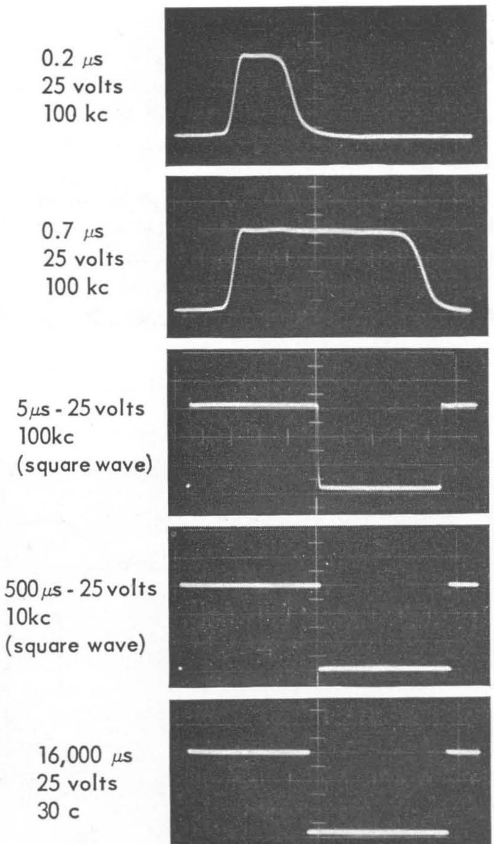


Figure 2. Oscillograms of typical pulse waveforms delivered by the Unit Pulser.

is designed to limit the output voltage without appreciable pulse-shape deterioration when the load demands too much power. The open-circuit output is about 25 volts behind 200 ohms. With a 50-ohm load, this output voltage drops to approximately two volts.

CIRCUITS

Figure 3 is a functional block diagram of the Unit Pulser. The circuits are: a blocking oscillator, which can also be driven as a trigger circuit; a monostable multivibrator, which controls the duration of the pulse; an amplitude control and limiter system; and a simple output stage capable of delivering either or both positive and negative pulses.

The oscillator that sets the repetition frequency (number of pulses per second) is an RC-timed blocking oscillator.[2] When the period for the pulses is to be determined by an externally generated signal (sine wave or pulse), the blocking oscillator tube is biased beyond cutoff. This form of oscillator is used, first, because it provides a lot of energy in a brief pulse, which increases the rate of rise of the leading edge of the pulse; and, second, because it is easily synchronized either at its fundamental period or at multiples and sub-multiples of this period. The oscillator frequency is switched in twelve steps, in a 1-2-5 series, from 100 cps. to 100 kc. The two lowest frequencies are locked to the power line; they are 30 and 60 cps. for standard U. S. power systems. An adjustment is provided to permit the oscillator to be locked to 25 and 50 cps. for 50-cycle power systems.

When the repetition frequency is to be determined by an external source, the blocking oscillator is disabled by adding a fixed bias voltage and is used as a trigger circuit to feed the pulse-forming system. Since the oscillator is completely inoperative in the absence of an external trigger pulse, trigger pulses can be used to produce periods as long as the user desires. The upper frequency limit with external triggers depends upon the type of trigger waveform, its amplitude, and the repetition-rate switch setting. For frequencies lying below 10 kc, five-volt sine waves are adequate for continuous locking; as the upper limit of 100 kc is approached, the amplitude of the locking voltage must be increased to about 25 volts.

The monostable multivibrator is of the conventional grid-coupled type.[3] A potentiometer adjusts a reference voltage for continuous control of pulse duration over a 12 : 1 range. An RC network is selected by the decade range

[2] Benjamin, R., "Blocking Oscillators," *Journal of the I. E. E.*, pt. III-A, 1947, p. 1170.

[3] Chance, B., et al., *Waveforms*, Radiation Laboratory Series, Vol. 19, p. 166.

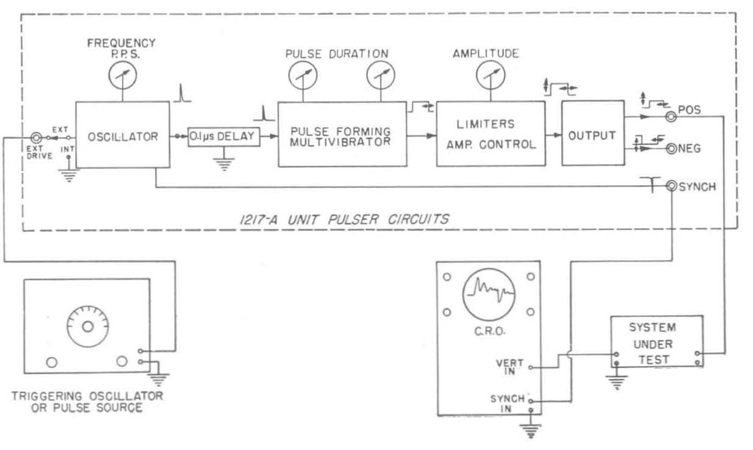


Figure 3. Block diagram of the Unit Pulser showing the functional arrangement of internal circuits and connections to external equipment.

switch to provide time-constant multipliers covering durations from 0.5 to 60,000 μsec in five steps.

The analysis set forth on page 178 of reference (3) shows that the pulse duration is expressed by

$$T_{\text{pulse}} = RC \log_e \frac{E + e_{p_1}}{E + e_{co_1}} \qquad (1)$$

Where E is the adjustable reference voltage controlled by the time duration knob, e_{p_1} is the plate swing of the second tube, and e_{co_1} the cutoff voltage of the first tube.

Thus the pulse duration varies logarithmically with the reference voltage. A "logarithmic" potentiometer is so connected that its variation of resistance with angle tends to compensate for the resulting non-linearity and yield a desirable scale distribution.

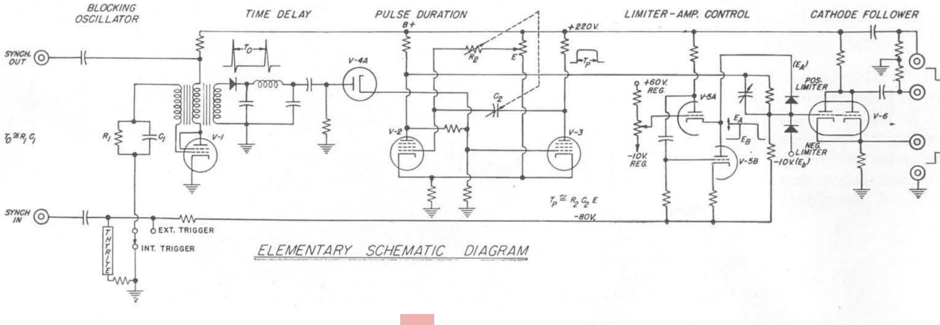
Some energy obtained directly from the blocking oscillator during the brief period of its conduction is added to that produced during transition of the monostable multivibrator to produce a steep wavefront. Even though the monostable stage is aided by the oscillator, it still must have all of the bandwidth possible to produce the steep wavefront desired, so two pentode tubes, a 6AK5 and 6AH6, are used.

The limiter and amplitude-control circuit consists of two germanium-diode limiters, which set the maximum and minimum voltage limits of the pulse and clip the extremes of voltage corresponding to the "top" or "bottom" of the pulse. The lower diode voltage is fixed. The amplitude-control potentiometer provides d-c grid voltage for a cathode-follower circuit, which applies an adjustable voltage at a low impedance to the upper-limit diode. The pulse "top" is clipped by the conduction of the diode between 1 and 25 volts above the level set by the lower diode. The amplitude-control voltage, corresponding to the "top" of the pulse, is regulated with respect to ground to make the amplitude of the pulse essentially independent of pulse duration, repetition rate, and line voltage transients.

The output circuit comprises both sections of a 12AT7. This tube is connected in such a way that it can be used as (1) a cathode follower for the positive pulse, (2) as a phase splitter to produce equal-amplitude positive and negative pulses, or (3) as an amplifier to produce a negative pulse of about 60 volts amplitude at an impedance level of about 1200 ohms. The necessary wiring changes are made by moving a shorting bar at the output terminals.

At this point it should be noted that the connections from the monostable multivibrator through the limiter-amplitude control are all d-c coupled; so that, even with a 50-ohm load resistor on the positive-output terminals, pulses of the longest durations maintain the flat tops desirable in checking low-frequency response. Since the negative pulse is pro-

Figure 4. Elementary schematic circuit diagram of the Unit Pulser.



duced at the plate of the output stage, a blocking capacitor must be used, and load impedances of the order of 5 megohms are necessary to preserve pulse shape at the longest durations.

With the limiter form of amplitude-control circuit chosen for this design, there is some tendency for a small amount of high-frequency energy to be coupled around the limiter into the output circuit. These noise components only become noticeable when the amplitude control is set near its minimum value, so an accessory voltage divider is supplied with the instrument to reduce the maximum amplitude to 2.5 volts and to reduce the noise proportionately. The output impedance of this attenuator is approximately 200 ohms.

APPLICATIONS

Once the specifications for the Unit Pulser have been listed, it seems almost redundant to point out specific applications to the interested reader. It has been shown in the first portion of this article that the TYPE 1217-A Unit Pulser is capable of approximating all three basic pulse-source waveforms: impulse, step function, and periodically repeated pulse of adjustable duration. Whether or not the approximation these waveforms provide is acceptable depends upon the particular application. Since the Unit Pulser produces pulses with rise and fall times requiring video bandwidths equivalent to those obtained in all but the most expensive oscilloscopes currently available, it is satisfactory for most applications requiring an oscilloscope as an indicator.

In applications in which the pulser is inserted in a system to produce a synchronizing or gating pulse, it is often necessary to move the time position of this pulse relative to the time reference set by a master trigger. This operation requires the insertion of a time delay between the master trigger and the initiation of the synchronizing or gating pulse. Figure 5 shows how a TYPE 1217-A Unit Pulser can be used, with a simply constructed differentiating circuit, to provide a delayed trigger pulse after a time interval equal to its arbitrarily set pulse duration. The external triggering circuit of a second Unit Pulser will accept this pulse to initiate a final output pulse, so the combination of two instruments will provide a very flexible "phasing" unit and source of delayed pulses. The time diagram accompanying Figure 5 shows the over-all time relationships between the master trig-

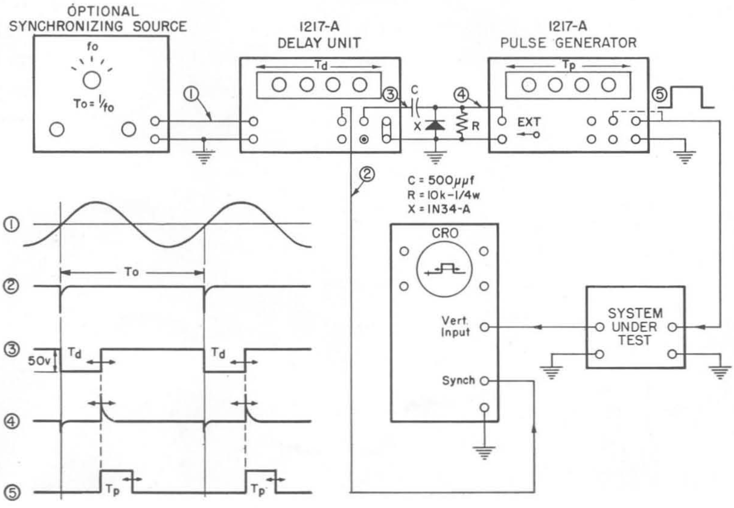


Figure 5. Block diagram of a system using two Unit Pulsers to provide pulses with adjustable time delay.

ger, delayed trigger, and final output pulses.

A Unit Pulser alone, or with another pulser as a delay generator, offers the engineer, scientist, and teacher a simple and inexpensive energy source for many pulse systems. A few of these uses follow:

1. Audio Systems: A single pulse generator can be used to generate a square wave from 10 c to 100 kc. The pulse can be used to operate an external gate to switch a sine wave to provide tone bursts. Square-wave outputs up to three watts can be obtained using a TYPE 1206-B Unit Amplifier following the Unit Pulser.

2. Computing Systems: As a substitution (block diagram) element to provide a gate over an adjustable period of time or a time-delay unit.

3. Nuclear Systems: The 1217-A can be used as a gate or time-delay generator. Two Unit Pulsers with an additional unit used as a delay stage can be used to check resolution times for low- or moderate-speed, coincidence systems.

4. Television Systems: A single Unit Pulser can be locked at the horizontal synchronizing frequency to check overall transient response of the video system, using the kinescope as an indicator. The 30- and 60-cycle internal lock, with the possibility of using a second unit for a delay circuit, makes possible the injection of a timed pulse anywhere during the period of a field or frame.

5. Pulse-Communication or Telemetering Systems: The Unit Pulser can be used as a "substitution block" in design, for producing a time-delay or monostable gate stage for example. With a stable source of synchronizing frequency, a clean and stable synchronizing pulse of adjustable phase can be formed.

6. Transient Analysis — Electro-Mechanical Analogues, etc.: The TYPE 1217-A Unit Pulser with an oscilloscope can be used for numerous experiments on linear, passive, networks. Since pulses are available over a wide frequency range, almost any sort of oscilloscope

Figure 6. The Unit Pulser used for production tests on amplifier assemblies.

can be used and, hence, economical laboratory experiments in transient effects can be designed for school laboratories.

7. Spectrum Generation: The Unit Pulser, either (1) alone, (2) with an r-f modulator, or (3) with a gated oscillator, will produce a pulse- or pulse-modulated-signal spectrum.

In the first case the spectrum for a train of pulses is produced.[4] This spectrum has lines with frequency intervals determined by the repetition rate, and with maxima and minima of amplitude determined by the pulse duration. If the pulse is triggered by a TYPE 1213-A Unit Crystal Oscillator, accurate calibration frequencies at harmonics of 100 kc and 10 kc can be generated over a wider frequency range than can be generated by the Unit Crystal Oscillator alone, and accurate time markers at 10- and 100-microsecond intervals can also be obtained.

[4]*Reference Data for Radio Engineers*, 3rd ed., Federal Telephone and Radio Corp., I. T. T., 1949, p. 298.

The spectrum of the pulse-modulated r-f carrier of the second case is similar in line structure to that of the pulse train, but is translated to lie centered at the r-f frequency as symmetrical sideband components.[5]

This modulation can be conveniently accomplished with the TYPE 1000-P7 Balanced Modulator.[6]

Finally, the pulser can be used to switch an r-f oscillator so that the oscillator's output voltage is coherent with the pulse and many interesting and useful spectra can be produced.[7]

— R. W. FRANK

[5]Cherry, Colin, *Pulses and Transients in Communication Circuits*, Chapman & Hall, 1949, p. 149.

[6]To be described in next month's issue of the *Experimenter*.

[7]Hanel, Alwin, "Multichannel Control of U-H-F Oscillators," *Proc. I. R. E.*, Vol. 41, No. 1, January, 1953, p. 79.

SPECIFICATIONS

Pulse Repetition Rates:
30 c, 60 c, both synchronized to power line. 100 c, 200 c, 500 c, 1000 c, 2000 c, 5000 c, 10 kc, 20 kc, 50 kc, 100 kc, all ±15% or 20 c, whichever is greater.

Pulse Durations: Continuous coverage in four ranges 0.2 to 60,000 μsec. Accuracy ±15% or 0.2 μsec, whichever is greater.

Pulse Shape: Rise time 0.05 μsec.
Fall time 0.15 μsec. with output terminals shunted by 15 μμf and 1 MΩ.

The overshoot may be set to be less than 5% of one-half maximum amplitude and the top of the pulse is flat to within 5% of maximum amplitude at all durations.

External Synchronization:
With sine waves, 5 volts, rms, is adequate for continuous locking at frequencies up to 1 kc. Increasing voltages to 25 volts, rms, are necessary to lock continuously to 100 kc. A 10-volt pulse will lock continuously from 0 to 25 kc.

Output Impedance: Approximately 200 ohms for positive pulses and 1500 ohms for negative pulses.

Open Circuit Output Voltage: 20 volts for pulses of either polarity.

Stability: No time jitter is visible when a full period is displayed on an oscilloscope.

Tubes: 6AH6, 6AK5, 6AN5, 6AL5, and two 12AT7.

Accessories Supplied: One multipoint connector, 10 : 1 200 Ω attenuator.

Power Supply: 300 volts, 55 ma; 6.3 volts, 2 a. TYPE 1203-A Unit Power Supply is recommended.

Dimensions: (Width) 10⅝ x (height) 5¾ x (depth) 6¼ inches, over-all, not including power-line connector cord.

Net Weight: 5¼ pounds.

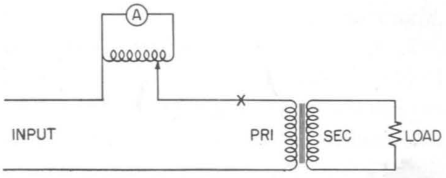
Type		*Code Word*	*Price*
1217-A	**Unit Pulser***	AMASS	**$195.00**
1203-A	**Unit Power Supply**	ALIVE	**40.00**

*Licensed under patents of the Radio Corporation of America. Patent Applied For.

THE VARIAC® AS AN ADJUSTABLE RATIO CURRENT TRANSFORMER

From Mr. A. Schevtchuk of Ballastran Corporation, Fort Wayne, Indiana, comes the following suggestion for using the Variac® autotransformer:

"In testing a transformer, we lacked an ammeter with a high enough current scale to measure the primary current. However, we found that we could use a Variac as a current transformer and were thereby able to read the current on the ammeter. The circuit used is shown below.



"In setting up the circuit, the meter across the Variac was calibrated by using another ammeter in the primary circuit and carefully adjusting the position of the arm. Although this method may not be completely accurate, it was found to be sufficiently accurate for our purpose."

MISCELLANY

RECENT VISITORS from overseas to our Cambridge plant and laboratories include Jacques Forestier, Direction Technical Advisor, Roger Helfer, Chief Development Engineer, and Maurice Laloue, Chief Production Engineer, of Chauvin Arnoux, S. A., Paris; and Iwao Honjoh, Director, Matsudo Research Laboratory, Tokyo Shibaura Electric Co., Ltd., Kawasaki Kavagawa-Ken, Japan.

THE General Radio EXPERIMENTER

VOLUME XXVIII No. 11 APRIL, 1954

ELECTRONIC APPARATUS FOR SCIENCE AND INDUSTRY

A BALANCED MODULATOR FOR PULSE APPLICATIONS

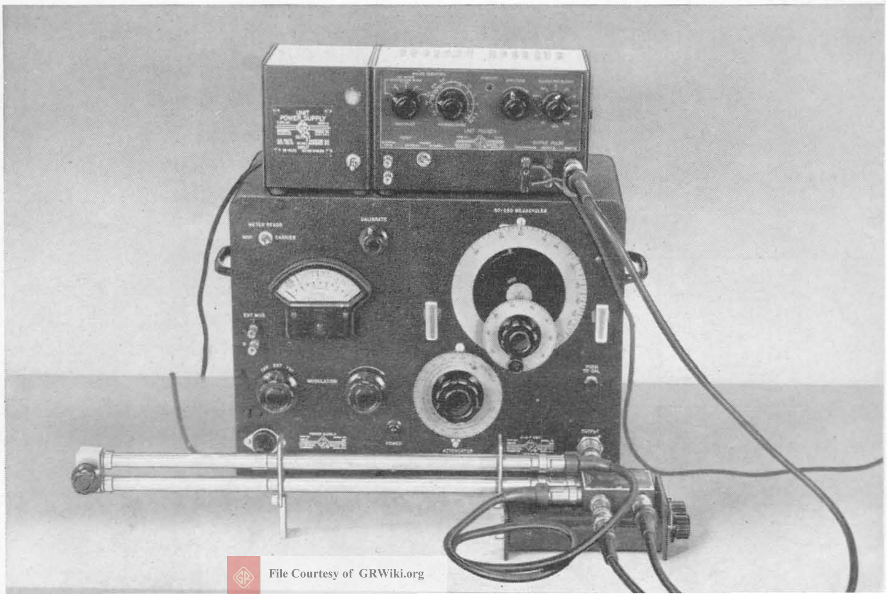
Also

IN THIS ISSUE

● **IN THE MARCH, 1950, EXPERIMENTER,** a simple loss-type modulator (TYPE 1000-P6) using a silicon-crystal diode was described. This device made possible wide-frequency-range amplitude modulation of existing oscillators and signal generators. At a nominal expenditure, test sources for pulse and video systems were therefore made available to the engineer, previously hampered by lack of even expensive alternatives.

Not only did this device permit modulation frequencies far in excess of those previously available in test instruments, but also the generation of the amplitude modulation substantially without incidental frequency

Figure 1. The Type 1000-P7 Balanced Modulator (in foreground) set up with the Type 1217-A Unit Pulser to pulse-modulate the Type 1021-A Standard Signal Generator.



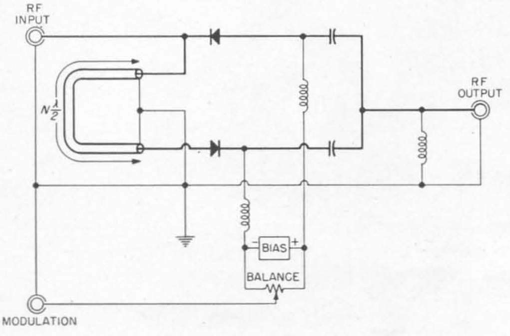
modulation. The modulator was therefore useful not only for television, radar, and other applications requiring wide-band modulation but also for a-m tests on f-m systems and for tests of omni-range equipment, where freedom from fm is essential.

The success of this device for simple uses has led to the development of a more sophisticated device, the Type 1000-P7 Balanced Modulator, which has a still wider range of applications than the single-diode model.

The limitations of the Type 1000-P6 Crystal-Diode Modulator arose principally from the capacitive leakage that occurred when the crystal impedance was high. This reduced the percentage modulation at high carrier frequencies below that which could be obtained at low frequencies and thereby limited its usefulness.

This capacitive leakage can be materially reduced and, in fact, a nearly perfect null obtained at a particular value of modulating voltage, by adjusting the resistive balance as well as the capacitive balance in a balanced-modulator circuit using two crystals. With this method of operation, used in the Type 1000-P7 Balanced Modulator, pulse modulation with 60 db ratios of off-on can be achieved, as well as substantially perfect 100 per cent modulation for video testing.

Figure 2. Elementary schematic circuit diagram of the Type 1000-P7 Balanced Modulator.



CIRCUIT

The elementary schematic illustrates the principle of operation of the Type 1000-P7 Balanced Modulator. Two crystals are used, with a phasing line so arranged that the carrier voltage applied to one diode is 180 degrees out of phase with the carrier voltage applied to the other. The relative bias currents applied to the diodes can be adjusted to equalize their impedances and consequently produce a null in the carrier output.

The adjustable phasing line is a "trombone" section of coaxial line, which must be set to an odd multiple of one-half wavelength at the carrier frequency. The BALANCE control is a differential control in the bias supply. A BIAS control, not shown in the schematic, is provided which permits setting the operating point on the diode characteristics for best linearity and which also operates a switch in the extreme counterclockwise position to disconnect the bias battery.

The diodes are oppositely poled so that an applied pulse or modulating signal increases the impedance of one while decreasing the impedance of the other. A pulse of either polarity will drive the circuit from the initial balanced condition to produce a pulse of radio-frequency output. The carrier level between pulses depends on the degree of balance of the circuit. It is relatively easy to obtain a residual carrier level 60 decibels below the pulsed level.

For the usual amplitude-modulation applications, the BALANCE control can be offset to insert the desired amount of carrier. Since the modulator can be operated as close to balance as desired, very good linearity can be obtained. With proper adjustment of BIAS and BALANCE controls, good linearity at 100 per cent modulation can be obtained with 10 millivolts of radio-frequency output on modulation peaks. The oscillogram of Figure 3 shows the modulation characteristic obtained at a carrier frequency of 900 megacycles at this output level.

CONSTRUCTION

The cutaway view of the basic modulator unit shows the internal arrangement of components. The radio-frequency-input connector is at the top right of the picture, the adjustable line connectors are at the top, and the radio-frequency-output connector is at the top left. The modulation-input connector is at the bottom left. The two crystal diodes join the output connector via two built-in capacitors. The modulation-bias-feed chokes are in the middle compartment. The resistors in the lower compartment constitute a mixing pad for superposing the d-c battery bias and modulating signal.

PERFORMANCE

Figure 1 shows the TYPE 1000-P7 Balanced Modulator set up to pulse-modulate the TYPE 1021-A U-H-F Signal Generator with the TYPE 1217-A Unit Pulser supplying the modulation. The Adjustable Line is shown with one of the flexible line extensions which are used at carrier frequencies below 400 megacycles.

This method of pulsing oscillators and signal generators has a number of advantages over the conventional method of starting and stopping the oscillator.

The wave-shape of the modulating pulse is preserved in the pulsed output,

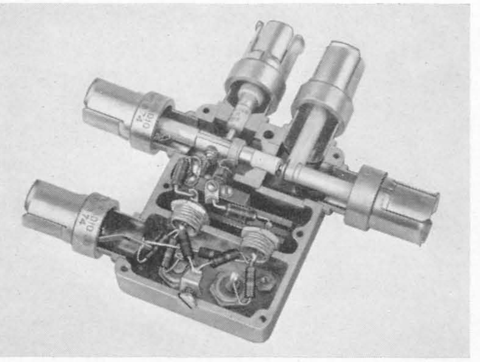


Figure 4. Cutaway view of the modulator, showing internal construction and arrangement of elements.

and yet a high on-off ratio is obtained. In addition, the r-f output is coherent with itself from pulse to pulse, i.e., the phase of the r-f carrier at the beginning of each pulse is the same as it would be at that instant if the carrier were unmodulated.

The coherent r-f signal with pulse modulation is difficult to obtain in the pulsed oscillator, but with the external modulator it is provided automatically.

With an internally modulated generator, the wave-shape of the leading edge of the pulse is modified by the starting conditions of the oscillator, which must depend upon circuit noise, feedback, and impedance relationships. The oscillogram of Figure 5 shows the applied pulse from the TYPE 1217-A Unit Pulser and the resulting radio-frequency pulse. The rise time of the applied pulse is about 50 millimicroseconds and the fall time is 150 millimicroseconds. The resulting radio-frequency envelope shows no degradation of pulse shape.

Figure 3. Amplitude modulation characteristic at 900 megacycles. Peak r-f output is 10 millivolts; r-f input, 50 millivolts.

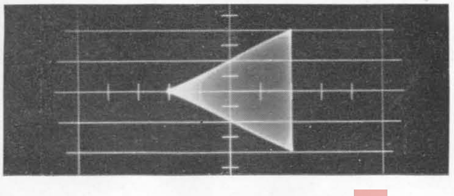
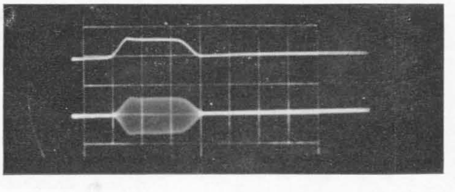


Figure 5. Oscillogram showing modulating pulse and r-f output pulse. Pulse duration is 0.25 μsec with 0.05 μsec rise time. Carrier frequency is 60 megacycles. Scale is 0.1 μsec per horizontal division.



The high on-off ratio (60 db) is an advantage in testing radar and other pulsed systems because it permits the test condition to approximate very closely the normal operating condition of the system.

USES

The modulation frequency response is flat to 20 megacycles, making the modulator suitable not only for short pulses but for any wide-band modulation. Television video is easily accommodated and, since the modulation characteristic is flat to dc, even a d-c component can be included with the modulating signal. Since linear 100-percent modulation can be obtained throughout the U-H-F TV band, the TYPE 1000-P7 is superior to the TYPE 1000-P6 for TV applications. As with the earlier type, the resulting signal has double side bands and, if it is desired to simulate exactly a standard TV picture signal, a vestigial sideband filter must be provided at the radio-frequency output.

Other uses include tests on microwave relay systems using multiplex pulse-code modulation, on omni-range and DME equipment, on telemetering circuits, and on high-resolution radar.

— W. F. BYERS

SPECIFICATIONS

Carrier-Frequency Range: 60 to 2300 megacycles.

Modulation-Frequency Range: Flat from 0 to 20 megacycles. For pulsing, the rise-time contribution is less than 20 millimicroseconds.

Impedance: The impedance looking into either input or output terminals is a function of the bias and modulating voltages. The source and load impedances should be 50 ohms. The impedance at the modulation input is 50 ohms ±5%. It is recommended that a TYPE 874-GF (20 db) or a TYPE 874-GG (10 db) fixed attenuator be used at the input and another at the output whenever the attenuation can be tolerated. The attenuator at the input is useful for isolation to minimize reaction on the oscillator frequency and hence frequency modulation. The attenuator at the output provides a known source impedance for gain and noise measurements and insures that the proper load is presented.

