the GENERAL RADIO Experimenter

INDEX

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the GENERAL RADIO **Experimenter**

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 30 No. 8 **JANUARY, 1956**

NEW MODELS OF THE "STRIPPED-DOWN" VARIAC® SPEED CONTROLS

***Also* IN THIS ISSUE**

Enclosed models of the so-called "stripped-down" VARIAC® Speed Controls are now available in ¾, ⅓, and ⅙-hp sizes, Types 1702-BW, 1700-CW and 1703-BW, respectively, in addition to the 1 and 1½-hp ratings,[1] Types 1704-BW and 1705-BW, announced in October, 1955. Variac Speed Controls operate from the a-c power line to control shunt and compound d-c motors.

Earlier models in these ratings were supplied without cabinet or braking resistor, primarily for machine manufacturers. Even when the unit was incorporated in a machine cabinet, however, a covering was often needed to protect the equipment or the operator. The dynamic braking feature has proved so generally desirable that the necessary resistor is now included in the standard chassis. As now supplied these controls are complete except for the switching necessary for starting, stopping and reversing, and for the fuses and line cutout switch. The latter may frequently be the main switch to the machine and may control other circuits also.

The appearance of the new controls with covers in place is shown in Figure 1. A new hammertone gray finish is employed throughout. The covers have ventilating holes at the bottom and louvres at the sides, and are removable from the front. Since access to the

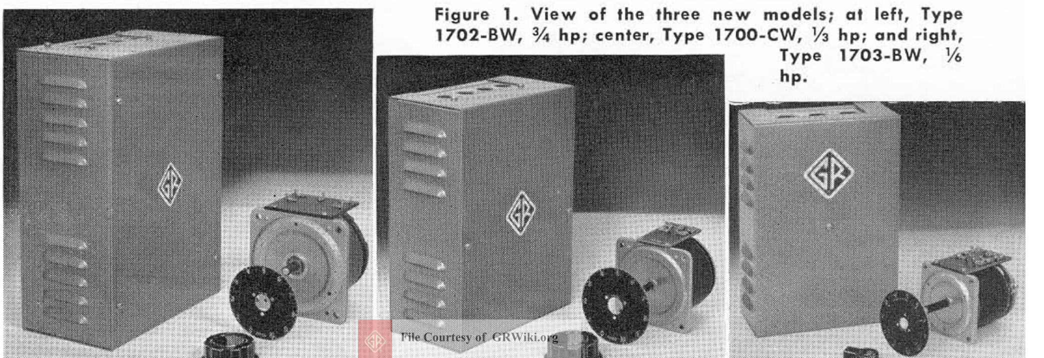

Figure 1. View of the three new models; at left, Type 1702-BW, ¾ hp; center, Type 1700-CW, ⅓ hp; and right, Type 1703-BW, ⅙ hp.

cabinets is required only for servicing, they may be placed in any location where there is adequate circulation of air. The depth has been kept as shallow as possible in all cases. The VARIAC and control switches are usually mounted by the user on a single panel.

Circuits

These controls are offered for users who want switching arrangements different from those in the standard complete controls or who do not have room for the cabinet at the operator's position and wish to separate it from the switches and VARIAC. Various circuit arrangements to meet particular requirements are described in the operating instructions for the different models of the controls. Some of these will be reviewed briefly here.

3-Position Switch

The availability of suitable switches and relays in the various ratings determines to some extent the choice of circuit. For example, the appliance-type switch supplied in the Type 1700-B and Type 1702-A controls has enough contacts to break the a-c and d-c circuits simultaneously and also to handle reversing and dynamic braking. An important safety feature is that the lever can not be thrown directly from forward to reverse but must be held momentarily in the intermediate stop position. The standard connections for this switch are shown in Figure 2.

Drum Controller

The appliance-type switch is not particularly suitable for machine-shop production work, and the higher cost of a drum controller, as used with the larger Variac Speed Controls, may be justified for heavy duty of this kind. We have several installations of drum controllers in our own plant. Connections are the same as those given in Figure 2 for the appliance switch except that extra series contacts are provided in both the a-c and d-c portions of the circuit.

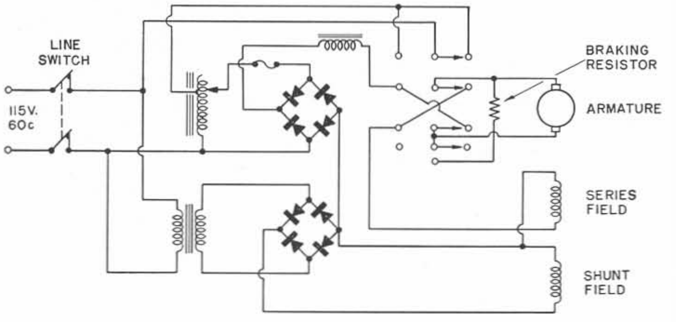

Figure 2. Connections for three-position appliance-type switch.

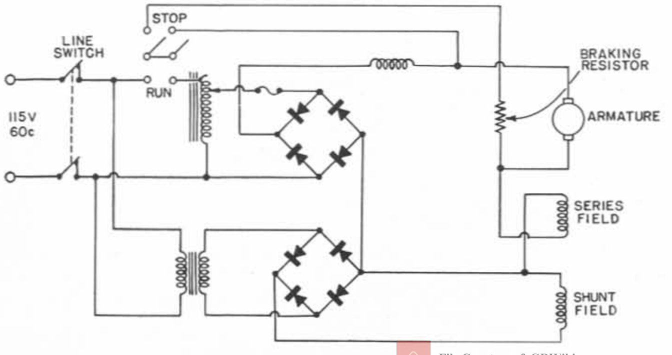

Figure 3. Connections for start-stop switch, used when reversing is not required.

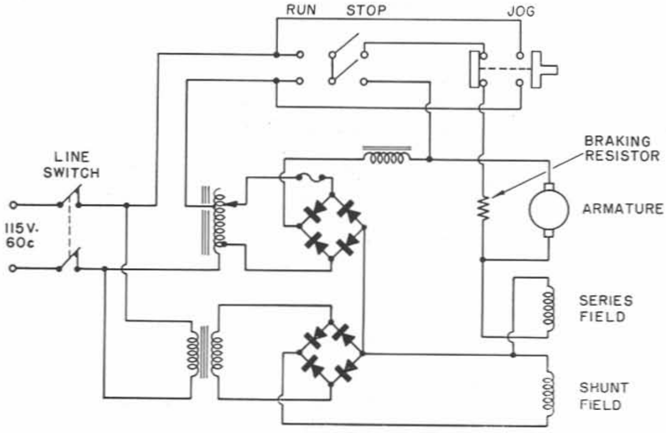

Figure 4. Connections for jogging button.

Start-Stop Switch

In some applications reversing is never required, and a DPDT toggle switch can be used for starting and stopping with dynamic braking. The diagram is shown in Figure 3. A jogging button can be added as shown in Figure 4, the braking circuits of the switch and button being in series and the power connections in parallel.

A limit switch of the manual-resetting, snap-acting type can be used with a relay in the circuit of Figure 3 to stop a machine at a predetermined point. This switch will stay in the off position while the machine is set up for the next operation, and the reset button can be used for restarting. If dynamic braking is not required, the relay can be omitted and the limit switch inserted directly in the a-c input line. An arrangement of this kind is used on the machines that wind General Radio VARIACS. Controls of ¾ hp and lower ratings are controlled directly by the limit switch, and the larger controls through a relay.

Push Buttons

The use of standard reversing contactors is straightforward where the additional cost is justified. A less-expensive circuit is available [2] for push-button operation using two 4PDT relays, but the rating is limited to controls of ⅙ hp and below.

The new "stripped-down" models should greatly increase the flexibility of application of Variac Speed Controls, making the entire line from $1/15$ hp to 1½ hp available either with or without switching. All types have been in demand to meet the ever-growing list of applications. Characteristics which have proved most important in making the controls successful have been the simple, long-life construction, reduced maintenance requirements, heavy overload capacity for fast and repeated starting, low torque pulsation, and the smoothly controlled torque available for starting delicate operations.

A user of these controls commented at the recent Chicago Exposition of Power and Mechanical Engineering that the Variac Speed Control is "a masterpiece of simplicity and essentially service free."

The appliance-type switch and the drum controller mentioned in this article are available from the General Radio Company, as listed below.

— W. N. Tuttle

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[1] W. N. Tuttle, "New Variac® Speed Controls in 1 and 1½ hp Ratings," *General Radio Experimenter*, 30, 5, October 1954, pp. 1–4.

[2] Described in Operating Instructions for Type 1703-BW Variac Speed Control.

SPECIFICATIONS

		Type 1703-BW	Type 1700-CW	Type 1702-BW
Motor Horsepower Range:		1/12 to 1/6	¼ and ⅓	½ and ¾
Power Supply Single-Phase	Volts	115	115	115
	Full-load Amperes	2.2	5	10
Line-Voltage Limits	At 60 Cycles	105–125	105–125	105–125
	At 50 Cycles	105–125	Note 2	
Input Power Watts	Full Load	325	560	1150
	Stand-by	30	38	65
Motor Control Output DC — Armature	Amperes	1.5	3	6.5
	Volts	0–115	0–115	0–115
Motor Control Output DC — Field	Amperes	0.2	0.4	0.4
	Volts	115 / 66 / 48	115 / 75	115 / 75
Speed range		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
Dynamic Braking		Braking Resistor Furnished		
Armature Overload Protection		None Furnished		
Control Station		Variac furnished; Switching to be Provided by User		
Over-all Dimensions in inches	Chassis	7½ × 10¼ × 3½	9¾ × 12⅝ × 5	11¼ × 15¼ × 5⅞
	Variac	3¼ × 3 11/16 × 4⅜	4½ × 4 15/16 × 5½	5¾ × 6¼ × 5⅞
Net Weight in Pounds	Chassis	4½	17	27½
	Variac	3½	6½	11¼
Code Word		SABOT	SALTY	SATIN
Prices, Net F.O.B. Factory	1 to 4 units	**$72.00 ea.**	**$135.00 ea.**	**$195.00 ea.**
	5 to 19 units	**68.50**	**122.00**	**177.50**
	20 units and up	**65.50**	**116.00**	**170.00**

MOTORS FOR USE WITH ABOVE SPEED CONTROLS (Note 1)

Motor ratings: open, drip-proof, reversible, 40°C rise continuous, horizontal, rigid base	Compound	Compound	Compound with interpoles
General Radio Designation	MOD-11	MOD-3	MOD-6
Horsepower	1/6	⅓	¾
Speed (RPM)	1725	1725	1725
Leads (brought out separately)	6	6	6
Bearings	Sleeve	Sleeve	Sleeve
Frame Size	F-56	H-56	H-66
Net Weight — Pounds	25	30	60
Code Word (Note 3)	MOTOR *	MOTOR *	MOTOR *
Price	**$52.50**	**$59.00**	**$100.00**

Note 1. Any motor within control rating can be used. Compound motors for use with Type 1703-BW must have separate series-field leads.
Note 2. 50-cycle model available on special order.
Note 3. To order motor with Variac Speed Control, add motor to the code word of the corresponding speed control; thus SATIN MOTOR is the code word for the Type 1702-BW Variac Speed Control with MOD-6 motor. Motors are not sold separately.

Type		*Code Word*	*Price*
1702-P2	**Switch**	FLIPO	**$ 6.00**
1705-P1	**Drum Controller**	DRUMO	**22.00**

A TUNED FILTER FOR USE IN CAPACITANCE MEASUREMENTS AT ONE MEGACYCLE

Figure 1. View of the Type 1212-P2 1-Megacycle Filter.

The Type 716-CS1 Capacitance Bridge,[1] which operates at a frequency of one megacycle per second, is well suited to the measurement of small capacitors, such as the disc-ceramic type, and low-loss dielectrics. To realize the full precision of which the bridge is capable, however, the null detector should be provided with a filter to reduce the magnitude of harmonics and noise. An experimental filter was illustrated in a previous article.[2]

The commercial version of this filter is now available and is shown in Figure 1. This convenient plug-in unit, the TYPE 1212-P2 1-megacycle Filter, when used with the TYPE 1212-A Unit Null Detector, results in high selectivity against harmonics and noise and also provides considerably increased sensitivity. These features are particularly important for dissipation-factor measurements on low-loss capacitors. When this combination is used with the TYPE 716-CS1 Capacitance Bridge and the TYPE 1330-A Bridge Oscillator,[3] the dissipation factor balance can be set to a precision of .00002, or ⅕ of the smallest dial division.

Figure 2 is a schematic diagram of the filter. The LC ladder section provides insertion gain at 1 MC and attenuation at higher frequencies. The bridge output impedance is capacitive (in the normal oscillator-detector connection) so that there are effectively two R-C ladder sections for low frequency rejection. Gain and rejection figures for a typical filter are:

[1] Ivan G. Easton, "A 1-Megacycle Schering Bridge," *General Radio Experimenter*, XXVI, 9, February, 1952, pp. 4–8.
[2] "A Convenient Test Fixture for Small Capacitors," *General Radio Experimenter*, 30, 4, September, 1955, pp. 4–6.
[3] The TYPE 1211-A Unit Oscillator with the TYPE 1203-A Unit Power Supply is equally satisfactory.

Equipment for 1-mc capacitance measurements. The generator is the Type 1330-A Bridge Oscillator, the bridge the Type 716-CS1 Capacitance Bridge. The null detector (Type 1212-A) is shown at the right. The filter shown is the experimental model; the Type 1212-P2 plugs into the detector in the same way.

Unknown Capacitor	100 $\mu\mu f$	1000 $\mu\mu f$
Insertion Gain 1 Mc	22 db	32 db
Relative 2nd Harmonic Rejection	39 db	47 db

The resonant frequency of the filter is affected but slightly by the setting of the bridge, and a single tuning adjustment suffices for all bridge settings. If the filter is tuned for the 100 $\mu\mu f$ bridge setting, the net sensitivity actually increases for higher capacitance values, because the decreasing output impedance of the bridge causes enough increase of inherent sensitivity to more than compensate for the slight detuning of the filter.

The filter plugs directly into the input terminals of the TYPE 1212-A Unit Null Detector through TYPE 874 Coaxial Connectors, which provide complete shielding. — HENRY P. HALL

SPECIFICATIONS

Net Weight: **Dimensions: 2" diameter, 5" long.**

Type		*Code Word*	*Price*
1212-P2	**One-Megacycle Filter**	**ANNUL**	**$30.00**

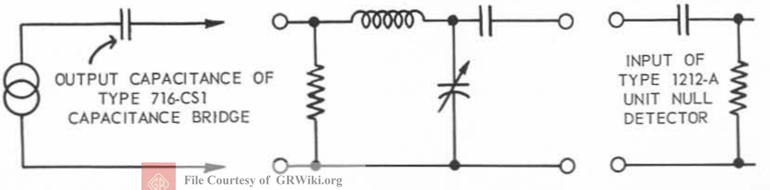


Figure 2. Schematic diagram of the filter circuit.

DIELECTRIC MEASUREMENTS

This filter is particularly useful in the measurement of dissipation factor of low-loss dielectrics at one megacycle. Complete equipment for the measurement comprises:

Type		*Code Word*	*Price*
716-CMS1	Capacitance Bridge*......................	BOGEY	$640.00
1330-A	Bridge Oscillator..........................	ACORN	525.00
1212-A	Unit Null Detector.........................	ALACK	145.00
1203-A	Unit Power Supply.........................	ALIVE	40.00
1212-P2	One-Megacycle Filter......................	ANNUL	30.00
1690-A	Dielectric Sample Holder..................	LOYAL	435.00

* A relay-rack model is also available.

CAPACITOR MEASUREMENTS

When small capacitors with closely spaced parallel leads are to be measured, the Type 1691-A Capacitance Test Fixture should be substituted for the Dielectric Sample Holder.

Type		*Code Word*	*Price*
1691-A	Capacitance Test Fixture..................	EDICT	$22.50

AN INGREDIENT OF QUALITY

To the manufacturer of precision instruments, the search for improvement in product quality is never ended. Not only in engineering development and design, but also in manufacturing methods and material, a constant attention to detail has proved over the years to be a basic ingredient of quality.

To illustrate the point, it was back in the early part of 1947 that growing dissatisfaction at General Radio with instrument cables culminated in a specific project to develop methods for improving the appearance of this component. For many years, the trunk and subsidiary cables, which carry the major wiring of an instrument, had been hand laced with armature twine. Though functionally these cables were perfectly acceptable, esthetically they seemed to add little to the appearance of an instrument.

At this time, on multiple-strand, straight-through cables, braided coverings of various materials were quite common. But unfortunately, to braid a cable with many diverging arms of various lengths, different diameters, and of any configuration needed, and to do it uniformly, repetitively, and economically all called for quite a different application of existing braiding machinery and methods.

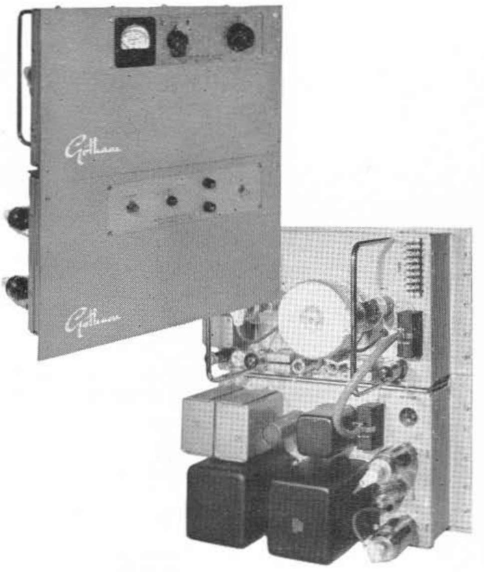
Nevertheless, late in 1947, for experimental purposes, a conventional braiding machine was purchased. Modifications proceeded, and during the months which followed, trial and error gradually accumulated into a practicable method. The machine, and, of course, subsequent units, were suitably mounted, equipped with Variac® Speed Controls, and modified with special movable stops on the main drive wheel. Cotton, rayon, and nylon thread were in turn tested, with nylon in the end proving the superior material, not only for its ability to wrap tightly and uniformly around any diameter, but also for its non-hygroscopic quality, which insures against trapping moisture within the cable.

Since mid-1948 when production of nylon-braided cables was first begun for a few new instruments, nearly all GR equipment has now incorporated this improved component. And, too, with the increasing quantities and further refinements in methods and equipment, it is interesting to note that, although the initial desire was for enhanced appearance and quality, a parallel and unexpected result has been a welcome 40% reduction in labor cost in the improved braided cable.

Of course, a cable is only one component, one detail, among hundreds or even thousands in an instrument. But constant attention to these details, both in engineering and manufacturing, helps to build quality into General Radio instruments. — P. W. POWERS

HIGH POWER WITH LOW DISTORTION

The General Radio TYPE 942-A Output Transformer [1] is designed to meet the exacting requirements of high-power, low-distortion audio amplifiers. A typical application is the Model PFB-150WD Power Amplifier manufactured by Gotham Audio Development Corporation, and shown in the accompanying photographs. Manufacturers' specifications for this amplifier indicate a continuous rating of 150 watts output at less than 0.7% harmonic distortion and less than 1% intermodulation distortion. Complete specifications can be obtained from the manufacturer at 2 West 46 Street, New York 36.



Front and rear views of the Gotham PFB-150 WD. The Type 942-A Output Transformer is shown at the top center of the rear view.

[1] H. W. Lamson, "A High-Power Toroidal Output Transformer," *General Radio Experimenter*, XXVI, 6, November, 1951, pp. 5–8.

MISCELLANY

During the past few months we have welcomed visits from many friends from overseas.

Among these are:

W. M. Ferris, Director, Ferris Bros. Pty. Ltd., Sydney, Australia.

Tan Chan, Dean and Acting President, and Liau-Tsung Lin, Instructor, Taiwan College of Engineering, Taiwan, Formosa-China.

Knud Blendstrup, Instructor, Elektroteknisk Laboratory, Polyteknisk

Laeranstalt, Copenhagen, Denmark.

S. W. Gough, Manager, Physical Research Division, Dunlop Research Center, Birmingham; Dr. George L. Grisdale, Chief of Communication Research Group, and R. E. Burnett, Marconi's Wireless Telegraph Company, Ltd., London; and E. R. Ponsford, Production Manager and Engineer, Solartron Electronic Group, Ltd., Surrey, England.

L. Bignon, Regul-France, Paris.

V. Balasubramanyam, Research Engineer, All India Radio, Bombay.

Nello Meoni, President, and Ing. M. Federici, Consultant, LESA Company, Milan; and Ing. A. Beltrami, Professor, Head of Institute, Instituto Radiotecnica, Milan, Italy.

Tomizo Ariska, Midoriya Electric Company, Tokyo; Y. Nozaka, Chief of Automatic Control and Special Instruments, Yawata Iron & Steel Company, Ltd , Fukuoka, Japan.

M. Gruenberg, Business Manager, Etabilissement Mehmet Vasfi, Istanbul, distributors of General Radio products in Turkey.

MID-WINTER EXHIBITS

General Radio products will be on display at two mid-winter meetings. If you are attending either of these, we extend to you a cordial invitation to visit the GR booth. General Radio engineers will be in attendance to discuss your measurement problems.

American Institute of Physics
25th Anniversary Meeting and Exhibit
Hotel New Yorker, New York, N. Y.
January 30 to February 4
Booth 22

Eighth Annual Southwestern Regional IRE Conference and Electronics Show
Municipal Auditorium
Oklahoma City, Oklahoma
February 9 to 11
Booths 84 and 85

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PRICE CORRECTION

Prices for Variac Speed Controls are incorrectly listed in the January, 1956 issue of the **General Radio Experimenter.**

Correct prices are as follows:

Type	Quantity	Unit Price
1703-BW	1-4 units	$85.00
	5-19	82.50
	20 and up	80.00
1700-CW	1-4 units	$145.00
	5-19	141.50
	20 and up	138.00
1702-BW	1-4 units	$205.00
	5-19	196.00
	20 and up	187.00

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VOLUME 30 No. 9 FEBRUARY, 1956

THE MEASUREMENT OF IMPACT NOISE

Many of the everyday noises that we hear are impact noises. They range in intensity from the "tick-tock" of a watch to the tremendous crash of a huge drop hammer. In the industrial plant impact noises are produced by hammers, riveters, chippers, and punch presses; and in the office, by typewriters and business machines of various sorts. A related class of noise is explosive noise as in gun fire or even the repeated explosions of gasoline engines in autos and trucks. To industry, some of these noises can be a serious problem, particularly those produced by large drop hammers, because of the possible hearing loss that can result from continued exposure to the noise.[1] This problem has led to considerable research in the fields of hearing damage from noise, of noise reduction, and of noise measurement.

Noise measurements with sound-level meters and spectrum analyzers are inadequate for evaluating impact noise. A cathode-ray oscillograph can be used to study this type of noise, but the measurement is so complicated that it is performed mainly in the research laboratory.

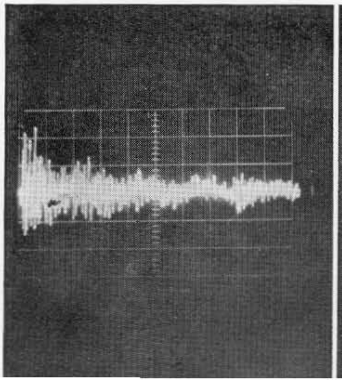
A new instrument, the TYPE 1556-A

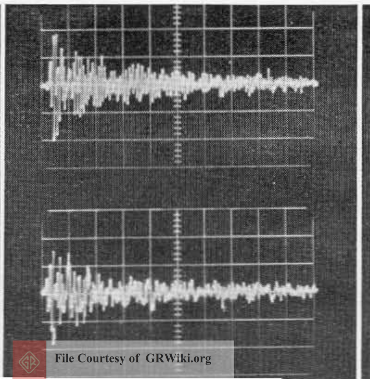
[1] Subcommittee Z24-X-2, "The Relation of Hearing Loss to Noise Exposure," American Standards Association, New York, 1954, p. 49.

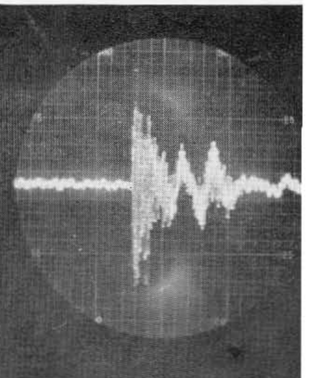
Figure 1 *(left)*. Oscillogram of noise from a single strike of a punch press doing a simple forming operation. The time scale along the horizontal axis is 10 milliseconds per division. The instantaneous sound pressure is displayed on the vertical axis, and the peak level recorded is 120 db re 0.002 microbar.

Figure 2 *(center)*. Oscillograms of noise from two separate handclaps. The time scale along the horizontal axis is 2 milliseconds per division.

Figure 3 *(right)*. Oscillogram of noise from a small drop hammer. The time scale along the horizontal axis is 10 milliseconds per scale division.







Impact Noise Analyzer, shown in Figure 4, has been recently developed to simplify these measurements. This instrument is an accessory for a sound-level meter, and it can be used to measure certain significant characteristics of an impact noise. It is also useful as an accessory for spectrum analyzers, such as the TYPE 1550-A Octave Band Noise Analyzer, for magnetic tape recorders and for the TYPE 761-A Vibration Meter.

The considerations underlying the design, operation, and application of this new instrument will be better understood if we consider first some of the characteristics of impact noises.

Characteristics of Impact Noise

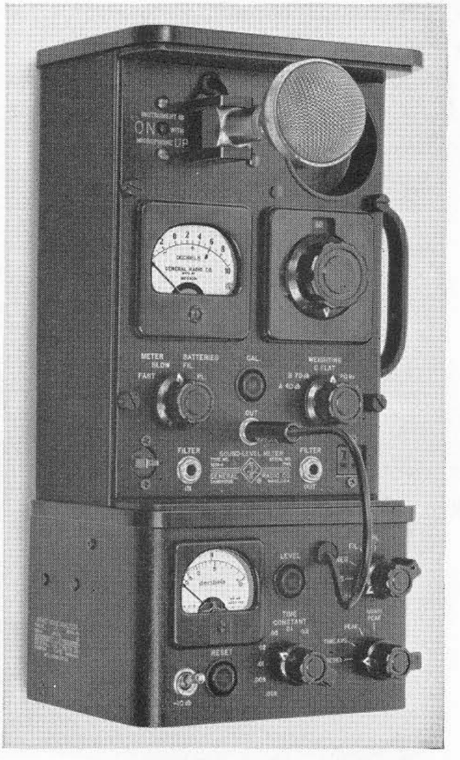
Figures 1, 2, and 3 are oscillographic records of instantaneous sound pressure (the vertical ordinate) versus time (horizontal axis). Figure 1 is the oscillogram of the electrical output of a condenser microphone placed 4 feet from a punch press doing a simple forming operation. The time scale along the horizontal axis is 10 milliseconds per division, that is, 0.1 second for the full sweep. The instantaneous peak level shown in the oscillogram is 120 db (*re* 0.0002 microbar) and occurs about 5 milliseconds after the first sound from the impact. At 1 millisecond, a level of about 119 db is reached. After this initial rapid rise, the level decays, so that after about 30 milliseconds it is appreciably below its maximum. One interesting feature of this impact sound is the random nature of the individual peak amplitudes. That is, although there is the general trend of a rapid rise to a maximum value and a slower but still rapid decay, successive peak amplitudes vary appreciably. This behavior is shown more clearly in succeeding oscillograms. The sound-pressure wave is also dissymmetrical, with the positive, or excess, pressure wave having the highest instantaneous peak level.

The oscillograms in Figure 2 correspond to the sound pressure waves of two separate handclaps about 18 inches from the condenser microphone. Here the time scale has been spread out, each division being 2 milliseconds. The instantaneous peak positive levels, attained in a fraction of a millisecond, are 117 db and 115 db, and the negative levels are 118 db and 117 db. The decay is appreciably longer, being several milliseconds. The dissymmetry here is not marked, but the randomness of the individual amplitudes of the oscillations is clearly shown.

The oscillogram* of Figure 3 is a

*Courtesy of Liberty Mutual Insurance Company, Boston, Massachusetts.

Figure 4. View of Impact Noise Analyzer attached to a sound-level meter.



display of the sound wave from a small 1800-lb drop hammer in an open field. The microphone was 24 feet from the hammer, and the maximum level observed is 119 db. (This is the very faint peak 8.5 small divisions above the reference line.) The time scale along the horizontal axis is 10 milliseconds per small division. The usual very rapid rise and fast decay is very clearly shown here. But in addition there is a low-frequency variation having a period of about 25 milliseconds (40 cps), which is a ringing of the hammer. This type of oscillation is not so apparent in the oscillograms taken close to the hammer. At a distance of 3 feet, for example, the oscillograms are very similar to those of Figures 1 and 2. A typical peak level for this small hammer at a distance of 3 feet is 127 db. The difference in shape of the oscillograms at these distances is a result of the appreciable attenuation of high-frequency components and relatively small attenuation of the low-frequency component.

Need for a New Instrument

When a standard sound-level meter is used to measure such noises, the momentary reading obtained at each impact seems to have little significance. The sound level meter is inadequate because an impact sound does not remain at any particular level for a time that is comparable to the time constants of the meter, which are of the order of two-tenths of a second. The meter reading does show a momentary rise and decay, but the maximum reading obtained is commonly 15 to 30 db below the peak level of the wave.

A cathode-ray oscillograph does not have this limitation. Its moving element is an electron beam, which has so little mass that it can easily be made to move in accordance with the instantaneous sound pressure. By photographing the displayed oscillograph pattern, one obtains a record of a noise of the type shown in Figures 1, 2, and 3.

The equipment required to obtain such a record is complicated, expensive, and bulky. A cathode-ray oscillograph, alone, has many controls, and displaying transient sounds on this device is a complicated operation. As a result, only a few, well-equipped, research laboratories have undertaken a serious study of impact sounds. To set up useful criteria for judging the significance of these sounds, a great deal of experimental data must be accumulated. The collection of these data has been seriously hampered by the lack of simple means of measurement.

The variability of some impact sounds provides further evidence of the need for simple measuring equipment. For example, tools using explosive cartridges for setting fastening devices in concrete produce sounds that vary considerably in level from one shot to the next. Therefore, a number of samples of such sounds should be measured to determine this variability; and a simple measuring instrument makes such a study practical.

The response of the hearing mechanism to impact sounds is appreciably different from that to steady sounds. This difference is due in part at least to certain delays inherent in the action of the hearing mechanism. These delays are comparable to the time constants of impact sounds. The delay in the action of the middle ear muscles, for example, is probably of the order of ten milliseconds or more.[2] Thus, on some impact sounds no appreciable action of these muscles will occur until after the sound

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[2] W. A. Rosenblith, "Electrical Responses from the Auditory Nervous System," *Annals of Otology, Rhinology and Laryngology*, September, 1954, Vol. 63, No. 3, pp. 839–860.

is essentially completed. Because of this delay, one would expect the character of an impact noise in the first few milliseconds to be of greater significance than the behavior after longer periods.

The measurement of impact sounds by cathode-ray oscillographs can yield a large amount of information. But oscillograms cannot be used directly in rating a noise. We need to have a few numbers that will characterize the sound wave, so that we can use the numbers in plotting graphs and in setting up tentative criteria for impact noises. A study of the patterns of impact noise oscillograms leads to the conclusion that two obvious numbers to use are the maximum instantaneous level and some measure of the time duration of the wave.

Description of Impact Noise Analyzer

These two values are readily measured by the new TYPE 1556-A Impact Noise Analyzer, shown in Figure 4 attached to a sound-level meter. Both the peak level and the duration of a single impact can be measured. The instrument contains a battery-operated transistor amplifier, which is highly stabilized by negative feedback. This amplifier simultaneously drives three a-c voltmeter circuits, which consist of rectifiers, storage capacitors, and a common electronic d-c voltmeter, as illustrated in the simplified schematic of Figure 5.

The electrical storage system, which is a capacitor charged by the rectifier, makes it possible to measure all three characteristics on a single impact with only one indicating meter. This storage system is an essential element in obtaining a satisfactory reading on an indicating instrument for these very short duration sounds. In order that the charge remain stored in the capacitor for some time, the electrical leakage of the rectifier must be extremely low in the reverse direction. This characteristic is obtained in recently developed silicon-junction diode rectifiers.

When the measurement of a single impact is completed, the capacitors in the metering circuit are discharged by switching to a position called "RESET." Then the instrument is ready for measuring another impact.

The three characteristics of a sound that can be measured by means of the Impact Noise Analyzer are labeled on the instrument as "QUASI PEAK," "PEAK," and "TIME AVG" (time average).

The "QUASI PEAK" is a continuously indicating measure of the higher sound-pressure levels occurring just before the time of indication. The electrical circuit of the "QUASI PEAK"

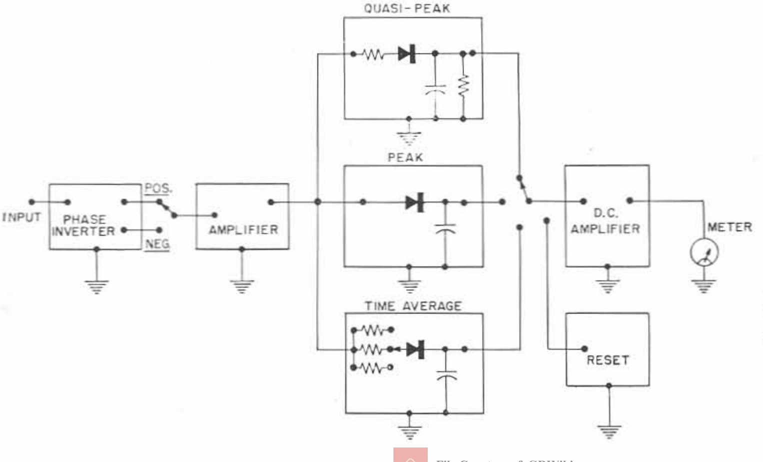


Figure 5. Simplified functional diagram of the Impact Noise Analyzer.

system has a fast rise time (a fraction of one millisecond) and a slow decay time (about six-tenths of a second) so that the fast indicating meter on the instrument can follow reasonably well the peak levels of sound. This measure of a sound is useful for repeated impacts. It also serves as a convenient indicator for calibrating the system, and it has the characteristics proposed as standard for measuring electrical impulse noise.[3] Incidentally, there is some evidence that in general it can be used as a single measure of loudness of noise with appreciably better results than is possible with the rms meter specified in the sound-level meter standard.

The "PEAK" is the maximum sound-pressure level reached by the noise after the analyzer control is switched out of the "RESET" position. The time required for this instrument to note the peak level is so short (of the order of one ten-thousandth of a second) that for sound waves it can be regarded as instantaneous. This "PEAK" level is stored electrically for a number of seconds, so that the level can be read on the indicating instrument at leisure.

Comparisons have been made between the peak levels of impact sounds measured on this instrument and those measured by the cathode-ray oscillograph technique. The agreement is very satisfactory, being generally within one decibel.

The time-average level is obtained by charging a capacitor through a rectifier and a series resistor. Seven different values of charging time are provided, ranging from 2 milliseconds to 0.2 second. This time-average level is a measure of the level maintained over a period of time. The actual averaging time is set by the charging time and the shape of the pressure wave. The time-average level is also stored in an electrical capacitor, so that it can be read on the indicating instrument at leisure.

The difference between the peak level and the averaged level is a measure of the time duration of the wave. How a particular time duration for these complicated impact waves is to be specified is not obvious. If they were simple rectangular pulses, there would be no problem. Such pulses will be used to illustrate the basis of the procedure adopted for more complicated waves.

Assume that the charging time of a rectifier circuit is set to be 0.01 second. If a constant voltage is suddenly applied to this rectifier circuit, current flowing into the capacitor will result in an increase in voltage across it. The longer this voltage is applied, the closer will the voltage across the capacitor approach the applied voltage. Thus, if it lasts for 0.01 second, the capacitor voltage should be 4 decibels less than the applied voltage. If it lasts for only 0.002 second, however, it should be 15 decibels less than the applied voltage. This relation is shown as the lower curve in Figure 6. Some experimental results obtained by using the impact noise analyzer to measure known rectangular pulses are shown also in Figure 6. The ratio of the applied voltage to the voltage across the capacitor is plotted in decibels along the horizontal axis, and the ratio of the duration of the applied voltage to the charging time of the rectifier circuit is plotted along the vertical axis. The close agreement of the measured values to the theoretical relation indicates that the circuits are operating as expected.

If a rectangular pulse of unknown duration is applied to this instrument, its duration can be determined from

[3] American Standards Association, C63.2-1950, "Proposed American Standard Specifications for a Radio Noise Meter, 0.015 to 2.5 Megacycles/Second."

these measurements. The "PEAK" circuit charges very quickly to the full applied voltage so it is used as the reference, and the difference in decibels between the peak value and the averaged value is used with the chart to determine the duration of the pulse. For example, assume that the indicated peak level is 138 db and the level with an averaging time of 0.002 second is 130 db. The difference in level is 8 decibels. From the chart it is seen that this level difference corresponds to a time ratio of 0.5. The pulse, therefore, was one-half of 0.002 second, which is 0.001 second, or 1 millisecond.

Impact noises are not so simple as rectangular pulses, however, as is shown by the oscillograms of Figures 1, 2, and 3. Rather, they appear to be, to a first approximation, exponentially decaying random noises. For such an applied wave, a relation of the type previously given for rectangular pulses can be computed, and is shown in Figure 6.* Here the decay time constant is defined in the same way as it is done in electrical circuits. The time constant is the time required for the wave to drop 8.7 db in level from its initial value.

A particular example will show how this relation can be used. Measurements of a small punch press stamping out blanks gave a peak level of 115 db and a time-averaged level of 98 db when a time constant of 0.01 second was used. The difference in level is 17 decibels. From the chart this difference corresponds to a time ratio of 2. The equivalent impact decay time is then 2 times 0.01, which is 0.02 second, or 20 milliseconds.