Modulation: Double-sideband suppressed-carrier modulation, pulse modulation with 60-db carrier suppression between pulses, and 100% amplitude modulation can be obtained throughout the carrier frequency range. One volt, peak, at the modulation terminals is sufficient to produce full r-f output from a zero output initial condition.

R-F Output: A maximum output of 10 millivolts into a 50-ohm load can be obtained during pulses or at modulation peaks, with a source of 50 millivolts behind 50 ohms. At this level and at lower input levels, the modulation characteristics are independent of input voltage. However, somewhat higher input voltages and, consequently, higher output voltages are permissible if bias and balance readjustments are made for each change in level. The r-f source must not exceed 0.5 volt behind 50 ohms or the crystal diodes may be damaged.

Bias Supply: Bias is supplied by a self-contained battery consisting of readily available, inexpensive flashlight cells.

Terminals: The radio-frequency input and output terminals and the modulation input terminals are TYPE 874 Coaxial Connectors. The radio-frequency input terminal is of proper elevation to plug directly into the output connector of the TYPE 1021-A Signal Generator.

Crystal Diodes: Two TYPE 1N21-B.

Accessories Supplied: One TYPE 1000-P7-28 40-cm Cable; one TYPE 1000-P7-28-2 80-cm Cable; one TYPE 874-C Cable Connector; four 1.5-volt bias cells.

Other Accessories Required: Terminal adaptors, unless generator and load are equipped with TYPE 874 Coaxial Connectors; suitable coaxial cable for connecting modulation source.

Accessories Available: TYPE 874-GF Fixed Attenuator, 20 db; TYPE 874-GG Fixed Attenuator, 10 db; TYPE 1000-P5 V-H-F Transformer; TYPE 874-R20 Patch Cord; TYPE 874 Adaptor to types N, BNC, C, and UHF connectors and to TYPE 938 Binding Posts.

Dimensions: (Including fully extended adjustable line) 30 inches (width) x 3 inches (height) x 5 inches (depth) over-all.

Net Weight: 6 pounds.

Type		*Code Word*	*Price*
1000-P7	**Balanced Modulator**	AWAKE	**$225.00**

U. S. Patents Nos. 2,125,816 and 2,548,457.

AND NOW—TO MONITOR COLOR TV

The action of the Federal Communications Commission on December 17, 1953, in approving the NTSC recommendation of technical transmission standards for commercial color television broadcasting in the United States has resulted in widespread activity in the entire television industry. The implications for the TV transmitter manufacturer and station operator are many and complex — but the frequency-monitoring and aural-modulation-monitoring problems can immediately be crossed off as having been solved at their inception.

Figure 1. Panel view of the Type 1181-AT Color-Subcarrier Monitor.

FCC Color Specifications

The new specifications for commercial color broadcast leave the visual carrier tolerance unchanged and substitute for the relatively broad aural-carrier tolerance a much tighter tolerance in terms of the 4.5-Mc intercarrier separation frequency. Finally, to maintain a high-quality signal even in the presence of the added color information, the color-subcarrier frequency of 3.579545 Mc and the related line and frame frequencies are required to be held to within ±3 parts per million. Although the FCC does not specifically state that a monitor be used for maintaining this high accuracy of color-subcarrier frequency, the need for such an instrument is obvious and has already been expressed by major television transmitter manufacturers.

Table I summarizes the accuracies required by the FCC and shows also the implied minimum accuracies of monitors designed to measure the listed frequencies. Reference will be made at a later point in this discussion to the third column which shows the monitoring accuracies provided by General Radio equipment which is now in production.

TABLE I

Comparison of FCC transmitter requirements with implied monitor accuracies and General Radio guaranteed minimum accuracies in NTSC color television.

	FCC requirement (transmitted signal accuracy)	*Implied Monitor accuracy*	*GR guaranteed minimum accuracy*
Visual Carrier Frequency	±1000 cycles	±500 cycles	±500 cycles for 10 to 90 days*
Intercarrier Separation Frequency (4.5 Mc)	±1000 cycles	±500 cycles	±500 cycles for 6 months
Color Subcarrier Frequency (3.579545 Mc)	±3 ppm (±10.7 cycles)	±5.35 cycles	±1 cycle for 30 days ±5 cycles for 1 year

*Depending upon channel.

Station Monitor Performance — Black-and-White vs Color

The TYPE 1183-T TV Station Monitor has been in full production for well over a year, and more than three hundred are now in operation with black-and-white transmitters in the United States and abroad. In this service, the monitor is required to provide accuracies of ±500 cycles on indication of visual-transmitter carrier frequency and ±2000 cycles on indication of aural-transmitter center frequency. Actually, when an appropriate frequency-checking schedule is followed for the visual carrier, the maximum error in the aural monitor is less than ±1000 cycles per year.

The deviation of the intercarrier separation frequency from 4.5 megacycles is given by the algebraic difference of the indications of the aural- and visual-carrier deviation meters.

It will be recalled by users of the Station Monitor that its circuit design utilizes a *single* master reference crystal for *both* of these functions. Any error in the determination of intercarrier deviation is therefore independent of this crystal and is almost completely determined by the stabilities of the metering circuits used in the aural and visual monitors. The former is better than ±200 cycles and the latter better than ±100 cycles for any thirty-day period. The maximum instability of relative frequency indication that can result is less than ±300 cycles for a comparable period.

Further, experience over much longer periods of time shows that *the relative indications will provide a measure of intercarrier separation frequency to better than ±500 cycles for a period of at least six months.* This is not at all surprising when it is realized that meter and metering circuit instabilities are of a random nature and do not normally produce a progressive drift in any one direction.

Time-honored Monitor — New Application to Subcarrier Monitoring

The new TYPE 1181-AT Color Subcarrier Monitor is an adaptation of the universally employed and widely acclaimed TYPE 1181-A A-M Frequency Deviation Monitor, about 1400 of which are now in service in a-m broadcasting stations. This monitor provides a deviation range of ±30 cycles with one-cycle divisions and affords a stability of better than one part per million when used in the frequency range from 500 to 2000 kilocycles. Except for this frequency-range limitation, the A-M Frequency Deviation Monitor is adequate without modification for service as a color subcarrier monitor.

A high-stability plated quartz crystal developed by the Bell Telephone Laboratories a few years ago has been a major factor in the success of the TV Station Monitor. On the premise that color-transmitter engineers will want to avail themselves of as much of the 3-ppm tolerance on the color subcarrier as they can, the General Radio monitor-engineering group has built this crystal into the new TYPE 376-Q Crystal Assembly. Substitution of this assembly, adjusted for monitoring 3.579545 Mc, in place of the older TYPE 376-L Quartz Plate — without further change in the circuits of the instrument — resulted in immediate satisfactory performance, and subsequent long-time checks permit stability ratings of ±1 cycle for thirty days and ±5 cycles for one year.

The monitor incorporating the TYPE 376-Q Crystal Assembly has been identified as the TYPE 1181-AT Color Subcarrier Monitor. A TYPE 274-ND Shielded Plug is supplied for coupling to the color-subcarrier source in the transmitter through a suitable length of shielded cable. All of the desirable features of the original A-M Monitor are retained. Some of these are:

(1) Ability to operate on input signals ranging from 10 mv to 1 volt;
(2) High noise rejection in narrow-band i-f system;
(3) Performance unaffected by amplitude modulation whether extraneous or otherwise;
(4) Panel adjustment of frequency deviation indication to bring monitor into agreement with independent frequency measurements;
(5) Panel lamp indication of failure of monitor input signal;
(6) Remote metering facilities.

To sum up, the combination of the Type 1183-T TV Station Monitor and the Type 1181-AT Color Subcarrier Monitor provides complete facilities well within the latest requirements of the Federal Communications Commission for monitoring the frequencies involved in commercial color-television transmissions. Comparison of the second and third columns of Table I shows that minimum guaranteed stabilities suggest the need for:

(1) Independent frequency measurement of the picture carrier frequency at intervals ranging from ten days for Channel 83 to over three months for Channel 2;
(2) Concurrent measurement of the sound carrier or intercarrier separation no more frequently than once in six months regardless of channel;
(3) Independent measurement of the color subcarrier about once a year.

All of these periods represent minimum requirements compatible with guaranteed accuracy, and experience on the part of the operator will in most instances permit his extending the interval between frequency checks markedly after the equipment has been in service some time.

— W. R. Saylor

MAY—MONTH OF EXHIBITS

The month of May will find General Radio engineers setting up exhibits of equipment in many parts of the country. If you attend any of the various meetings and conferences listed below, we hope that you will drop in to see the General Radio display and to talk over your measurement problems with General Radio engineers.

NEW ENGLAND RADIO ENGINEERING MEETING

Hotel Sheraton Plaza — Boston
May 7 and 8

Sponsored by the North Atlantic Region of the Institute of Radio Engineers, the NEREM was the first of the regional IRE annual meetings. The Seventh Annual Meeting this year is a two-day affair with a well-balanced technical program. General Radio will be there in Booths 40 and 41.

NATIONAL CONFERENCE ON AIRBORNE ELECTRONICS

Dayton Biltmore Hotel — Dayton, Ohio
May 10-12

This annual conference, sponsored jointly by the Dayton Section of the IRE and the Professional Group on Airborne Electronics, has for its motto "Electronics — the Key to Air Supremacy." General Radio will be in Booth 11-A, as in previous years. Engineers in attendance will be Frank D. Lewis, Robert E. Bard, Kipling Adams, and William M. Ihde.

SYMPOSIUM ON INDUSTRIAL HYGIENE INSTRUMENTATION
University of Michigan
Ann Arbor, Michigan — May 24-27

The purpose of this Symposium, conducted by the School of Public Health and the Institute of Industrial Health of the University of Michigan, is to present what is known, what is available, and what is needed in instrumentation for industrial hygiene through the medium of exhibits, discussions, comprehensive reviews, and technical papers. Here, the General Radio Company will exhibit its complete line of sound-measuring equipment, as well as other items of interest to industrial hygienists. Ervin E. Gross, Jr., of our development staff at Cambridge and William M. Ihde from our Chicago office will be in attendance.

NATIONAL INSTITUTES OF HEALTH
Bethesda, Maryland — May 24-27

The fourth annual exhibit of research equipment will be held in the main Clinical Building on these dates. Drop in to see us at Booth 16. General Radio engineers in attendance will be Myron T. Smith, Robert J. Caldwell, and John C. Gray.

IRE SEVENTH REGIONAL TECHNICAL CONFERENCE
Multnomah Hotel — Portland, Oregon
May 5-7

General Radio will participate in the show held in conjunction with the conference. On hand to greet you will be Frederick Ireland of our Los Angeles office.

INSTRUMENT SOCIETY OF AMERICA SEATTLE SECTION MEETING
May 19-20

Frederick Ireland of our Los Angeles office will exhibit a group of General Radio instruments at this meeting.

DELIVERIES ARE GOOD

Of the 175 major type categories listed in our latest general catalog, 171 are available *for immediate delivery.* Of the remainder, only 4 are temporarily back-ordered for delivery longer than 30 days. They will be in stock soon after that.

The Type 1000-P7 Balanced Diode Modulator, described in this issue, a new and especially interesting instrument, is available in limited quantities now — many more are in process for stock delivery this summer.

GENERAL RADIO COMPANY

SINCE 1915—MANUFACTURERS OF ELECTRONIC APPARATUS FOR SCIENCE AND INDUSTRY

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VOLUME XXVIII No. 12 MAY, 1954

ELECTRONIC APPARATUS FOR SCIENCE AND INDUSTRY

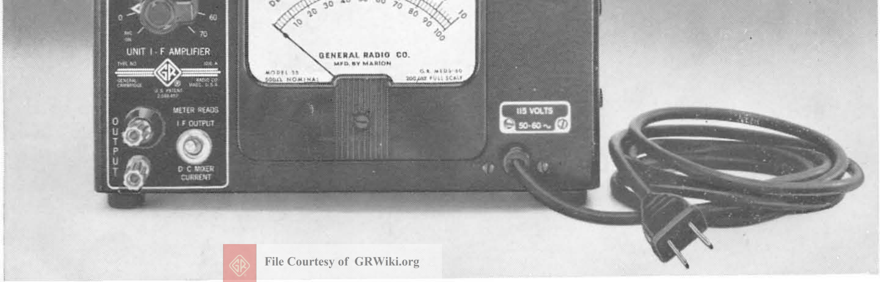
A NEW SENSITIVE, HIGH-FREQUENCY, GENERAL-PURPOSE DETECTOR

> **Deliveries Are Good**
>
> *Delivery* of this new Type 1216-A Unit I-F Amplifier is from *stock*.
>
> Speed and accuracy of order handling has always been a particular GR aim. Now, with adequate stocks of most products, about 85% of orders are shipped within less than 48 hours from their receipt. Technical or commercial questions may hold up an order, but only for long enough to assure a correct and satisfactory shipment.

● **ONE OF THE BASIC TOOLS** necessary for carrying out development work at any frequency is a sensitive detector. At low frequencies, vacuum-tube amplifiers and commercially available communications receivers are usually satisfactory for this purpose.

For operating frequencies above some 50 megacycles, however, very few receivers are available, and the problem of obtaining a satisfactory detector is a difficult one to solve. One method of extending the range of a communications receiver is to add a converter ahead of it to heterodyne the high frequency signals down to frequencies within the range of the receiver. A wide-band converter of this type can be made up of a Type 874-MR Mixer Rectifier and one of the General Radio Unit Oscillators as shown in the block diagram in Figure 2. Although a communications receiver in this arrangement can be made to perform satis-

Figure 1. Panel view of the Type 1216-A Unit I-F Amplifier.



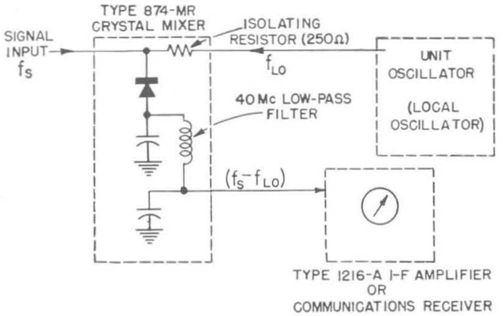


Figure 2. Block diagram of a heterodyne detector system for high frequencies.

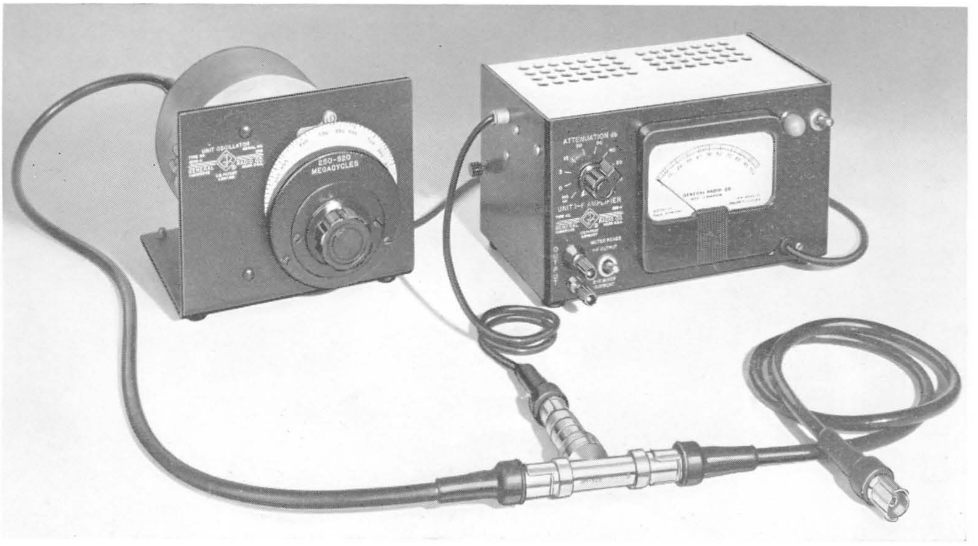
factorily at the lower frequencies, and has good sensitivity and excellent shielding, it has two important limitations: (1) its bandwidth is so narrow that slight changes in the frequency of either the signal or the oscillator cause serious detuning, and (2) it is large and unwieldy compared to other elements in the system.

To overcome these limitations a new instrument, the Type 1216-A Unit I-F Amplifier, has been designed especially for use in the detector system of Figure 2. This small high-gain, wide-band, 30-Mc amplifier is shown in Figure 1 and, in conjunction with the Type 874-MR Mixer Rectifier and a Unit Oscillator, as a unit of a DNT Detector Assembly in Figure 3. With this combination, signals from 25 to 5000 megacycles can be detected, depending upon the range of the Unit Oscillator used.

The Type 1216-A Unit I-F Amplifier, latest of General Radio's extensive line of Unit Instruments, has many features which make it well adapted for use in the general-purpose detector circuit. Some of these features are:

1. High sensitivity.
2. Broad bandwidth with good selectivity.
3. Small physical size.
4. Light weight.
5. Built-in precision attenuator.
6. Meter has both a linear relative-voltage scale and a db scale.
7. Automatic volume control.
8. Excellent shielding.
9. Provision for measuring rectified mixer current.
10. Cathode-follower output amplifier for demodulated signal.
11. Two separate internal power supplies, one for operating a Unit Oscillator.

Figure 3. View of the DNT-3 Detector Assembly, utilizing General Radio coaxial elements and Unit Instruments.



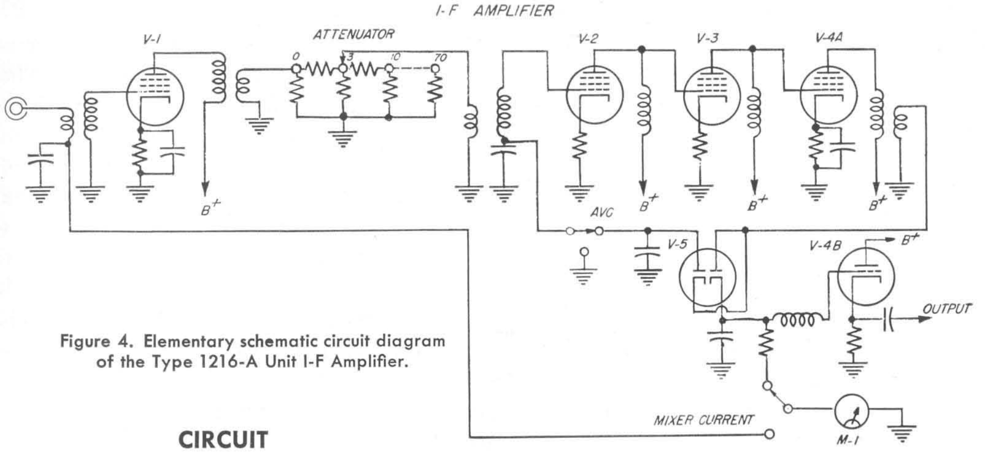


Figure 4. Elementary schematic circuit diagram of the Type 1216-A Unit I-F Amplifier.

CIRCUIT

A simplified circuit diagram of the amplifier is shown in Figure 4. There are four i-f amplifier stages, followed by a diode detector and a cathode-follower low-frequency amplifier.

Amplifier

A tuned step-up transformer is used at the input to obtain a better impedance match between a crystal mixer and the grid of the first tube. A step-down transformer is used between the output circuit of the first stage and the input to the attenuator in order to minimize the mismatch loss caused by the use of a 50-ohm attenuator. A step-up transformer is provided at the output of the attenuator for the same reason. These tuned transformers have very wide bandwidths in order to keep negligibly small the attenuator error at the extremes of the pass band.

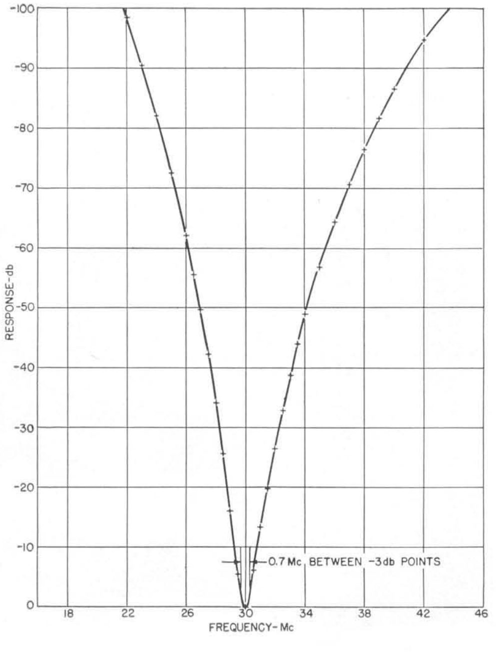
The over-all bandwidth of the amplifier between half-power points is about 0.7 Mc, and a high degree of selectivity to frequencies outside of the pass band is obtained. The over-all frequency response curve of a typical instrument is shown in Figure 5.

Figure 5. Over-all selectivity curve of a typical Type 1216-A Unit I-F Amplifier.

The 100-db gain makes possible high sensitivity. A 30-Mc input of less than $2\mu v$ is required for a meter deflection of 1% over the residual noise, and an input of less than 50 μv produces a full-scale meter deflection when the avc is not used.

Attenuator

The built-in attenuator is located between the first and second stages and uses carbon-film resistors mounted on a shielded wafer switch. The 50-ohm im-



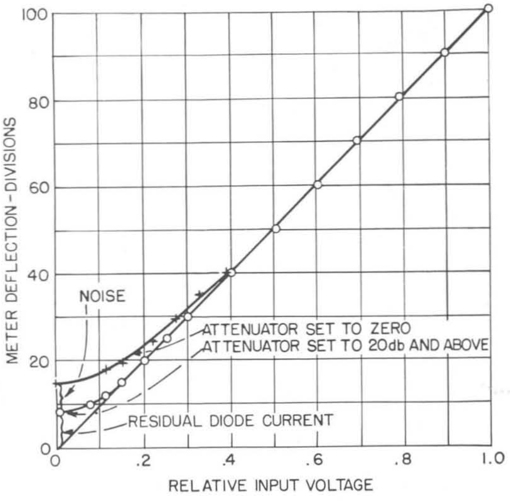


Figure 6. Curve showing linearity of amplitude response.

pedance level minimizes errors caused by residual capacitance and inductance. Steps of 0, 3, 10, 20, 30, 40, 50, 60, and 70 db are included. A straight-through connection is made between the input and output for the zero db positions, and individual π-type sections are switched into the circuit for the 3- and 10-db steps. At all higher steps a ladder-type network is used. An accuracy of $\pm(1\% + 0.3$ db) in the indicated attenuation is obtained. The attenuator can be seen at the left of Figure 7.

Diode Detectors

The output of the 30-Mc amplifier is rectified by a double-diode detector. The d-c output from one diode is applied to the meter and is a measure of the signal level. In order to obtain a high degree of linearity, the diode is operated at a high voltage level; 6 volts are required for a full-scale meter deflection. Figure 6 shows the amplitude response of a typical unit. The db scale of the meter permits interpolation between attenuator steps.

The meter can be switched to indicate the rectified current produced by the action of the local-oscillator voltage on the mixer. A full-scale reading corresponds to a voltage of about two volts applied across the mixer crystal.

The a-c output of the same diode, which follows the modulation envelope of the 30-Mc signal, is amplified and brought out on binding posts on the panel. The bandwidth of the low-frequency circuits is about 0.4 Mc and the output impedance is 600 ohms. The maximum open-circuit output voltage is two volts.

The second diode is used to supply an a-v-c voltage which can be applied to the second amplifier stage. A typical a-v-c characteristic is shown in Figure 8.

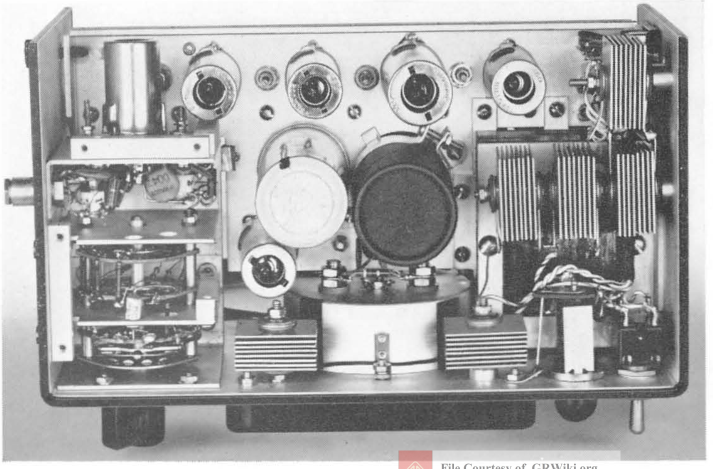


Figure 7. View of chassis from top with shields removed. The attenuator and first amplifier stage are in the shielded compartment at the left.

Power Supply

The two internal power supplies are provided to reduce the number of units involved in a detector assembly, thereby improving portability and simplifying interconnection. Regulation of the screen voltages on the i-f amplifier tubes is provided by means of a Type OB2 Regulator Tube.

As shown in Figures 7 and 9, the internal parts of the unit are individually shielded and numerous filters are provided for isolation.

The complete assembly is housed in a standard General Radio Unit Instrument cabinet, with over-all dimensions of 10 x 5⅝ x 6⅜ inches.

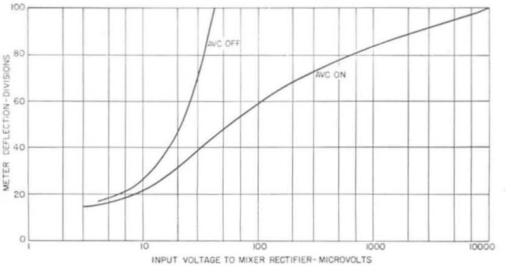


Figure 8. A-V-C characteristic of a typical instrument.

SPECIFICATIONS

Center Frequency: 30 Mc.

Bandwidth: 0.7 Mc at 3 db down; 9.5 Mc at 60 db down.

Sensitivity: Less than 2 μvolt input from a 400-ohm source required for a 1% meter deflection (above noise). Less than 50 μvolt input from a 400-ohm source required for full-scale meter deflection. Input voltages referred to are open-circuit source voltages.

Attenuator Range: 0 to 70 db in 10-db steps. A single 3-db step is also provided.

Accuracy of Attenuator: ±(0.3 db + 1% of indicated attenuation).

Bandwidth of Low-Frequency Output Circuits: 0.4 Mc.

Output Impedance (Low-Frequency Circuits): 600 ohms.

Maximum Output Voltage: 2 volts open circuit.

Terminals: Input — Type 874 Connector on end of 2-foot cable.
Output — Binding posts on ¾-inch spacing.

Supplementary Power Supply Output: 300 volts dc at 40 ma; 6.3 volts ac at 1 a.

Power Supply: 105-125 or 210-250 volts, 50 to 60 cycles. Power input with no load on supplementary power supply — 26 watts at 115 volts. Power input with Type 1209-A Oscillator connected to supplementary power supply — 40 watts at 115 volts.

Tubes: Supplied with instrument:

1 — 6AK5	1 — 6AL5
1 — 6U8	1 — OB2
2 — 6CB6	

Accessories Supplied: Spare fuses; power cord is integral with the unit.

Other Accessories Available: Type 874-MR Mixer Rectifier. Unit oscillator of appropriate frequency range to provide heterodyning signal. Type 1208-A, 1209-A, or 1215-A is recommended.

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

Dimensions: (Height) 5⅝ x (width) 10 x (depth) 6⅜ inches, over-all.

Net Weight: 8¼ pounds.

Type		*Code Word*	*Price*
1216-A	**Unit I-F Amplifier***	AMONG	**$365.00**

*U. S. Patents Nos. 2,125,816 and 2,548,457.

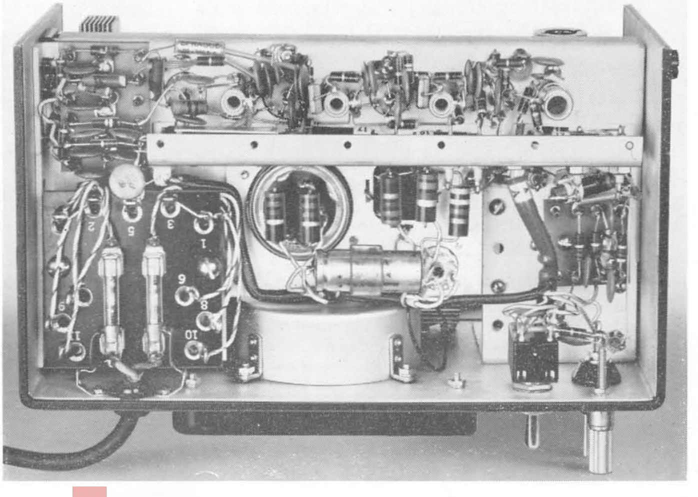


Figure 9. View from below with shields removed. The i-f amplifier section extends along the rear of the chassis and is normally completely enclosed in a shield.