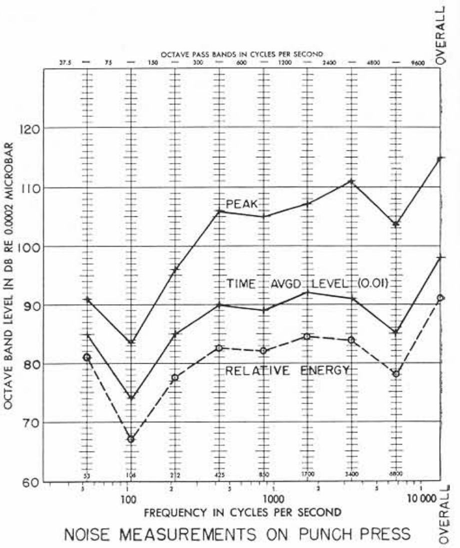
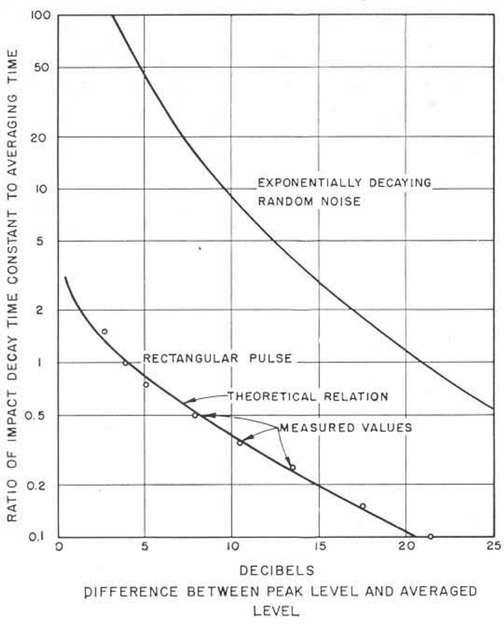


Figure 7. The results of an octave-band analysis of the noise from a single impact of a punch press as measured by the impact noise analyzer on the output of the octave-band analyzer.

Figure 6. Chart showing the relations between the ratio of the peak to averaged value and the time constants of an impact and of the circuit. The lower curve is for a rectangular pulse, and the upper one is for the usual impact noises.



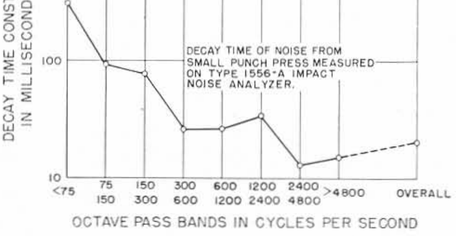
* The computed relation shown in Figure 6 is based on the assumption that the charging time of the peak circuit is of the order of a hundredth to a thousandth the decay time of the exponentially decaying wave. This assumption appears to be justified for most of the impact noises encountered in industry.

When this procedure is used on the impact noises, whose oscillograms are shown in Figures 1 and 2, equivalent decay times of about 30 milliseconds for the punch press and about 4 milliseconds for the handclaps are obtained. These values appear to correspond reasonably well with estimates made from the oscillograms.

In addition to its use for measuring impact noise directly, the impact noise analyzer can measure the output of a spectrum analyzer. For example, the impact noise of a punch press was measured by using an octave-band analyzer and the new impact meter. The results are shown in Figure 7. The upper curve is a plot of the peak level observed in the band, and the middle curve is a plot of the time-averaged level. The overall levels are shown at the right.

It is not clear that the measured peak level in a band has real significance by itself, since this peak is not one that actually occurs in the physical sound wave. But, when it is taken in conjunction with the time-averaged level, one can get an estimate of how the energy in the sound is distributed in frequency. Thus, the peak and time-averaged level can be used to determine an equivalent decay time for the noise in each band. Then, with the assumption that the noise wave in each band is an exponentially decaying one, the square of the pressure wave can be integrated with time and the result is plotted on the chart as relative energy. The absolute position here is purely arbitrary. These points show a distribution in frequency that is more uniform than the distribution shown for the peak level, which means that, in general, lower frequency components decay less rapidly than do higher frequency ones.

Figure 8. The time constant of analyzed noise from a punch press.



The calculated decay time of the noise in the different bands is shown in the curve of Figure 8. These results show a variation in decay time constant from 300 milliseconds, or 0.3 second, in the lowest band to a time constant of only 13 milliseconds for the noise in the band from 2400 to 4800 cycles per second. This result is what one would expect, since the high-frequency energy is usually dissipated much more rapidly than the low-frequency energy.

Other Uses

In addition to its use in evaluating impact noise and vibration, the Impact Noise Analyzer shows promise of being useful in many other types of measurement. Among those already suggested are the measurement of reverberation time, of loudness, and of the damping effect of sprayed coatings.

— Arnold P. G. Peterson

Acknowledgment—The author wishes to acknowledge helpful discussions on this subject with Dr. Jerome R. Cox, Jr. of the Central Institute for the Deaf; and the assistance of Mr. Robert J. Ruplenas of the General Radio Company, in the development of the instrument described here.

SPECIFICATIONS

Input Level: Any voltage between 1 and 10 volts for normal range. Levels below 1 volt reduce the range of reading.

Input Impedance: Between 25,000 and 100,000 ohms, depending on LEVEL control setting.

Frequency Range: 5c to 20 kc

Level Indication: Meter calibrated in decibels from −10 to +10. Added attenuator switch increases range by 10 db.

Peak Reading: Rise time is less than 50 microseconds for a value within 1 db of peak value (for rectangular pulses). Storage time at normal room temperature is greater than 10 seconds for 1 db decrease in value.

Quasi Peak Reading: Rise time of less than ¼ millisecond and decay time of 600 ± 120 milliseconds for rectifier circuit.

Time Average Reading: Charge time of rectifier circuit selected by seven position switch, having times of .002, .005, .01, .02, .05, .1, and .2 seconds for the resistance-capacitance time constant. Storage time at normal room temperature is greater than 1 minute for 1 db decrease in value.

Source: A sound-level meter or spectrum analyzer should ordinarily be used to supply the analyzer input.

Input Terminals: An attached cord with phone plug at one end.

Batteries: One 1½-volt size D flashlight cell (Rayovac 2LP or equivalent) and one 45-volt B battery (Eveready 455 or equivalent) are supplied.

Tube Complement: One TYPE CK-6418 tube; Three TYPE 2N105 transistors or equivalents.

Cabinet: Aluminum, finished in organic black. Carrying case supplied.

Mounting: May be fastened to end frame of TYPE 1551-A Sound Level Meter.

Dimensions: 7½″ (wide) × 4¼″ (deep) × 6½″ (high).

Net Weight: Instrument, 4½ pounds; Carrying case, 1 pound.

Type		*Code Word*	*Price*
1556-A	**Impact Noise Analyzer**	MEDAL	**$210.00**

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A NEW, HIGH-SENSITIVITY ELECTROMETER

Also IN THIS ISSUE

The new TYPE 1230-A D-C Amplifier and Electrometer is basically a high-resistance millivoltmeter. Voltage, current, and resistance is indicated on a panel meter and can also be indicated on a recorder.

Because of its high sensitivity and excellent stability, this instrument has a wide range of applications in science, engineering, and industry. Typical examples include the measurement of:

Ionization currents, photo currents, grid currents in electron tubes, and time-current curves of capacitors during charge and discharge.

Piezo-electric potentials, bioelectric potentials, contact potentials, electrostatic field potentials, and pH indications.

Silicon-diode back resistance, interconductor resistance of cables, insulation resistance of electrical equipment and voltage coefficient of resistance.

The amplifier in this instrument is strictly direct coupled. It uses neither the relatively low input-resistance chopper system nor the high-cost vibrating capacitor system. Its stability is due to excellent supply regulation, shock mounting, liberal use of wire-wound resistors at the important places, and adequate aging of both tubes and com-

Figure 1. Panel view of the Type 1230-A D-C Amplifier and Electrometer.

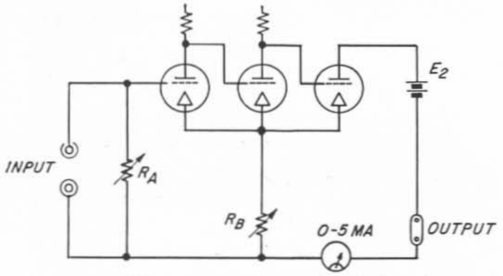


Figure 2. Elementary schematic of the Electrometer. The circuit is, fundamentally, a cathode follower in which the "tube" is a 3-stage, direct-coupled amplifier. The magnitude of the cathode resistor, RB, determines the voltage sensitivity.

ponents. As a consequence, drift after warm-up is normally less than 2 millivolts per hour.

Grid current at the input of the 3-tube direct-coupled amplifier is negligible, because the tube in the first stage is an electrometer type. The input resistance is determined by the setting of a switch that provides resistance standards in decimal steps from 10 kilohms to a hundred thousand megohms (10^{11} ohms).

The ability to measure from 30 millivolts full-scale to 10 volts full-scale, coupled with the wide range of resistance standards, permits current measurements from one milliampere full scale to 0.3 micro-microampere (3×10^{-13} amp.) full scale at an effective "ammeter" resistance appreciably less than the value of the resistance standard.

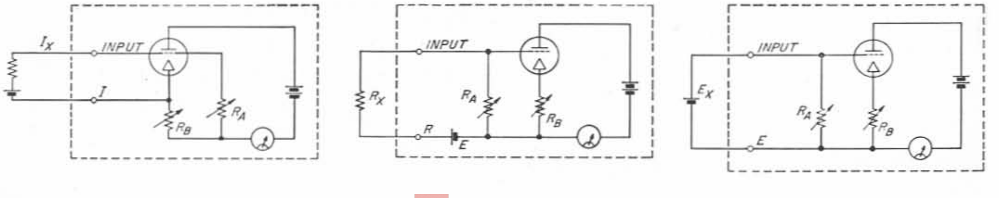
An internal stabilized-voltage source permits direct-reading resistance measurements from 300 kilohms to ten megamegohms at full scale (5×10^{14} ohms at the smallest meter division). Through use of the most sensitive voltage range and readily available external batteries, the resistance range can be extended by a factor of two hundred or more.

Circuit

Fundamentally, the circuit is a simple cathode follower where the "tube" is a three-stage amplifier as shown in the elementary schematic of Figure 2. Figure 3 shows the elementary circuit for each type of measurement. The effective transconductance is the product of the trans-conductance of the third stage and the voltage gain of the first two stages. The result is a transconductance in the millions of micromhos. Consequently, the input voltage is duplicated within a few microvolts across the cathode resistor, and excellent linearity is obtained even at the 30-millivolt scale. Voltage ranges are selected by changing the value of the cathode resistor.

The first two stages of the amplifier use sub-miniature tubes with ten-milliampere filaments. The filaments are in a resistor chain fed from a doubly stabilized voltage-regulating system. The plate and screen voltages of the first stage, as well as the screen voltage of the second stage, are obtained from this same highly stabilized supply. As a consequence of the great care used for stabilization, line voltage fluctuations have a negligible effect on performance. Balanced amplifier systems were tried but more reliable results were obtained by using the fully stabilized supply rather than the balancing method, which depends on perfect matching for adequate results.

Figure 3. Elementary schematics, showing, left to right, the circuits for measuring current, resistance, and voltage. The batteries are symbolic only; the instrument is entirely a-c operated.



High Input Resistance

The input resistance of the amplifier is about 10^{14} ohms when the input-resistance switch is at the open position. This extremely high resistance level is due not only to the use of an electrometer tube but also to unusual construction features. Every effort was made to obtain reliable operation under high humidity conditions. The glass envelope around the grid lead is treated with silicone. The resistance-standard selector switch uses switch contacts that are mounted on individual teflon bushings set in a metal base that connects to a guard point.

Internal Standards Calibration

To permit checking the high-resistance internal standards in terms of the low-resistance wire-wound standards, a check position is provided on the function switch. This has meant further elaboration of a switch already unusual in construction to meet the requirement of excellent performance at a 10^{14}-ohm level under adverse humidity conditions. The effort is well repaid in the ease with which the resistance of even the 10^{11}-ohm standard can be checked. A photograph of the switch is shown in Figure 4.

No Switching Transients

A switch is provided for readily disconnecting the unknown from the input without otherwise disturbing either the unknown circuit or the electrometer input circuit; to accomplish the switching without causing an electrostatic surge (due to friction of metal on dielectric) and without causing a change in capacitance with resultant voltage surge due to redistribution of charge, the contactor is raised by a teflon button with a metal rim in permanent contact with one of the blades.

Figure 4. View of the function switch.

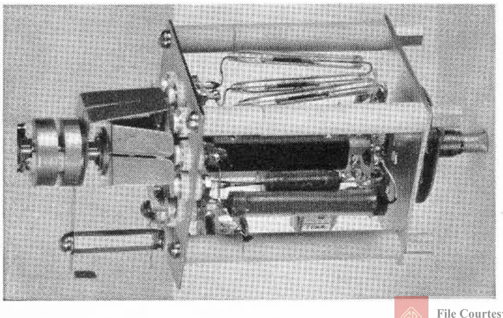


Figure 5. View of the Type 1230-P1 Component Shield plugged into the rear of the Electrometer.

Shielding

Complete shielding of the shock-mounted electrometer stage is important to eliminate grid currents due to ambient light, to prevent dust from entering and affecting the high resistance, and especially to isolate the input from random electrostatic potentials that are not usually noticed, but that become obvious at resistance levels in excess of 10^9 ohms.

The input connection is through a teflon-insulated coaxial terminal, and available accessories permit extension of the complete shielding to the unit under test. In particular, the TYPE 1230-P1 Component Shield provides a fully-shielded compartment within which components under measurement can be quickly and easily connected. The ground and guard terminals are duplicated on the panel of the Component Shield for greatest adaptability. Figure 5 shows the Component Shield plugged into the rear of the Electrometer.

Guard Terminals

While most measurements can be made by connecting the unknown (voltage, current or resistance) from the high input terminal to ground, there are some applications, especially in three-terminal resistance measurements, where guard points are necessary. Accordingly, the TYPE 1230-A Amplifier is provided with three guard terminals which can be grounded or not as desired. This arrangement is shown in Figure 6.

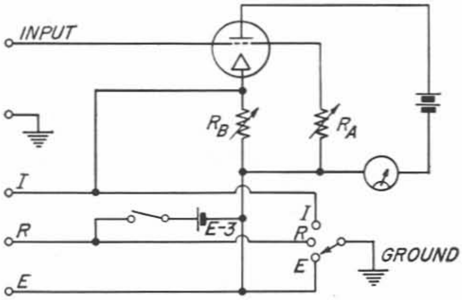


Figure 6. The I, R, and E terminals add appreciably to the versatility of the instrument. Any one of the three terminals can be used as a guard point (as in 3-terminal resistance measurements) and can be grounded by a panel switch.

Output

The output system comprises a 0–5 milliampere panel meter and a pair of terminals in series with the meter. The panel meter has two scales calibrated in volts and two scales calibrated in ohms so that both have two ranges per decade. Any external meter or recorder at the output terminals can have as much as 1500 ohms resistance without affecting performance. Thus, either the 5 ma or the 1 ma Esterline-Angus recorder can be connected to obtain permanent recordings of results. The amplifier is an ideal companion instrument to this Graphic Recorder since it can be mounted in the same type of case. The dynamic output resistance of the amplifier is but a fraction of an ohm; therefore, it is well adapted for operation with most recorders.

Applications

This latter feature adds appreciably to the long list of uses for the amplifier (see page 1). The leakage resistance of capacitors, as well as time-current curves under charge or discharge conditions, are readily obtained. This Electrometer is well suited to the measurement of the high back resistance of silicon-junction diodes, because the potential applied to the unknown resistance is only 9.1 volts, which is within the safe operating range of the diode.

—A. G. BOUSQUET

SPECIFICATIONS

Voltage Ranges: ± 30, 100, and 300 millivolts, ± 1, 3, and 10 volts, dc, full scale. Accuracy is ± 2% of full scale on the five highest ranges; ± 4% of full scale on the 30-mv range.

Current Ranges: ± 1 milliampere d-c (10^{-3} amp.) full scale to ± 300 milli-micromicroamperes (3×10^{-13} amp.) full scale, in twenty ranges (two per decade). Accuracy is ± 3% of full scale from 10^{-3} amp to 3×10^{-9} amp; ± 10% of full scale from 10^{-10} amp to 3×10^{-13} amp.

Resistance Ranges: Direct reading in resistance from 300 kilohms to 10 mega-megohms (10^{13} ohms) at full scale (5×10^{14} ohms at smallest meter division). There are sixteen ranges (two per decade). At full scale (low-frequency end) accuracy is ± 3% from 3×10^5 ohms to 10^{10} ohms; ± 8% from 3×10^{10} ohms to 10^{13} ohms. The voltage across the unknown resistance is 9.1 volts.

The resistance range may be extended considerably, and voltage coefficients of resistors determined, by the use of external batteries. With a 300-volt battery, the highest resistance range is 10^{15} ohms full scale (6×10^{16} ohms at the smallest meter division). The full battery voltage appears across the unknown resistance.

Resistance Standards: 10^4, 10^5, 10^6, 10^7, 10^8, 10^9, 10^{10}, and 10^{11} ohms. The switch also includes "zero" and "infinity" positions. The 10^4- and 10^5-ohms resistors are wire wound and are accurate to ± 0.25%. The 10^6-, 10^7- and 10^8-ohm resistors are of deposited-carbon construction and are accurate to ± 1%. The 10^9, 10^{10} and 10^{11} resistors are carbon, have been treated to prevent adverse humidity effects and are accurate to ± 5%. A switch position permits quick checking of the higher resistance standards in terms of the wire-wound units.

Input Resistance: The input resistance is determined by the setting of the resistance standards switch. In the infinity position, it is approximately 10^{14} ohms.

Drift: Less than 2 mv per hour after one-hour warmup.

Output: Voltage, current and resistance are indicated on a panel meter. Terminals are available for connecting a recorder (such as the Esterline-Angus 5-ma or 1-ma graphic recorder). The recorder can have a resistance of up to 1500 ohms.

Frequency Characteristic: With a 1500-ohm load at the OUTPUT terminals, the frequency characteristic is flat within 5% from zero to 10, 30, 100, 300, 1000 and 3000 cycles at the 30-, 100-, 300-millivolt, 1-, 3-, and 10-volt ranges respectively.

Terminals: The input is connected through an 874-type coaxial terminal assembly. In addition, there are three "low" terminals to provide versatility in guard and ground connections, as required, for example, in three-terminal network measurements.

Input Switch: A panel switch permits disconnection of the unknown without transient electrical disturbances in either the unknown or the measuring circuit.

Input Insulation: Entirely teflon or silicone-treated glass.

Temperature, Humidity, Line Voltage Effects: Negligible.

Tube Complement: One 5886 electrometer, one CK6418, one 6AN5, one 6AL5, one 6627, and three 0B2.

Accessories Supplied: One Type 874-411 Adaptor, one Type 1230-P1-300 Panel Adaptor Assembly, two Type 274-MB Plugs, one Type 274-SB Plug, spare fuses and Type CAP-35 Power Cord.

Accessories Available: Type 1230-P1 Component Shield.

Mounting: Aluminum front and rear panels finished in black-crackle lacquer and encased in an aluminum black-wrinkle-finished sleeve-like cabinet. The instrument is also available mounted inside a recorder case.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. Power input is approximately 35 watts at 115 volts.