CHARACTERISTICS OF THE TYPE DNT DETECTOR

The Type DNT Detector, made up of the combination of the Type 874-MR Mixer Rectifier, the Type 1216-A 30-Mc Unit I-F Amplifier, and a Unit Oscillator, has many characteristics that make it a very valuable instrument for laboratory, production, and field work. Some of these characteristics are the following:

1. *Convenience and Small Size.* As shown in Figure 3, the detector is physically small and easily transportable. The built-in power supply for the Unit Oscillator and the built-in means of measuring the rectified crystal current add to the convenience of operation.

2. *Wide Frequency Range.* The range is primarily determined by that of the Unit Oscillator used, with the low-frequency limit of 25 Mc[1] determined by the frequency at which the local oscillator voltage starts to produce a significant residual meter reading, and the high-frequency limit of 5000 Mc arbitrarily set at the point at which the sensitivity tends to drop off rather rapidly. Satisfactory detection can be obtained using either the fundamental or a harmonic of the local-oscillator signal, but with harmonic operation the sensitivity is slightly lower (see Figure 10) and more care must be exercised to insure setting to the proper signal particularly at the higher harmonics. A low-pass filter, such as the Type 874-F500 or Type 874-F1000, can be used to eliminate harmonic responses. The following frequency ranges can be obtained with General Radio Unit Oscillators operating on the fundamental.

[1]Both the signal itself and its beat with the local oscillator will be present when the signal frequency is near 30 Mc. Since all components depend upon the signal magnitude, however, the presence of what would normally constitute spurious signals is not detrimental to detection of a null or indication of relative signal levels.

Unit Oscillator Type Number	*Detector Fundamental Frequency Range*
1215-A	25 to 280 Mc
1208-A	35 to 530 Mc
1209-A	220 to 950 Mc

3. *Excellent Shielding.* The high-frequency circuit is confined to the internal parts of the mixer, and a 40-Mc low-pass filter, located between the mixer and the 30-Mc output, prevents r-f signals leaking into the mixer through the i-f amplifier. This is more than adequate to meet the stringent shielding requirements when the detector is used as a null-detector for high-frequency bridges or other null-type devices, as a standing-wave detector for slotted lines, or in attenuation measurements, particularly when a radiating circuit is being measured.

4. *Calibrated 80-db Range.* Relative signal levels at high frequencies can be measured by determining the corresponding 30-megacycle levels as measured by the attenuator and meter in the amplifier. When adequate local-oscillator voltage is applied, the crystal mixer is an accurate linear conversion device over the whole range of the attenuator and meter, and levels differing by as much as 80 db can be measured directly. Figure 10 is a chart showing the variation in conversion efficiency with rectifier mixer current for a typical crystal, and Figure 11 shows the measured over-all error in attenuation for various values of rectified mixer current for a typical detector assembly.

5. *AVC.* The automatic volume control makes it more convenient to balance null-type instruments, as the meter remains on scale over a wide range of input signal levels with no reduction in maximum sensitivity.

6. *Uniform High Sensitivity.* The sensitivity is reasonably constant over wide

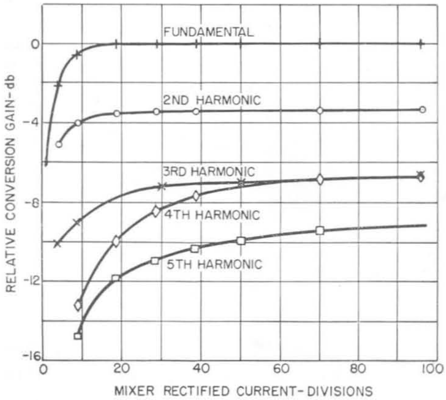


Figure 10. Curves showing relative conversion gain as function of rectified mixer current for the fundamental and harmonics of the local oscillator.

frequency ranges. Figure 12 shows typical variation over the lower part of the frequency range. The impedance of the local-oscillator circuit at the signal frequency appears in series with the 250-ohm isolating resistor in the mixer rectifier, and the combination appears in parallel with the crystal. As the local oscillator impedance at the signal frequency varies from zero to infinity, the effective sensitivity varies by 1.6 db for a 50-ohm signal source. Figure 12 shows such a variation occurring rather rapidly with frequency when a patch cord is connected between the Unit Oscillator and the mixer. When the mixer is connected directly to the Unit Oscillator, the variation occurs much more slowly with frequency as shown.

Note that a signal input voltage of only about 50 microvolts produces a full-scale meter deflection. An r-f input of about 3μv is detectable above the noise on the meter in typical units.

At frequencies below 50 Mc, the sensitivity is further affected by the finite input impedance of the 40-Mc low-pass filter, which appears in series with the crystal.

7. *Matching to 50 ohms.* The input impedance of the detector is high compared to 50 ohms, but it can be made to match a 50-ohm line by inserting a Type 874-GG 10-DB Pad or a Type 874-GF 20-DB Pad between the mixer and the signal input. With the 10-db pad, the VSWR looking into the detector will be less than 1.1 at low frequencies, less than 1.3 at 1000 Mc, and less than 1.5 at 2000 Mc. With the 20-db pad, the input VSWR will be less than 1.05 at low frequencies, less than 1.2 at 1000 Mc, and less than 1.4 at 2000 Mc.

APPLICATIONS OF THE DETECTOR

1. *Detector for Null-Type Measuring Devices.*

The Type DNT Detector, consisting of a Type 874-MR Mixer Rectifier, a Type 1216-A 30-Mc Unit I-F Amplifier, a Unit Oscillator and accessories, is well suited for use with high-frequency null-type measuring instruments such as the Type 1602 U-H-F Admittance Meter.

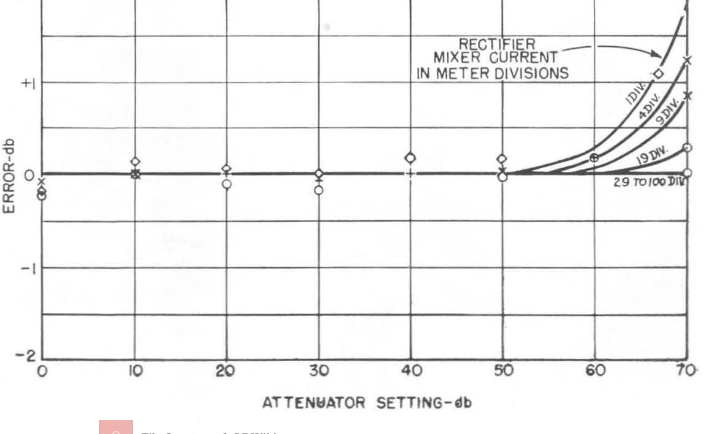


Figure 11. Over-all error in signal-level measurements for a typical Type DNT Detector Assembly as a function of attenuator setting for various values of rectified mixer current. Full-scale meter deflection was used in determining these data.

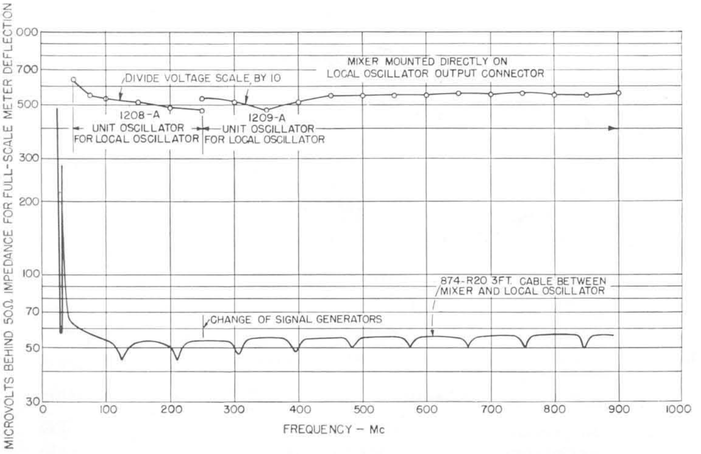


Figure 12. Sensitivity vs. frequency for a typical Type DNT Detector Assembly. Note that about 50 microvolts are required for full-scale deflection. For a 1% meter deflection, above noise, only 3 microvolts are required.

The detector is compact, well shielded, and very sensitive, has a good avc, and covers a wide frequency range. Figure 13 shows a typical setup for the measurement of the VSWR of a coaxial switch.

2. *Detector for Voltage-Ratio-Type Measurements.*

The detector is also well suited for application to instruments such as directional couplers, slotted lines, and the admittance meter using voltage ratio methods, since the relative voltage differences can be measured accurately and quickly by means of the step attenuator and calibrated meter. Its high degree of sensitivity, linearity, and harmonic rejection, and its usefulness with c-w signals make the instrument particularly well suited to high VSWR measurements on slotted lines.

3. *Insertion-loss and Attenuation Measurements of Filters, Attenuators, and Cables.*

The combination of the detector and an additional Unit Oscillator, each fitted with a 10- or 20-db pad to make its impedance approximate 50 ohms, forms a simple setup for measuring the accuracy of attenuators, the attenuation of coaxial cables, and the insertion loss of filters both in the pass and rejection bands. In this type of measurement the substitution method is used. The Unit Oscillator and detector are first connected directly together through the two pads and the attenuator is set to obtain an on-scale meter reading. The circuit is then broken at the junction of the two pads, the circuit under test inserted, and the attenuator adjusted for an on-scale meter read-

Figure 13. The Type DNT Detector Assembly is an excellent detector for use with the Type 1602-B U-H-F Admittance Meter, as shown here in a setup for measuring VSWR of a coaxial switch. The Type 1204-B Unit Variable Power Supply shown below the i-f amplifier is used to energize the solenoid in the coaxial switch.

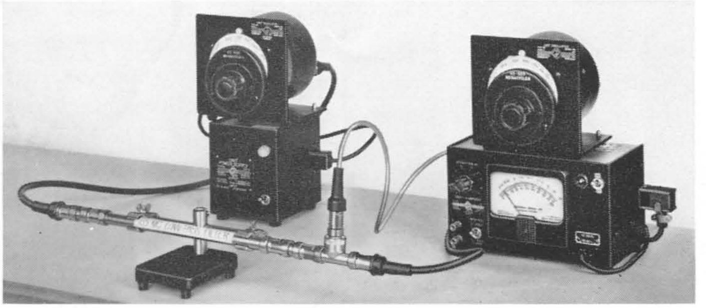


Figure 14. View of the Type DNT-1 Detector Assembly and a Type 1208-A Unit Oscillator set up for insertion-loss measurements on a 185-megacycle low-pass filter.

ing. The difference in the sums of the attenuator and meter readings is equal to the insertion loss of the sample. Samples having insertion losses as high as 80 db can be measured directly, and up to about 95 db can be measured with the insertion of extra pads. The excellent shielding of the detector makes high-insertion-loss measurements reliable.

The detector can also be used with a signal generator having a calibrated r-f attenuator for insertion-loss measurements. In this case the attenuator in the generator can be used, if desired, rather than the attenuator in the amplifier. With either method, the high sensitivity, excellent shielding, and wide frequency range of the detector contribute greatly to the convenience and reliability of the measurements.

The results of measurements made on the insertion loss of the 185-Mc low-pass filter shown in Figure 14 are presented in Figure 15. The measurements were made by two methods. In one case a Unit Oscillator was used as a source and the loss measured in terms of the attenuator in the Unit I-F Amplifier. In the second method a Type 1021-A Signal Generator was used and the measurement made with its calibrated attenuator. It will be noted that the agreement is extremely close.

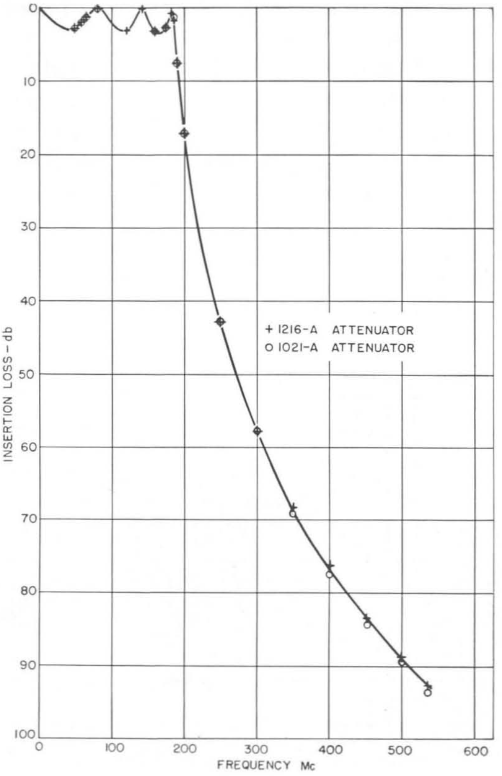
Figure 15. Results of measurements made with the set-up of Figure 14.

4. *Calibration of High-Frequency Attenuators.*

The calibration of variable high-frequency attenuators such as those used on signal generators can be easily and rapidly measured over wide frequency ranges by comparison with the built-in 30-Mc attenuator.

5. *VSWR and Cross-Talk Measurements in Coaxial Switches.*

Measurements of the input VSWR on coaxial switches can be easily made using the admittance meter setup as outlined



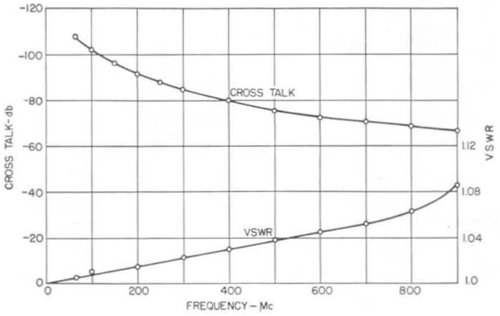


Figure 16. Cross-talk and VSWR characteristics of a coaxial switch as measured with the equipment shown in Figures 13 and 14.

in (1) with the switch terminated in a Type 874-WM 50-ohm Termination. Figure 13 shows a typical setup. The same equipment, with two pads substituted for the admittance meter, can be used for cross-talk measurements as outlined in (3) and shown in Figure 14. Results of typical measurements are plotted in Figure 16.

6. *General-Purpose, Sensitive, Tuned Voltmeter.*

The detector itself can be used to monitor and to measure relative changes in voltage levels at voltages as low as 10μv over a wide frequency range. For absolute measurements, the mixer can be calibrated at one reasonably high signal level, additional pads being used, if necessary, by means of a high-level voltmeter or bolometer power-measuring device such as the Type 1651-A Bolometer Bridge.

7. *Wave Analysis.*

With some limitations the detector can be used as a v-h-f or u-h-f wave analyzer. The limitations arise from (1) the responses obtainable on images and harmonics of the local-oscillator signal and (2) the non-linear crystal characteristic, which generates significant harmonics when the signal level is high. The first limitation can in many cases be overcome by the use of low-pass or band-pass filters. The second limitation places a limit on the minimum measurable harmonic percentage. Figure 17 is a series of curves showing the relative harmonic voltage generated as a function of the fundamental signal voltage level for various local-oscillator excitations.

The Type 1216-A Unit I-F Amplifier and the complete Type DNT Detector Assemblies fill an important need in high-frequency measuring systems. Their versatility and adaptability lead to applications in measurement and testing in the laboratory, in the field, and on the production line.

— R. A. Soderman

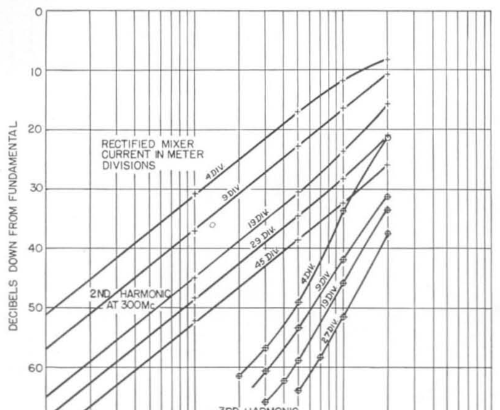


Figure 17. Curves showing the relative amplitudes of harmonic generated in the mixer as a function of fundamental signal voltage level for various local-oscillator excitations.

TYPE DNT DETECTOR ASSEMBLIES

To facilitate ordering auxiliary equipment for use with the TYPE 1216-A Unit I-F Amplifier, complete detector assemblies are available for fundamental operation at frequencies between 25 and 950 megacycles. Higher-frequency operation is obtainable by using oscillator harmonics. Additional oscillator equipment for fundamental frequencies up to 2,000 megacycles will be announced within the next few months.

TYPE DNT-1 DETECTOR ASSEMBLY

Fundamental range: 35 to 530 Mc.

Consisting of:

- 1 TYPE 874-MR Mixer Rectifier.
- 1 TYPE 1216-A Unit I-F Amplifier.
- 1 TYPE 874-F500 L-P Filter.
- 1 TYPE 874-GG 10-db Pad.
- 1 TYPE 874-EL 90° Ell.
- 1 TYPE 1208-A Unit Oscillator.

Type		*Code Word*	*Price*
DNT-1	**Detector Assembly**	NALTO	**$628.00**

TYPE DNT-2 DETECTOR ASSEMBLY

Fundamental range: 25 to 280 Mc.

Consisting of the same components as listed above with the exception of the Unit Oscillator, which in this assembly is a TYPE 1215-A.

Type		*Code Word*	*Price*
DNT-2	**Detector Assembly**	NERVO	**$628.00**

TYPE DNT-3 DETECTOR ASSEMBLY

Fundamental range: 220 to 950 Mc.

Similar to above assemblies but with TYPE 1209-A Unit Oscillator and TYPE 874-F1000 Low-Pass Filter.

Type		*Code Word*	*Price*
DNT-3	**Detector Assembly**	NULLO	**$667.00**

ACCESSORIES—CONNECTORS, ADAPTORS

All General Radio high-frequency instruments are equipped with TYPE 874 Coaxial Connectors, a universal type, any two of which plug directly together.

These connectors are designed specifically for use in measuring equipment and have excellent electrical characteristics.

A sufficient number of patch cords are supplied with General Radio Unit Oscillators, the TYPE 874-LB Slotted Line, and the TYPE 1602-B U-H-F Admittance Meter to take care of all connections to the Type DNT Detector Assemblies. When the detectors are used with other equipment, patch cords and, if necessary, adaptors should be ordered.

The TYPE 874-MR Mixer Rectifier will plug directly into any signal source equipped with a TYPE 874 Coaxial Connector. If the mixer is to be used at a distance from the source, one or more TYPE 874-R20 Flexible Lines (3-foot patch cords) will be needed. A flexible line is included with the Unit Oscillator so that it can be connected to the mixer. Similarly, a cord with TYPE 874 Coaxial Connector is attached to the i-f amplifier to plug into the mixer.

When connections are to be made to systems using other types of coaxial connectors, TYPE 874-Q Coaxial Adaptors should be used. These are available in both plug and jack models for the following types: N, C, BNC, HN, and UHF, as well as 1⅝″ and 3⅛″, 51.5-ohm rigid line, and 3⅛″, 50-ohm rigid line. Most of these were described in the *Experimenter* for October, 1952.

PATCH CORD

Type		*Code Word*	*Price*
874-R20	**3-foot Flexible Line**	COAXHATTER	**$6.00**

ADAPTORS

Type No.	*Elements Used in Adaptor*	*Code Word*	*Price*
874-QNP	**Type 874 and Type N Plug**	COAXNUTTER	**$4.50**
874-QNJ	**Type 874 and Type N Jack**	COAXNAGGER	**3.75**
874-QBP	**Type 874 and Type BNC Plug**	COAXBUNNER	**4.75**
874-QBJ	**Type 874 and Type BNC Jack**	COAXBOGGER	**4.75**
874-QCP	**Type 874 and Type C Plug**	COAXCUFFER	**6.25**
874-QCJ	**Type 874 and Type C Jack**	COAXCOGGER	**4.75**
874-QHP	**Type 874 and Type HN Plug**	COAXHANGER	**6.50**
874-QHJ	**Type 874 and Type HN Jack**	COAXHAWSER	**6.50**
874-QUP	**Type 874 and Type UHF Plug**	COAXYUPPER	**4.25**
874-QUJ	**Type 874 and Type UHF Jack**	COAXYUNDER	**4.00**
874-QV3	**Adaptor to V-H-F 3⅛″ rigid line (51.5 ohms)**	COAXYWAGER	**87.00**
874-QU3	**Adaptor to U-H-F 3⅛″ rigid line (50.0 ohms)**	COAXYULTRA	**87.00**
874-QV2A	**Adaptor to V-H-F 1⅝″ rigid line (51.5 ohms)**	COAXYVERRA	**46.00**

TYPE 874 Coaxial Connectors are manufactured and sold under U. S. Patents 2,125,816 and 2,548,457.

the GENERAL RADIO Experimenter

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 1 JUNE, 1954

THE TYPE 1304-B BEAT-FREQUENCY AUDIO GENERATOR

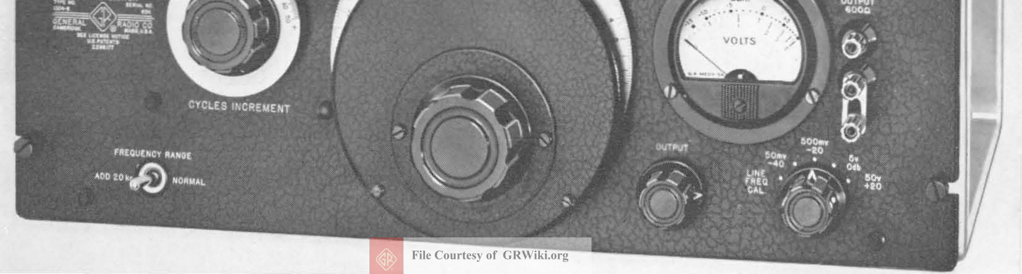
● **IN THE 27 YEARS** of its existence as a commercial instrument, the beat-frequency oscillator has become recognized as the most satisfactory audio-frequency power source for general-purpose use. Because of its constant output over wide frequency ranges and its excellent waveform, it meets particularly well the stringent requirements of a signal source in the measurement of response and distortion characteristics of all audio-frequency equipment. It is widely used, for instance, in testing broadcast equipment, p-a systems, hi-fi installations and their components, such as filters, transformers, and speakers.

The most important advantages[1] of the beat-frequency oscillator can be summarized as follows:

(1) Constant output amplitude over the working frequency range.
(2) Excellent waveform.
(3) Wide frequency range — 3 decades on one sweep of dial.
(4) Additional range obtainable by shifting the frequency of the fixed oscillator.
(5) No frequency change with load or with output control setting.
(6) High stability of frequency, with slight, easily correctable warm-up drift.
(7) No lock-in at multiples of line frequency.

[1] "Oscillator Considerations," *General Radio Experimenter*, Vol. xxviii, No. 6, November, 1953, pp. 6-7.

Figure 1. Panel view of the Type 1304-B Beat-Frequency Audio Generator.



Also

IN THIS ISSUE

The General Radio Company has been manufacturing beat-frequency oscillators since 1927, when we introduced the first commercial version of this popular instrument. The latest design, the Type 1304-B Beat-Frequency Audio Generator, is, we believe, the finest beat-frequency audio oscillator that has ever been offered for sale.

This new instrument has been improved over its predecessor[2] in several important respects:

(1) The frequency range of 20 cycles to 20 kc has been extended by the addition of a second frequency range of 20 kc to 40 kc.

(2) The amplifier has been replaced by one of a new and improved design.

(3) A voltmeter and a step attenuator have been added to the output system. These changes convert the oscillator to an audio signal generator whose output voltage is accurately calibrated.

Oscillators

The basic operation of the beat-frequency audio generator can be seen by referring to the schematic diagram, Figure 2.

The voltages from two oscillators are amplified and mixed to obtain a voltage at the difference of the two oscillator frequencies. Any variation in the frequency of either oscillator results in a variation of the beat-frequency. One oscillator is normally fixed in frequency and the other is made adjustable to vary the beat frequency.

The stability of the output frequency is determined by the relative stability of the two beating oscillators, which are made inherently stable by the use of the best quality components. For example, the oscillator coils are multilayer, universal-wound coils on ceramic forms to obtain high dimensional stability. The fixed capacitors in the oscillator circuit are high-quality, silvered-mica capacitors. Furthermore, the capacitors are matched in the finished instrument by actual test during a heat run. The two oscillator circuits are also mounted on the same rugged aluminum casting to insure equalization of temperature of the two circuits.

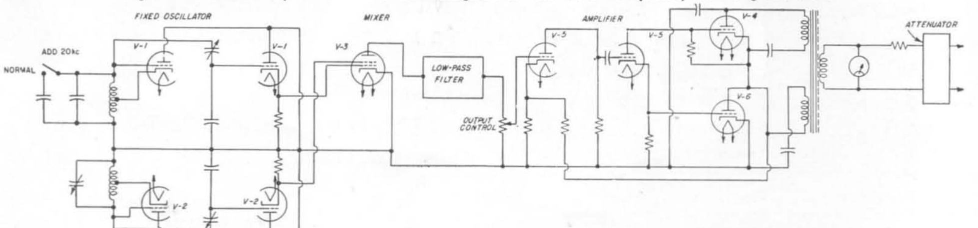
By this process of careful design to obtain high inherent stability and equalization of the two oscillator systems, it has been possible to keep the frequency drift on warm-up to a very low value.

The frequency of the variable oscillator is tuned over the range from 190 kc to 170 kc, approximately, by the main tuning capacitor.

This capacitor, shown in Figure 3, is accurately assembled on a rugged aluminum casting, with the aid of a precision assembly jig. Carefully designed

[2] D. B. Sinclair, "Making a Good Instrument Better," *General Radio Experimenter*, Vol. xxiii, No. 1, June, 1948.

Figure 2. Elementary schematic circuit diagram of the beat-frequency audio generator.



compensating plates are provided for adjusting the capacitance so that the output beat-frequency accurately tracks the exact logarithmic calibration of the precalibrated dial, which covers a frequency span of three decades, 20 c to 20 kc, with a rotation of 240°, or 80° per decade.

The logarithmic calibration is particularly advantageous on any audio oscillator, because it is common practice to plot frequency characteristics on a logarithmic frequency scale. When the oscillator is used in conjunction with a recorder that records on logarithmic or semi-logarithmic paper, the dial can be geared directly to the recorder mechanism.[3]

For normal operation, the fixed oscillator generates a voltage at a frequency of approximately 190 kc, which beats with the voltage from the variable oscillator to cover the range from 20 c to 20 kc. The added range from 20 kc to 40 kc is obtained by shifting the fixed oscillator frequency to approximately 210 kc. Of course, for this range the frequency scale is no longer logarithmic.

The frequency of the so-called fixed oscillator is actually adjustable over a small range by means of a frequency-increment control, having a dial that is direct reading over the range of ±50 cycles, independent of the output frequency. This control makes possible a precise incremental change in frequency at any setting of the main dial. For example, if the main dial is set to 1000 cps, the output frequency can be varied from 950 cps to 1050 cps by means of the frequency-increment control. Such a control is invaluable for measurements on tuned circuits, on narrow band filters, on mechanically resonant systems, on acoustic resonators, and, in general, for determining the fine structure of frequency-dependent phenomena.

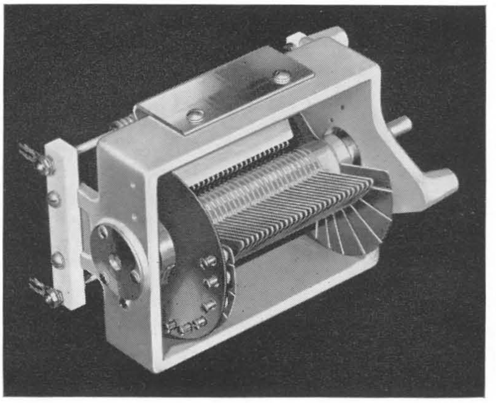


Figure 3. View of the logarithmic capacitor used for the main frequency control element.

In order to make the frequency-increment control direct reading on the extended range of 40 kc as well as the normal range, a compensating capacitive network is switched in by the range switch. This compensation is necessary because of the large change in the capacitor of the tuned circuit required to shift the fixed oscillator frequency by 20 kc.

Buffer Amplifiers

A buffer amplifier is used for each oscillator. The primary function of these amplifiers is to isolate the oscillators so that cross coupling through the mixer is negligible, and the locking of the oscillators is kept to a point where beats of less than 1 cycle can be sustained without pull-in. The amplifiers also make possible coupling to a high-impedance point of the oscillator circuit, and the coil of the oscillator is thereby kept simple with the concomitant advantage of ease in making the coil uniform and stable.