Dimensions: (height) 13¼ × (width) 7⅝ × (depth) 9 inches, over-all.

Net Weight: 15¼ lbs.

Type		*Code Word*	*Price*
1230-A	**D-C Amplifier and Electrometer**	MASON	**$440.00**
1230-AE	**D-C Amplifier and Electrometer in Esterline-Angus Case**	MISTY	**502.00**
1230-P1	**Component Shield**	MANOR	**40.00**

A LOW-COST MICROWAVE SIGNAL SOURCE

One of the most frequently needed instruments in the electronics laboratory is a simple, convenient, and inexpensive signal source. General Radio Unit Oscillators were developed in answer to this need, and their constantly increasing popularity is conclusive evidence of how well they perform their tasks.

Unit Oscillators have been available

Figure 1. Panel view of the Type 1220-A Unit Klystron Oscillator with a Type 1201-A Unit Regulated Power Supply.

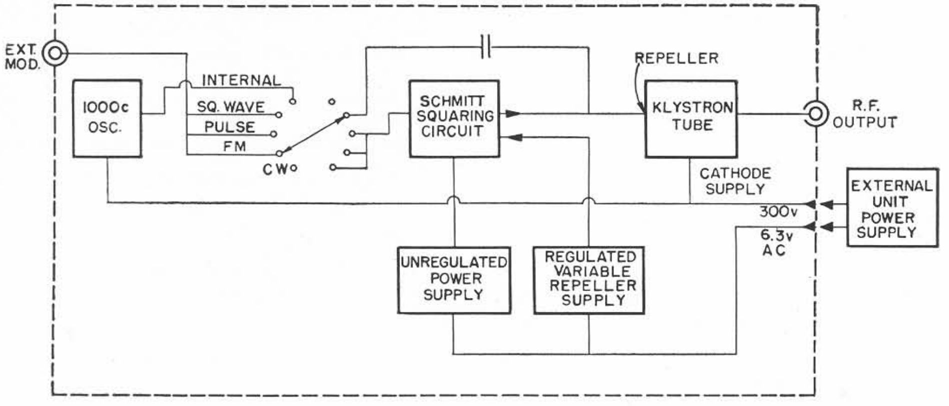


Figure 2. Block diagram showing the elements of the oscillator.

covering all frequencies from 20 cps to 2000 Mc, but there has been an obvious need for a unit to operate at still higher frequencies. The new Type 1220-A Unit Klystron Oscillator shown in Figure 1 meets this need for applications where frequent changes in frequency are not required.

It produces a c-w, square-wave-, pulse-, or frequency-modulated signal at frequencies between 2700 and 7450 megacycles by means of eight plug-in reflex klystrons. Each tube has a self-contained resonant cavity, which can be tuned over a range of the order of 500 megacycles. Tube changing can be accomplished quickly and simply. The oscillator is available either without tubes or with any number of the tubes in the available series.

Tuning is accomplished by flexing a copper diaphragm in the resonant cavity by means of a screw which is accessible from the rear of the instrument.

For testing on the production line, for measurements in the laboratory, and for demonstrations in the classroom, the Type 1220-A Unit Klystron Oscillator offers the advantages of low cost, small size, and convenient adaptability to the problem at hand.

Circuit

As shown in the block diagram of Figure 2, the Type 1220-A Unit Klystron Oscillator contains a variable regulated voltage supply for the repeller electrode of the klystron, a Schmitt squaring circuit for square-wave and pulse modulation of the repeller, a power supply for the Schmitt circuit, a 1000-cycle R-C oscillator, and a socket and output connections for the reflex klystron tube.

The cathode current for the klystron is supplied by an external Unit Power Supply. For maximum frequency stability, a Type 1201-A Unit Regulated Power Supply is recommended, although in less critical applications a Type 1203-A Unit Power Supply can be used. For field work, where only 6 or 12 volts d-c power is available, the instrument can be operated from a Type 1202-A Unit Vibrator Power Supply.

Klystron Oscillator

The reflex klystron is an excellent microwave oscillator. It produces a substantial amount of r-f power, operates on reasonably low voltages and can be modulated easily. Klystrons used in this instrument are completely self-contained oscillators and are similar in appearance and size to conventional metal-shell receiving tubes. The tuning ranges for the various tube types are given in the specifications at the end of this article.

As shown in Figure 3, the tubes plug into an octal socket in the instrument and the repeller voltage connection is made by means of a grid cap at the top of the tube. The r-f output lead from the tube is a coaxial line which extends through the tube socket and connects to the TYPE 874 Coaxial Connector on the panel of the instrument by means of a short length of coaxial cable with an adaptor for the tube line on one end.

Tuning is accomplished by means of a tuning screw, permanently attached to the side of the metal envelope, which controls the flexing of one end of the resonator and thus changes the capacitance across the resonant cavity in the oscillator. A special tool is supplied for making tuning adjustments through a hole in the back of the dust cover. The frequency thus can be adjusted without removing the dust cover, although no frequency calibration is provided.

Since the diaphragm will not stand an indefinite number of flexings without fatiguing, these tubes are not recommended for applications where continual frequency changing is required.

The repeller voltage must also be set at a level which produces oscillations at the resonant frequency of the cavity. For this purpose a calibrated repeller voltage control is provided on the front panel.

One of these tubes, TYPE 6043 Klystron, covering frequencies between 2950 and 3275 Mc, differs physically from all the other tubes. Its output connection is made near the top of the tube and tuning is accomplished by adjusting a series of screws in the outer wall of the cavity. This tube can be tuned indefinitely without damage but the dust cover must be removed to make the tuning adjustments. A special output lead is supplied for use with this tube. Both types of output lead are supplied with each instrument.

R-F Output

The power output obtainable varies from tube to tube and over the frequency range of each tube. The average power output for all tubes into a 50-ohm load is of the order of 75 milliwatts. A table showing the average power output of each tube type is included in the specifications appearing at the end of this article. This figure is the average of the power output over the frequency range for a typical tube. The output is usually a maximum at the center of the tuning range.

In most applications an isolating pad should be used between the oscillator and the load. One of the following pads is recommended:

TYPE 874-G6	6 db Pad
TYPE 874-G10	10 db Pad
TYPE 874-G20	20 db Pad

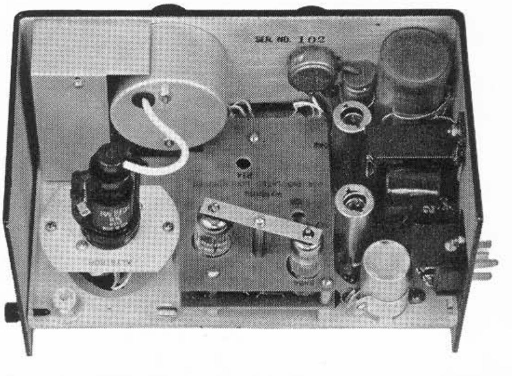


Figure 3. Top view of the oscillator with shield cover removed, showing the klystron tube.

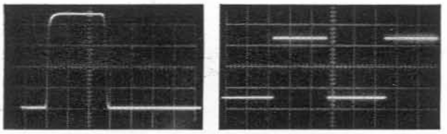


Figure 4. Oscillograms of modulation waveforms at 3800 Mc, as recovered by a Type 874-VR detector. Left, 1-μ sec pulse: right, 1000-cycle square wave.

Modulation

The klystron can be square-wave, pulse, or frequency modulated by modulating the repeller voltage. The Schmitt squaring circuit provides a voltage which switches the repeller voltage between the normal oscillating level and a non-oscillating level for 100% amplitude modulation. In order to make the klystron oscillate at exactly the same frequency when modulated as when unmodulated, the Schmitt circuit is d-c coupled to the repeller, and the whole circuit floats at the repeller potential. Since the klystron oscillates when the output stage of the Schmitt circuit is cut off, the repeller voltage (and hence the oscillating frequency) in the modulated condition is the same as the frequency in the unmodulated condition. A modulation voltage control is included in the plate circuit of the Schmitt circuit so that the klystron can be prevented from oscillating in other modes on the off part of the modulating cycle.

The Schmitt squaring circuit can be driven by a sine-wave, square-wave, or pulse signal. An internal R-C oscillator is provided for producing a 1000-cycle signal for square-wave modulation. The frequency of this oscillator is adjustable to any frequency between 985 and 1015 cycles so that maximum sensitivity can be obtained when very sharply tuned 1000-cycle amplifiers are used in the detector circuit. Square-wave modulation at frequencies between 50 cycles and 200 kc can be obtained from external sine- or square-wave sources, producing inputs of at least 15 volts rms. The Type 1210-B Unit R-C Oscillator is a satisfactory external modulator.

The klystron oscillator can be satisfactorily modulated by an external pulse generator with pulses having lengths from 1 μs to 10,000 μs and repetition rates between 50 cycles and 200 kc. The peak input voltage should be at least 25 volts. The rise and decay times of the r-f pulses are less than 0.2 μs. The Type 1217-A Unit Pulser is an excellent modulator.

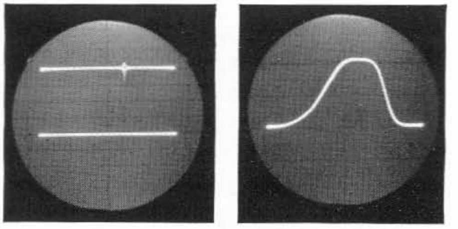


Figure 5. Left, frequency modulated output of the klystron; total swing, 8 Mc; modulating frequency, 60 cycles; carrier, 3800 Mc. The marker pip was introduced by an external oscillator. Base line added.

Right, band-pass characteristic of an f-m receiver with signal shown at left applied to receiver input. Signal was recovered from second detector.

Frequency modulation can be produced by the application of a small modulating voltage to the repeller electrode. The frequency deviation obtainable varies from tube to tube, but at least a 15 Mc total excursion is obtainable with a maximum change of 3 db in amplitude of the r-f signal. The amplitude variation decreases rapidly as the excursion is decreased. Provision is made for applying a frequency-modulating voltage from an external source. Approximately 10 volts, rms, across 47 kilohms is required for maximum frequency modulation.

Power Supply

The cathode current for the klystron is obtained from a Unit Power Supply. The Type 1201-A Unit Regulated Power Supply is recommended for maxi-

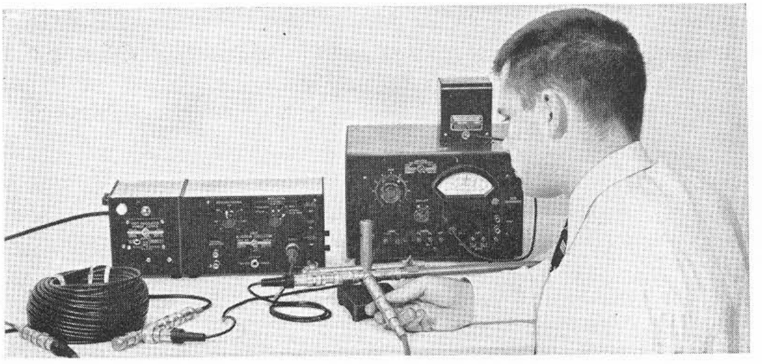


Figure 6. Unit Klystron Oscillator and Type 874 Coaxial equipment set up for the measurement of cable attenuation at 3000 megacycles.

mum frequency stability. A jack is provided for measuring the current and a rheostat is included for adjusting it.

The repeller voltage is obtained from a well-filtered, regulated, internal power supply derived from the 6.3v a-c output of the Unit Power Supply. A calibrated potentiometer, adjustable from the panel, is used to control the voltage from 30 to 300 volts below the cathode potential.

The power supply for the Schmitt circuit is also derived from the 6.3 a-c volt input from the Unit Power Supply.

Typical Applications

The Type 1220-A Unit Klystron Oscillator is well adapted to measurement applications in which the frequency does not have to be changed frequently.

On the production line, these relatively inexpensive units can be set up for measurements at specified frequencies on impedance, VSWR, attenuation, bandwidth, for adjusting circuits to a specified frequency, and for many other types of measurements.

In the laboratory the unit is a suitable signal source for driving a slotted line.

In the classroom, the low cost, small size, ruggedness, and high power output makes the oscillator ideal for supplying r-f power for various classroom demonstrations and student exercises.

Cable Attenuation Measurements

The oscillator is an excellent source of r-f power for making attenuation measurements on coaxial cable at the 3000 Mc frequency specified in Military Specification JAN C17A. One method of making this measurement is described in an article by W. R. Thurston entitled "The Measurement of Cable Characteristics." Figure 6 shows a typical setup for this measurement.

Measurement of VSWR of Fixed Attenuators at 4000 Mc

The klystron oscillator makes a good

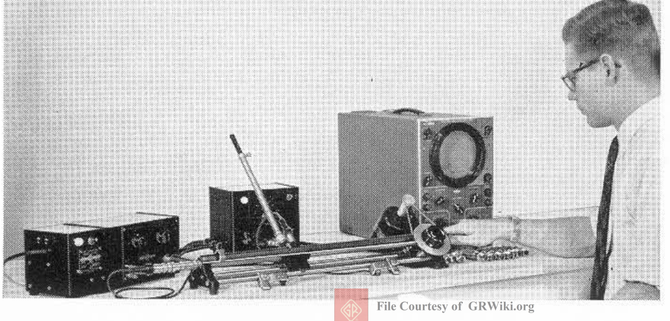


Figure 7. Unit Klystron Oscillator and Type 874-LBA Slotted Line with Motor Drive, set up for measurements of standing-wave ratio on coaxial attenuators.

source of power for VSWR measurements at one frequency on a number of elements. Figure 7 shows a setup for VSWR measurements on a group of fixed Attenuators at 4000 Mc, using a Type 874-LBA Slotted Line with a Type 874-MD Motor Drive and an oscilloscopic display of standing-wave ratio.

The oscillator can be used to excite waveguide circuits through a standard waveguide-to-coaxial adaptor. Adaptors to connect between the Type 874 output connector of the oscillator and the waveguide adaptor (and to other types of connectors) are listed in the price table.

— Benedict O'Brien
— R. A. Soderman

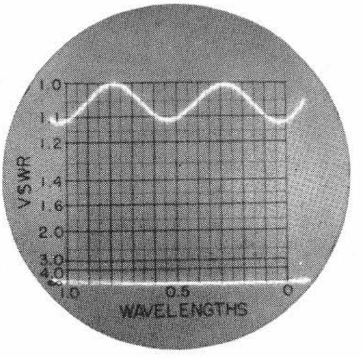


Figure 8. Oscilloscope display of VSWR of a Type 874-G20 Coaxial Attenuator at 4000 Mc, as measured with the equipment shown in Figure 7.

SPECIFICATIONS

Frequency Range: Depends on klystron tube used (see price table below); all units are identical except for klystron tube — frequency range of any unit can be changed to that of any other by inserting the appropriate klystron tube.

Frequency Calibration: None

Modulation:

Internal 1-kc square wave, adjustable ± 15 cycles.

External

Square wave, 50 c to 200 kc; sine or square-wave modulating signal of at least 15v, rms required — Type 1210-B R-C Oscillator recommended modulator.

Pulse, 1 to 10,000 μs duration, less than 0.2 μs rise and fall time, 50 c to 200 kc repetition rate; at least 20v peak pulse voltage required — Type 1217-A Unit Pulser recommended modulator.

Frequency Modulation, at least 15 Mc excursion obtainable with less than 3 db change in output — at 60 c, an rms input of the order of 10 v is suitable.

Output Connector: 50-ohm Type 874-Coaxial Connector. Adaptors to other connector types available.

Tube Complement: Klystron, as specified, for Types 1220-A1 through A-8; one 6AB4, one 5963, two OA2.

Accessories Required: Unit Power Supply; see price table below.

Type 1201-A Unit Regulated Power Supply recommended for high stability and minimum incidental fm.

Type 1203-A Unit Power Supply, for less critical applications where cost is an important factor.

Type 1202-A Unit Vibrator Power Supply, for use in the field from 6 v to 12 v, d-c power.

Accessories Recommended: Fixed attenuator pad for isolating oscillator from load; adaptors to other coaxial connectors. See price table below.

Dimensions: $9\frac{7}{8} \times 5\frac{3}{4} \times 6\frac{1}{4}$ inches, not including plugs, knobs, and terminals.

Net Weight: 6 pounds, with klystron.

Type	*Klystron Oscillator with klystron, for*	*Nominal Power Output in Milliwatts*	*Code Word*	*Price*
1220-A1	**2700–2960 Mc........**	**100**	KAWUN	**$254.65**
1220-A2	**2950–3275 Mc........**	**90**	KATOO	**272.90**
1220-A3	**3400–3960 Mc........**	**90**	KATRE	**265.75**
1220-A4	**3840–4460 Mc........**	**75**	KAFOR	**312.15**
1220-A5	**4240–4910 Mc........**	**100**	KAFIN	**261.45**
1220-A6	**5100–5900 Mc........**	**80**	KASIX	**301.45**
1220-A7	**5925–6450 Mc........**	**100**	KASET	**272.90**
1220-A8	**6200–7425 Mc........**	**90**	KALOC	**272.90**
1220-A	**Without Tube.........**		KANOT	**205.00**

ACCESSORIES

KLYSTRON TUBES

Type		Code Word	Price
726-C	Klystron, 2700–2960 Mc	KLYSTRONAY	$49.65
6043	Klystron, 2950–3275 Mc	KLYSTROBEE	67.90
2K29	Klystron, 3400–3960 Mc	KLYSTROSEE	60.75
2K56	Klystron, 3840–4460 Mc	KLYSTRODEE	107.15
2K22	Klystron, 4240–4910 Mc	KLYSTRONEE	56.45
6115	Klystron, 5100–5900 Mc	KLYSTRONEF	96.45
QK404	Klystron, 5925–6450 Mc	KLYSTROGEE	67.90
5976	Klystron, 6200–7425 Mc	KLYSTROJAY	67.90

The following klystron tubes can also be used in the instrument, but are not stocked by the General Radio Company: 2K25 (8500-9660 Mc), 2K26 (6250–7060).

All klystron tubes in these oscillators except for the 6043 are designed for relatively infrequent tuning.

POWER SUPPLIES (One required)

Type		Code Word	Price
1201-A	Unit Regulated Power Supply	ASSET	$80.00
1203-A	Unit Power Supply	ALIVE	40.00
1202-A	Unit Vibrator Power Supply	AURAL	125.00

PADS

Type		Code Word	Price
874-G6	Attenuator Pad, 6 db	COAXNODDER	$25.00
874-G10	Attenuator Pad, 10 db	COAXBELLER	25.00
874-G20	Attenuator Pad, 20 db	COAXNEPPER	25.00

ADAPTORS

Type	Contains Type 874 Connector and	Fits	Code Word	Price
874-QBJ	Type BNC Jack	Type BNC Plug	COAXBOGGER	$4.75
874-QBP	Type BNC Plug	Type BNC Jack	COAXBUNNER	4.75
874-QCJ	Type C Jack	Type C Plug	COAXCOGGER	4.75
874-QCP	Type C Plug	Type C Jack	COAXCUFFER	6.25
874-QHJ	Type HN Jack	Type HN Plug	COAXHAWSER	6.50
874-QHP	Type HN Plug	Type HN Jack	COAXHANGER	6.50
874-QLJ	Type LC Jack	Type LC Plug	COAXLITTER	17.50
874-QLP	Type LC Plug	Type LC Jack	COAXLUGGER	17.50
874-QNJ	Type N Jack	Type N Plug	COAXNAGGER	3.75
874-QNP	Type N Plug	Type N Jack	COAXNUTTER	4.50
874-QUJ	Type UHF Jack	Type UHF Plug	COAXYUNDER	4.00
874-QUP	Type UHF Plug	Type UHF Jack	COAXYUPPER	4.25

NEW DIAL BRINGS NEW CONVENIENCE TO OCTAVE-BAND NOISE MEASUREMENTS

A user of the Type 1550-A Octave-Band Analyzer recently suggested that the speed and convenience of noise measurements could be increased by the use of an adjustable dial on the attenuator control. This dial has been designed and is available to all users of the analyzer.