Mixers

The outputs of the buffer amplifiers are applied to the grids of a pentagrid

[3]L. P. Reitz and I. G. Easton, "Automatic Recording with the Beat-Frequency Oscillator," *General Radio Experimenter*, Vol. xxii. No. 8, January, 1948.

converter tube used as a mixer. The exceptionally low distortion from the mixer is achieved in part by an unusual pair of bias adjustments. A common cathode bias for the two grids of the pentagrid mixer is adjusted by a rheostat, and the bias for the signal grid by a potentiometer in parallel with the rheostat. The two adjustments for output voltage and minimum distortion are thereby made essentially independent. These adjustments, together with separate controls on the voltage from each oscillator and the isolation achieved by the buffer amplifiers, contribute an important part in making possible the remarkable performance of this beat-frequency oscillator.

Filter

The desired beat signal at the output of the mixer is separated from the higher frequency components by a low-pass filter.

The extension of range to 40 kc necessitated a redesign of this low-pass filter. The cut-off frequency of the filter had to be increased by a factor of two, and at the same time the attenuation at the oscillator frequencies had to be increased because the response of the new amplifier is good even at the oscillator frequencies of about 200 kc.

Amplifier

The extended frequency range of this generator necessitated a new design for the output amplifier. This greatly improved amplifier uses the new single-ended push-pull output stage previously described[4] and supplies an output of one watt to a 600-ohm load with very low distortion. Distortion at high frequencies, always a serious problem in audio amplifiers, has been kept low by means of negative feedback and good high-frequency balance. Curves showing catalog specifications for distortion and measured values for a typical generator are given in Figure 4.

Output Circuit

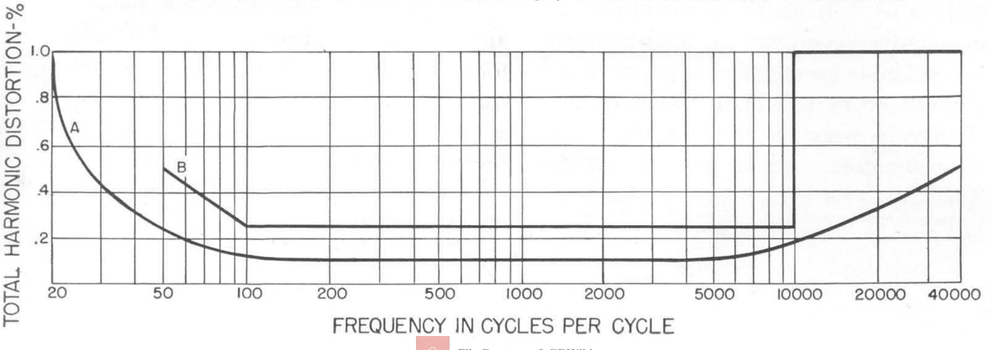
One of the important features of this generator is its calibrated output voltage. Output level is indicated by a meter and an attenuator setting, in both volts and dbm. For voltage, the attenuator dial indicates full-scale values for the voltmeter; for dbm, the attenuator reading in dbm is added to the meter reading in dbm.

The output circuit is shown in the schematic diagram of Figure 2. A simple level control at the input to the amplifier adjusts the output continuously from zero to maximum.

Following the amplifier output transformer is a 600-ohm attenuator whose input voltage is monitored by the voltmeter. The attenuator consists of two T-

[4] A. P. G. Peterson, "A New Push-Pull Amplifier Circuit," *General Radio Experimenter*, Vol. xxvi, No. 5, October, 1951.

Figure 4. Curve A, harmonic distortion as a function of frequency as measured on a typical Type 1304-B Beat-Frequency Audio Generator. Curve B, catalog specifications for distortion in this oscillator.



pads, controlled by a switch to give steps of 0, 20, 40, and 60 db attenuation. Over-all attenuator accuracy is ±1% of nominal value.

The meter circuit is designed to respond to the average of the voltage waveform and is calibrated in r-m-s voltage. The voltmeter rectifying elements are two 1N54-A germanium diodes used in a full-wave rectifier circuit. Accuracy of the meter indication is ±5% of actual reading.

When the attenuator is set at the +20 db position and the ground strap is disconnected from the lower output terminal, the output circuit is sufficiently well balanced for operation into most balanced audio-frequency equipment. The other attenuator positions should be used only for single-ended output, because the attenuator is inserted only in the lead connected to the upper output terminal.

Zero-Beat Indicator

The output voltmeter is an excellent zero-beat indicator. Thus there is no necessity for any other means. As an accurate calibrating system, a small voltage of power line frequency can be injected to be zero beat with the generated frequency as indicated on the voltmeter. A convenient fifth position of the output attenuator switch is used for this calibration. The frequency is brought to the calibration value by adjustment of the zero control. Warm-up drift is compensated for in the same manner.

Applications

The Type 1304-B Beat Frequency Audio Generator is an excellent oscillator for use in practically any application within its frequency range.

It is ideal as a signal source for measurements of amplifier and filter characteristics in the sonic and ultrasonic range, for measuring the amplifier and loudspeaker response of sound reproducing systems, for determining the frequency characteristics of audio transmission lines, networks, meters, and meter circuits, and for many other similar applications where a flat output-voltage characteristic is preferred.

For use with a recorder in these applications, it is particularly advantageous that the frequency dial can be geared to, and rotated by, the mechanism of a recorder, and that the 20-cycles-to-20-kc logarithmic scale of the dial can be synchronized with the logarithmic scale of the recorder paper.

The generator can be used as a signal source, for measurements of harmonic distortion generated in audio-frequency equipment. It can be used as a sine-wave source for modulating r-f signal generators and test oscillators or to trigger pulse generators. A very frequent use is as a generator for audio-frequency bridges. It is also an excellent signal source for psycho-acoustical work.

The metered output voltage makes it convenient for setting operating levels of amplifiers, oscillographs, and other equipment. It can also be used to measure voltage by substitution methods. The frequency of other audio and ultrasonic signals can be measured by use of Lissajous' figures on a cathode-ray oscillograph.

In brief, it is indispensable for use in any audio and ultrasonic work — both for the numerous, small, unexacting jobs that constantly arise, and for those exacting jobs requiring the utmost in performance from all equipment used.

— C. A. Woodward

SPECIFICATIONS

Frequency Range: 20 to 40,000 cycles in two ranges.

Frequency Controls: The main control is engraved from 20 to 20,000 cycles per second and has a true logarithmic frequency scale. The total scale length is approximately 12 inches. The effective angle of rotation is 240°, or 80° per decade of frequency. For the higher range, throwing a panel switch adds 20 kc to the scale frequency. The frequency increment dial is calibrated from +50 to −50 cycles.

Frequency Calibration: The calibration of the frequency control dial can be relied upon within ±(1% + 0.5 cycle) after the oscillator has been correctly set to the line frequency or to zero beat. The 20 kc added by the range switch is accurate within ±0.5%. The accuracy of calibration of the frequency-increment dial is ±1 cycle.

Zero-Beat Indicator: The output voltmeter is used to indicate zero beat.

Frequency Stability: The drift from a cold start is less than 7 cycles in the first hour and is essentially completed within two hours.

Output Attenuator: The output attenuator is for use only with single-ended output. It has three steps of 20 db each, with an accuracy of ±1% of the nominal attenuation.

Output Control: For each step of the attenuator, the output voltage can be varied continuously from zero to the maximum voltage.

Output Voltage: Full-scale, open-circuit output voltages of 50 millivolts, 500 millivolts, 5 volts, and 50 volts are provided. For a 600-ohm resistive load, the variation of output voltage with frequency is as follows:

NORMAL Range: Between 20 and 20,000 cycles the output voltage varies less than ±0.25 db.

ADD 20 KC Range: Between 20 and 30 kc the output voltage varies less than ±0.5 db. Between 30 and 40 kc the variation is less than ±1 db. For open-circuit operation, the output voltage rises considerably at the higher frequencies.

Output Voltmeter: Calibrated in volts output at open circuit, and in dbm. Above 10% of full scale the calibration is accurate within ±5% of the reading.

Output Impedance: 600 ohms, resistive, within ±2%. With zero attenuation setting of the output attenuator, the output may be used either balanced or with one side grounded. With one side of the output grounded, the attenuator may be used throughout its entire range.

Output Power: 1 watt maximum into a 600-ohm resistive load.

Harmonic Distortion: The total harmonic content is less than 0.25% from 100 to 10,000 cycles. Below 100 cycles the harmonic content increases and may reach 0.5% at 50 cycles. Above 10,000 cycles the harmonic content is less than 1%.

A-C Hum: Less than 0.1% of the output voltage for output voltmeter readings above 10% of full scale.

Terminals: Type 938 Binding Posts and standard Western Electric double output jack on panel; a standard four-terminal socket at the rear.

Mounting: Aluminum, 19-inch, relay-rack panel; aluminum cabinet. For table mounting (Type 1304-BM), aluminum end frames are supplied to fit ends of cabinet; for relay-rack mounting (Type 1304-BR), brackets for holding cabinet in rack are supplied. Relay rack mounting is so arranged that panel and chassis can be removed from cabinet, leaving cabinet in rack, or cabinet can be removed from rear of rack, leaving panel attached to rack.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. Power consumption is about 100 watts.

Tubes:

2 — 6SL7-GT	1 — 6SA7
2 — 6AU5-GT	1 — 12AT7
2 — 0D3	1 — 5V4-G

Accessories Supplied: Power cord, four-terminal plug, and spare fuses.

Dimensions: 19⅜ x 15¼ x 7¼ inches, over-all.

Net Weight: 39 pounds.

Type		*Code Word*	*Price*
1304-BM	Beat-Frequency Oscillator (Table Mounting)	CAROL	$555.00
1304-BR	Beat-Frequency Oscillator (Relay-Rack Mounting)	CARGO	555.00

U. S. Patent 2,298,177.
Patent Applied For.
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BETTER SERVICE FOR CUSTOMERS IN WASHINGTON, D. C., AND VICINITY —NEW BRANCH OFFICE

To provide better service to our customers in the District of Columbia and adjacent territory, we have opened a branch engineering office at Silver Spring, Maryland.

Through this office we can furnish technical and commercial information promptly about General Radio products and aid in the selection of equipment to meet specific measurement problems.

William R. Saylor, formerly of the Sales Engineering Staff at Cambridge, is Manager of the new office. Mr. Saylor received his S.B. and S.M. degrees from M.I.T. in 1937 and joined our organization in 1943. Since that date his work has included both development engineering and sales engineering, and he has an extensive knowledge of the performance and application of General Radio instruments.

Willam R. Saylor

The address of the new office is

GENERAL RADIO COMPANY

8055 13th Street, Silver Spring, Maryland

Telephone: JUniper 5-1088

SUMMER CLOSING

Vacation

During the weeks of July 25 and August 1, our Manufacturing Departments will be closed for vacation.

There will be business as usual in the Sales Engineering and Commercial Departments. Inquiries, including requests for technical and sales information, will receive our usual prompt attention.

Our Service Department requests that, because of absences in the manufacturing and repair groups, shipments of material be scheduled to reach us either well before or delayed until after the vacation period.

PROMPT DELIVERY

Remember — you can get delivery from stock on 98% of our standard catalog items.

MISCELLANY

VISITORS: We have welcomed recently at our Cambridge plant the following visitors from foreign countries: D. J. Fuings and Norman Lea, Baddow Research Laboratories, Marconi's Wireless Telegraphy Company, Ltd., Great Baddow, Essex, England; Mr. and Mrs. K. L. Nyman of Helsinki, distributors of General Radio products in Finland; E. P. Courtillot, Assistant Chief Engineer of Electronic Group, French Thompson Houston Company, Paris, France; Dr. H. Bienfait and M. M. Jansen-Gration of Phillips Laboratories, Eindthoven, Holland; Ing. Virgilio Floriana, President, and L. Confalonieri of S.P.A. "Telettra," Milan, Italy; Professor Gino Morandi of the University of Bologna, Bologna, Italy; Gunner Lindstrom and Dag Hartman, Production Supervisor, Saab Aircraft Company, Linkoping, Sweden; Dr. Y. Tsuji, Sub-Manager of the Engineering Division, Sumitomo Electric Industries, Ltd., Osaka, Japan; S. Nakamura and K. Ozawa of Meidensha Electric Manufacturing Company, Ltd., Tokyo, Japan; T. Tsumura, Chief, Engineering Section of Electronic Products Works, Mitsubishi Electric Manufacturing Company, Amagasaki, Japan; Dr. Koji Kobayashi, Vice-President and Works Manager, Nippon Electric Company, Ltd., Minatoku, Tokyo, Japan.

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Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 2 JULY, 1954

AN ACCURATE, HIGH-SPEED, AUTOMATIC LINE-VOLTAGE REGULATOR

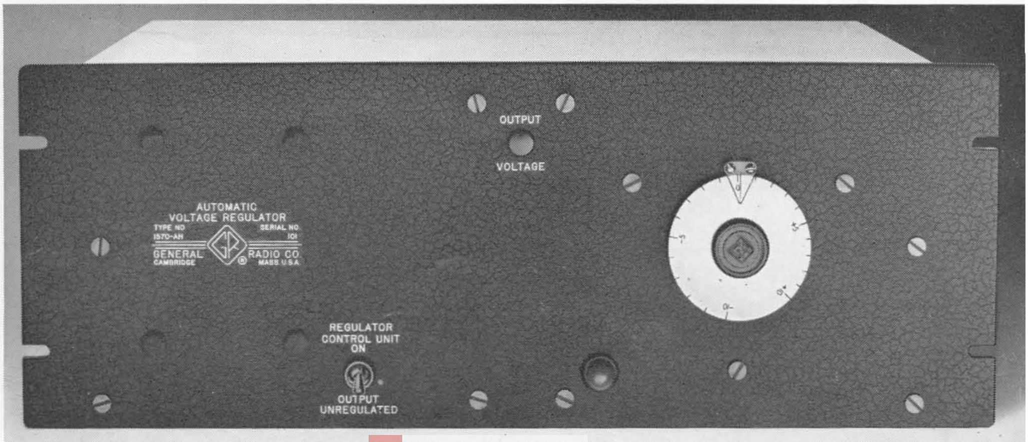
● **STABILITY OF A-C LINE VOLTAGE** is a primary requirement both in the laboratory concerned with precise measurement and in the industrial plant where processes must be precisely controlled. While manual control with a Variac® Autotransformer is adequate for many purposes, a completely automatic control system, which eliminates the need for an operator, is more satisfactory.

Most automatic regulators use vacuum tubes, saturating core devices, or mechanical systems as the regulating elements. For industrial and general laboratory use, the relatively high power rating required precludes the use of vacuum tubes. The magnetic type, using a saturable-core reactor as a series impedance, although fast-acting and economical in small sizes, requires a restriction on load power factor and distorts the output waveform.

For many applications, the mechanical regulating system is, therefore, the most suitable. A Variac® adjustable autotransformer and an automatically controlled motor drive make an excellent regulator of this type. Although this regulator is inherently somewhat slower in response than the magnetic type, its speed is still adequate, it has high efficiency, it has no power-factor restrictions, and it adds no harmonic distortion to the input voltage.

The Type 1570-A Automatic Voltage Regulator is a high-speed mechanical regulator with ±0.25% accuracy and excellent transient response, combined

Figure 1. Panel view of the Type 1570-A Automatic Voltage Regulator.



with 6KVA capacity, 98% efficiency, and no distortion or power-factor restrictions. Basically, this new regulator consists of a Variac autotransformer that adjusts the output voltage, a "buck-or-boost," step-down transformer that effectively multiplies the power rating of the Variac, and a servomechanism that positions the Variac.

VOLTAGE ADJUSTING SYSTEM

The "buck-or-boost" circuit used as the means of control is shown at the left in the functional diagram of Figure 2. This circuit, which we have previously[1] recommended for manual line-voltage compensation, permits the control of high-power circuits with a low-power Variac, thus effectively multiplying the Variac rating.

The auxiliary transformer uses multiple windings to provide either a ±10% or ±20% correction range at 115 or 230 volts. The Variac autotransformer is a special ball-bearing model. Its Duratrak contact surface provides a stable brush track capable of withstanding severe overloads, while the ball bearings minimize friction and give long life in a service demanding continual motion of the brush.

[1]See operating instructions for Variac® Autotransformers.

SERVOMECHANISM

A two-phase servo-motor operated by a control circuit positions the Variac so that the output voltage is held constant. The superior performance of this regulator is due in large part to the excellent design of the control circuit:

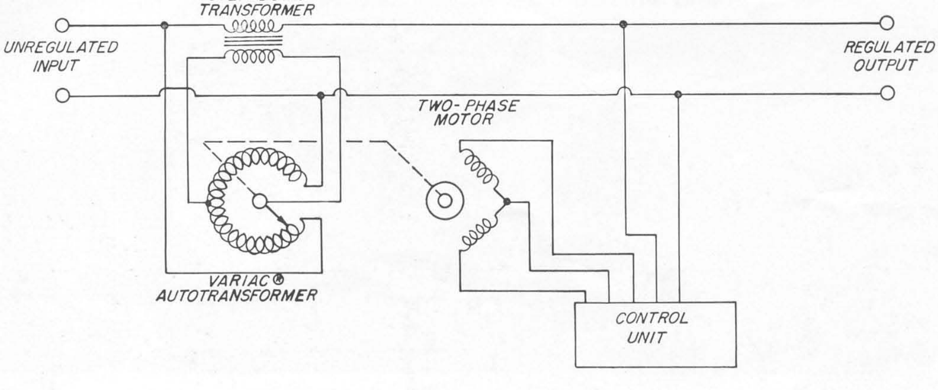
(1) The system utilizes a proportional-control servomechanism rather than the on-off type of control often used in this type of equipment. This yields better accuracy than would be obtained with relays.

(2) A low-inertia servo motor with dynamic braking gives good band width and resultant excellent transient response.

(3) No power amplifiers to supply the motor control windings are used. Motor power is obtained directly from the a-c line. The control unit controls the phase angle between the voltages applied to the two-phase armature and, thus, the rotation of the motor.

(4) Optimum design of the control unit utilizing appropriate lead and lag networks results in high response speed,

Figure 2. Functional diagram showing the buck-or-boost circuit.



accuracy, and excellent overshoot characteristics.

Figure 3 is an elementary circuit diagram of the control unit. The regulated output voltage is measured with an average-response full-wave rectifier to obtain a d-c voltage proportional to the a-c output voltage. The d-c value of this rectified voltage is obtained by providing a resistive load for the rectifiers and filtering the ripple voltage. The use of a full-wave rectifier separates the undesired ripple frequency as far as possible from the pass band of the regulator; and the ripple filter provides an infinite rejection at the 120-cycle ripple frequency, with negligible phase shift below 5 cps. The rectifiers are germanium junction diodes, which provide a high rectifier efficiency and thus minimize any effect of changes in rectifier characteristics.

This filtered voltage is compared with a standard voltage from a 5651-type voltage reference tube. The difference between these voltages is the error voltage and is used ultimately to reposition the Variac.

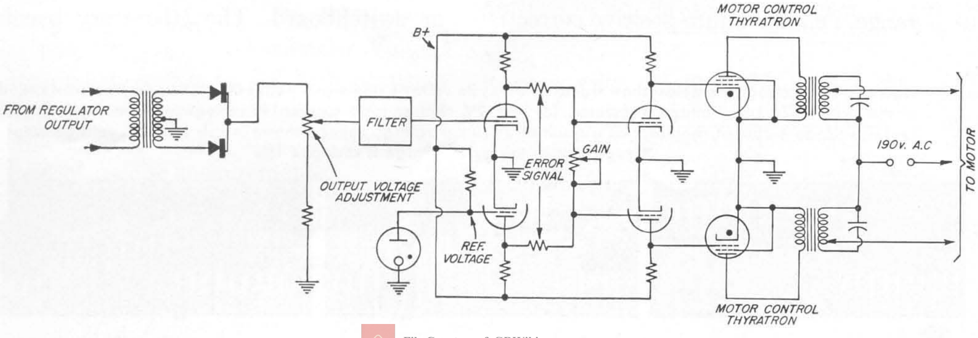
The amplified error voltage is applied in push-pull to a thyratron motor control circuit. The thyratrons are provided with a 60-cycle bias voltage at a 90° phase angle with respect to the a-c plate voltage. The amplified d-c error voltage superimposed on this a-c bias voltage smoothly changes the thyratron firing angle from near 0° to 180°.

A two-phase motor is supplied with 60-cycle power from the power line through the thyratron control circuit. Through variations in their firing angles, the thyratrons control the relative phase angle between the motor-winding voltages. Their distorted output voltages are filtered with resonant circuits and applied to the motor windings. As the thyratron firing angle changes from 0° to 180°, the angle between the motor voltages changes continuously from approximately +90° to −90°. At balance, full voltage is applied to both motor windings at a zero-degree phase angle. The resultant dynamic braking improves the transient response.

ACCURACY

The motor torque is proportional to the error voltage and any error voltage greater than that required to overcome frictional forces results in acceleration of the motor until this error voltage is substantially eliminated. A limit on the ultimate accuracy of control is imposed by the fact that the motor cannot reposition the Variac until its torque is greater than the small friction losses in the system. These have been reduced to the point where other factors, such as limitations in the accuracy of the voltage reference tube, the magnitude of the voltage steps from the Variac, and initial-electron-velocity effects in the input amplifier, would combine to prevent any substantial increase in accuracy from a further decrease in friction.

Figure 3. Elementary schematic diagram of the control circuits.



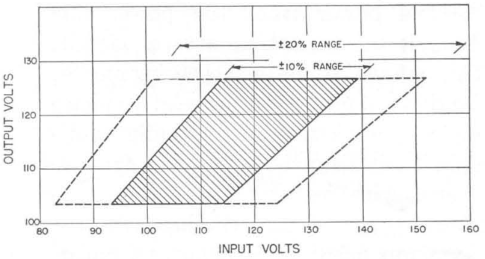


Figure 4. Range of operation for 115-volt models; for 230-volt models, multiply voltage scales by 2.

OPERATING CHARACTERISTICS

The excellent performance characteristics of the Type 1570-A Automatic Voltage Regulator — speed, accuracy, range, etc. — were mentioned briefly at the beginning of this article and are given in detail in the specifications at the end.

The range of operation is shown graphically in Figure 4 for 115-volt models. Multiplying both voltage scales by 2 gives the range for 230-volt models. It should be noted that when the range of control is doubled (from ±10% to ±20%), the KVA rating is halved. A change of internal connections is necessary to change from one range to the other.

Response time, accuracy, and transient response are all interrelated. The response time for the ±10% range on the 115-volt model is 0.1 second per volt; for the ±20% range on the 230-volt model, it is 0.025 second per volt. Regardless of voltage rating or range connection, the time required for correction over any given fraction of the available range is constant. For the complete range, i.e., maximum positive correction to maximum negative, the time is 2 seconds or less.

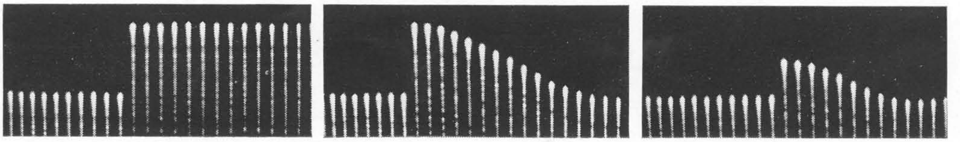
Accuracy is better by a factor of 2 on the narrower range. For either connection, accuracy can be increased slightly by adjustment of the gain control, if greater-than-normal overshoot can be tolerated. Normal adjustment is for negligible overshoot. When the degree of overshoot is thus increased, the total time required for the correction is unchanged.

As shown in Figure 1, there are but two panel controls — a switch to cut out the control unit and an output voltage adjustment accessible with a screwdriver. The gain control referred to above is behind the panel. The dial shown at the right of the panel is on the Variac shaft. Calibrated from −10 to +10, it indicates continuously the angular setting of the Variac and hence acts as a visual monitor to show how much of the range of control is being used at any instant. The calibration corresponds approximately to per cent of nominal line voltage for the ±10% range.

APPLICATIONS

The outstanding performance and large capacity of the Type 1570-A Automatic Voltage Regulator make it useful for a large number of applications. Models are available for both 115 and 230 volts, in three types of mounting: (1) metal cabinet with end frames for laboratory bench use; (2) metal cabinet with fittings for relay-rack mounting; and (3) metal box for mounting on wall or switchboard. The laboratory bench

Figure 5. The oscillograms below show traces of 60-cycle voltage sine-wave peaks illustrating the response speed of the Type 1570 Line Voltage Regulator. (a) Left, 2% change (step function) in voltage input to regulator; (b) center, voltage output of regulator as a result of 2% input voltage change shown in (a); (c) right, voltage output of regulator as the input voltage is changed 1%.



models, TYPES 1570-ALM,—AHM, are provided with standard 15-ampere line cords, so that the regulator plugs directly between line and load where the load current is small. In addition, for higher current applications, 50-ampere terminals are provided. The TYPES 1570-ALR, -AHR can be relay-rack mounted to regulate the supply to an entire rack or group of racks.

In our own plant we use the 115-volt wall-mounting model, TYPE 1570-ALW, with a fuse box and disconnect switch, to regulate one side of the balanced 230-volt line in the engineering laboratories. Thus each room is provided with half its 115-volt Pierceway outlets regulated and the other half unregulated. This installation is shown in Figure 6.

For the laboratory engaged in electrical and electronic measurements, regulated line voltage is an essential. In a measurement setup using a number of indicating instruments — meters and oscilloscopes — for measuring gain, power, waveform, etc., regulated a-c supply assures stable, repeatable indications. In the adjustment and calibration of bolometer bridges; in performance tests on rectifiers; in sensitive electro-medical instruments such as electrocardiographs and electroencephalographs, regulated line voltage facilitates accurate measurements. Light measurements with a-c lamps are particularly affected by supply-voltage variations; in photometry as well as in photographic work where color temperature is important, a line-voltage regulator finds many uses.

The TYPE 1570-A Automatic Voltage Regulator, owing to its high accuracy and speed of response, is particularly well suited to these applications in the field of precise meaurement.

— M. C. HOLTJE

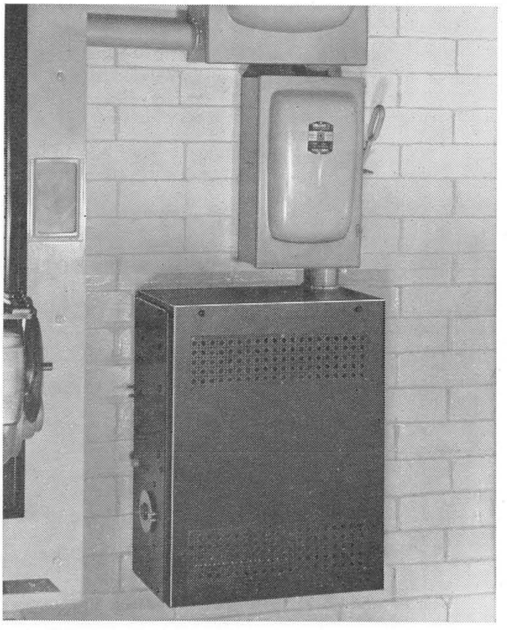


Figure 6. Wall-mounting model, Type 1570-ALW, as installed in the General Radio engineering laboratories.

SPECIFICATIONS

Output Voltage: Adjustable over a range of ±10% from a base value of 115 volts (for TYPE 1570-AL) or 230 volts (for TYPE 1570-AH) by means of a screw-driver adjustment on panel.

Input Voltage Range: The desired output voltage will be maintained if the input voltage does not vary by more than ±10% from this value of output voltage. A ±20% range connection is also available (see footnote below).

Output Voltage	*115 Nominal Adjustable* ±10%		*230 Nominal Adjustable* ±10%	
Input voltage as a percentage of output voltage*	90% to 110%	80% to 120%	90% to 110%	80% to 120%
Output current amperes	50	25	20	10
KVA	6	3	5	2.5
Accuracy in % of output voltage	0.25%	0.5%	0.25%	0.5%
Speed of Response volts per second†	10	20	20	40

*TYPES 1570-AL and 1570-AH can be connected for either ±10% or ±20% input voltage range. Instruments are shipped connected for ±10% range unless 20% range is specified on order.

†Slightly less for very small voltage corrections.

Waveform Distortion: No distortion. Output waveform same as input.