The dial covers the panel engraving behind the attenuator knob, and carries a new number scale so that the Octave-Band Analyzer is direct reading, thus avoiding the mental computations (and possible sources of error) previously necessary. For example, in the measurement of octave-band pressure levels greater than 70 db, where the Octave-Band Analyzer is used directly with a microphone, the system can be calibrated with the Type 1552-B Sound-Level Calibrator to be direct reading on the 20c-to-10kc range (over-all sound-pressure level), whereupon the system is automatically direct-reading in octave-band pressure levels.

To achieve the same result where the Octave-Band Analyzer is used in conjunction with the Type 1551-A Sound-Level Meter, it is necessary only to position the new dial and to adjust the "gain" control so that the Octave-Band Analyzer in its 20c-to-10kc position reads the same as the Sound-Level Meter on its "C" weighting network.

One of these dials will be sent, free of charge, to the owner of each Type 1550-A Octave-Band Analyzer who writes us, giving his name and address, and the serial number of the instrument. This new dial is now shipped as standard equipment with each new Octave-Band Analyzer.

— J. J. Faran, Jr.

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A HIGH-PRECISION IMPEDANCE COMPARATOR

Also IN THIS ISSUE

The increased need for means of rapid sorting of electrical components has led to the extensive use of impedance comparators, which indicate directly the percent difference between two impedances without requiring a bridge balance. Most of these operate either at dc or at a fixed low frequency and are limited in scope to simple applications. The new Type 1605-A Impedance Comparator[1] can be used to compare complex impedances of any phase angle and has several important features which allow a much greater degree of precision and considerably more versatility than other instruments available.

This instrument indicates not only the difference in magnitude between the

[1] Holtje, Hall, and Easton, "An Instrument for the Precise Comparison of Impedance and Dissipation Factor," *Proceedings of the National Electronics Conference*, Vol. 10, 1955.

Figure 1. Panel View, Type 1605-A Impedance Comparator.

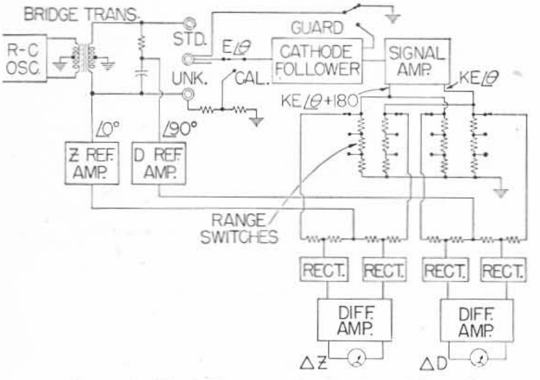


Figure 2. Block Diagram, Type 1605-A Impedance Comparator.

two components that are compared, but also indicates simultaneously the phase-angle difference, which is often of equal importance. The difference in these quantities can be determined to 0.01% and .0001 radian, respectively, on the most sensitive ranges. Both magnitude and phase-angle differences are indicated directly on panel meters.

The Impedance Comparator will indicate differences between components, whether resistive, capacitive, or inductive, with a precision hitherto unobtainable in direct-indicating instruments; measure the phase-angle difference between different types of resistors; indicate the departure from uniformity of units in a gang; measure the degree of unbalance in transformer windings; compare dielectric samples; and facilitate the adjustment of inductors to precise values.

The comparator is completely self-contained, including a calibrating voltage to check the operation of the instrument. The meter voltages are available externally to operate recorders, remote indicators, or automatic selecting devices. If the unknown is remote, the internal guard circuit can be used to minimize the effect of stray impedances.

The internal oscillator provides frequencies from 100 cycles to 100 kc in decade steps, so that components may be checked over a wide frequency range. This feature is particularly important for components that must be checked at a frequency near the desired operating frequency.

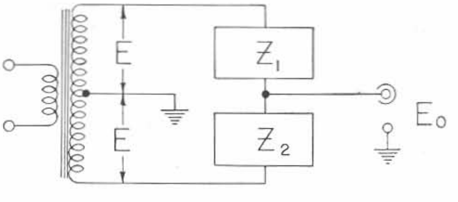
Circuit

The electronic circuitry and the components necessary to provide the impedance-difference and phase-angle-difference information at the desired precision in a single, self-contained unit have produced several interesting development problems.

A block diagram of the instrument is shown in Figure 2. An amplitude-stabilized, R-C oscillator provides the four test frequencies. The oscillator is coupled to the bridge through a special bridge transformer, which also provides the inductively coupled unity-ratio arms. The standard and unknown impedances form the other two arms.

The unbalance voltage from the bridge is amplified, and the push-pull output attenuated with two separate range switches to provide independent magnitude and phase-difference ranges. Separate phase-sensitive detectors are used to measure the in-phase and quadrature voltage components. The two orthogonal components are fed to differential amplifiers, which drive the output meters.

Figure 3. Basic Bridge Circuit.



$$\frac{E_0}{E} = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

The instrument is calibrated by injecting a 1% unbalance voltage and setting the oscillator level to give the correct reading.

The Bridge Equations

The basic bridge circuit is shown in Figure 3. If the voltages across the windings are equal, the complex unbalance voltage is

$$\frac{E_0}{E_{in}} = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

The real part of this voltage (component in phase with E_{in}) is

$$Re\left(\frac{E_0}{E_{in}}\right) = \frac{\dfrac{|Z_1| - |Z_2|}{|Z_1| + |Z_2|}}{1 + \dfrac{cos(\Theta_1 - \Theta_2) - 1}{\dfrac{|Z_1|}{2|Z_2|} + \dfrac{|Z_2|}{2|Z_1|} + 1}}$$

If $\Theta_1 - \Theta_2$ is small, the above equation reduces to:

$$Re\left(\frac{E_0}{E_{in}}\right) = \frac{|Z_1| - |Z_2|}{|Z_1| + |Z_2|}$$

Within the range of the instrument ($\Theta_1 - \Theta_2 = .1$ radian), this approximation is extremely good, producing an error of less than 0.25% of the actual impedance-difference range, which is insignificant on all ranges. For example, in a measured difference of 0.3%, this error would amount to 0.25% × 0.3% or 7.5 parts per million.

Since the difference is usually desired as a percentage of the standard impedance rather than as a percentage of the sum of the standard and unknown impedances, another approximation is necessary. If $Z_1 - Z_2$ is small

$$Re\left(\frac{E_0}{E_{in}}\right) = \frac{1}{2}\,\frac{|Z_1| - |Z_2|}{|Z_2|}$$

The error due to this last approximation is negligible except on the 10% range, where the scale becomes non-linear, indicating 9.5% instead of 10% on one side and 10.5% on the other. This is not an error in measurement, but rather a non-linearity of scale. To avoid complicated meter scales, the tolerance can be modified, or the zero shifted, when 10% components are to be sorted to better than ±0.5%.

The imaginary part of the bridge unbalance voltage can be written as

$$Im\left(\frac{E_0}{E_{in}}\right) = \frac{sin\ (\Theta_1 - \Theta_2)}{cos\ (\Theta_1 - \Theta_2) + \frac{1}{2}\left(\frac{|Z_1|}{|Z_2|} + \frac{|Z_2|}{|Z_1|}\right)}$$

If the magnitude difference is less than 10%, and the phase-angle difference is less than 0.1 radian (the maximum ranges), the above expression reduces to

$$Im\left(\frac{E_0}{E_{in}}\right) = \frac{1}{2}(\Theta_1 - \Theta_2)$$

with an error of less than 0.25 percent. Note again that this error is a percent of the indicated difference and, therefore, completely negligible.

The Bridge Transformer

In the above calculations on the bridge voltage, it was assumed that the voltages across the two windings of the transformer were equal. A difference in these voltages would cause a corresponding difference on the meter indication. Not only must the two voltages be equal, but the source impedances of the windings must be matched, or an error will result when the low-impedance components are measured. It is also desirable to have the two windings tightly coupled, so that stray impedance shunting one winding will not cause a voltage unbalance.

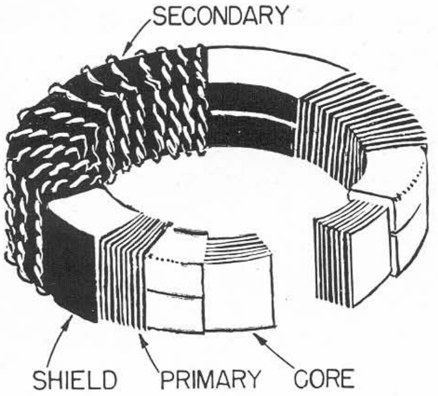


Figure 4. Bridge-Transformer Construction.

Figure 4 is a sketch of this transformer, showing its construction. It is a toroidal structure, with a high-permeability, wound-ribbon core. The inside winding is the primary, which is a modified banked winding, completely and symmetrically covering the core. Over this are two copper cup-shaped shields to prevent unwanted electrostatic coupling to the secondary.

The secondary windings are made by twisting together two identical wires and winding the pair. This is a practical approximation to the ideal situation where the wires of the two windings would occupy the same volume so that the flux linkage would be equal, producing unity coupling and equal output voltages.

This construction works extremely well. The open-circuit voltages are balanced to within 1 part in 10^6, the impedance difference (at 1 kc) is less than 50 microhms, and the coefficient of coupling is greater than 0.9997. These quantities approach the ideal so closely that 0.1 μf placed across one winding at 1 kc will cause an impedance-difference error of .0002% and a phase-angle error of .00005 radian. At 100 kc, with 1000 $\mu\mu$f shunting one winding, corresponding errors are 0.02% and .00005.

With resistive ratio arms, a resistance value as low as 0.1 ohm would be necessary to obtain an equal degree of immunity from shunt capacitance effects.

The Guard Circuit

The output voltage from the bridge is fed to a high-input-impedance cathode-follower-type circuit, which also provides a low-impedance guard voltage isolated from the signal. This guard circuit makes possible measurements of large impedances located at some distance from the instrument itself, as for example, a component in an environmental test chamber.

Since capacitance from one side of the transformer to ground has so little effect, the lead from this terminal to the unknown can be shielded without introducing error. However, capacitance to ground of the other lead, which is connected to the amplifier input, produces attenuation and phase shift of the signal voltage if the measured component is of high impedance. This capacitance is especially large if the lead is shielded to prevent unwanted pickup. In order to reduce this effect, a guard voltage is brought out, which can be used to drive the amplifier input shield. Since the guard voltage is approximately 0.97 of the amplifier input, the capacitance to the shield is effectively reduced by a factor of 30.

The Phase-Sensitive Detector

The circuit of the phase-sensitive detector used to separate the in-phase and quadrature components of the unbalance voltage was chosen for its precision and stability.

The output of the signal amplifier (E_s) is added to and subtracted from the reference voltages (E_r) which are derived from the bridge voltage.

One reference is in phase with the bridge voltage; the other is at ninety degrees.

If the reference voltage is much larger than the signal voltage (Figure 5), the difference in magnitude between the resulting sum and difference is equal to twice that component of the signal which is in phase with the reference.

The condition that the reference be much larger than the signal is easily met when the two meters are set to corresponding ranges, in which case the signal is about one one-hundredth of the reference. However, if one meter is indicating full scale on the 10% (or .1 radian) scale, and the other on the 0.3% (.003 radian) scale, it is possible to increase this voltage ratio to ⅓, causing the readings on the more sensitive scale to be low by 5%. This produces a maximum error of 5% × 0.3% = 0.015%.

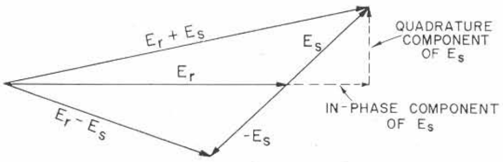


Figure 5. Phase-Sensitive Detector Operation.

Ranges

Four independent ranges are provided for the impedance-difference and phase-angle-difference meters. The impedance-difference ranges are 10%, 3%, 1% and 0.3%, and the phase-angle-difference ranges are 0.1, 0.03, 0.01 and 0.003 radian full scale. On the most sensitive ranges, one scale division represents 0.01% or .0001 radian. The ranges can be increased to 20 or 30 percent by calibrating at half scale, or on a lower scale, which reduces the bridge voltages. If the D or Q of the standard is less than 0.1, the phase-angle difference in radians is very nearly equal numerically to the D or Q difference.

The range of impedances that the instrument will compare is limited by practical considerations at both ends. For reactive components, the wide frequency range makes it possible to extend the range of inductance or capacitance which can be measured.

The low-impedance limit is determined by the difficulty in making low-resistance connections to the comparator and by the power available from the bridge oscillator. The nominal limit is 2 ohms, so that the smallest unbalance that can be determined is 200 μohms. This two-ohm limit can be decreased somewhat by reducing the oscillator voltage, but the sensitivity is also reduced.

The upper impedance limit for this type of instrument depends upon the input impedance of the detector circuit.

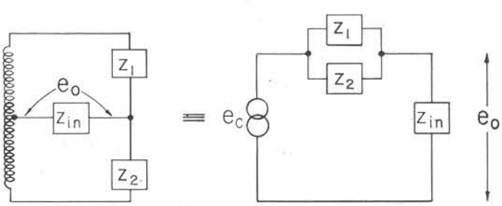


Figure 6. Equivalent Circuit of Loaded Bridge.

This dependence can be seen from the equivalent circuit shown in Figure 6.

The amplifier input impedance attenuates the bridge unbalance voltage so that the actual detector voltage is

$$e_o = \frac{Z_{in}}{Z_{in} + \dfrac{Z_1 Z_2}{Z_1 + Z_2}} e_c$$

where e_c is the correct or unattenuated output signal.

To minimize this effect, Z_{in} should be large as possible. The input impedance is approximately 4 $\mu\mu$f in parallel with 200 megohms. Therefore, the indicated difference will be low by 10% when 20-$\mu\mu$f capacitors are compared.

The input resistance will cause a phase-angle error. This error, however, is frequency dependent and can be made small if the measurement is made at high frequencies.

When resistors are measured, the indicated difference will be low by 10% when the value of the standard and unknown components reaches 40 megohms. The phase-angle error due to input capacitance can be minimized by measurement at low frequencies.

Another limitation when high impedances are measured is hum pickup, which can overload the amplifier if the impedances are high at power-line frequencies. This difficulty can usually be overcome by proper grounding and shielding.

Errors

The errors produced by the approximation made in evaluating the real and imaginary parts of the bridge voltage were shown to be completely negligible when the bridge was used within its ranges. The only difficulty here is the scale non-linearity when the impedance difference approaches 10%. This is not really an error, but rather a known calibration change, which can be corrected.

The error in separating the voltage components is negligible, except for the small error produced when the measurement is made on the most sensitive range on one meter with the other meter indicating nearly full scale on its least sensitive range.

The possibility of a 30-to-1 difference in full-scale sensitivity results in several restrictions on the oscillator and phase-shift networks. If the impedance magnitude unbalance is very large, a small departure of the reference-voltage phase angle from 90° will cause some of the large in-phase voltage to produce a small indication on the phase-difference meter when it is set to its most sensitive range. This error is proportional to the impedance difference. If $\triangle|Z|$ is 10%, a 0.1% change in frequency, or in the elements of the phase-shift network, will produce an error of .0001 radian.

Oscillator harmonics will also cause an error since they are not shifted 90° in the phase-shift network.

These errors should be less than a few divisions when $\triangle|Z|$ is 10% and therefore only important when very small phase-angle differences are to be measured with a large impedance difference.

By far the largest error is caused by the one-percent meter. This can produce a measurement error of 2% of full scale since a zero center scale is used. Thus, the over-all accuracy of difference indications is about 3%. This is one meter division or 0.01% on the 0.3% range. If either meter is used on the 10% range, the errors can be slightly larger.

Applications

The versatility of this bridge can be indicated by a brief summary of the uses to which the early models have already been applied. Among these are:

1. Measuring the drift of deposited-carbon resistors. The changes to be measured were very small, and repeated measurements were made on thousands of units. Without the accuracy and the speed of measurement offered by the Impedance Comparator, these studies would have been so time consuming as to be impractical.

2. Inspection of silvered-mica sheets for use in standard capacitors. Sheets

with excessive losses are rapidly identified and rejected.

3. Measuring the phase shift in various types of wire-wound resistors. Here, the problem was to select resistors for audio-frequency voltage dividers in which phase shift could not be tolerated.

4. Measurement of the coefficients of temperature and humidity of components in an environmental test chamber. In this application the guard terminal is used, and, since the meter voltages are brought out to terminals, a graphic recorder is operated to yield a permanent record of the test data.

5. Inspection and adjustment of ganged capacitors and potentiometers for desired tolerance in tracking.

6. Adjusting inductors to precise tolerances by adding or removing turns.

7. Comparing samples of dielectric materials.

8. Inspection of balanced transformer windings.

9. Automatic sorting — two units are already scheduled for use in automatic sorters. The ability to measure both magnitude and phase differences makes possible the automatic inspection of complex networks. An example of this is the testing of etched circuits by measurement at test points.

The precision and speed of this comparator bring laboratory accuracy to production-line testing; conversely, it brings production-test speed to laboratory measurements. Its unusual combination of features make it a truly universal instrument, equally useful in both fields of application.

— MALCOLM C. HOLTJE
— HENRY P. HALL

SPECIFICATIONS

Impedance Ranges:

Resistance or impedance magnitude: 2 Ω to 20 MΩ.

Capacitance: 40 μμf to 500 μf; to 0.1 μμf with reduced sensitivity.

Inductance: 10 μh to 10,000 h.

Internal Oscillator Frequencies: 100 c, 1 kc, 10 kc, and 100 kc; all ± 3%.

Meter Ranges:

Impedance Magnitude Difference: ± 0.3%, ± 1%, ± 3%, ± 10% full scale.

Phase Angle Difference: ± 0.003, ± 0.01, ± 0.003, ± 0.1 radian full scale.

Accuracy of Difference Readings: 3% of full scale.

Voltage Across Standard and Unknown: approx. 0.15 volt.

Tube Complement:

1-5651	5-12AT7
1-5751	3-6U8
3-12AX7	1-6AS7G
4-6AL5	1-3A10
1-VE-65A1	

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles; 100 watts input at 115 v line.

Mounting: Relay-rack panel with cabinet; TYPE 1605-AR has fittings to permit either instrument or cabinet to be removed from rack without disturbing the other; TYPE 1605-AM has end supports for table or bench use.

Dimensions: Panel 10 x 8¾ inches; depth behind panel, 12 inches.

Net Weight: 29½ lbs.

Type		*Code Word*	*Price*
1605-AR	**Impedance Comparator (relay-rack mounting)...**	GUNNY	**$790.00**
1605-AM	**Impedance Comparator (bench mounting)......**	GIPSY	**790.00**

U. S. Patent No. 2,548,457.

NEW COAXIAL ELEMENTS
ATTENUATORS, FILTERS, LINE STRETCHERS, DETECTORS, ADAPTORS

The continuing development program for improving and expanding the line of TYPE 874 Coaxial Elements has resulted in the addition of several new components. A new series of fixed attenuators having very low VSWR and high stability have been developed, along with two new low-pass filters, two different types of constant-impedance adjustable-length line, adaptors from TYPE 874 Connectors to TYPE LC Connectors, and a new crystal detector.

FIXED ATTENUATORS

A fixed attenuator is often used to reduce the VSWR of a generator, detector, or other element; to reduce the signal level by a known amount; or to provide isolation between two parts of a circuit. The requirements for these applications are very satisfactorily met by the new TYPE 874-G Fixed Attenuators (Figure 1), which are available in 3-, 6-, 10-, and 20-db sizes and have a high power-handling capacity, a low VSWR up to 4000 Mc, and small size.

Figure 1. Type 874-G Fixed Attenuator.

The attenuating element is a resistive T-pad made up of deposited-carbon resistance elements on a ceramic base. The resistor assembly is a single integral unit. The use of deposited-carbon resistance elements gives the pads high

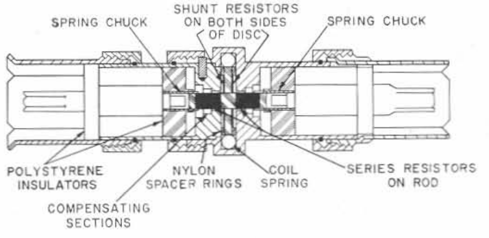


Figure 2. Cross-Section of Fixed Attenuator.

stability and accuracy. All resistances are held within ±1%.

The T elements are mounted as shown in Figure 2, with the series elements connected to the center conductors of the input and output lines by means of spring chucks, and the shunt element connected to the outer shell of the line by means of a coil spring, which is pressed into a groove in the outer conductor. The outer edge of the disk on the T element slides into the ring formed by the spring, compressing the spring radially and causing each coil of the spring to make a good connection between the walls of the groove and the outer rim of the disk. In this manner, an excellent low-inductance connection is produced. The reactances of the elements in the tee are controlled by shaping the outer conductor in the vicinity of the resistive elements.

These pads are equipped with TYPE 874 Coaxial Connectors at each end. An extensive series of adaptors is available, which makes possible very low-reflection connections to most of the commonly used types of coaxial fittings.[1]

[1] See *General Radio Experimenter* for March 1956, page 11.

VSWR

These pads have excellent VSWR characteristics. The VSWR of a typical unit from dc to 4000 Mc is shown in Figure 3. For a 20-db pad, the VSWR is below 1.1 up to 1000 Mc and below 1.30 up to 4000 Mc. The VSWR tends to be slightly higher in the lower attenuation units.

Attenuation

The magnitude of the attenuation varies only slightly with frequency and very slightly between units. At dc the 1% tolerance on the resistance elements can cause a maximum error of 0.17 db in the 20-db pad. This maximum error decreases with the attenuation of the pad. The variation in attenuation with frequency of a typical unit is plotted in Figure 3.

Power-Handling Capacity

The continuous power rating of 1 watt cw is adequate for most applications. In pulse applications, the deposited-carbon elements will easily stand a pulse having a peak power of 3 kw as long as the average power does not exceed 1 watt.

Constant-Impedance Adjustable-Length Lines

Two new adjustable-length lines have been developed. One, the TYPE 874-LT, consists of two TYPE 874-LK20* Constant-Impedance Adjustable Lines permanently connected to a U-block to form a "trombone" as shown in Figure 4. The advantage of this arrangement is that the length of line can be varied without moving either the input or output connections. In many applications, a considerable amount of bench space can be saved if the trombone is mounted vertically on a TYPE 874-Z Stand. Two

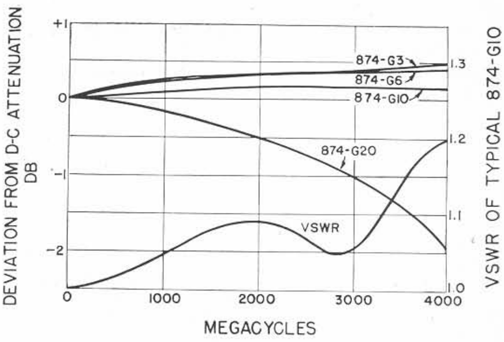


Figure 3. VSWR and Variation in Attenuation with Frequency for Type 874-G Fixed Attenuators.

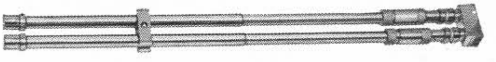


Figure 4. Type 874-LT Trombone Constant-Impedance Adjustable Line.

TYPE 874-EL Ells can be connected to the ends of the line to make the input and output connectors face back-to-back on the same line.

The maximum variation in line length is 44 cm or one-half wavelength at 340 Mc. The VSWR of a typical unit is shown in Figure 5. This line stretcher is primarily designed for use below 2000 Mc, but can be used up to 5000 Mc.

Threaded holes are provided for attaching the unit to a lead-screw or rack-and-pinion drive if desired.

The second new adjustable line is the TYPE 874-LK10 Constant-Impedance Adjustable Line, which is a shorter version of the TYPE 874-LK20* Line. The new line is primarily designed for use above 1500 Mc since its length can be varied over a half wavelength at this and higher frequencies. There is, however, no low-frequency limitation on its use. Its small size makes it more convenient to use at the higher frequencies. The VSWR of a typical unit is shown in Figure 5.

* Formerly, TYPE 874-LK.

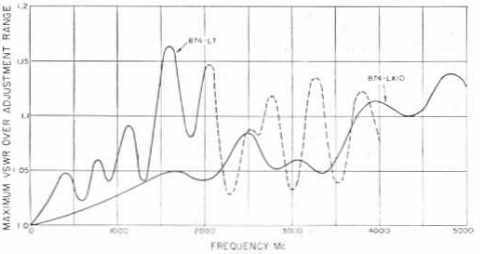


Figure 5. VSWR of Types 874-LT and 874-LK10 Adjustable Lines.

LOW-PASS FILTERS

Two new low-pass filters have been added to the line, for measurement applications in the frequency range above 1000 Mc. These units, the TYPE 874-F2000 and -F4000 Low-Pass Filters, cut off at 2000 Mc and 4000 Mc respectively and are similar to the TYPE 874-F185, -F500 and -F1000 Low-Pass Filters already available. All these filters are designed on a Tsychebyscheff basis, in order to obtain the maximum rate of cutoff and minimum spurious responses in the passband. The design allows a maximum of 4 db of insertion loss in the passband.

In measurements of high standing-wave ratios or of large values of insertion loss, the use of a low-pass filter to eliminate harmonics is usually necessary. The TYPE 874-F series of filters is well suited to these measurements. Figure 6 shows a typical frequency characteristic.

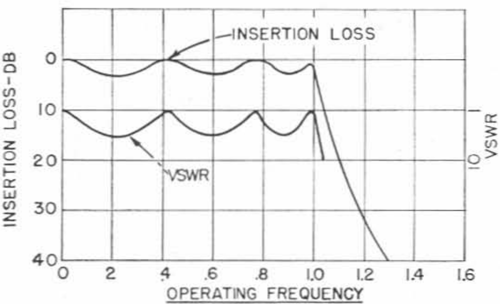


Figure 6. Typical Frequency Characteristic, Type 874-F Low-Pass Filter.

CRYSTAL VOLTMETER DETECTOR

In many measurements, a well-matched detector is needed, or a voltage at some point along a 50-ohm line must be measured or monitored without introducing a large discontinuity in the line. The TYPE 874-VQ Voltmeter Detector will perform either of these functions. As shown in Figures 7 and 8, it is similar to the TYPE 874-VR Voltmeter Rectifier, except that it does not contain a series 50-ohm resistor, and it does contain compensating elements to minimize the discontinuity produced by the shunt reactance of the crystal diode. As shown in Figure 9, this unit produces a very low VSWR in a matched 50-ohm line at frequencies up to 2000

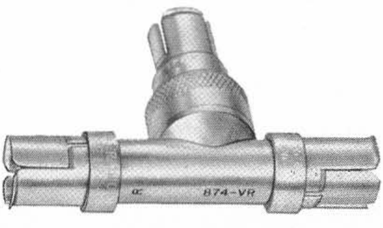


Figure 7. Type 874-VR Voltmeter Rectifier (similar to Type 874-VQ Voltmeter Detector).

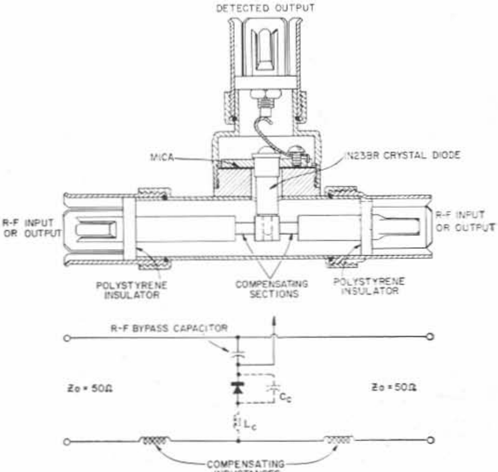


Figure 8. Cross-Section of Type 874-VQ Voltmeter Detector.

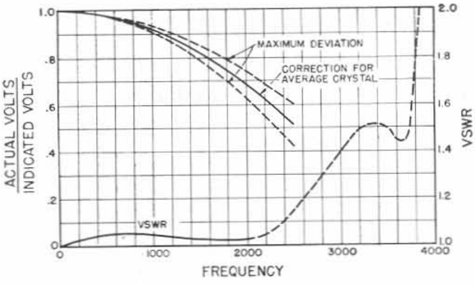


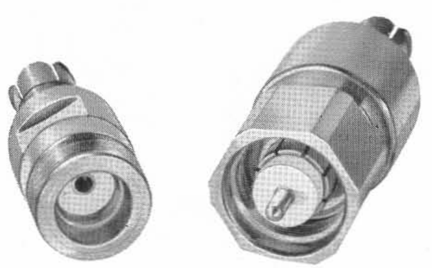
Figure 9. VSWR and Frequency Response of Type 874-VQ Voltmeter Detector.

Mc. The detector can therefore be inserted in a 50-ohm line without destroying the match. Above 2000 Mc, resonances in the crystal cause the VSWR to rise rather rapidly. For voltage measurement, the TYPE 874-VI Voltmeter Indicator is used. An ordinary d-c voltmeter can be used for monitoring power.

This detector can also be used to recover the modulation from the r-f signal; the modulation appears across the output connector. The output r-f bypass capacitor is 300 $\mu\mu$f; and, therefore, for modulation signals that include high-frequency components, a suitable load resistor must be connected across the output. When one end of the coaxial line is terminated in a TYPE 874-WM Termination Unit, the assembly can be used as a well-matched detector.

One important application is in conjunction with the TYPE 874-VR Voltmeter Rectifier, the TYPE 1263-A Regulating Power Supply, and the TYPE 1750-A Sweep Drive[2] for measurements of the transmission characteristics of various elements and networks. The voltmeter rectifier is used at the input to the unknown to keep the input voltage constant, and the voltmeter detector, terminated in a TYPE 874-WM Termination Unit, is used at the output to measure the output signal. A TYPE 1N23BR Reversed-Polarity Crystal Diode is supplied in order to present a right-side-up response curve on the face of an oscilloscope.

Figure 10. Types 874-QLJ and 874-QLP Adaptors.

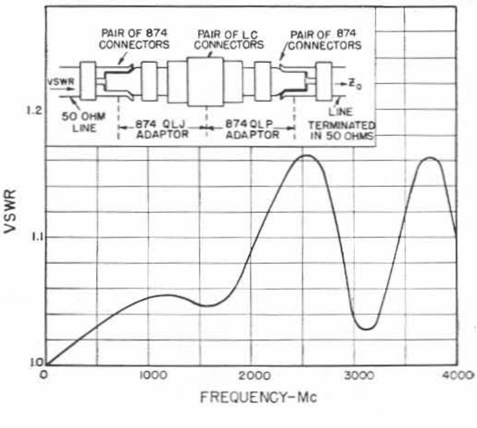


ADAPTORS TO TYPE LC CONNECTORS

With the increased activity in the use of large-sized coaxial cable in high-power applications, there has been an increasing demand for adaptors to TYPE 874 Connectors to facilitate measurements on circuits fitted with TYPE LC Connectors. The TYPE 874-QLJ Adaptor mates with low-voltage TYPE LC plug-type connectors for TYPE RG17/U cable, similar to TYPE UG154/U; and the TYPE 874 QLP Adaptor mates with low-voltage jack-type connectors, similar to TYPE UG352A/U.

[2] See *General Radio Experimenter* for April, 1955.

Figure 11. VSWR and Diagram of Types 874-QLJ and 874-QLP Adaptors.



SPECIFICATIONS

TYPES 874-G3, G6, G10, G20 FIXED ATTENUATORS

Impedance: 50 ohms ± 1%.
VSWR: Less than 1.1 to 1000 Mc, 1.30 to 4000 Mc for 874-G20, 1.35 to 4000 Mc for all other attenuators.
Maximum Continuous Power Input: 1 watt.
Maximum Peak Power Input: 3000 watts.
Physical Length: 3½ inches over-all.
Weight: 2 ounces.
Accuracy of Attenuation in 50-ohm System: ± 1.5% of nominal attenuation at dc, ± 0.2 db from value indicated in Figure 3 to 1000 Mc, ± 0.4 db to 2000 Mc, ±0.6 db to 4000 Mc.
Temperature Coefficient: Less than 0 0003 db/°C/db.

TYPE 874-LT TROMBONE CONSTANT-IMPEDANCE ADJUSTABLE LINE

Characteristic Impedance: 50 ohms.
Frequency Range: D-c to 2000 Mc.
Adjustment Range: 44 cm (half-wave at 340 Mc).
Physical Length: Adjustable from 61 to 83 cm.
Spacing: 1 3/16 inches between centers.
VSWR: Less than 1.10 to 1000 Mc, and 1.25 to 2000 Mc.

TYPE 874-LK10 10-CM CONSTANT-IMPEDANCE ADJUSTABLE LINE*

Characteristic Impedance: 50 ohms.
Physical Length: Adjustable from 35 to 45 cm (half-wave at 1500 Mc).
VSWR: Less than 1.03 at 500 Mc, 1.06 at 1000 Mc, 1.08 at 1500 Mc, 1.10 at 2000 Mc, less than 1.15 at 3000 Mc, 1.2 at 4000 Mc, and 1.25 at 5000 Mc.
Weight: 10 ounces.

TYPES 874-F2000 AND 874-4000 LOW-PASS FILTERS

Accuracy of Cut-off Frequency: −0%, +10%.
Physical Length: Type 874-F2000, 4⅜ inches; Type 874-F4000, 2⅞ inches.
Weight: Type 874-F2000, 5 ounces; Type 874-F4000, 4 ounces.

TYPE 874-VQ VOLTMETER DETECTOR*

Maximum Voltage: 2 volts.
Resonant Frequency: Approximately 3600 Mc; correction curve supplied.
VSWR Introduced in a Matched 50-ohm Line: Less than 1.1 at 1000 Mc, less than 1.2 at 2000 Mc. Bypass Capacitance: Approximately 300 $\mu\mu$f.
Frequency Range For Use as Matched Detector: 500 kc to 2000 Mc. Can be used at frequencies up to 5000 Mc and down to 60 cycles (with external bypass capacitor).
Crystal: Type 1N23-BR Reversed Crystal to provide proper output polarity for use with d-c oscilloscopes.
Frequency Response: See Figure 9.
Dimensions: 3¾ by 2½ inches.
Weight: 5 ounces.

* Available in July, 1956.

Type	*Description*	*Code Word*	*Price*
874-G3	Fixed Attenuator, 3 db	COAXFULLER	$25.00
874-G6	Fixed Attenuator, 6 db	COAXNODDER	25.00
874-G10	Fixed Attenuator, 10 db	COAXBELLER	25.00
874-G20	Fixed Attenuator, 20 db	COAXNEPPER	25.00
874-LT	Trombone Constant-Impedance Adjustable Line	COAXTROMBO	85.00
874-LK10	10-Cm Constant-Impedance Adjustable Line	COAXKENTER	33.00
874-F2000	Low-Pass Filter, 2000-Mc Cut-off	COAXPUSHER	14.00
874-F4000	Low-Pass Filter, 4000-Mc Cut-off	COAXLENDER	14.00
874-VQ	Voltmeter Detector	COAXVOQUER	30.00
874-QLJ	Adaptor to UG154/U or A/U Type LC Connector	COAXLITTER	17.50
874-QLP	Adaptor to UG352A/U Type LC Connector	COAXLUGGER	27.00

U. S. Patent No. 2,548,457

GENERAL RADIO COMPANY

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VOLUME 30 No. 12 MAY, 1956

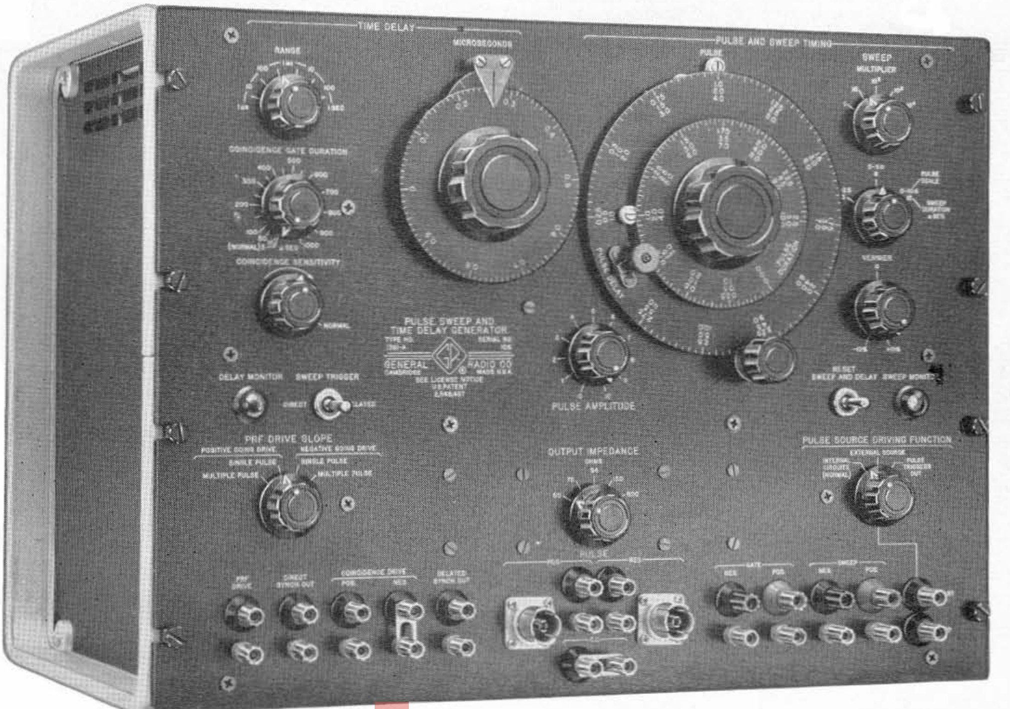
A VERSATILE GENERATOR FOR TIME-DOMAIN MEASUREMENTS

Also IN THIS ISSUE

The new Type 1391-A Pulse, Sweep, and Time-Delay Generator is a pulse source and measuring device designed to meet the diverse requirements of laboratories engaged in time-domain measurements.[1] It produces pulses of medium power and good rise-time, over an extremely wide range of durations and repetition rates, and it generates time delays and saw-tooth sweeps over comparably wide time intervals.