Waveform Error: The voltage sensing device responds to the average value of the rectified output voltage. Therefore, the average value of the output voltage is held constant, and a loaded d-c power supply operated from the output of the regulator will give constant output voltage regardless of the harmonic distortion present in the power line. The rms output voltage will also remain constant, regardless of the harmonic distortion present, as long as the phase and amplitude of these harmonics are constant. If the harmonic content changes, the rms value will change by an amount less than $\Delta R/n$, where ΔR is the change in the harmonic amplitude and n is the harmonic number.

Efficiency: 98%

Ambient Temperature: Full ratings apply up to 40°C.

Frequency: Standard models, 60 cycles. The instrument can be modified at the factory for operation at 50 cycles. There is a nominal charge for this modification, which must be made before shipment.

Power Consumption: No Load 35 watts
Full Load 100 watts

Mounting: Relay rack (-R model), table top (-M model), or wall (-W model).

Dimensions: (Width) 19 x (height) 7 x (depth) 12⅞ inches, over-all; depth behind panel 11¾ inches, for -R and -M models; -W models, (width) 13½ x (height) 19½ x (depth) 8¼ inches, over-all, in position shown in Figure 6.

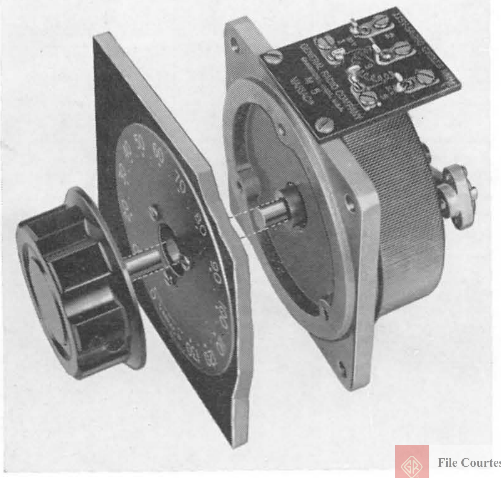
Net Weight: Relay-rack and table models, 56½ pounds; wall model, 63½ pounds.

Type		*Code Word*	*Price*
1570-ALM	**Line Voltage Regulator, 115 volts, table top model**	CEDAR	**$470.00**
1570-ALR	**Line Voltage Regulator, 115 volts, relay rack model**	CHARY	**465.00**
1570-ALW	**Line Voltage Regulator, 115 volts, wall model . . .**	CLOWN	**465.00**
1570-AHM	**Line Voltage Regulator, 230 volts, table top model**	CHALK	**470.00**
1570-AHR	**Line Voltage Regulator, 230 volts, relay rack model**	CURLY	**465.00**
1570-AHW	**Line Voltage Regulator, 230 volts, wall model. . . . .**	CLOSE	**465.00**

Patent Applied For.
Delivery from stock as with most General Radio instruments.

NEW VARIAC® AUTOTRANSFORMERS FOR 350- TO 1200-CYCLE SERVICE

Increasing use of higher-frequency power in aeronautical and marine designs, with its consequent saving in bulk and weight of iron-cored electrical devices, calls for voltage-control apparatus designed with the particular requirements of these services in mind. Two new Variac® autotransformers, the Type M-2, rated at 2 amperes, and the Type M-5, rated at 5 amperes, are designed specifically to meet these requirements. The M-5 Variac supplants the older Type 60-A. Smaller and lighter than their sixty-cycle counterparts, they have been "beefed-up" to withstand shock, vibration, and environmental tests under MIL-T-945A specifications. This "ruggedizing," while not of primary concern to the civilian user, does assure exceptional reliability under both ordinary and extraordinary service conditions. The use of a *Duratrak*[2] contact surface on all units is a still further guarantee of trouble-free operation.



[2]A New Standard of Reliability in Variable Autotransformers, Variac® with Duratrak — *General Radio Experimenter*, April, 1953.

Figure 1. View of the Type M-2 Variac® Autotransformer.

FEATURES

The Type M-2 and Type M-5 Variacs incorporate several new features that, we feel, constitute distinct improvements over previous designs.

The rectangular base, with its four corner holes, permits attachment of the Variac to walls and bulkheads without rear access, although the three tapped holes used in Types V-2 and V-5 Variacs are also provided. The base is also in better thermal contact with the coil, and with the panel, for improved conduction of heat from the unit to its environment. An additional design feature permits back-to-back mounting of two coils on a single base for further weight and space economy in ganged assemblies.

The radiators are counterbalanced to hold their setting under shock and vibration. This has formerly been a feature of larger Variacs only.

Winding taps are concealed to preclude the possibility of damage to taps, leads, and winding during handling and installation. End-taps are not self-leads, but are deliberately brought in a few turns from the end of the winding. This permits the brush to reach zero or maximum voltage without traversing the end turn, which, owing to its position, is usually somewhat less secure and mechanically stable than the other turns. It also avoids the possibility of the brush leaving the end of the winding at limit travel.

"Angel-cake pan" coil cups are another feature. These molded cups, shown in Figure 2, fit tightly over the core to form a rigid, firm support for the winding. First used in Types 200-B, V-2, and V-5 Variac autotransformers, these coil cups resist deformation of the brush track far more effectively than do flat end-plates, because of their channel section. Their use also eliminates the need for fiber or paper wrap-arounds on the cylindrical core surfaces, thus effectively up-grading insulation quality.

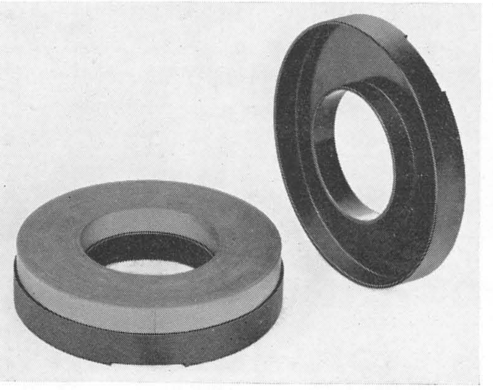
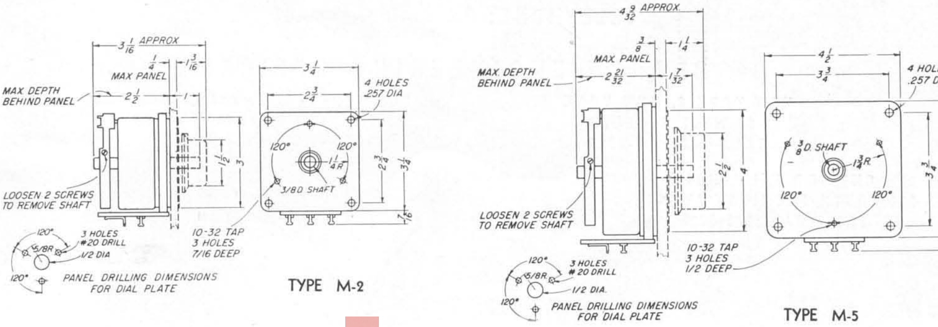


Figure 2. View of the coil cups which enclose the core and constitute the winding form.

VOLTAGE RATINGS

The Types M-2 and M-5 Variacs are designed for 115-volt, 350- to 1200-cycle, input; 0-115 or 0-135 volt output, determined by connections. Two-gang assemblies (G2) may be used in 115 volt, 3-phase, open delta circuits, in two-phase circuits, or for the simultaneous control of two independent loads. Three-gang as-

Figure 3. Dimensions of the Type M-5 and the Type M-2 Variacs®.



semblies (G3) are particularly adapted for wye connection in 208-230 volt, three-phase service. This use of the wye connection is possible since the wye voltage of a 230-volt circuit is 133 volts, and M-2 and M-5 coils are wound for 135 volts.

LOW-VOLTAGE USE AT 60 CYCLES

The Type M-2 and M-5 Variacs are also applicable to low-voltage 50-60 cycle service. They have 37.5% of the core stack of comparable V-line Variacs and can thus be operated to ⅜ of V-line maximum voltage, 50 volts at 50 cycles. This suggests their use for the single-phase or polyphase control of intermediate-voltage rectifiers, etc., particularly where space and weight may be at a premium.

— Gilbert Smiley

SPECIFICATIONS

	Type M-2	*Type M-5*
Line Frequency:	350 to 1200 cps.	350 to 1200 cps.
Input Voltage:	115 nominal	115 nominal
Output Voltage:	0 to 135 or 0 to 115	0 to 135 or 0 to 115
Rated Output Current:	2 amperes	5 amperes
Maximum Output Current (for line-voltage connection only):	3 amperes	7.5 amperes

	Type M-2	*Type M-5*
No-Load Loss at 400 Cycles, watts:	3	6
Number of Turns on Winding:	402	293
D-C Resistance of Winding:	6.6 ohms	1.3 ohms
Driving Torque:	10–20 ounce-inches	15–30 ounce-inches
Net Weight, pounds:	1⅞	3¼
Dimensions:	see Figure 3	see Figure 3

Type	*Description*	*Code Word*	*Price*
M-2	**Variac**	BAGGY	**$15.50**
M-2G2	**2-Gang Type M-2 Variac Assembly**	BAGGYGANDU	**35.00**
M-2G3	**3-Gang Type M-2 Variac Assembly**	BAGGYGANTY	**52.50**
M-5	**Variac**	CANNY	**22.50**
M-5G2	**2-Gang Type M-5 Variac Assembly**	CANNYGANDU	**49.00**
M-5G3	**3-Gang Type M-5 Variac Assembly**	CANNYGANTY	**73.50**

Patent applied for.

SUMMER CLOSING

During the weeks of July 26 and August 2, our Manufacturing Departments will be closed for vacation.

Our Sales, Engineering and Commercial Departments will be operating normally. Shipments of material in stock can be made promptly. Inquiries, including requests for technical and sales information, will receive immediate attention.

Our Service Department requests that, because of absences in the manufacturing and repair groups, shipments of material be scheduled to reach us either well before or delayed until after the vacation period.

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VOLUME XXIX No. 3 **AUGUST, 1954**

A POCKET-SIZE TRANSISTOR OSCILLATOR FOR AUDIO-FREQUENCY TESTING

● **FOR SEVERAL YEARS,** the General Radio Company has carried on an experimental development program in transistor circuits and their applications. The first instrument to result from this program is the TYPE 1307-A Transistor Oscillator, a pocket-size source of test voltage at 400 and 1000 cycles.

Completely self-contained, including batteries and output meter, it can be easily held in the hand, as shown in Figure 1. The small and convenient size of this oscillator, together with its output meter (an unusual feature in so small an oscillator), makes it an extremely useful test device. Because of its small size, it is easy to carry and use in any location, particularly in the field, where transportation is usually a problem and stable power lines are rare. The output meter makes possible quantitative tests, such as supplying a known calibration voltage to the TYPE 1552-A Sound-Level Calibrator for standardizing sound-measuring equipment, as shown in Figure 3. Others include making continuity checks of audio equipment, setting operating levels, checking the sensitivity of oscillographs, and making preliminary calibrations of electronic systems. It is also a convenient power source for bridge measurements at 400 and 1000 cycles.

Circuit

As shown in the schematic diagram of Figure 2, the TYPE 1307-A Transistor Oscillator uses a P-N-P junction transistor in a Hartley oscillator circuit. The inductor of this tuned circuit is an iron-cored coil with an air gap. The coil is divided into two parts to aid in obtaining the proper d-c operating voltages on the transistor, but the large by-pass capacitor connects the two parts in series for the oscillatory currents. The tuning capacitor is connected across the full

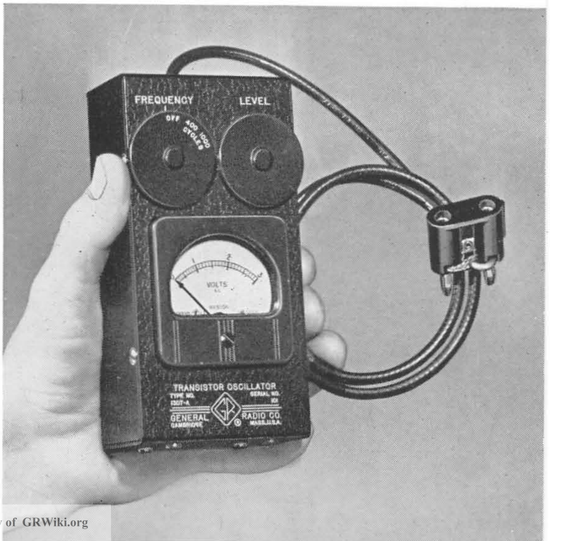


Figure 1. View of the Transistor Oscillator.

Also

IN THIS ISSUE

coil for 400-cycle operation, and it is switched to be across only part of the coil for 1000 cycles. The control at the left in Figure 1 operates the switch for shifting the frequency.

The circuit of Figure 2 is readily understood in terms of the analogous vacuum-tube-triode circuit. Here, the emitter of the transistor corresponds to the cathode of the vacuum tube; the base, to the grid; and the collector, to the plate. The main part of the tuned circuit for 400-cycle operation is connected between the base and collector (grid and plate), and the emitter (cathode) is connected to the coil at a point between those two elements. The circuit obviously then is equivalent to a Hartley oscillator circuit.

A germanium diode is used as part of the circuit that sets the bias voltage for the base. The operating characteristics of this diode approximate those of the emitter-base junction of the transistor so that oscillations will start for a wider range of temperature, of battery voltage, and of transistors than is readily possible with a linear-resistor in the bias circuit.[1]

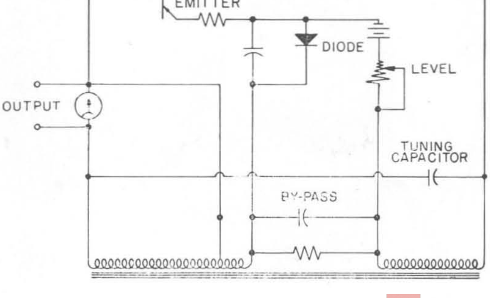


Figure 3. The Transistor Oscillator used as a tone source for the Type 1552-A Sound-Level Calibrator to standardize the Type 1551-A Sound-Level Meter.

A small resistance in the emitter circuit provides degenerative feedback to improve the waveform of the oscillation. As much feedback is used as is consistent with the output requirements and reliability of starting.

Inductor

The inductor used for the tuned circuit was chosen on the basis of a compromise between size and low losses. A large coil with low losses leads to good efficiency and possible low distortion in the output wave. But a relatively small inductor was desired in order to make the whole oscillator small. By the use of high-quality iron, by careful selection of the air gap, and by setting the impedance at the correct level, the distortion in the output wave was held to 5% even with reasonably efficient generation of the signal, using a "postage-stamp" coil.

[1] D. E. Thomas, "Low-Drain Transistor Audio Oscillator," *Proc. I.R.E.*, 40, 11; November, 1952, pp. 1385-1395.

Figure 2. Simplified schematic circuit diagram of the Transistor Oscillator.

Output Circuit

The inductor is also used as an output transformer for supplying a 600-ohm load, one of the standard impedance loads for audio-frequencies. For efficient energy transfer, the load is coupled directly to the oscillator. As a result of this direct coupling, a reactive load will shift the frequency of oscillation. Advantage can be taken of this effect, if one desires to shift the oscillator frequency by a small amount from the nominal values of 400 and 1000 cps, although normally an effect of the load on the frequency of oscillation is somewhat of a disadvantage. In actual practice, however, the effect of the load is relatively small, because of the low source impedance of the oscillator output. If the load is resistive, the frequency is essentially independent of the load. Even as low a reactance as 400 ohms at 400 cps (that of a one-microfarad capacitor) shifts the frequency by less than 10%.

The output voltage can be set by an adjustable resistance in series with the battery supply. This circuit arrangement conserves battery life when only low output is needed. The output control is on the right in Figure 1. The maximum output is at least 2 volts across a 600-ohm load.

The rectifier-type voltmeter, 3 volts full scale, indicates the output voltage. As a good compromise between small size and good readability of scale, a 2½" meter was chosen. This meter size was one important factor in determining the ultimate size of the instrument, as can readily be seen from the picture of Figure 1.

Battery

The transistor oscillator has a much better over-all efficiency than can be obtained with a vacuum-tube oscillator, because of the power required to heat the filament of the vacuum tube. The good efficiency means low battery drain and long battery life. The average life of the three mercury batteries used is over 100 hours.

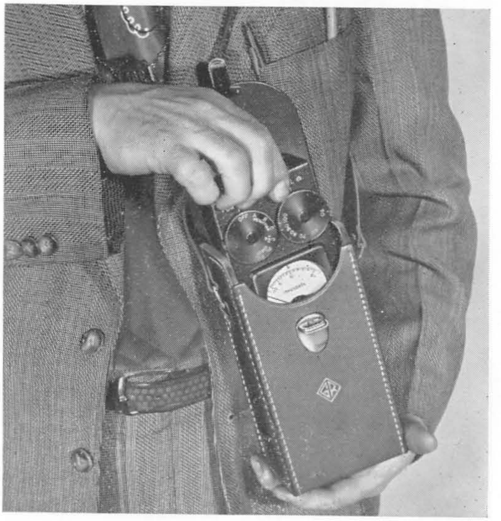
The battery circuit is opened by setting the FREQUENCY control switch in the OFF position. No warm-up time is required for this oscillator so that the switch can normally be left OFF except when the oscillator is actually being used.

Carrying Case

The over-all size of the TYPE 1307-A Transistor Oscillator is identical with that of the TYPE 1555-A Sound-Survey Meter, and hence the same carrying case can be used, as shown in Figure 4. For field use, the case provides both protection and ease of carrying.

— ARNOLD PETERSON

Figure 4. The Transistor Oscillator fits into the same convenient leather carrying case as the Sound-Survey Meter.



CORRECTION

The price of the TYPE 1570-ALM and TYPE 1570-AHM Automatic Voltage Regulator is $465. The price of $470 given in last month's *Experimenter* is in error.

SPECIFICATIONS

Frequency: 400 and 1000 cycles accurate to ±3% at 2 volts output into a 600-ohm resistive load. The frequency decreases slightly with increase in output level. A reactive load will shift the frequency, since the load is coupled directly into the tuned circuit.

Output: Adjustable. Maximum output is at least 2 volts across 600-ohm load.

Distortion: Less than 5% at 400 c and at 2 volts across 600-ohm load. It may be slightly higher at 1000 c.

Voltmeter: 3 volts full scale, calibrated directly in volts at the output terminals.

Output Circuit: The output cable is terminated in a 274-MB double plug. No connection is made to the case.

Batteries: Three mercury A batteries (Mallory RM-1 or equivalent) are supplied.

Transistor: One P-N-P junction transistor (Raytheon Type 721 or equivalent) is supplied.

Case: Aluminum, black finish.

Carrying Case: A leather case with straps is available, TYPE 1555-P1.

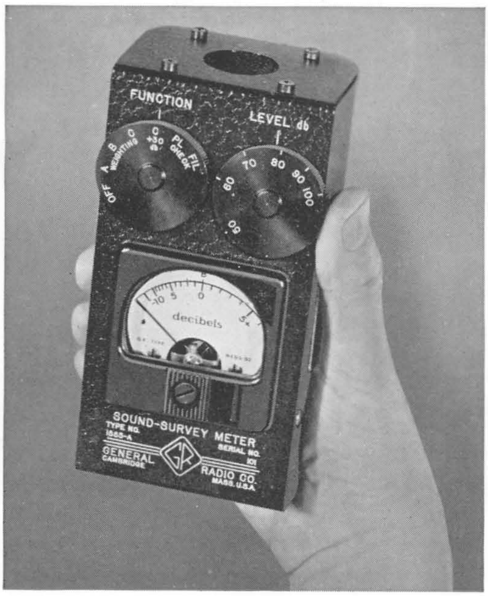
Dimensions: 6 x 3⅛ x 2½ inches over-all, but excluding output cable.

Net Weight: 1 pound, 14 ounces, with batteries.

Type		*Code Word*	*Price*
1307-A	**Transistor Oscillator**	OMEGA	**$88.00**
1555-P1	**Leather Carrying Case**	CASER	**10.00**

SOUND-SURVEY METER AS AN AID TO CHORAL DIRECTORS

In the April, 1952, issue of the *General Radio Experimenter*, Dr. Arnold Peterson described the TYPE 1555-A Sound-Survey Meter and suggested many uses for the instrument. In this note still another application of this versatile instrument is pointed out: it is a valuable aid in teaching proper control of volume to choral groups.



As a teaching aid, the meter is best mounted within view of the singers so that they can see the result themselves. The novelty of the situation appeals to students, and they seem more eager to correct a defect when it is implied by an impersonal meter reading than when it is pointed out by a director.

Consider now some specific applications. The untrained ear — and most choral groups have an abundance of them — has little concept of the distinction between mezzoforte and forte. The question is "How loud is loud?" But once a sound-level criterion has been established, the question is answered. The level of an unchanging tone may be easily read on the Sound-Survey Meter by simply zeroing the meter with the level adjustment knob. And by practicing with the meter, a group may be taught to produce closely any indicated volume level. Such an approach — although it may not appeal to a finished musician — is very effective in teaching fundamentals.

Many singers are deficient in volume range. A great help in overcoming this defect is to point out the normal variation in volume range and then to allow the student to utilize the Sound-Survey Meter to record his present ability in that regard, and also to note his improvement from time to time.

But perhaps the Sound-Survey Meter is best appreciated by a choral director when he applies it to the problem of obtaining volume balance among sections in polyphonic music. A factor contributing to the difficulty of obtaining tonal balance is the fact that most singers are not adequately aware of the dependence of loudness on pitch, and tend rather to correlate physiological effort with loudness. Thus in a very loud passage each section tends to exert its physiological maximum, with the result that the first tenors far outbalance the basses, completely destroying the tonal blend. Over the normal frequency and volume range of choral music, the instrument with the function switch in the B position indicates quite well when a loudness balance at different frequencies is achieved. By use of the Sound-Survey Meter, the singers can see for themselves the relative loudness of their "maximum effort" at different pitches. The problem, once understood, is half solved.

In general, the tenor sections have the ability to get louder than the bass sections. Therefore, if volume balance is to be maintained, the tenors must restrain themselves somewhat. Suppose that in a given musical passage the first tenors are too outstanding. Using the Sound-Survey Meter, the director may quickly show them not only that they are too loud, but also exactly how loud they must be in order to blend with the other sections.

Considering its many applications, the Sound-Survey Meter deserves to be part of the standard equipment of choral directors. And indeed it would seem that band and orchestra directors could profitably make similar use of the instrument.

— Brother Romard Barthel
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Editor's Note:

We are glad to be able to publish this article on the value of the Sound-Survey Meter to choral directors. One of the difficulties encountered in writing about sound measurements in the musical field is the difference in meaning attached to such words as "loudness" by the musician and the physicist. Similarly, the word "volume" has no standard definition, but is nevertheless a definite, although somewhat intangible, psychological characteristic of music. As the author points out, by establishing a sound-level criterion, one can, as a practical matter, ignore the definitions.

CATALOGS FOR STUDENT USE

Colleges and engineering schools have often inquired about the availability of our general catalog for student use. While the cost of our catalog precludes regular distribution to students, we often have available, when a new edition is published, a quantity of the previous edition.

At present we have on hand a considerable number of our 1951 Catalog M's, and we shall be glad to furnish them to teachers for classroom or student use as long as the supply lasts. Please request them on your department letterhead stating the quantity desired and the point to which shipment should be made.

WE SELL DIRECT

The General Radio Company maintains no sales agencies in the United States, but distributes its products directly to the user on a net-price basis. The Company maintains factory branch offices in several major cities of the United States which are staffed by skilled, factory-trained engineers.

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For your information, we are listing below the members of our Sales Engineering Staff. When you need technical or commercial information about General Radio products, get in touch with one of these men. They are as near to you as your telephone or the nearest mailbox.

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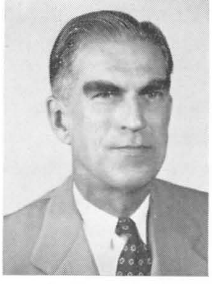

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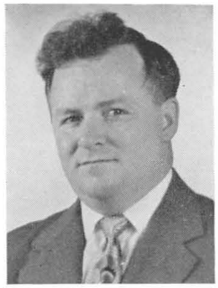

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A. S. T. M. HONORS R. F. FIELD

R. F. Field

At the 57th Annual Meeting of the American Society for Testing Materials, Robert F. Field was presented with the Society Award of Merit "for intensive service in Committee D-9 on Electrical Insulating Materials, especially in establishing important test methods, and extending knowledge of these materials."

Mr. Field, who retired from the General Radio Engineering Staff in 1950, first joined the ASTM in 1934 and became a member of Committee D-9 the following year, representing the General Radio Company.

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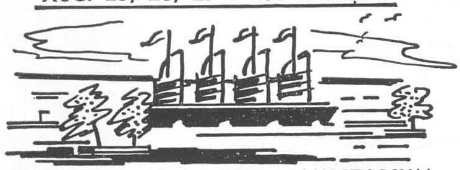

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VOLUME XXIX No. 4 SEPTEMBER, 1954

SOUND MEASUREMENTS AT VERY HIGH LEVELS

● **AS A RESULT** of the increasing use of jet and rocket propulsion, noise levels of 150 db and higher are becoming relatively common. Such levels are beyond the range of most sound-level meters. For the measurement of these high levels, new microphones are now available, which extend the range of the General Radio Sound-Level Meter well beyond the nominal upper limit of 140 db above the standard reference level.

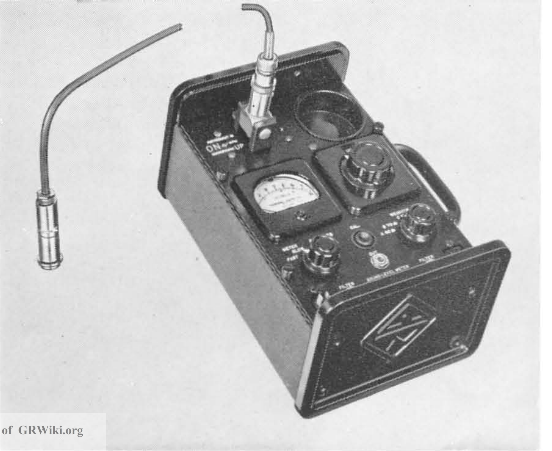
One of these, the Massa Model M-141B Standard Microphone, shown in Figure 1, can be used directly on the sound-level meter, replacing the Rochelle-salt type furnished as standard equipment. The other, the Altec 21-BR-180 Condenser Microphone, for use with the Type 1551-P1 Condenser Microphone System, is shown in Figure 2.

These high-level microphones are well suited for measuring sound levels in engine test cells and near high-powered airplanes, and for measuring the blast pressures of gun fire and other explosions. Furthermore, they have such good frequency-response characteristics that they are particularly useful for measuring noises characterized by strong high-frequency components, as, for example, turbine-blade noise, jet-engine noise, and textile machinery noise. The small size of these microphones makes it possible to bring the microphone near to noisy parts of a machine, a procedure which is often invaluable in tracking down sources of noise. The small size also helps in exploring sound fields with a minimum of disturbance from the microphone. In addition, the Massa microphone, because of its exceptionally rigid construction, is particularly suited to direct measurements of pressure variations in pressure chambers by mounting the microphone to form part of the chamber wall.

BEHAVIOR OF REGULAR MICROPHONES AT HIGH LEVELS

Before describing these newer microphones in detail, however, we shall re-

Figure 1. View of the Massa Model M-141B Standard Microphone with the General Radio Type 1551-A Sound-Level Meter.



view the high-pressure limitations of the other microphones available from the General Radio Company.

Rochelle-Salt Type

A Rochelle-salt crystal microphone, Shure Model 98-98, is regularly supplied with the TYPE 1551-A Sound-Level Meter. This sensitive microphone is designed to cover the usual levels encountered in sound measurements, and its use at high levels is limited by possible damage to the crystal and by possible non-linearity of the output voltage with respect to the input sound pressure.

Tests indicate that neither damage nor appreciable non-linearity occurs at levels up to 154 db. This microphone can, therefore, be used at somewhat higher levels than the normal upper limit of the sound-level meter. Levels only a few decibels above 140 db can be measured if the calibration control of the instrument is set so that the gain is lower than normal. The reading is then corrected by adding to it the number of decibels by which the gain was set low. This number of decibels can be measured by using the line-calibration system provided on the TYPE 1551-A.

To facilitate the measurement of still higher levels, a new accessory, the TYPE 1551-P11 20-db Pad, shown in Figure 3, is being made available. This pad is a resistance network connected between two phone plugs, which fit the "FILTER IN" and "FILTER OUT" jacks of the TYPE 1551-A Sound-Level Meter.