[1] Frank, R. W., "A Wide Range Pulse Generator for Laboratory Applications," *Proceedings of the National Electronic Conference*, Vol. 8, Jan. 1953.

Figure 1A. Panel view of the generator unit; for view with power supply unit, see page 2.



This instrument contains, in a single assembly, (1) a pulse generator, (2) a time-delay generator, and (3) a linear saw-tooth sweep generator. The time-delay generator has a calibrated range from one microsecond to 1.1 seconds; the linear sweep generator produces saw-tooth waveforms ranging in duration from 3.0 microseconds to 0.12 second. The start and stop times of pulses continuously adjustable in duration from 0.05 microsecond to 0.1 second can be precisely set at any point along this sweep by amplitude comparators.[2] The pulse repetition rate is set by an external generator, which may have almost any waveform.

The generator not only covers wide ranges, but it produces its time delays, pulses, and sweeps with high accuracy and stability. Its over-all usefulness is greatly enhanced by its many terminals, which permit access to the various basic circuit groups that perform the sequential operations involved; and by its internal switching, which permits the user to obtain many different combinations for optimum solutions to particular problems.

[2] The amplitude comparators used throughout this instrument are Schmitt trigger circuits. (Note 3) For a complete discussion, including a circuit for a sensitive comparator, see M. C. Holtje, "A New Circuit for Amplitude Comparison," *General Radio Experimenter*, Vol. 30, No. 6, November, 1955, p. 1.

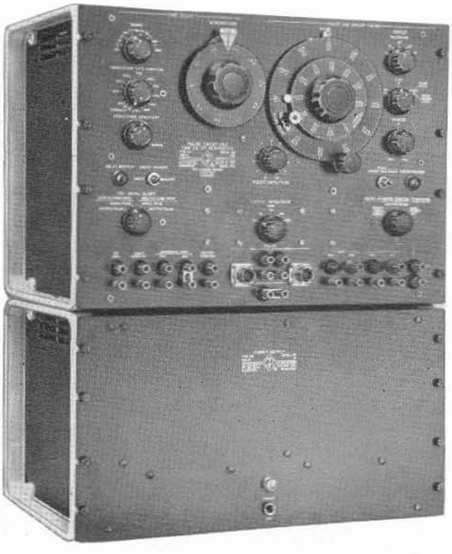


Figure 1B. View of the complete Pulse, Sweep, and Time-Delay Generator, with power supply.

Throughout this instrument timing is accomplished by the combination of R-C integrator sweep circuits and amplitude comparators. The application of these simple, fundamental timing systems leads to circuits that are practically independent of tube characteristics, have fast recovery times, and good signal-to-noise ratios. Additional dividends are linear dial scales and absolute accuracies dependent only upon the stability of the resistors and capacitors of the integrator circuits.

In addition to accuracy and reliability, this instrument provides the user with conveniences and effects not previously available in other pulse generators. For example, a completely new type of push-pull, bistable pulse-output circuit was incorporated. This output circuit provides a moderately high current (150 ma) into a number of internally contained, switched, source impedances. This balanced system has no limit on duty ratio, and, since the output is fed directly to the pulse output terminals, pulses of any duration can be produced without ramp-off effects.

BASIC CIRCUITS

The basic circuit groups shown in Fig. 2 perform the necessary timing and shaping operations. The groups consist of:

(1) Input synchronizing circuits that produce a single trigger pulse per cycle from *any* timing waveform. This trigger pulse, referred to hereafter as the direct trigger, serves as the basic timing signal. It drives

(2) Delay circuits capable of produc-

ing an accurately timed delayed trigger pulse over the range 1 μsec to 1.1 sec after the direct trigger. These delay circuits comprise: (a.) a main delay-circuit group producing a delayed pulse of 1 μsec to 1 sec, and, (b.) a coincidence system consisting of a monostable gate, a coincidence circuit, and pulse-forming circuits to produce a delayed synchronizing pulse. This coincidence system permits such operations, as television-line selection, stabilized delays, and multiple pulsing of the pulse generator.

(3) A linear sweep circuit, producing a 250-volt push-pull sawtooth available at panel terminals and variable in steps of 3, 6, and 12 μsec, with a 5-decade multiplier to provide for a maximum sweep duration of 0.12 sec. The sweep duration is continuously adjustable over a range of ± 10% so that any repetition frequency can be used. In addition to the sweep voltage, push-pull 40-volt gate pulses of sweep duration are provided at front-panel terminals.

(4) Pulse generating circuits whose timing is controlled by trigger pulses derived by amplitude comparison from

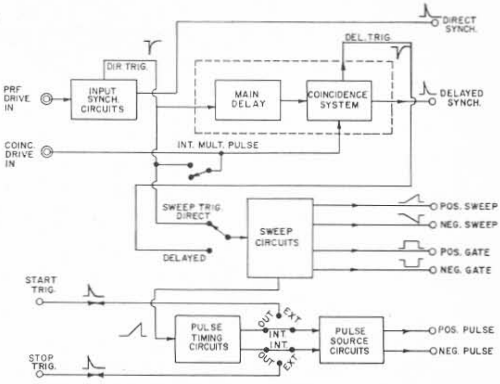


Figure 2A. System block diagram, showing major circuit groups and their interconnections.

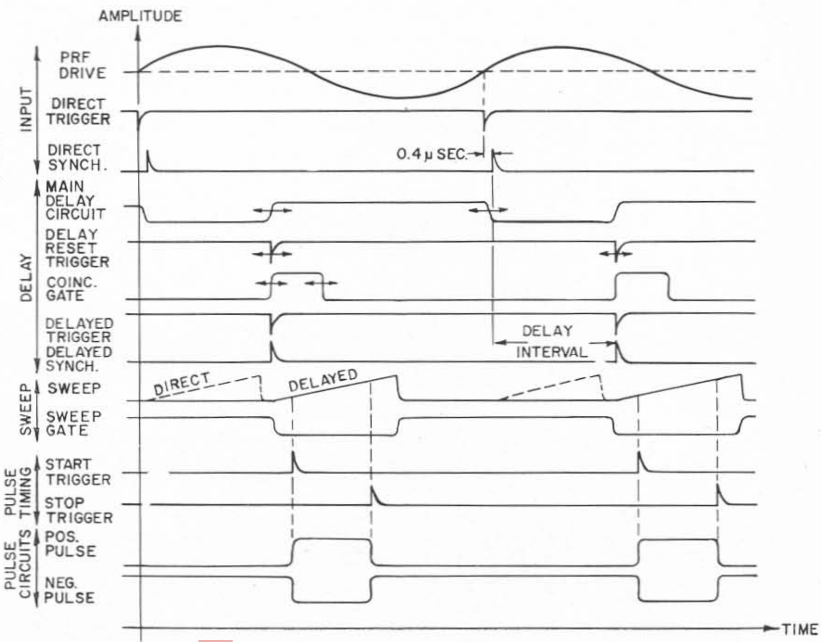
the sweep voltage. The pulse duration is continuously and accurately adjustable over a gamut of 0.05 μsec to 100,000 μsec by this method of timing. A switch on the front panel

(a) provides normal operation as described,

(b) connects the input of the pulse-generating circuits to panel terminals for external control of start and stop times, or

(c) makes available at panel terminals the start-and-stop trigger pulses that normally time the main pulse.

Figure 2B. Timing diagram for the complete system.



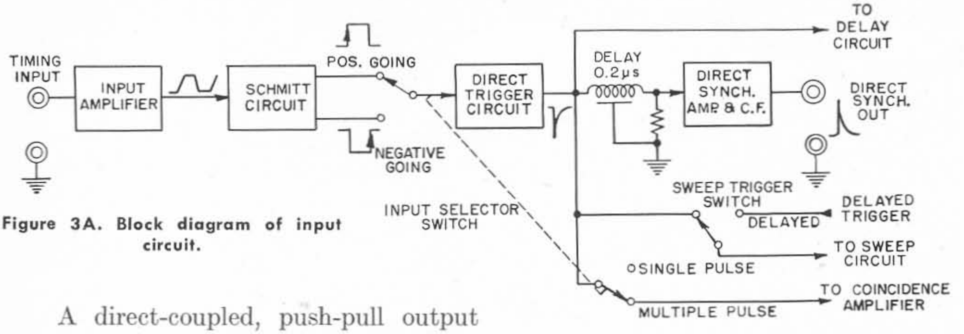


Figure 3A. Block diagram of input circuit.

A direct-coupled, push-pull output system makes the output pulses useful over their large range of durations. The output impedance can be set at values of 50, 75, 100, 300, and 600 ohms with a rotary switch.

Throughout the system no circuits have been used that must be restricted in duty ratio, so that there is no limit except recovery time on the maximum duration of sweep or pulses. The maximum duty ratio is limited by recovery-time to approximately 90% of the period set by repetition rate.

CIRCUITS, CONTROLS, AND INTERCONNECTIONS

Input Circuits. (Figure 3) The input circuits consist of an input amplifier, Schmitt circuit,[3] pulse-forming circuit, amplifier, and output cathode follower. The Schmitt circuit, driven by the direct-coupled amplifier, in turn drives the direct-trigger pulse-forming circuit to produce the direct-trigger pulses at prf's between about 3 cycles and 500 kilocycles. This direct-trigger pulse is used to synchronize the rest of the circuit groups within the instrument. It can be formed on whichever zero crossing the user selects. For sine-wave and square-wave inputs, the trigger-generating system requires approximately 0.5 volt peak; for brief pulses of either polarity, approximately 10 volts.

The panel switch that selects positive-going or negative-going voltages has positions in which the direct-trigger pulse is fed to the coincidence circuit to provide for multiple pulsing.

The sweep circuit and the delay circuit can be triggered simultaneously by the direct-trigger pulse, or the sweep circuit can be triggered by the delayed synchronizing pulse. These two modes of operation, selectable by a panel toggle switch, make available the delayed synchronizing pulse during the sweep time, or, alternatively, make use of the delay circuit to delay the sweep with respect to the direct-trigger pulse.

The direct synchronizing pulse is a 100-volt, 1.5 μsec, positive pulse fed from a cathode follower to a pair of binding posts on the front panel. Lagging slightly behind the direct-trigger pulse, it can be used to trigger auxiliary equipment such as oscilloscopes and

[3] Schmitt, Otto F., "A Thermionic Trigger." *Jour. Sci. Insts.*, 1938, XV, p. 24.

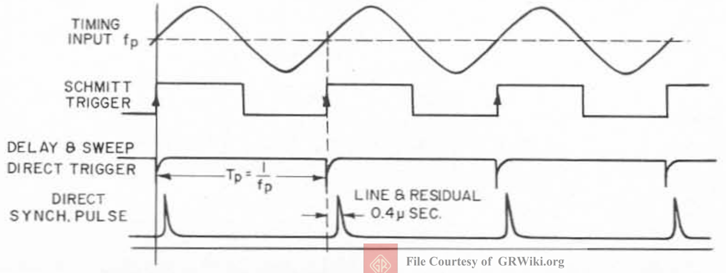


Figure 3B. Time relationships in input circuit.

counters. It can also be used to initiate the main pulse when the pulse duration is to be determined by the delay circuit.

Except for an input-coupling capacitor, the input amplifier and the Schmitt circuit are d-c stable. If it is desired to trigger the generator at very low rates of change of input voltage, the input capacitor can be shorted out. The Schmitt circuit is adjusted in the laboratory for maximum sensitivity for sine-wave and square-wave inputs. If the particular application of the pulser requires that it be sensitive to either a positive or negative pulse of low amplitude (less than 10 volts) an internal screw-driver adjustment permits setting the circuit to be more sensitive to one or the other pulse polarities. This control can also be adjusted so that the Schmitt circuit will trigger precisely at either positive or negative zero crossing.

When the generator is driven by a brief, rapidly rising, input pulse, there is a time delay of 0.4 μsec between the input pulse and the direct-synchronizing pulse. This time delay permits: (a.) the establishment of an accurately predetermined minimum delay and, (b.) the observation of the direct synchronizing pulse on almost any oscilloscope triggered by the input pulse.

Delay Circuits. (Figure 4) The direct-trigger pulse starts the delay circuit by opening a bistable gate. The opening of the gate starts a sweep, which produces a rising voltage whose slope is determined by an R-C circuit. The delay control, a ten-turn potentiometer, provides a voltage reference for an amplitude comparator. When the sweep voltage reaches the level set by the delay control, the amplitude comparator operates to form a trigger pulse that closes the bistable gate, ending the sweep and returning the loop to its original state.

The dial for the ten-turn potentiometer is calibrated linearily in 1000 divisions and provides an accurate reading of the delay with high incremental resolution. Delay is direct reading in microseconds, the basic range being from 1 to 11 microseconds with a six-decade range switch, which changes the R-C circuit constants.

This form of delay circuit, where the basic R-C timing circuit is an integrator, has lower noise than the simpler forms of monostable circuits. Careful measurement shows time jitters caused by circuit noise to be as low as 1 part in 50,000. Care has been taken in the design of the circuit to minimize drifts and transients resulting from line-voltage variations, and all timing errors caused by a ± 10% change in line voltage have been reduced to less than 0.01% of the dial reading.

Coincidence Circuit. A monostable coincidence gate, adjustable from approximately 3 to 1000 μsec, is a part of the delay circuit. This gate is opened by the trigger pulse produced by the main delay circuit, 1 μsec to 1.1 sec after the direct-trigger pulse. The coincidence gate permits many useful time-selection operations.[4] (See Figure 4C, and D).

In normal operation, the opening of the coincidence gate produces the delayed synchronizing pulse (Fig. 4B). If, however, the sensitivity of the coincidence amplifier is reduced, it can no longer be switched by the opening of the coincidence gate and the circuits are prepared for coincidence operation. The injection of a positive or negative pulse at the coincidence-drive terminals during the time that the gate is open will cause the coincidence amplifier to operate, and a delayed synchronizing pulse to be produced. While the coincidence

[4] Chance, B., etal., *Waveforms, Radiation Laboratory Series*, Vol. 19, McGraw Hill, New York, 1949. (Chapter 10 contains an excellent discussion of time selection and coincidence systems.)

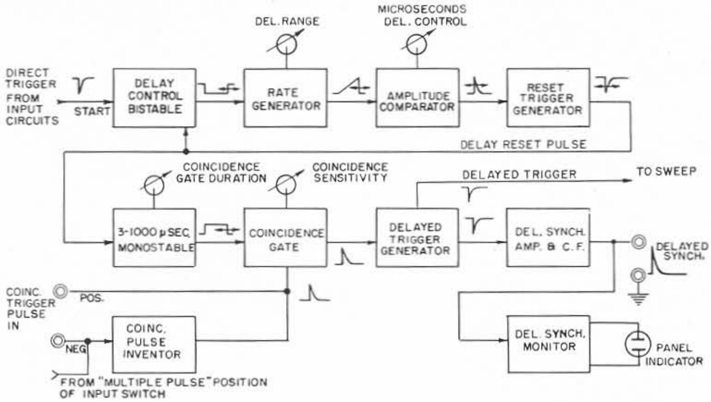


Figure 4A. Block diagram of delay circuits.

gate is open, as many delayed synchronizing pulses will be produced as there are input pulses to the coincidence circuit.

Provisions have been made for producing multiple-pulse groups internally by proper use of the main delay circuit and coincidence system. An illustrative timing diagram is shown in Figure 4D. In this mode of operation, the main delay circuit is used to "count-down" the input prf by any desired number up to about 20 by appropriate setting of the delay controls. The direct-trigger pulses, which occur at the input prf, are fed to the coincidence amplifier. All of the direct-trigger pulses that exist during the time the coincidence gate is

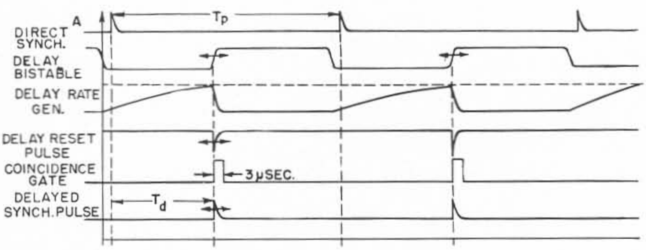


Figure 4B. Delay-circuit timing; coincidence circuit set for normal operation.

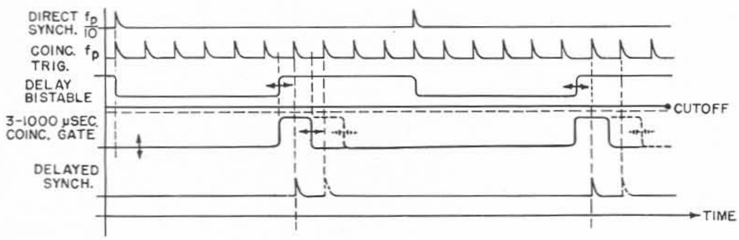


Figure 4C. Timing of multiple pulses when delay circuit is connected for multiple-pulse operation.

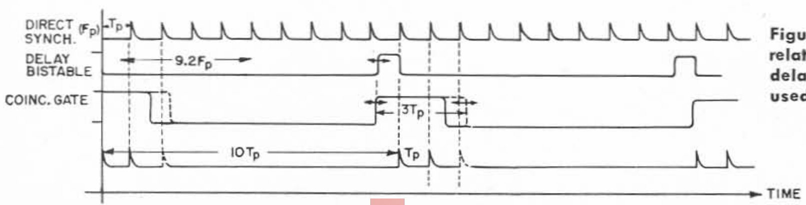


Figure 4D. Time relationships when delay circuit is used as a prf divider.

open will operate the delayed-trigger pulse-forming circuit to produce a group of pulses.

Let us assume that the input frequency setting the basic prf is 100 kc. The main delay circuit is set between 90 and 100 μsec to divide this input frequency by ten. Let it be set to 92 μsec. The coincidence gate is set for 20 microseconds, and coincidences are established by the 10th and 11th direct-trigger pulses to produce a pair of delayed synchronizing pulses separated by 10 μsec at a 10 kc rate. Increasing the coincidence-gate duration to 30 μsec will add a third pulse to this pair and so on. Since delayed synchronizing pulses can always be used to start the action of the pulse generator, groups of output pulses or sweeps can be produced (See Figure 9).

To illustrate a use of the coincidence circuits with an external associated timing generator, consider the example shown in Figure 4C. Here the basic repetition rate, f, is set by the timing generator. Additional outputs at 10 f, $10^2 f$ . . . $10^n f$ are also available from the timing generator. Any of these higher-frequency pulses can be fed into the coincidence input terminals. The timing diagram of Figure 4C shows how multiple pulses, precise delays and standardization of the time-delay circuits can be obtained.