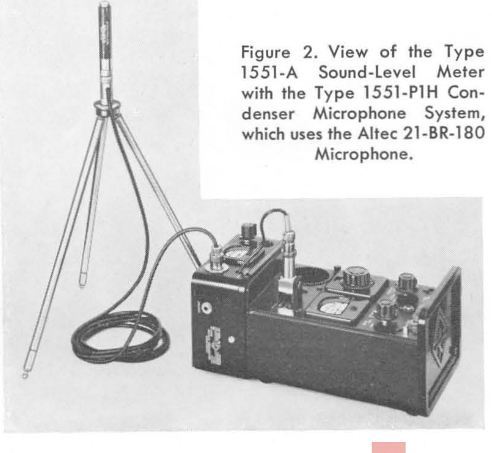


Figure 2. View of the Type 1551-A Sound-Level Meter with the Type 1551-P1H Condenser Microphone System, which uses the Altec 21-BR-180 Microphone.

When they are thus connected, a 20-db correction is to be added to the level reading of the instrument. The nominal level range is, then, consequently, 44 to 160 db above the standard reference level of 0.0002 microbar.

Not only does this accessory extend the range of levels that can be measured by the TYPE 1551-A Sound-Level Meter, but it also helps to solve the microphonic problem, which is so serious when high levels are measured (see below, page 7). The 20-db pad also makes it easier to measure by means of an analyzer a comparatively weak high-frequency sound in the presence of a high-level low-frequency sound. This feature results from an improvement in the signal-to-noise ratio when the pad is used.

Dynamic Type

The dynamic microphone in the TYPE 759-P25 Dynamic Microphone Assembly is limited to a maximum sound-pressure level of about 140 db at low frequencies. At higher levels the microphone may be damaged.

Condenser Type

The Altec Type 21-BR-150 Condenser Microphone[1] used in the TYPE 1551-P1 Condenser Microphone System is, in contrast, not damaged by high sound levels. Its high-level limit is determined by the permissible distortion. At high sound levels, the motion of the diaphragm is great enough to result in non-linearity of the output voltage with respect to the input sound pressure. The

[1]The Altec Type 21-C Condenser Microphone was formerly used in the TYPE 1551-P1 Condenser Microphone System. That microphone has now been replaced by the newer TYPE 21-BR-150, which is an improved version for measurement applications.

distortion from this effect is generally less than 1 per cent at levels up to 135 db, increasing with level to about 10 per cent at 155 db. When a level higher than 140 db is to be measured using this microphone, the TYPE 1551-P11 20-db Pad must be used to keep the signal within the range of the TYPE 1551-A Sound-Level Meter.

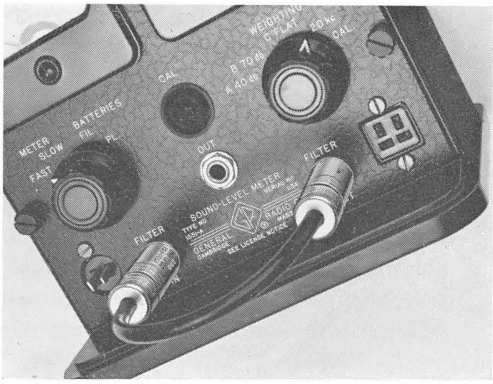


Figure 3. As shown here, the Type 1551-P11 20-db Pad plugs into jacks on the sound-level-meter panel.

MICROPHONES FOR HIGH LEVELS

Altec Type 21-BR-180 Condenser Microphone

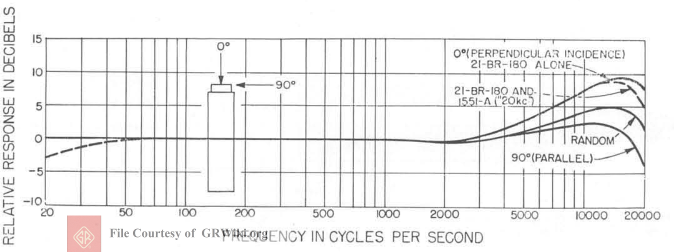
As mentioned in the introduction, another condenser microphone, the Altec Type 21-BR-180, is also available for use with the TYPE 1551-P1 System. Its sensitivity is about 15 db less than that of the Type 21-BR-150. Then the level of distortion discussed above is below 1 per cent up to about 150 db and below 10 per cent up to about 170 db. For some applications even more distortion would be permissible for a measurement of a noise of high pressure level. Above 150 db with the Type 21-BR-180, the Type 1551-P11 20-db Pad is necessary.

The Type 21-BR-180 Microphone is similar to the one regularly supplied with the TYPE 1551-P1 System. The diaphragm of the microphone is more rigid, however, so that the sensitivity is less. In addition, some acoustic damping has been introduced to reduce the resonant rise in response that is more serious with a stiffer diaphragm. As a result of these changes, the response of this high-level microphone is even better than that of the Type 21-BR-150.

A typical frequency response for this condenser microphone is shown in Figure 4. The response to 20 kc is seen to be very good, particularly for parallel incidence, that is, when the sound grazes the face of the microphone. In order to reduce the effects of unwanted disturbances in the sound field, it is often recommended that perpendicular incidence be used; and then the upper response curve of Figure 5 applies. If it is desired to reduce the peak in response that occurs, the "C"-weighting network of the TYPE 1551-A Sound-Level Meter can be used, with a result for perpendicular incidence that is essentially the same as the curve shown for parallel incidence.

The Type 21-BR-180 Microphone is not seriously affected by comparatively high temperatures, but the preamplifier of the TYPE 1551-P1 System is limited by its vacuum tube to operation at temperatures below about 100° C. (212° F.). Also, because of the high electrical impedances involved, this microphone system is not recommended for operation at high humidities, although no permanent damage results from exposure to high

Figure 4. Typical frequency response characteristic for the Altec 21-BR-180 Microphone.



humidity. High humidity can cause enough electrical leakage so that the required bias on the microphone cannot be obtained. This condition will be obvious in operation, since one will not be able to set the indicating meter on the power supply of the TYPE 1551-P1 System to the correct level. Sometimes the effects of humidity can be reduced to an adequate degree by heating the microphone well above the ambient temperature.

Massa Model M-141B Standard Microphone

The new Massa Model M-141B Standard Microphone, which is rated at 200 db, goes well beyond any of these microphones in the measurement of high levels. With the TYPE 1551-A Sound-Level Meter, it can be used up to 190 db.

Satisfactory operation at these extremely high levels is achieved by using a stack of ammonium-dihydrogen phosphate (ADP) crystals as the pressure-sensitive piezoelectric element. These crystals are mounted in a small, cylindrical, stainless-steel housing, having the dimensions shown in the drawing of Figure 5. This straightforward, rugged construction results in a microphone having very stable characteristics.

The front metal plate of the housing contacts the ADP crystals through a thermal isolation plate. When a sound pressure wave strikes this plate, a very small motion of the plate and a corresponding compression or expansion of the crystals results. Since the crystals are piezoelectric, the change in the dimensions of the crystals produces a voltage, without requiring any separate power supply. A 20-foot cable attached to the housing connects the microphone to the sound-level meter.

Sensitivity

The Massa Model M-141B can be purchased from the Massa Laboratories[2] with the sensitivity adjusted to be exactly 50 db less than that of the regular microphone furnished with the TYPE 1551-A Sound-Level Meter. The sensitivity of the regular microphone varies from unit to unit, and the gain of each sound-level meter is set to correspond to the sensitivity of the microphone supplied with it. Therefore, if the customer wants the Massa microphone adjusted, it is essential that he send, with his order to the Massa Laboratories, the serial number of his sound-level meter and the sensitivity figure given in the microphone well, if available. When the sensitivity of the Massa Model M-141B Microphone is set in this fashion, the measured sound-pressure level is simply 50 db higher than the pressure level indicated on the sound-level meter.

Range

The nominal range of the instrument when using the Massa Model M-141B Microphone is then 74 to 190 db. The upper limit is set by the sound-level meter, and it is still within the rating of the microphone. To illustrate how high this upper limit is, we can compare it to atmospheric pressure. For example, if there were a periodic sinusoidal variation in pressure covering a peak-to-peak range from 0.1 atmospheric pressure to 1.9 atmospheres, the corresponding

[2] 5 Fottler Road, Hingham, Mass.

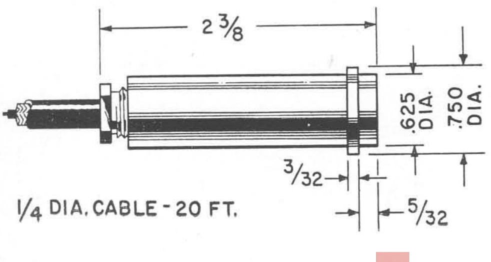


Figure 5. Dimensions of the Massa Model M-141B Standard Microphone. The 20-foot cable is terminated in an Amphenol connector, which fits the sound-level meter.

sound-pressure level would be 190 db. At such high levels, of course, the variation in pressure would normally be something different from a simple sine wave.

As a consequence of the high-level use for which the microphone was designed, the minimum level at which it can be used is comparatively high. The basic limiting factor is the inherent noise level of the input circuit of the sound-level meter when the microphone, which has a capacitance with the attached cable of about 460 $\mu\mu$f, is connected across it. This noise level over the audio range is only about 4 microvolts; but, because of the low microphone sensitivity, the corresponding sound-pressure level is about 73 db. This circuit noise is negligible for levels of 80 db and higher.

Frequency Response

The frequency response of one of these microphones at perpendicular sound incidence was measured at the General Radio Company, and the smoothed result is shown in Figure 6 as the curve labeled "M-141B alone."[3]

The first resonance of this microphone is at 34 kc, well beyond the audio range. The resonant rise in response is large, because it is impractical to dampen this rigid structure to any great extent. But some of this rise in response is a diffraction effect of the sound striking the rigid cylinder. This effect is less important (for parallel incidence), where the response is essentially uniform ("flat") at high frequencies up to 20 kc as shown in Figure 7.

If the advantages of using the microphone with perpendicular incidence are desired, the "C"-weighting network of the TYPE 1551-A Sound-Level Meter can be used; and the resultant response, shown in Figure 6, is essentially uniform to about 30 kc. Such a uniform response is valuable for many measurements. It practically eliminates the need for correcting the data for the effects of variations in frequency response of the microphone. For those measurements where such correction is impossible, a response as uniform as that shown will yield as reliable data as possible. It can also simplify the application of automatic recording systems for obtaining sound-pressure levels as a function of frequency in the testing of loud-speakers and other sound sources. The uniform response to 30 kc indicates that the transient response to blast or shock waves in the audio range will be exceptionally good.

The capacitance of the Massa microphone and its associated cable is not so large as that of the Shure Model 98-98 Microphone regularly supplied with the sound-level meter, and the low-frequency response of the combination is somewhat poorer as a result of this lower capacitance, as shown in Figure 6.

[3]The relative levels shown beyond 15 kc should be regarded as approximate, since they are based on an extrapolated characteristic of a W. E. Type 640-AA Microphone, which had been calibrated at the National Bureau of Standards to 15 kc.

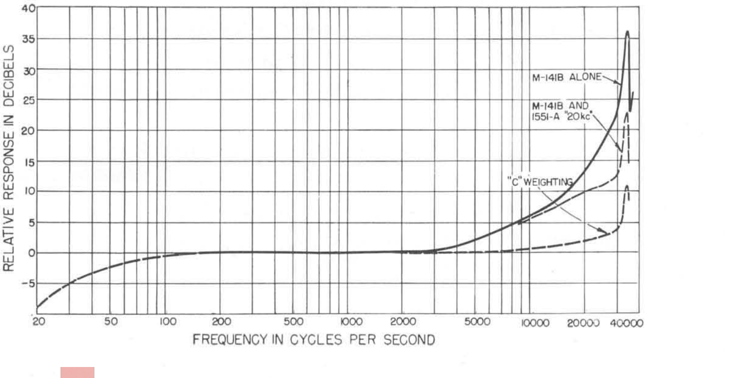


Figure 6. Frequency-response characteristics of the Massa Model M-141B Standard Microphone and Type 1551-A Sound-Level Meter for perpendicular sound incidence.

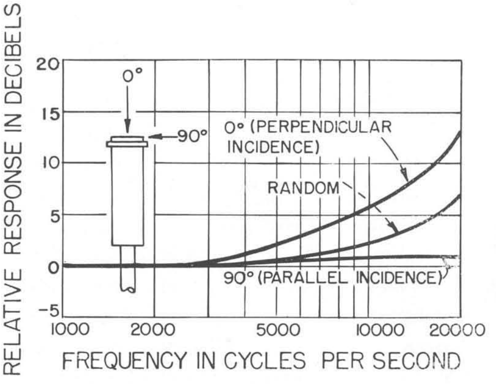


Figure 7. Frequency response characteristics of the Massa Model M-141B Standard Microphone alone.

The maximum safe operating temperature of the Massa M-141B Microphone is about 75° C. (167° F.), a limit set by the cements used in the construction of the microphone. The unit is sufficiently well sealed so that exposure to normal humidity conditions will not affect the operation, but it is recommended that prolonged exposure to relative humidities in excess of 94 per cent be avoided.

SPECIAL PRECAUTIONS

When microphones of low sensitivity, such as the Massa Model M-141B and the Altec Type 21-BR-180, are used, the microphone should be mounted carefully to insure that a correct measurement is being made. In addition, when sounds of high level are being measured, any associated vacuum-tube apparatus should be kept out of the high-level sound field, if possible.

Method of Supporting Microphone

Mechanical vibration of a microphone will produce an output signal. It is necessary, then, to support a microphone so that the signal from existing vibrations is appreciably less than the desired signal from airborne sound. For microphones having high sensitivity to sound, this requirement is usually met even with fairly rigid mounting methods, but low-sensitivity microphones must be mounted carefully. These requirements can often be met by suspending the microphone by its cable, and the cable can be held in place by cords.

One way of detecting vibration errors is to note the effects on the measured levels of different microphone mounting methods.

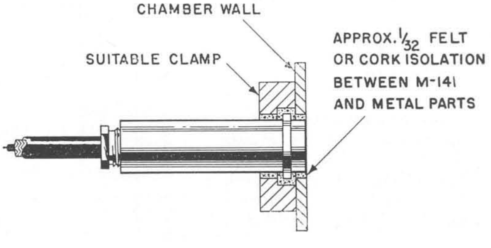
In general, very resilient supports should be used, with a low natural period of vibration, say below 10 cps. Looping the cable before the end support may also improve conditions, since it is particularly important to keep axial vibrations of the microphone to a very low level.

The small flange on the Massa Model M-141B Microphone simplifies the mounting of the microphone in the solid wall of a chamber. But here the isolation of the microphone from the solid-borne vibrations is particularly important, and an assembly such as that shown in Figure 9 is recommended by the Massa Laboratories for such an application.

Microphonics

A vacuum tube exposed to a high-level sound field will vibrate, producing an electrical output, called microphonics, that interferes with the desired signal.

Figure 8. Diagram of recommended installation of the Massa Model M-141B Standard Microphone in the wall of a chamber.



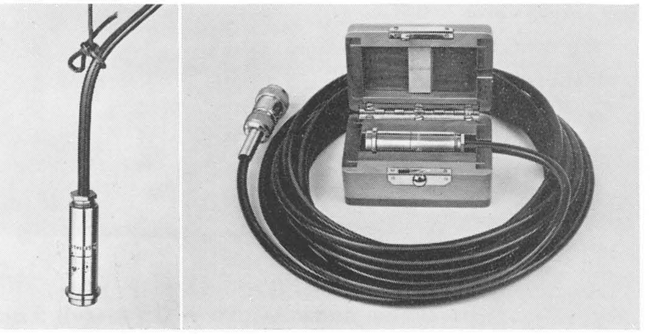


Figure 9. (Left) Microphone suspended by cord to avoid the effect of mechanical vibrations. (Right) View of the Massa M-141B Microphone in its storage box, with 20-foot cable and connector.

With the standard wide-range sound-level meter, the interference is usually unimportant until the sound level is well above 100 db. Microphonic effects can be detected by disconnecting the microphone and by then observing the reading on the instruments when exposed to the sound to be measured. When this test is made, the input terminals of the preamplifier should be shielded to prevent stray electrical pickup.

At high levels, the Type 1551-P11 20-db Pad can be used with the Type 1551-A Sound-Level Meter to reduce the effect of microphonics. This pad shifts the operating signal levels in the instrument so that the sensitive, early stages must operate with a higher signal, and the relative microphonic level is correspondingly lower.

The best solution to the microphonic problem is to keep the instruments using vacuum tubes away from vibrating surfaces and intense sound fields. But, of course, the microphone must be in the field to be measured, so that a cable must connect the microphone and the measuring instruments. The Massa Model M-141B Microphone includes a cable of about 20 feet, but a longer cable may be essential for adequately separating the microphone and the sound-level meter. Then a Type 759-P30 Extension Cable could be used, and 7 db should be added to the indicated level because of the cable capacitance.

When microphonics are troublesome, the most sensitive microphone that will handle the required level will usually give the most favorable signal conditions. But many other factors, for example, frequency response, size, temperature effects, are usually of so great importance that the very sensitive microphones cannot be used. The instruments should then be acoustically isolated from the sound field.

— Arnold Peterson

Note: We are indebted to the Massa Laboratories, Inc., the Altec-Lansing Corporation, and Shure Brothers, Inc., for furnishing much of the information on which this article is based.

For complete descriptions of the instruments mentioned in the foregoing article, see the issues of the *Experimenter* listed below:

Type 1551-A Sound-Level Meter .... March, 1952
Type 1551-P1 Condenser Microphone System .... May, 1953

Condenser Microphone System.

The Type 1551-P1 Condenser Microphone System can be supplied with either the Altec 21-BR-150 microphone for normal levels or the 21-BR-180 for high levels. Prices are as follows:

Type		*Code Word*	*Price*
1551-P1L	**With 21-BR-150 Microphone**	NONAL	**$260.00**
1551-P1H	**With 21-BR-180 Microphone**	NATAL	**275.00**

Type 1551-P11 20-db Pad:

Type		*Code Word*	*Price*
1551-P11	**20-db Pad**	LABEL	**$15.00**

Massa Model M-141B Standard Microphone.

The Massa M-141B Microphone should be ordered directly from the Massa Laboratories, 5 Fottler Road, Hingham, Mass. When ordering, please state the serial number of your TYPE 1551-A Sound-Level Meter and the sensitivity figure marked in the microphone well.

10th NATIONAL ELECTRONICS CONFERENCE

Hotel Sherman, Chicago — October 4, 5 and 6, 1954

The General Radio Company, in Booths 87 and 88, will exhibit a representative group of instruments, including new items recently described in the *Experimenter*. Among these are the Unit Pulser, the Unit I-F Amplifier and U-H-F Detector, the Automatic Line-Voltage Regulator, and the Transistor Oscillator. In addition, a completely new line of potentiometers will be shown for the first time.

General Radio engineers will be on hand to discuss your measurement problems with you.

General Radio deliveries are excellent. Practically everything on display at the Conference or listed in our catalogs can be delivered immediately from stock.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. 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.

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VOLUME XXIX No. 5 OCTOBER, 1954

UNMOUNTED MOTOR SPEED CONTROLS FOR ASSEMBLY INTO OTHER EQUIPMENT

● **TO MEET** a definite customer demand, we have for some time supplied, on special order, "stripped-down" models of our Variac® Motor Speed Controls. These have had such a wide acceptance by manufacturers of motor-powered equipment that they are now made available as standard catalog items and will be carried in stock.

These models include the basic components of the original controls but omit the switches, overload protection, and cabinet. The elements are mounted on a base plate, and all connections are brought out to a terminal strip. The Variac® Autotransformer, which is the speed control element, is included as a separate unit and can be mounted with the starting switch in any convenient location.

Although intended primarily for machine manufacturers, the stripped-down controls are also used frequently to avoid duplicating the auxiliary components in applications where special switching circuits are required. These controls should be considered for possible cost savings whenever special wiring is involved or when a suitable protected location for the basic unit is available, such as in the cabinet of the driven machine.

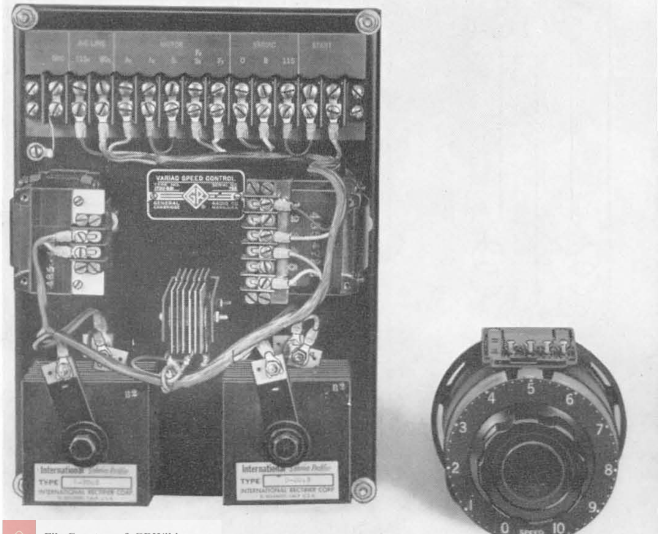


Figure 1. View of the Type 1700-BW Variac Speed Control. Transformers, rectifiers, and choke are assembled to a metal chassis, which can be mounted in the cabinet of the driven machine. Location of the Variac® Autotransformer and the necessary switching can then be dictated by operating convenience.

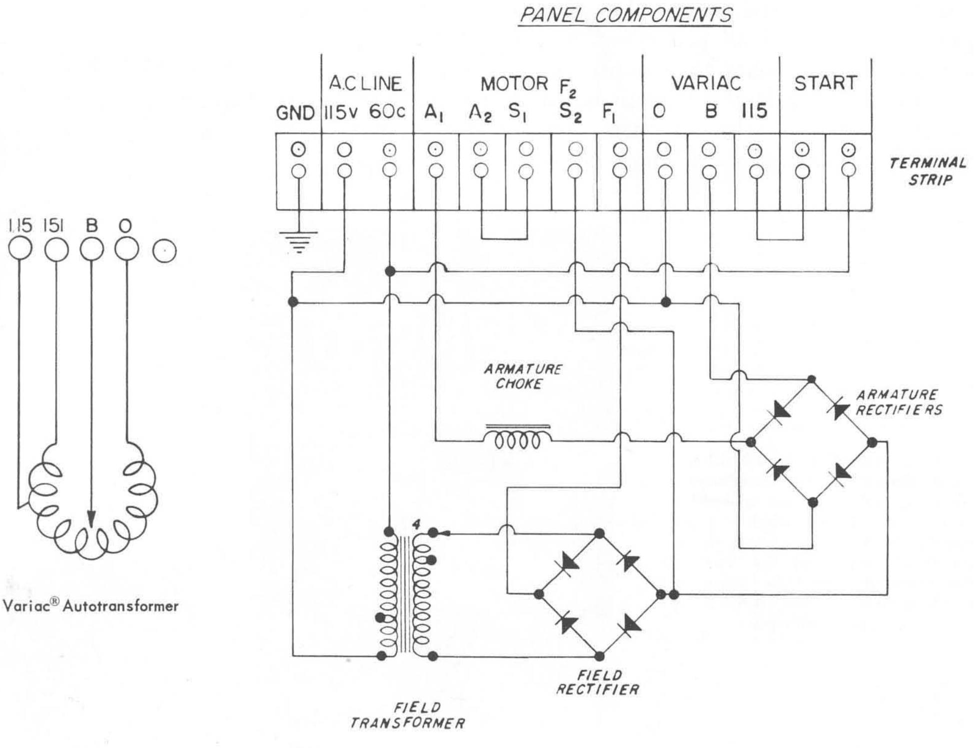
Also
IN THIS ISSUE

Figure 1 shows pictorially, and Figure 2 in schematic form, the components and connections in these basic control assemblies. The model shown is TYPE 1700-BW, with a rating of ⅓ horsepower. All parts are mounted on a metal chassis, with leads brought out to a convenient terminal strip for connection to the external control elements.

Figure 3 shows how connections are made to the terminal strip to perform the functions of starting, stopping, braking, reversing, and overload protection. The start-stop-reverse control may be either a toggle switch or drum-type controller. A magnetic circuit breaker of the relay type can be used instead of the fuses and line switch shown. When only a single direction of rotation is required without dynamic braking, the only auxiliary components needed are the line switch and fuses. Other circuit arrangements with a list of suitable components are given in the Operating Instructions.

Variac Motor Speed Controls are versatile, general-purpose devices for operating d-c shunt or compound motors from a-c power lines. They have constant-torque characteristics, that is, the same maximum torque can be provided at all speed settings. They are suitable for all applications except where speed must be precisely maintained under varying load or where speed must be

Figure 2. Schematic circuit diagram of the stripped-down speed control. All terminals are clearly identified, as shown.



SPECIFICATIONS

TYPE NUMBER		1701 AKW		1701 AUW	1703 AW			1700 BW		1702 AW		1704 AW			1705 AW		
Motor Horsepower Range		1/15 & less		1/15 & less	1/12 to 1/6			1/4 and 1/3		1/2 and 3/4		1			1 1/2		
Power Supply (Single Phase 60 cycles)	Volts	115		115	115			115		115		230			230		
	Full-Load Amperes	1.5		1.5	2.2			5		10		6.5			8.5		
Line-Voltage Limits		105–125		105–125	105–125			105–125		105–125		210–250			210–250		
Input Power—Watts	Full Load	175		175	255			560		1150		1500			1950		
	Standby	None		None	30			50 approx.		65		90			90		
Motor Control Output — DC																	
Armature	Amperes	0.8		0.8	1.5			3		6.5		4.5			6		
	Volts	0–115		0–115	0–115			0–115		0–115		0–230			0–230		
Field	Amperes	0.2		1.25 1.0	0.2			0.4		0.4		0.5			0.5		
	Volts	115	38	10 16	115	66	48	115	75	115	75	230	160	128	230	160	128
Speed Range		0 to rated	0 to 2 rated	0 to rated	0 to rated	0 to 1.25 rated	0 to 1.5 rated	0 to rated	0 to 1.15 rated	0 to rated	0 to 1.15 rated	0 to rated	0 to 1.12 rated	0 to 1.25 rated	0 to rated	0 to 1.12 rated	0 to 1.25 rated
Dynamic Braking		Not included — can be provided by user															
Armature Overload Protection		Not included — to be provided by user															
Control Station		Speed control element (Variac) furnished — Start, stop, reverse, and braking controls to be provided by user															
Over-all Dimensions (inches)	Chassis	6 3/4 × 9 3/8 × 2 3/4*			6 3/4 × 10 × 3			9 × 12 3/8 × 3 3/4		10 1/2 × 15 × 4 5/16		19 11/16 × 11 3/8 × 5 3/8			19 11/16 × 13 1/8 × 5 3/8*		
	Variac	3 1/4 × 3 11/16 × 4 3/8			3 1/4 × 3 11/16 × 4 3/8			4 7/8 × 5 × 5 3/8		6 5/32 × 6 19/32 × 5 1/16		7 7/8 × 9 11/16 × 5 11/16			7 7/8 × 9 11/16 × 5 11/16		
Net Weight (pounds)	Chassis	2 1/2*			3			11 1/2		17 1/2		24			30*		
	Variac	3 1/2			3 1/2			7		11 1/4		21 1/2			21 1/2		
Recommended Motor†		Mod-5		Mod-4	Mod-11			Mod-3		Mod-6		Mod-9			Mod-10		
Code Word					SABOT			SALTY		SATIN		SAVOR			SAXON		
Price††																	
1 to 4 units		$67.00		$67.00	$93.00 ea.			$135.00 ea.		$195.00 ea.		$310.00 ea.			$328.00 ea.		
5 to 19 units		63.50		63.50	83.70 ea.			122.00 ea.		177.50 ea.		295.00 ea.			315.00 ea.		
20 and up units		60.50		60.50	79.00 ea.			116.00 ea.		170.00 ea.		280.00 ea.			300.00 ea.		

*Approximate

†For motor specifications and prices, see *Experimenter* for December, 1953

††All prices are net, f.o.b. factory

adjusted in response to an electrical control voltage rather than by manually turning a control knob. Speed is maintained sufficiently closely for most process work, even under heavy load, provided that the load is reasonably constant.

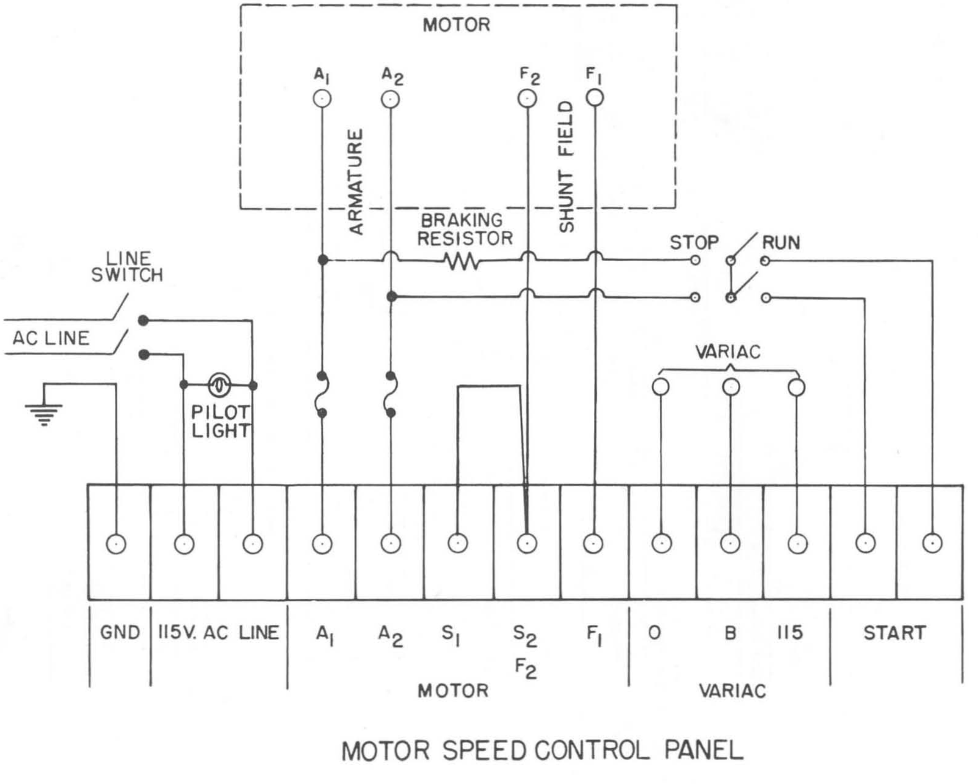
The many advantages of Variac Speed Controls — wide range, smooth adjustment, high starting torque, quick reversing, no torque pulsation, simple installation, and low maintenance — have made them unusually satisfactory in a variety of applications. On lathes and other machine tools, they are used for both spindle and feed drives; on precision grinders, their freedom from torque pulsation gives exceptional finish; they have performed well on winders, rewind and take-up drives of many kinds; their smoothness of adjustment is desirable in machining plastics and in lapping lenses; they have been very successfully used in conveyor drives.

The availability of stripped-down models in all standard ratings will make it possible to provide the superior performance of Variac Speed Controls in a wider field of applications.

SEND FOR BOOKLET

A new booklet, entitled "Performance Characteristics and Engineering Data for Variac Motor Speed Controls," is now available. We shall be glad to mail you a copy upon request.

Figure 3. Wiring diagram for simple switching to perform the basic functions of starting, stopping, reversing, and braking for a shunt motor. Armature overload protection is provided by fuses in the armature leads. Since the motor has no series field, the S_1S_2 terminals are shorted.



CABLE TESTING CONSOLES USE GENERAL RADIO EQUIPMENT

The test consoles described in this article are interesting examples of how the products of several manufacturers can be grouped together for making a specified series of tests. For the information on which this article is based, we are indebted to Mr. E. Mark Wolf, Electrical Engineer of Rome Cable Corporation.

One of the products of the Rome Cable Corporation of Rome, N. Y., is Spiral Four Cable, a four-conductor shielded cable, ⅜ inch in diameter, with polyethylene insulation and with polyvinyl chloride outer sheath. This cable is used by the Signal Corps, U. S. Army, for carrier voice communication and for teletype and facsimile communication. It is furnished to the Signal Corps in standard lengths with watertight connectors attached.

Because this cable is used at carrier frequencies, its capacitance and resistance must be held within narrow limits, and, hence, production tests must be made with laboratory precision. Tests are divided into four parts:

1. Preliminary electrical test.
2. Final electrical test.
3. AC/DC resistance measurement.
4. Connector water seal test.

Special test consoles for making the preliminary and final tests were designed by the Rome Cable Corporation and built for them by the Power Equipment Company of Detroit, Michigan.

Preliminary Electrical Tests

Figure 1 shows the console for preliminary electrical tests. The instruments shown are:

General Radio Type 716-C Capacitance Bridge

General Radio Type 1231-B Amplifier and Null Detector

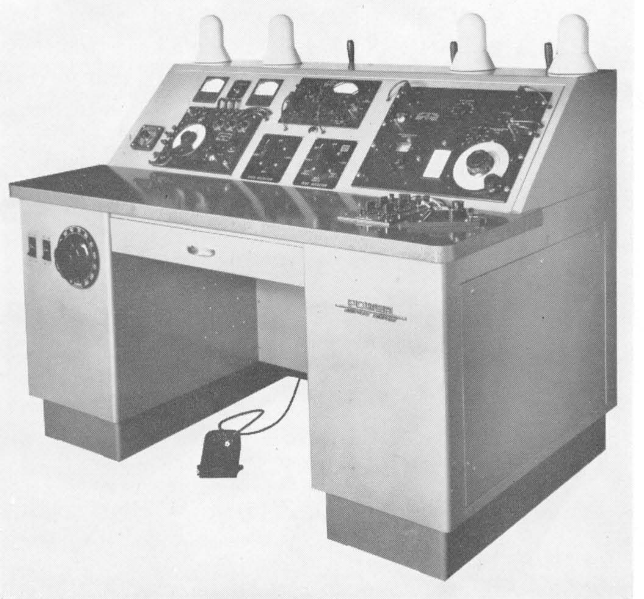


Figure 1. View of the console for preliminary electrical tests. The Type 716-C Capacitance Bridge is at the right, the Type 1231-B Amplifier and Null Detector at the top center of the pouch. At the left part face of the console is the Variac® Autotransformer.

General Radio Type 723-C 1000-cycle Vacuum-Tube Fork

General Radio Type V20M Variac® Autotransformer

Leeds and Northrup Wheatstone bridge and galvanometer

Siemens & Halske Coupling Meter

Peerless 115V to 1500V transformer, meters, timers, switches, indicators, etc.

Seven of these consoles are used at Rome Cable. Tests performed are as follows:

1. *High Voltage* — This test is performed to detect defective cable before the connectors are attached. 1500 volts is applied between all four conductors and shield for 15 seconds. Voltage is adjusted by means of the Variac.

2. *Mutual Capacitance* — Measured on each pair of the cables, using the Type 716-C Capacitance Bridge. The oscillator supplying power to the bridge is the Type 723-C Vacuum-Tube Fork, and the detector is the Type 1231-B Amplifier and Null Detector.

3. *Capacitance Unbalance* — Side-to-side and side-to-ground capacitance unbalance is measured with the Siemens & Halske Coupling Meter and the General Radio oscillator and null detector, as used in (2) above.

4. *D-C Copper Resistance* — Measured for each pair with the Leeds and Northrup bridge and galvanometer.

Final Electrical Tests

The console for these tests is shown in Figure 2. The instruments used are:

General Radio Variac Autotransformer and Peerless transformer, as in the preliminary test console.

General Radio Type 1861-A Megohmmeter

Leeds and Northrup Wheatstone bridge and galvanometer

Switching, meters, indicators, etc.

Five individual consoles are used.

Tests performed are as follows:

1. *High Voltage*—1500 volts ac for one minute, applied between each conductor in turn and the remaining three conductors and shield, all grounded. Test voltage is supplied by the Peerless transformer and adjusted by means of the Variac.

2. *Insulation Resistance* between each conductor in turn and the three remain-

Figure 2. View of the console for final electrical tests. The General Radio Megohmmeter is at the right of the panel, and the Variac at the front face of the left-hand pedestal.

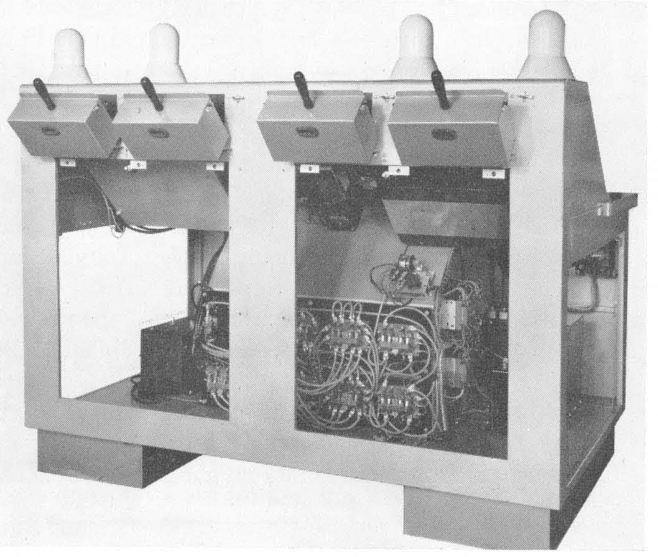


Figure 3. Rear view of the preliminary-electrical-test console, showing switching, relays, wiring, and details of construction.

ing conductors and shield, all grounded; measured with the General Radio Type 1861-A Megohmmeters.

3. *D-C Copper Resistance* of each pair is measured with the Leeds and Northrup bridge and galvanometer.

4. *Braid Continuity*, and

5. *Conductor Continuity* — These tests are made by completing an electrical circuit with the cable assembly in series with an indicating lamp and power source.

These test consoles have been in use for nearly three years and have been completely satisfactory. Other cable companies, with the permission of Rome Cable, have had similar units built for their use in testing the same type of cable.

In addition to the tests made at the consoles, two other measurements involve the use of General Radio instruments, the AC/DC Resistance Measurement and the Connector Water Seal Test.

The ratio of a-c resistance at 60 kc to the d-c resistance of the cable is measured with a 60-kc Network Manufacturing Co. Impedance Bridge, in which a number of General Radio components are used. The power source is a General Radio Type 1302-A Oscillator, and the detector a General Radio Type 1231-B Amplifier and Null Detector with a Type 1231-P5 Filter.

The Connector Water Seal Test checks the ability of mated or capped connectors to be immersed in water without a decrease in insulation resistance greater than that specified. Measurements are made before and after immersion, using a portable General Radio Type 1862-A Megohmmeter.

MISCELLANY

VISITORS: We have welcomed recently at our Cambridge plant the following visitors from foreign countries: G. R. Lawrance, Equipment Engineer, Standard Telephones & Cables, Ltd., Newport, England; Jean Brune, Chief Research Engineer, Lignes Telegraphiques et Telephoniques of Conflans, Ste. Honorine, France; Peter J. A. Goebels, Vocational Specialist, National Economic Ministry, Germany; Dr. Erwin K. H. Krause, Director, Institute for Vocational Education, Bonn, Germany; Prof. Erik Hallen, L'Ecole Royale Superieure Polytechnique, Stockholm, Sweden; Dr. Tino Gaumann, Organic Chemical Institute, Swiss Technical High School, Zurich, Switzerland; Nagatoshi Azuma, Chief, Design Section, Hitachi, Ltd., Yokohama, Japan; Yoshinohu Imamura, Engineer, Hitachi, Ltd., Yokohama, Japan; I. Kimura, Iida & Co., Tokyo, Japan; Dr. Yoji Ito, Koden Electronics Co., Ltd., Tokyo, Japan; Isokazu Tanaka, Director, Koden Electronics Co., Ltd., Tokyo, Japan; Ki Kato, Daisuke Kawata, Toku Uchida, Shigeki Yamato, Heijiro Yomezawa, Nippon Electric Co., Tokyo, Japan; S. Katsurai, Nippon Kikai Boeki Kaisha, Chuo-ku, Tokyo, Japan; Naokiti Tamaru, Manager, Shibaura Plant, Oki Electric Industry Co., Minato-Ku, Tokyo, Japan; Shuichiro Oka, Deputy Manager, Radio Engineering Dept., Tokyo Shibaura Electric Co., Ltd., Kawasaki, Japan.

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the GENERAL RADIO Experimenter

Since 1915 – Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 6 NOVEMBER, 1954

MOTOR DRIVES FOR PRECISION DIALS AND BEAT-FREQUENCY OSCILLATORS

● **GENERAL RADIO** beat-frequency oscillators, as well as a number of other General Radio instruments developed in the past few years, use as frequency controls the TYPE 908 or TYPE 907 Gear-Drive Precision Dials. These dials are so designed that a motor drive can be easily attached in place of the knob.

Shown in Figure 1 is a simple, low-cost motor drive unit for use on the dials. Available in two models with different speeds, the TYPE 908-P1 and TYPE 908-P2 Dial Drives have been designed particularly for use on the TYPES 1304-A and 1304-B Beat-Frequency Audio Generators and the TYPE 1303-A Two-Signal Audio Generator, but they can also be used on General Radio Unit Oscillators and Standard-Signal Generators, as well as on other instruments equipped with the TYPE 908 or TYPE 907 Gear-Drive Precision Dials.

The motor drives make possible the use of these instruments with recording systems as, for example, in recording the response of a network as a function of frequency. They can also be used as sweep drives and for producing warble

Figure 1. View of the Type 908-P2 Synchronous Dial Drive installed on a Type 1304-B Beat-Frequency Oscillator. The adjustable stops, which attach to the oscillator dial, are not shown.

tones. When installed on a TYPE 1304 Beat-Frequency Audio Generator, as shown in Figure 1, this type of drive can sweep the oscillator automatically back and forth over a range of frequencies. This technique has applications in many kinds of measurements. For example, with a cathode-ray oscillograph as a visual indicator, the study and adjustment of audio-frequency networks is accomplished rapidly and conveniently. Another example, in the field of mechanics, rather than electronics, occurs in vibration testing. When the beat-frequency oscillator is used to drive a shake table, the automatic sweep is helpful in spotting resonances.

The dial drive consists essentially of a small, synchronous, 115-volt, 60-cycle motor with a pinion gear on the output shaft. This motor drive is readily fastened in place of the knob drive of the precision dial so that the pinion gear on the motor shaft engages the dial ring gear.

A disengage lever, as well as a power switch, is provided. The lever can be used to lift the pinion off the ring gear and thus disengage the drive.

The drives reverse the direction of rotation whenever a stop is encountered. It is this feature that makes possible their use as sweep drives and their use to produce warble tones. Stops, which are provided, can be readily attached to the dial to limit the sweep to the desired part of the range.

With these adjustable stops the maximum angle of dial rotation is limited to 80° for the TYPE 908 Dial and 65° for the TYPE 907 Dial. The full range of dial rotation can be obtained when these stops are not used. Other types of stops to give intermediate angles of rotation can be devised by the user.

USE WITH RECORDERS

Because the drives are synchronous, they are readily used with recording systems. For example, the response of a network as a function of frequency can often be recorded very easily by applying to the network the output of a TYPE 1304-B Beat-Frequency Generator driven by a TYPE 908-P1 Dial Drive. The output of the network is then recorded as a function of time. Since the oscillator frequency and time are di-

Figure 2. Simple discriminator circuit for supplying the horizontal axis signal to a cathode-ray oscillograph.

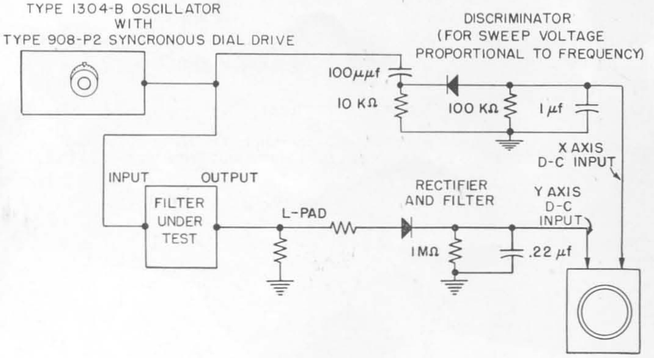
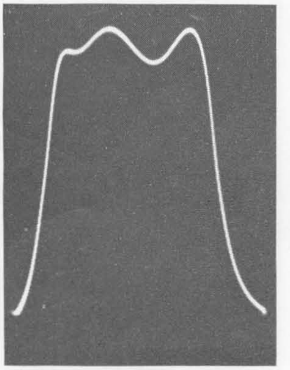


Figure 3. Oscillogram of the response characteristic of a filter as displayed by means of the arrangement of Figure 2.



rectly related by the dial drive, the response as a function of frequency is readily obtained. To facilitate the use of recorders in such applications, the speed of TYPE 908-P1 Drive has been selected to cover in 15 seconds a frequency interval of an octave on the TYPE 1304-B Generator. This rate is widely accepted as a standard. The TYPE 908-P2 Drive is particularly suitable for limited-sweep applications, with observations of the response on a cathode-ray oscillograph with a long persistence-screen. As a natural consequence of the higher speed, however, the torque available from the TYPE 908-P2 is small. Therefore, in order to avoid erratic operation, the driven part should generally use ball-bearing supports, as in the TYPES 1304-A, 1304-B, and 1303-A Oscillators.

For some recording applications, an output voltage is desired that is proportional to the angle of rotation of the dial. To do this, a linear potentiometer having low torque requirements can also be driven by the shaft on which the dial is mounted. Naturally, this arrangement is usable only if the complete system can be arranged so that the required torque does not exceed the torque that can be delivered by the drive. The linear potentiometer can then be energized by a constant d-c voltage, and the voltage between the tap and one end will be proportional to the dial rotation.

When a limited sweep is used to vary the frequency of an oscillator, a discriminator system can often be used to give a signal proportional to the instantaneous frequency. The output of the discriminator can then supply the voltage for one axis of an oscillographic display, for example. The circuit of a very simple type of discriminator, suitable for use with the TYPE 1304-B Generator, is shown in Figure 2. The output of this discriminator is used to supply the X-axis signal of a cathode-ray oscillograph having a d-c amplifier and a long persistence-screen.

The oscillogram of Figure 3 shows the response characteristic of a filter as displayed on an oscillograph screen by means of the arrangement of Figure 2.

In experimental work on audio-frequency circuits, sweep methods will save much valuable engineering time as compared to point-by-point methods. The availability of this economical motor drive for General Radio beat-frequency generators makes possible the application of sweep methods to existing laboratory equipment.

—H. C. LITTLEJOHN

SPECIFICATIONS

Speed:*

Type	*Pinion*	*908 Dial*	*907 Dial*
908-P1	4 RPM	4/15 RPM or 225 secs/rev	4/10 RPM or 150 secs/rev
908-P2	30 RPM	2 RPM or 30 secs/rev	3 RPM or 20 secs/rev

On logarithmic frequency dials used on TYPES 1304-A, 1303-A Oscillators, the sweep times are as follows:

908-P1 50 sec/frequency decade or 15 sec/octave
908-P2 6⅔ sec/frequency decade or 2 sec/octave

Pinion on Output Shaft: 48 D.P., full involute, 20° pressure angle, 10 teeth.

Torque at Pinion: 908-P1 5 inch-ounces
908-P2 ⅔ inch-ounce

Power Supply: 105 to 125 volts, 50-60 cycles, 3 watts.

Dimensions: 3⅝-inch diameter x 3 inches deep, overall, but excluding power line connecting cord.

Weight: 1 pound, 3 ounces.

*Data are for 60-cycle operation. On 50 cycles, speeds will be 5/6 of those given above and drive times will be 6/5 of those listed.

Type		*Code Word*	*Price*
908-P1	**Synchronous Dial Drive**	SYNDO	**$27.50**
908-P2	**Synchronous Dial Drive**	SYNKA	**27.50**

HISTORIC FIRSTS—THE R-C OSCILLATOR

The development of the resistance-capacitance-coupled oscillator in 1937 by the General Radio Company filled a recognized need in the industry. Although lacking some of the advantages[1] of the beat-frequency oscillator, it is capable of generating low frequencies with good stability and of covering wide frequency ranges with simpler switching and with less expensive and less bulky components than the L-C type.

The basic oscillator circuit, which combines a sharply selective R-C circuit with a degenerative, or inverse-feedback, amplifier, was first described in an article submitted to the Institute of Radio Engineers in 1937 and published in the *Proceedings* in 1938.[2] A patent application on the oscillator form of this circuit was filed in August, 1937, and U. S. Patent No. 2,193,427 was issued in September, 1939, and assigned to the General Radio Company. Practically all commercial R-C oscillators now on the market use this basic circuit. The General Radio Company today manufactures several R-C oscillators using the circuits described in this patent and also licenses other manufacturers to do so.

The instrument shown below is the first R-C type produced commercially and was used principally as an audio source for distortion measurements on equipment in broadcasting stations. It was first placed on the market in 1938. It has been superseded by improved models, two modern units being the TYPE 1301-A Low-Distortion Oscillator and the TYPE 1302-A Oscillator.

[1]"Oscillator Considerations," *General Radio Experimenter*, Vol. XXVIII, No. 6, November, 1953.
[2]H. H. Scott (Engineer, General Radio Company), "A New Type of Selective Circuit and Some Applications," *Proc. IRE*, Vol. 26, No. 2, February, 1938, pp. 226-235.

The first commercial R-C Oscillator — General Radio Type 608-A.

THREE-PHASE OPERATION OF AUTOMATIC VOLTAGE REGULATORS

Since publication of the article describing the new General Radio Automatic Voltage Regulator,[1] several readers have inquired about the possibility of using these regulators on three-phase circuits. Several connections are possible which will maintain the three output voltages to a ¼ per cent of the desired

[1]M. C. Holtje, "An Accurate, High-Speed, Automatic Line-Voltage Regulator," *General Radio Experimenter*, Vol. XXIX, No. 2, July, 1954.

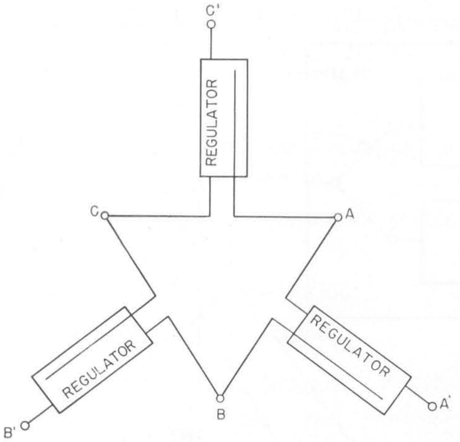


Figure 1. Circuit arrangement of three Type 1570-A Automatic Voltage Regulators for delta operation.

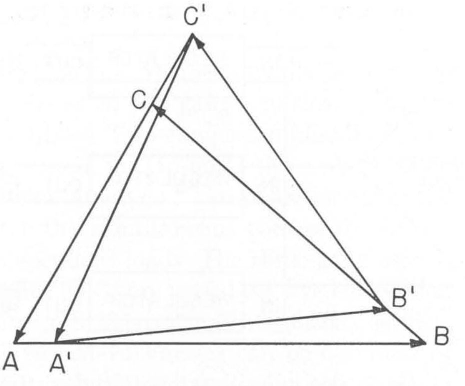


Figure 2. Vector diagram for the system of Figure 1. The unbalanced voltages AB, BC, and CA are the input voltages of the three regulators. The regulator outputs are in phase with their inputs and must lie along the lines AB, BC, and CA. The correction voltages being added are AA′, BB′, and CC′. These output voltages are A′B, B′C, and C′A. If the sensing circuits of the regulators are moved from their normal positions, A′B, B′C, and C′A, to the positions A′B′, B′C′, and C′A,′ these latter voltages will be held constant. Since they are delta-connected, the angles must also be equal.

value. In addition, for some connections the phase angles can be maintained accurately at 120 degrees.

If the voltages to be regulated are in a three-wire delta connection, a regulator can be connected as shown in Figure 1 to maintain each line-to-line voltage constant. In this connection, both the magnitudes and phase angles are held constant. Thus, the regulators can supply balanced voltages, even if both input line and load are unbalanced.

The vector diagram (Figure 2) shows how three regulators, acting as transformers with automatically adjustable turns ratios, can correct both the magnitudes and phase angles to give a balanced output from an unbalanced input. The unbalanced delta input voltages are shown as the vectors AB, BC, and CA. Since each regulator output must be in phase with its input voltage, the correction voltages must be along the vectors AB, BC, and CA. These correction voltages are shown as the vectors AA′, BB′, and CC′. Thus the output voltages from the regulators are A′B, B′C, and C′A. Normally, the regulators would maintain these voltages constant. However, by a change in the connections to the sensing circuits, the regulators can be made to maintain the voltages A′B′, B′C′, and C′A′ constant. This results in a delta-connected output with equal voltage magnitudes and equal phase angles.

If the voltages to be regulated are in a four-wire wye connection, a regulator can be connected between each input line and neutral, thus maintaining each line to neutral voltage constant. Since the regulator is in effect an adjustable turns ratio between input and output, only the magnitude of the voltages can be corrected. Thus the system is regulated as far as a wye-connected load is concerned but is not necessarily regulated for a delta-connected load. If the input voltage angles are incorrect, the output angles will also be incorrect, and the line-to-line voltages will not be regulated.

If it is necessary to use the regulators wye-connected and to maintain correct

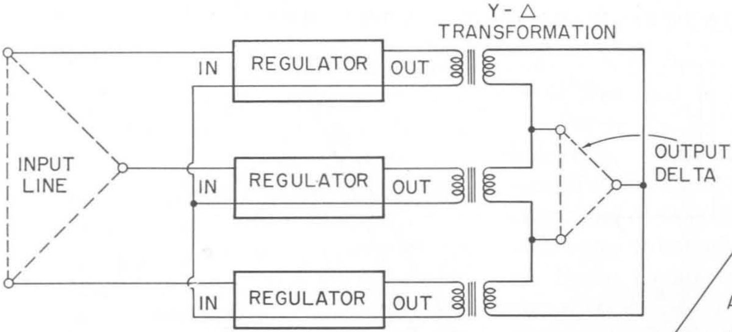


Figure 3. Circuit for wye-connected regulators with transformer for wye-delta transformation.

phase angles as well as magnitudes, the connection shown in Figure 3 can be used. The common connection of the three regulators is not connected to the input neutral but is left floating. The three regulators produce a wye system of equal voltages. The wye-delta transformation produces a completely-balanced delta system with the floating neutral in the regulator input shifting to such a position that only a small circulating current flows in the output delta. The operation of the system can be demonstrated by the vector diagram of Figure 4.

—M. C. Holtje

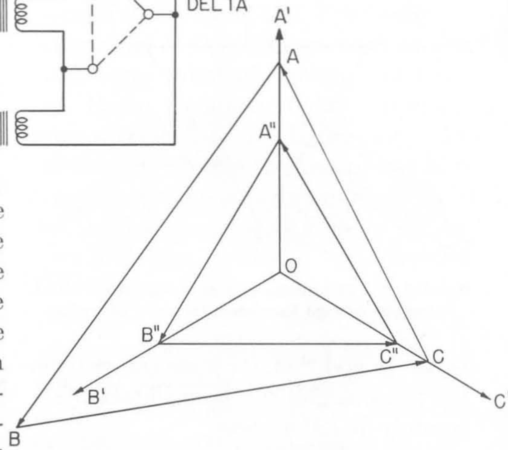


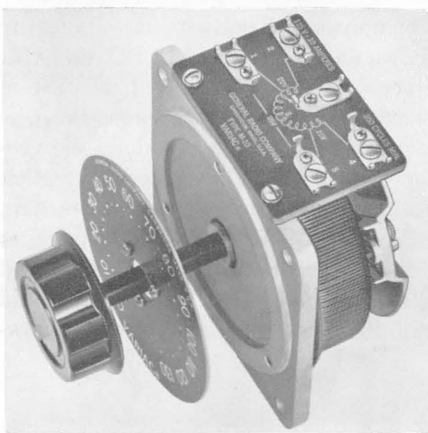
Figure 4. Vector diagram for the three-phase regulator system of Figure 3. The vectors AB, BC, and CA represent a delta line of unequal voltage magnitudes and phases. The wye-connected regulators produce the three equal voltages OA′, OB′, and OC′. The wye-delta transformation, however, resulting in the delta voltages A″B″, B″C″, and C″A″, will produce circulating currents in the transformer secondary if any unbalance exists and, as a result, the floating neutral changes its position to produce balanced phases and minimize circulating currents.

THE TYPE M-10
A 10-AMPERE VARIAC® AUTOTRANSFORMER FOR 350- TO 1200-CYCLE SERVICE

The mechanical and electrical features of Type M-2 and Type M-5 Variac® Autotransformers[1] are now available in a 10-ampere model, the Type M-10 Variac, which will operate on any supply frequency between 350 and 1200 cycles per second.

Among its features are:

(1) Rectangular base for convenient in-



[1]Gilbert Smiley, "New Variac® Autotransformers for 350- to 1200-cycle Service," *General Radio Experimenter*, Vol. XXIV, No. 2, July, 1954.

stallation, with two sets of mounting holes to facilitate its use as a replacement in existing equipment as well as in new designs.

(2) Simplified ganging, with economy in weight and space.

(3) Counterbalanced radiator for stable settings.

(4) Improved heat dissipation.

(5) *Duratrak* contact surface.

The TYPE M-10 is designed to withstand shock, vibration, and environmental tests under MIL-T-945-A specifications.

This new Variac is available in single units or in two-gang and three-gang assemblies. Two-gang assemblies (G-2) can be used in 115-volt, three-phase open delta circuits, in two-phase circuits, and for the simultaneous control of two independent loads. The three-gang assemblies (G-3) are useful for wye connection in 208-230-volt, three-phase service. TYPE M-10 Variacs can be operated at 60 cycles if voltage is limited to 3/8 of rated line voltage.

SPECIFICATIONS

Line-Frequency: 350 to 1200 cps.

Input Voltage: 115 volts, nominal.

Output Voltage: 0 to 135 volts or 0 to 115 volts.

Rated Output Current (for line-voltage connection only): 15 amperes.

No-load Loss at 400 cycles: 12 watts, maximum.

Net Weight: 6 5/8 pounds.

Dimensions: Base 5 3/4 x 5 3/4 inches; depth behind panel, 3 1/16 inches. A dimension drawing is available on request.

Type		*Code Word*	*Price*
M-10	**Variac**	CABIN	**$30.00**
M-10G2	**2-Gang Type M-10 Variac Assembly**	CABINGANDY	**65.00**
M-10G3	**3-Gang Type M-10 Variac Assembly**	CABINGANTY	**98.00**

Patent applied for.

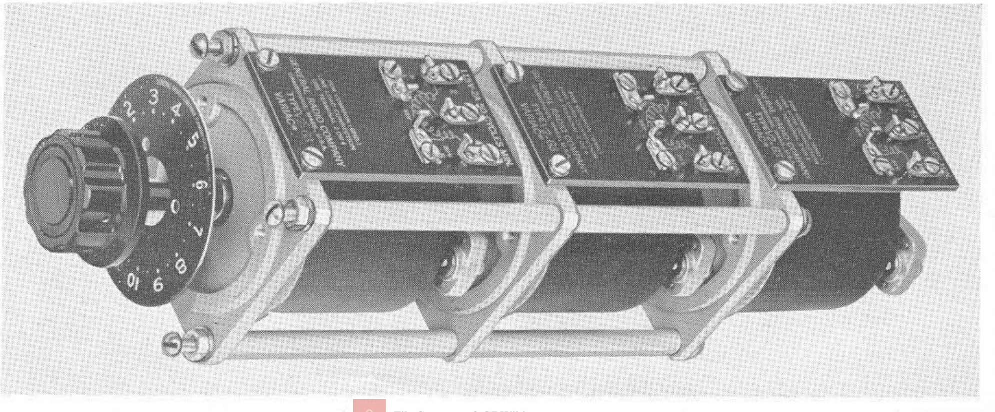
GANGED MODELS OF THE TYPE V-2 VARIAC® NOW AVAILABLE

The TYPE V-2 Variac,[1] which delivers a rated current of two amperes and is designed for 60-cycle service, is now available in two-gang and three-gang assemblies for simultaneous control of separate circuits and for three-phase operation.

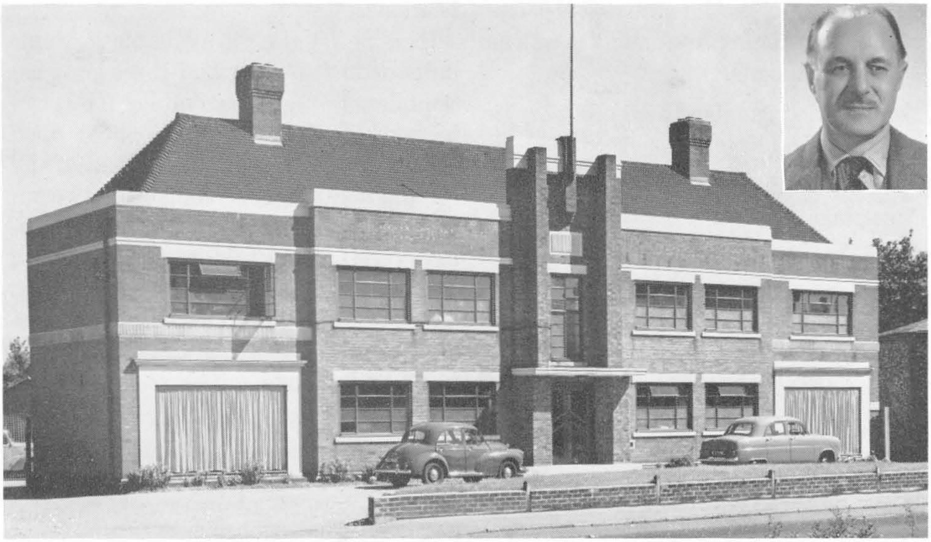
[1]Gilbert Smiley, "A New 2-Ampere Variac," *General Radio Experimenter*, Vol. XXVII, No. 12, May, 1953.

Type		*Code Word*	*Price*
V-2G2	**2-Gang Type V-2 Variac Assembly**	BEADYGANTY	**$35.00**
V-2G3	**3-Gang Type V-2 Variac Assembly**	BEADYGANDU	**52.50**

Patent applied for.



MISCELLANY



The firm of Claude Lyons, Ltd., with office, warehousing, and laboratory facilities in Liverpool, and general sales offices in London, has represented General Radio in Great Britain since 1925. The Liverpool facilities, under the direction of Mr. Alfred Kneen, are spacious and well equipped, but the London offices have not been really adequate for a number of years to handle a steadily growing business. After a long search the firm has been fortunate to find an attractive, new location west of London in Hoddesdon. Here are new calibration and testing laboratories, as well as sales, repair, and stocking facilities. Managing Director of the Lyons firm is Mr. Claude L. Lyons (see insert). The new address is Valley Works, Ware Road, Hoddesdon, Herts, England.

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Since 1915 – Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 7 DECEMBER, 1954

IMPROVED SLOTTED LINE INCREASES ACCURACY AND CONVENIENCE OF COAXIAL LINE MEASUREMENTS

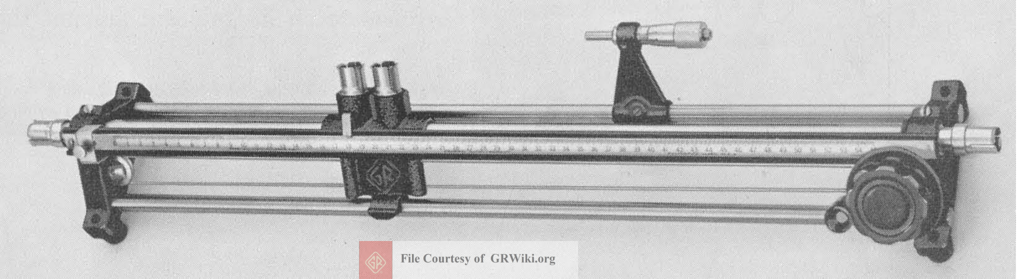
● **THE GENERAL RADIO** TYPE 874 Coaxial Connector has gained rapid acceptance as an outstandingly useful connector for measurement applications. Its universal nature, which permits any connector to plug into any other, simplifies setups, and fosters accuracy by eliminating the plug-to-plug and jack-to-jack adaptors that are so often necessary when plug-and-jack-type connectors are used. In addition, its quick-connect-and-disconnect feature has been found to be an important time saver in many applications.

Around this connector has been built an extensive line of coaxial components and instruments, which, because of their flexibility, accuracy, and economy, have been widely accepted in laboratories, on the production line, and in the field, for measurement work at frequencies from dc to 5000 megacycles.

One of the basic measuring devices used in measurements on coaxial-line circuits is the slotted line. With it the standing-wave pattern on a coaxial line can be measured, and standing-wave ratio, impedance, loss, and many other quantities can be determined. One of the most important General Radio coaxial devices is the TYPE 874-LB Slotted Line, which has been a popular commercial instrument for many years. A new version of this slotted line, the TYPE 874-LBA, has now been developed, which has higher accuracy and greater operating convenience than its predecessor.

The new instrument has an improved mechanism for driving the electrostatic pickup probe, a more constant probe coupling along the line, a sturdier supporting structure, negligible backlash, felt lubricating and cleaning washers, im-

Figure 1. View of the Type 874-LBA Slotted Line with Type 874-LV Micrometer Vernier.



proved center conductor and probe support, adaptability to motor drive, and many other mechanical and electrical improvements.

The new slotted line has a nominal frequency range from 300 to 5000 Mc, but measurements can be made at frequencies as low as 150 Mc and above 5000 Mc with some sacrifice in accuracy. The constancy of coupling of the pickup probe along its entire 50 cm of travel is within $\pm 1\frac{1}{2}\%$, and the residual voltage standing-wave ratio of the line and connectors is less than 1.025 at 1000 Mc and less than 1.07 at 4000 Mc.

Probe Carriage Drive

In order to minimize the distortion of the line and the changes in effective probe coupling resulting from forces applied to the knob that drives the probe carriage, the driving knob is mounted in a fixed position on the right-hand end casting as shown in Figure 1, and the carriage is driven by means of a nylon cord. The cord forms a complete loop, which is attached to the carriage at one point, and which passes over an idler pulley on one end of the line and around a drum attached to the knob shaft on the other, as shown in Figure 2. The connection between the cord and the driving drum is obtained by means of friction, and one and a half turns of the cord around the drum have been found sufficient for positive drive without slippage. Since there are no teeth or grooves involved in the drive mechanism, a very smooth adjustment is obtained. Ball bearings are used on the drum and pulley to reduce the driving force required and to minimize wear. A small ratchet-type take-up reel is mounted on the back of the carriage to permit adjustment of the tension in the nylon cord.

The fixed position of the driving knob, the use of ball bearings throughout, and the durability of the nylon cord make the line easily adapted to motor drive. A motor-drive attachment will be available in the near future.

Probe Carriage Construction

The probe carriage has several important features. It is made of cast bronze and hence slides on bronze bearings on the finely ground, chrome-plated surface of the outer conductor. Play in the carriage, which can cause rocking and consequent changes in probe coupling when the direction of travel is reversed, is eliminated by the use of two adjustable, spring-loaded nylon plugs, which bear against the bottom of the outer conductor of the line at each end of the carriage. A felt washer is mounted at each end of the carriage to prevent dirt and other foreign material, which may collect on the open surface of the outer conductor, from entering the bearing. Oil holes are provided to permit these washers to be filled with oil which provides long-lasting lubrication of the bearings in the sliding carriage. A long Teflon bushing is used to support the probe and reduces to an insignificant amount the

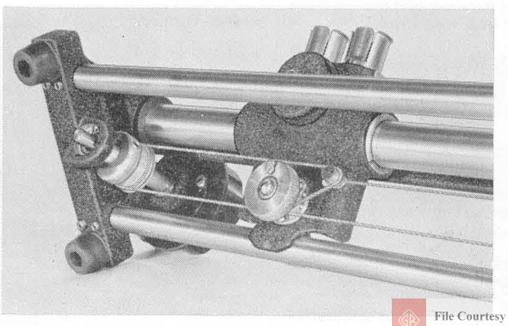


Figure 2: View of the drive mechanism showing the driving drum, ratchet take-up mechanism and nylon cord.

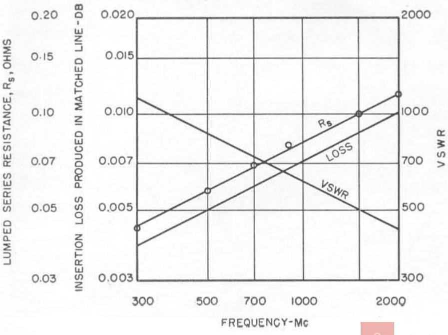
transmission of motion from the tuning stub to the probe.

Line Construction

The outer conductor of the line itself is rigidly clamped in heavy bronze castings at both ends and the structure is stiffened by means of two half-inch stainless rods, so that distortion of the conductor as a result of mechanical forces is very small. Two insulators at each end of the line support the center conductor in order to minimize the transmission of forces from the elements connected to the line, which might tend to deflect the center conductor. The supporting insulators are not located in the slotted section of the line and hence do not cause irregularities in the probe coupling. They are also electrically compensated to minimize reflections. The center conductor is made of steel tubing for rigidity, with heavy copper and silver platings applied for low electrical losses. The section in the slotted region is connected to the sections containing the supports by means of ball joints in order to reduce still further the transmission of deflecting forces.

The end castings are provided with holes which extend through the rubber feet to permit mounting the line permanently to a bench or board, if desired.

Figure 4. Plot of the effective lumped series resistance at the connector measured on a typical Type 874-LBA Slotted Line. The insertion-loss produced in a matched line by the measured value of lumped resistance is also indicated, as well as the VSWR which would be produced by the measured lumped resistance located at a current maximum in an open- or short-circuited 50-ohm line that has no other losses.



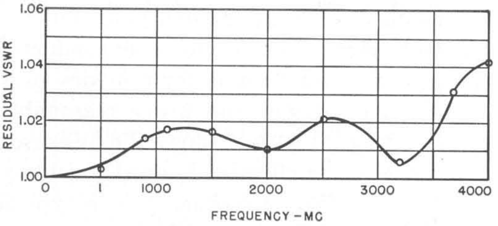


Figure 3. Residual VSWR of a typical slotted line and associated Type 874 Connectors, as measured by the sliding short-circuit method.

Performance

The high degree of constancy of probe coupling over the entire 50-cm length of probe travel is achieved by accurate straightening of the inner and outer conductors. Both conductors are straightened to within ±.001 inch. A further reduction in the variation in probe coupling is obtained by rotation of the center conductor after assembly until the highest degree of constancy is obtained. The resultant variation in probe coupling is always less than ±1½%.

The Type 874 Connector on the line provides a smooth transition between the line and the circuit under test. Figure 3 shows the results of measurements, made by the sliding-short-circuit method, of the residual VSWR of the line and the associated Type 874 Connector. Low-reflection adaptors are available to practically any commonly used 50-ohm connector series, including the large rigid lines which are used in television and radar transmission circuits. (See the list at end of article.)

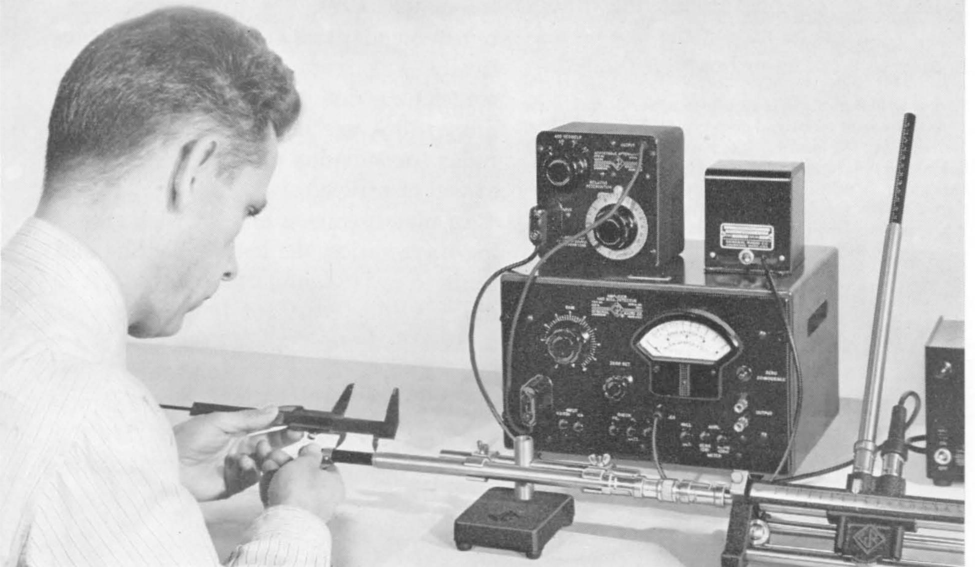
In measurements of very high standing-wave ratios, the loss in the line and connectors is of importance. Since it is difficult to correct for line losses that are not uniformly distributed, it is an advantage to have the losses both low and as uniformly distributed as possible. In the Type 874-LBA Slotted Line, some lumped loss is present at the connector and at the ball joint, but the large physical size of the inner conductor in the line and connector provides large contact surfaces and hence reasonably low losses. Figure 4 shows the measured value of the effective lumped resistance as a function of frequency in a typical TYPE 874-LBA Slotted Line.

Applications

The economy, size, and performance of the TYPE 874-LBA Slotted Line and the availability of numerous low-reflection adaptors and coaxial components make the line well suited to a wide variety of measurements in the laboratory, on the production line, and in the field. Measurements on dielectric materials, lumped components, coaxial elements and networks, and antennas in the u-h-f range can be made accurately and simply with this slotted line and its associated components.

One application is the measurement of the VSWR of adaptors such as the TYPE 874-QNP and -QNJ Adaptors to TYPE N Connectors. One method of making this measurement is to connect two adaptors back to back and to insert them between the end of the slotted line and a TYPE 874-D20 Adjustable Stub as shown in Figure 5. The VSWR of the pair of connectors is then measured by the sliding-short-circuit method. In this method, the stub is set to several accurately measured positions over a distance of at least a half wavelength, and the position of a voltage minimum on the slotted line is accurately determined for each stub setting. If a discontinuity is present, the linear distance between the stub and the voltage minimum on the slotted line will change with the position of the standing-wave pattern. For instance, if the discontinuity is a series inductance, the length of the line section will be decreased the maximum amount when a current maximum occurs at the series inductance. When a current minimum occurs at the series inductance, the line length is unaffected by the presence of the inductance. Hence, as the position of the short circuit in the stub is changed to move the standing-wave pattern

Figure 5. View of the slotted line and associated equipment set up for measuring VSWR of a pair of UG-type adaptors. The detector is a Type 1231-B Amplifier and Null Detector.



along the line under test, the apparent length of the line will change, and the distance between the position of the short circuit in the stub and the voltage minimum on the slotted line will vary. The maximum variation, Δ, is related to the VSWR introduced by the section of line under test by the approximation

$$VSWR \approx 1 + \frac{2\pi\Delta}{\lambda}.$$

The approximation is valid when the VSWR is small.

The actual distance between the short circuit and the voltage minimum need not be measured because the variation in length can be determined from the relative motion of the stub and probe. The change in stub position must be accurately set, and a pair of calipers or gauge blocks can be used for this purpose. The probe position can be determined with sufficient accuracy by use of the scale on the slotted line. Figure 6 shows the results of typical measurements on UG-type adaptors.

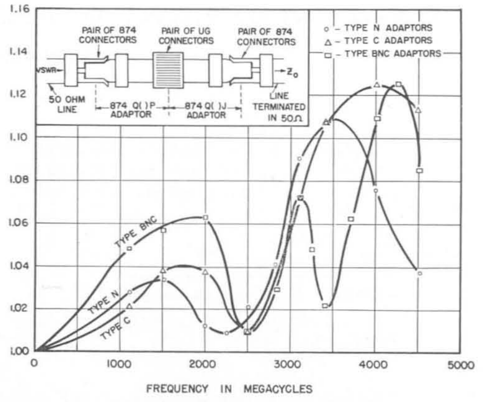


Figure 6. VSWR as a function of frequency for typical adaptors. Measurements were made on pairs of adaptor units, as shown in the sketch, and, hence, the standing-wave ratios shown are the totals produced by two pairs of Type 874 Connectors plus a pair of UG-type (i.e., N, C, or BNC) connectors.

The Type 874-LBA Slotted Line, in conjunction with the wide variety of oscillators, coaxial elements, and detectors produced by the General Radio Company, makes possible simple, accurate measurements of impedance, standing-wave ratio, attenuation, and many other quantities with relatively inexpensive equipment. The continual improvements of existing components and instruments and the development of new devices to expand the usefulness of the Type 874 Coaxial Elements will continue to broaden the applicability of this versatile line.

— R. A. Soderman

SPECIFICATIONS

Characteristic Impedance: 50 ohms ±1%.

Probe Travel: 50 centimeters; scale is calibrated in millimeters.

Frequency Range: 300 to 5000 megacycles. Operation at frequencies below 300 Mc is possible, if lengths of Type 874-L30 Air Line are added.

Dielectric: Air.

Accuracy: Constancy of Probe Penetration — ±1½%. VSWR of Terminal Connectors:
Less than 1.025 at 1000 Mc.
Less than 1.07 at 4000 Mc.

Crystal Rectifier: 1N21B-type silicon crystal.

Accessories Required: Suitable generator and detector (see next page).

Other Useful Accessories: Type 874-WM 50-ohm Termination; Type 874-WN3 Short-Circuit Termination; Type 874-W03 Open-Circuit Termination; Type 874-M Component Mount; Type 874-UB Balun; and other Type 874 Coaxial Elements. See current General Radio catalog for details and prices, or write our Sales Engineering Department. Coaxial adaptors as listed on page 6 are available for connecting to other types of coaxial connectors. Where standing-wave ratios greater than 10 are to be measured, a Type 874-LV Micrometer Vernier attachment and a harmonic filter should be used.

Dimensions: 26 x 4½ x 3½ inches, overall.

Net Weight: 8½ pounds.

Type		*Code Word*	*Price*
874-LBA	**Slotted Line**	COAXRUNNER	**$220.00**
874-LV	**Micrometer Vernier Attachment**	COAXREADER	**23.00**
874-F1000	**Low-Pass Filter**	COAXMEGGER	**10.00**
874-F500	**Low-Pass Filter**	COAXDIPPER	**16.00**

GENERATORS AND DETECTORS FOR THE SLOTTED LINE

GENERATORS

The following generators are recommended:

Type		Price
1208-A	Unit Oscillator, 65-500 Mc	$190.00
1209-A	Unit Oscillator, 250-920 Mc	235.00
1215-B	Unit Oscillator, 50-250 Mc	190.00

The above Unit Oscillators do not include power supply; the TYPE 1203-A Unit Power Supply is recommended.

Type		Price
1203-A	Unit Power Supply	$ 40.00

If a modulated signal is desired, the TYPE 1214-A Unit Oscillator is recommended, to supply the modulating signal.

Type		Price
1214-A	Unit Oscillator	$ 66.00

DETECTORS

Two satisfactory detector combinations are listed below:

1. *Using audio-frequency output of crystal rectifier in slotted line.* Requires a modulated generator (see above). Necessary equipment consists of the following items:

Type		Price
1231-B	Amplifier and Null Detector	$250.00
1231-P2	Tuned-Circuit Filter	25.00
1231-P4	Adjustable Attenuator	70.00
874-D20	Adjustable Stub, 275-5000 Mc	11.00
874-R32A	Patch Cord	5.50
TOTAL		$361.50

2. *Heterodyne system.* The signal from the generator and a signal from an auxiliary oscillator are combined in a TYPE 874-MR Mixer Rectifier to produce a 30-megacycle difference frequency, which is fed to a TYPE 1216-A Unit I-F Amplifier.

This method of detection affords much better shielding than a receiver used directly at the operating frequency, and, in addition, provides the high degree of selectivity needed for measuring high standing-wave ratios.

The TYPE DNT Detectors are complete heterodyne detector assemblies and were described in the *General Radio Experimenter* for May, 1954.

Type		Price
DNT-1	Detector Assembly, 35 to 530 Mc	$628.00
DNT-2	Detector Assembly, 25 to 280 Mc	628.00
DNT-3	Detector Assembly, 220 to 950 Mc	667.00

ADAPTORS

When connections are to be made to systems using other types of coaxial connectors, adaptors as listed below will be needed.

Type	Elements Used in Adaptor	Price
874-QNP	Type 874 and Type N Plug	$4.50
874-QNJ	Type 874 and Type N Jack	3.75
874-QBP	Type 874 and Type BNC Plug	4.75
874-QBJ	Type 874 and Type BNC Jack	4.75
874-QCP	Type 874 and Type C Plug	6.25
874-QCJ	Type 874 and Type C Jack	4.75
874-QHP	Type 874 and Type HN Plug	6.50
874-QHJ	Type 874 and Type HN Jack	6.50
874-QUP	Type 874 and Type UHF Plug	4.25
874-QUJ	Type 874 and Type UHF Jack	4.00
874-QV3	Adaptor to V-H-F 3⅛″ rigid line (51.5 ohms)	87.00
874-QU3A	Adaptor to U-H-F 3⅛″ rigid line (50.0 ohms)	87.00
874-QV2A	Adaptor to V-H-F 1⅝″ rigid line (51.5 ohms)	46.00

TYPE 874 Coaxial Connectors are manufactured and sold under U. S. Patents 2,125,816 and 2,548,457.

NEW MODEL OF THE MEGOHMMETER HAS TWO TEST VOLTAGES

The TYPE 1862-A Megohmmeter,[1] has found wide acceptance in the electrical and electronic industries for the rapid measurement of insulation resistance, the measurement of high-valued resistors, and for general resistance testing. In this instrument, the voltage across the resistance being measured is 500 volts, a value accepted as standard by most industrial and professional groups.

There have developed, however, a number of tests that should be made at a voltage considerably lower than 500, in order to avoid any damage to the specimen under test, and, to meet this requirement, a new model, the TYPE 1862-B, has been developed, in which two test voltages are provided, 500 volts and 50 volts, either of which can be selected by means of a panel switch.

The 50-volt test level will be found useful in resistance measurements on printed circuits and on components used in transistor circuits and in miniaturized equipment. The 500-volt level is used for measuring the insulation of rotating electrical machinery, transformers, capacitors, cables, appliances, and other power-line operated equipment.

From measurements made with both voltages, it is possible to determine the voltage coefficient of insulation resistance.

The selection of 50 volts as the low-voltage test potential permits a single meter scale to be used, thus preserving the simplicity and ease of interpretation inherent in the original design. The answer in megohms is still the product of a meter reading and a decimal multiplier. A neon lamp operated by the voltage-selection switch warns when the operating voltage is 500 volts.

Figure 1. View of the Type 1862-B Megohmmeter.

The low end of the resistance range is one half megohm for both operating-voltage conditions. For the 500-volt condition, the limiting factor is short-circuit current. When the unknown resistance is a short-circuit, the current that flows is about ten milliamperes at the lowest multiplier setting and is proportionately less at the higher settings. For the 50-volt condition, the limiting factor is the source resistance of the 50-volt supply (about 27 kilohms), which accounts for the larger error at the low range of the low-voltage condition (see specifications).

The high end of the resistance range is ten times as great (2,000,000 megohms) for the 500-volt condition as for the 50-volt condition. This is inherent in the circuitry, which consists essentially of a d-c supply (50 or 500 volts), an unknown, and a standard resistance, all in a series loop; a vacuum-tube voltmeter of two volts full scale is connected

[1] "A 500-Volt Megohmmeter for Insulation Testing," *General Radio Experimenter*, Vol. XXVI, No. 6, November, 1951.

across the standard and is calibrated to indicate megohms directly.

While the new megohmmeter is useful for measuring resistors and the leakage of both high-voltage and low-voltage capacitors and insulators, the facility with which voltage coefficient can now be determined opens up new fields of application.

—A. G. Bousquet

SPECIFICATIONS

Voltage Across Unknown: 500 volts or 50 volts, as selected by means of a panel toggle switch. A neon lamp warns when the 500-volt supply has been selected.

Over a 105-125-volt range in line voltage and over the resistance range of the instrument, the variation in voltage across the unknown resistor will be less than ±10 volts at 500 volts and less than ±4.0 volts at 50 volts.

Range: 0.5 megohm to 2,000,000 megohms at 500 volts and to 200,000 megohms at 50 volts. There are six decade steps as selected by a multiplier switch.

Scale: Each resistance decade up to 500,000 megohms (50,000 megohms for 50 volts) utilizes 90% of the meter scale. Center scale values are 1, 10, 100, 1000, and 10,000 megohms, with an additional center scale value of 100,000 megohms for 500-volt operation.

Accuracy: For 500-volt operation, the accuracy in per cent of indicated value at all but the highest multiplier setting is ±3% at the low-resistance end of each decade, ±8% at mid-scale, and ±12% at the high-resistance end. There can be an additional ±2% error at the highest multiplier setting.

For 50-volt operation, there can be an additional ±2% error on all but the 0.5-5 megohms decade where the additional error can be ±5%.

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 to be made 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 at 500 volts.

Design: Since field applications are more severe than laboratory use, the instrument 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 — OA2	1 — 6AB4
1 — 6X4	1 — 6AU6
1 — 5651	1 — NE-51

Controls: A switch for selecting the operating voltage, 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: 115 (or 230) 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", overall.

Net Weight: 15½ pounds.

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