To produce a group of pulses, the delay controls are first set to open the coincidence gate at the desired point in time. The coincidence-gate duration is then adjusted to an interval appropriate to produce the desired pulse group.

When the coincidence-gate duration is less than the time interval between input pulses to the coincidence circuit, only one delayed-trigger pulse (or none) will be produced. The timing of this delayed-trigger pulse relative to the direct-trigger pulse is precisely controlled by the timing generator.

The delay-circuit calibration can be checked by determining the point at which coincidence is just established by the opening of the coincidence gate. This method is accurate to only $\pm$ 0.2 μsec owing to the finite rise-time of the gate.

When the coincidence circuits are driven by externally generated trigger pulses, the delayed synchronizing pulse always occurs when, and only when, the pulse occurs at the coincidence input. Thus, the delayed synchronizing pulse will move step-wise in time as the main delay controls are operated, and the delay interval has the same accuracy as the timing generator.

The frequency dividers in the timing generator are usually much more stable in phase than R-C timed monostable circuits, and the selection of delayed pulses as described reduces the jitter present in the delayed output to that inherent in the timing generator.

Sweep Circuit. The sweep circuit is similar in form to the main delay generator, consisting of a bistable gate, a "bootstrap"[5] linear sweep circuit, an amplitude comparator fixed to trigger at 135 volts, and a reset trigger generator (Figure 5). The sweep timing is accomplished by the setting of R-C time constants to produce the basic 3, 6, and 12 μsec ranges and their decade multipliers. The push-pull sweep is fed from two cathode followers to two pairs of binding posts at which negative-going or positive-going sweeps are available. In addition, sweep-gate pulses are fed in push-pull to front-panel terminals where they are available, positive or negative, as a gate or for intensifying the trace on a cathode-ray oscilloscope.

The most obvious use of the sweep is

[5] *Waveforms*, p. 267

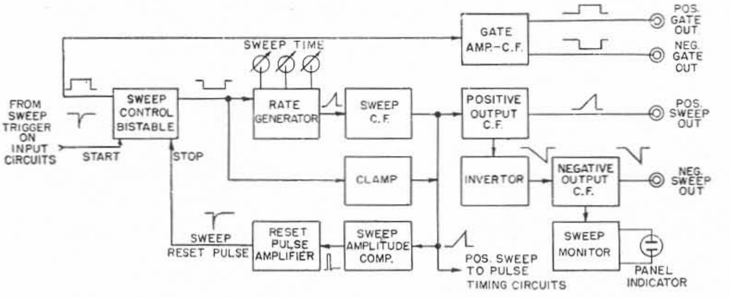


Figure 5A. Block diagram of the sweep circuits.

to provide a simple means for viewing the output pulse on any oscilloscope capable of being deflected by direct connection to the horizontal deflection plates. In addition, the sweep can be used to drive external amplitude comparators to generate additional pulses or delays.[6] The main pulse circuits can be started and stopped by external triggering pulses obtained from pairs of such amplitude comparators, to provide many pulses of independently controlled duration and delay. With their 40-volt amplitudes, sweep gates are adequate pulses for many testing purposes. The TYPE 1219-A Unit Pulse Amplifier, for instance, can be driven by these gates to produce excellent pulses for use as pedestals for the main output pulse. Since the main pulse always occurs during the time interval in which the sweep gate is open, this gate can be used to operate a keyed clamp[7] to restore d-c level for the main pulse anywhere in the external system.

Pulse Timing System. The positive-going sweep is used to time the main pulse generator. The linearly rising voltage operates two amplitude comparators, one to start and one to stop the pulse-generating circuits. The start and stop reference voltages can be independently set by front-panel controls (Figure 7). The start voltage sets the position of the "leading edge" of the pulse along the sweep, and the stop voltage sets the "trailing edge." The stop-voltage (or pulse duration) dial reads against an index carried by the start-voltage (or pulse-delay) dial and, therefore, reads directly in pulse duration. The excellent timing accuracy of this system results from the good linearity of the sweep as a function of time and of the voltage-setting potentiometers as a function of angle.

With this type of delay and duration control for the timing of the pulse relative to the start of the sweep, the sum of the pulse delay and pulse duration times must be equal to or less than 2.75, 5.5, or 11 μsec on the 3, 6, or 12 μsec sweep-duration control settings. On the 3 microsecond sweep, for example, a maximum pulse duration of 0–2.5 μsec can be set on the 100-division dial. Maximum pulse durations of 5 and 10 μsec, respectively, can be similarly

[6] Holtje, *op. cit.*
[7] Wendt, K. R., "Television D. C. Component," *R.C.A. Review*, Vol. IX, No. 1, March 1948, p. 100 ff.

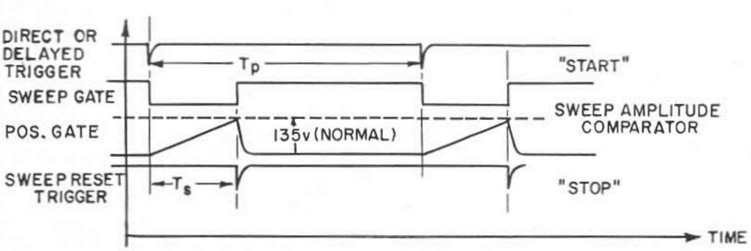


Figure 5B. Time relationships in the sweep circuit.

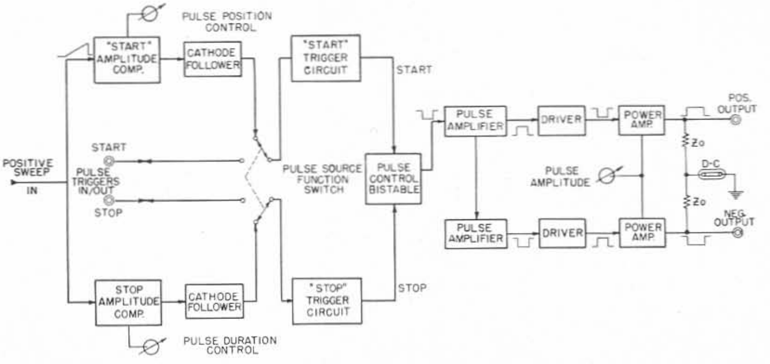


Figure 6A. Block diagram of pulse-timing and output circuits.

set on the 6 and 12 μsec ranges. The position of pulses of shorter duration than these maxima can be set within the stated limits. For instance, on a 12-μsec sweep, a 5-μsec pulse can be positioned over a range of 5 μsec. For highest accuracy and resolution the shortest sweep that will accommodate the desired pulse should be used. (See Figure 6)

Care in the circuit design and component choice equal to that in the delay circuits discussed previously leads to low jitter figures and a high degree of reliability. The extremely high resolution of the delay circuit is not provided in the pulse-timing system and is not usually needed. The delay circuit, however, can be used to control pulses of duration greater than 1 μsec if extremely high resolution should be needed.

The trigger-pulses for the pulse-generating circuits are fed through a switch to start and to stop a bistable pulse-controlling gate. This switch permits the operator:

(1) to start and stop the pulse with the internally generated triggers from the circuits just described.

(2) to start and to stop the pulse with triggers generated externally.

(3) to obtain the internally generated start-and-stop trigger pulses at individual binding posts on the panel. These positive-going pulses are obtained from cathode followers and can be used to control external circuits. They can, for example, be used to measure flip-flop resolution, since they can be set to occur simultaneously. In this switch position the main pulse is not generated.

Main Pulse-Generating Circuits. (Figure 8) The start-and-stop-trigger pulses operate a high-speed, bistable gate circuit. This circuit drives a pair of pulse amplifiers which, in turn, operate a pair of buffers for the output stage. The push-pull pulse-output stage is a single, 40-watt, 5894 dual beam-tetrode tube operated as a current source with switched load resistors across which the voltage

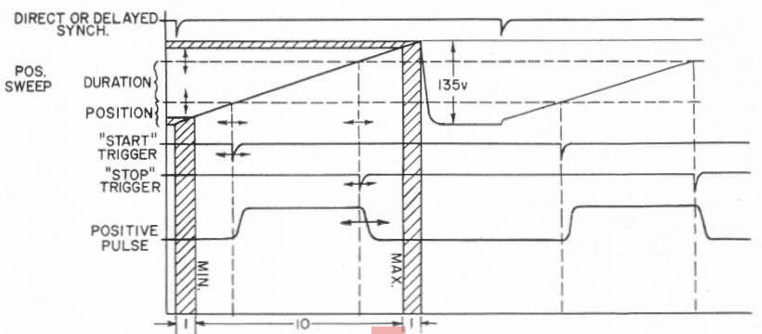


Figure 6B. Pulse timing diagram.

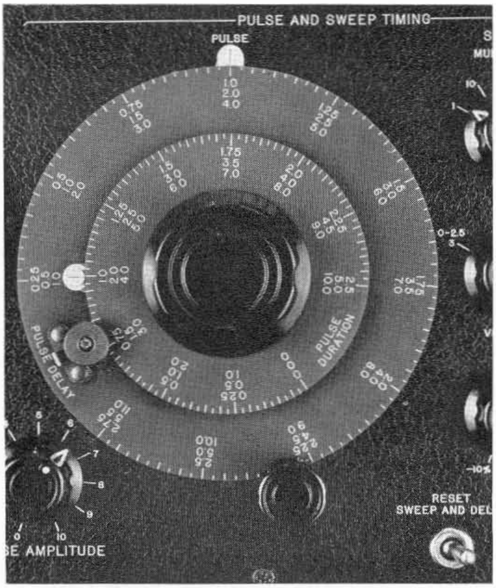


Figure 7. Close-up of pulse-position and pulse-duration dials.

pulse is developed. The conducting side of the 5894 draws a current of 150 ma. The output system is balanced, and the push-pull output voltages appear at coaxial connectors and parallel binding posts. The common midpoint of the load resistors is connected to an additional binding post that is normally grounded to the panel through a shorting link. Under these conditions the output pulses contain a negative d-c component with respect to ground. Variations in the d-c component of the order of ± 25 volts can be obtained by the removal of the shorting link and the insertion of an external voltage obtained from any low-voltage laboratory power supply or battery capable of supplying 200 milliamperes.

With this all-push-pull, direct-coupled system, no variation of pulse characteristics with duty-ratio occurs. Pulses at any impedance level and with any duration, no matter how timed, are available without ramp-off effects.

Pulse amplitude is varied by controlling the screen voltage on the push-pull output stage. This control is satisfactory for changing pulse amplitude by at least ten-to-one, but, where the best shape characteristics are desired in the attenuated pulse, an attenuator for the impedance level being used is preferable. Where output impedance is not critical, the desired reduction in voltage can be obtained by fixed resistors plugged into the front-panel binding-post pairs provided. The output voltage is always equal to 0.15 times the total load resistance. Thus an external 7.5 ohm resistor in parallel with the internal 50 ohm load will produce a 1-volt output pulse.

POWER SUPPLIES AND MECHANICAL DESIGN FEATURES

To reduce the weight and bulk of the pulse-generator itself, all the power supplies are contained in a separate unit (TYPE 1391-P1) that connects to the main operating unit through 5-foot cables. This design feature reduces hum and vibration in the main unit and simplifies cooling. All the d-c voltages are produced by conservatively operated selenium-rectifier supplies. The sele-

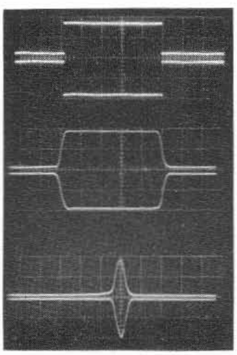


Figure 8. Output pulses.

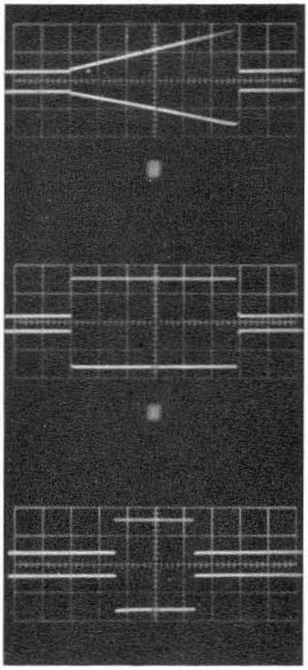


Figure 9. Sweep, sweep gate, and pulse.

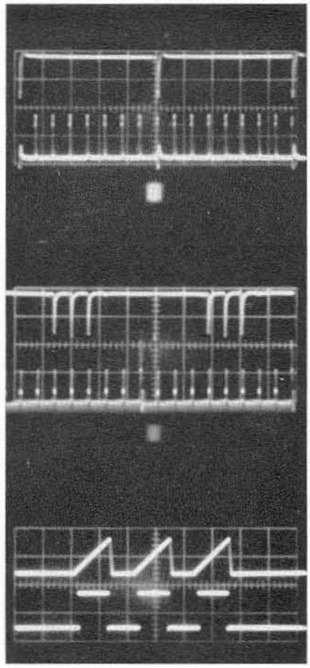


Figure 10. Time selection to produce a multiple pulse.

nium units are carefully located for maximum cooling and are derated by about 2:1. Although rectifier life expectancy is over 20,000 hours, they have been made readily accessible for ease in replacement.

The main unit has also been carefully designed for both cooling and accessibility of components. Forced-air cooling using a quiet 3-inch squirrel-cage blower maintains the hottest point of the cabinet at a safe 20°C above ambient.

Many features to aid in maintenance have been included. The multiplicity of input and output binding-post connections to the various circuit groups within the instrument makes it simple to isolate a trouble. In addition, every stage that does not have a front panel connection is provided with a clearly labeled and numbered test point, and all vacuum tubes are marked by type, V-number, and circuit function. All screwdriver adjustments are likewise numbered and labeled to show their circuit function.

As with all General Radio designs, great care has been taken to make the operating circuits independent of the characteristics of vacuum tubes and as reliable as possible, consistent with the high performance requirements. All panel-mounted variable resistors are precision, wire-wound potentiometers and, wherever possible, computer-type vacuum tubes have been used. Etched circuits are used wherever circuit capacitance is critical in order to insure maximum reproducibility of characteristics.

— R. W. Frank

The author wishes to acknowledge the many helpful suggestions and criticisms made during the course of this development by M. C. Holtje, W. F. Byers, D. B. Sinclair, and W. P. Buuck; and, in addition, the contributions of W. P. Buuck in the establishment of test and calibration procedures. — R. W. F.

SPECIFICATIONS

Pulse Generating Circuit:

Pulse Duration: (Timed by sweep) 0.05 to 2.5, 0.05 to 5.0 and 0.05 to 10.0 between half amplitude points, with decade multipliers to a maximum of 100,000 μsec. Pulse length can be extended to 1.1 seconds if pulse is timed by delay circuit.

Pulse Duration Accuracy: After sweep calibration, ± (1% + 0.05 μsec).

Pulse Position Accuracy: 0.5 μsec ± 1% of dial reading.

Pulse Rise Time: Depends on output impedance chosen. Into a terminated 50-ohm coaxial line, it can vary from 0.025 μsec by ±0.01 μsec. The following are typical (0.1 μsec pulse as measured on oscilloscope; rise time of vertical amplifier 0.006 μsec):

Impedance	*Positive Pulse*		*Negative Pulse*	
	Rise μsec	*Decay μsec*	*Rise μsec*	*Decay μsec*
Terminated Coax 50 ohms	0.03	0.015	0.02	0.03
15 μμf Probe 72 ohms	0.03	0.025	0.02	0.03
95 ohms	0.03	0.025	0.025	0.03
150 ohms	0.03	0.03	0.025	0.03
600 ohms	0.05	0.05	0.04	0.05

Pulse Shape: Overshoots and other defects are less than 5% of pulse amplitude when the pulse generator is correctly terminated. Pulse ramp-off does not exist, owing to direct coupling of output circuits.

Pulse Duty Ratio: Push-pull circuit with unity duty ratio possible.

Output Impedance, Z_0: 50, 72, 94, 150, 600 ohms, all ±10%.

Output Pulse Amplitude: 150-ma current source; voltage from each phase of push-pull channel, 0.15 Z_0 ±20%.

Typical nominal amplitudes, 50 ohms, 7.5v; 72 ohms, 10v; 94 ohms, 14v; 150 ohms, 22v; 600 ohms, 90v.

D-C Component Insertion: Binding posts provided for this purpose. DC can be moved ±25 volts for all output impedances except 600 ohms.

Input Synchronizing Signal: Signals of almost any shape will trigger the input timing circuits. Average value must be approximately 0.2 volt, minimum.

Typical input signal minimum amplitudes are:

(1) Sine wave, 0.2 volt, rms.
(2) Square waves, 0.5 volt, peak-to-peak.
(3) Brief positive pulse, 10 volts, peak-to-peak.
(4) Brief negative pulse, 10 volts, peak-to-peak.

Internal screwdriver adjustment permits increasing trigger-circuit sensitivity for either positive or negative pulses.

Direct Synchronizing Pulse:

Polarity-positive amplitude: 75 volts peak-to-peak.

Duration: (½ amplitude) 1 μsec.

Output Impedance: 600 ohms.

Repetition Rate: Amplitude constant to 300 kc; down 20% at 500 kc.

Time-Delay Circuits:

Range: 1.0 μsec to 1.1 sec in six ranges.

Delay Dial Calibration: 1.00 to 11.00 in 1000 divisions.

Delay Dial Resolution: 1 part in 8800.

Accuracy: Absolute, ±2% of full scale, or ±3% of scale reading + .005 μsec, whichever is smaller; incremental delay, ± (1% + .05 μsec).

Maximum PRF: 400 kc.

Duty Ratio Effects: Less than 2% error in delay for duty ratios up to 60%, at the low end of each range, and up to 90% at the high end of each range; proportional effects between.

Delayed Synchronizing Pulse Characteristics: Positive, 60 v, 1.0-μsec half-amplitude duration, 600 ohm cathode-follower output.

Stability:

	Low End of Dial	*High End of Dial*
Time Jitter	1:10,000	1:50,000
10% Line Change	2:1000	2:10,000
Sudden 10% Line Transient	3:1000	3:10,000

Coincidence Circuits:

Gate Duration: 3 to 1000 μsec.

Gate Accuracy: ±15% or ±1 μsec, whichever is larger.

Coincidence driving circuit will accept either positive or negative input pulses. Source impedance should be low, have rise time less than 0.2 μsec. Amplitudes between 5 and 20 volts are acceptable for negative pulses, and between 10 and 100 for positive pulses.

Sweep Circuit:

Sweep Duration: 3, 6, 12 μsec with 5-decade multiplier.

Sweep Linearity: Determined by the accuracy of pulse timing. On longer ranges, where time delay effects are absent, the linearity is better than 1%.

Sweep Amplitude: Push-pull, each phase, 135 volts ±10%.

Sweep Gate Amplitude: Push-pull, each phase 40 volts ±10%. Negative and positive sweeps and the positive sweep gate are cathode-follower output circuits with a 1-μf coupling capacitor.

Duty Ratio and Repetition Rate Effects: Maximum repetition rate, 3 μsec sweep, 250 kc.

Range	*Maximum Frequency for 5% Error in Sweep Slope*		
Sweep Time	*3 μsec*	*6 μsec*	*12 μsec*
x 1	150 kc	100 kc	60 kc
x 10	160 kc	12 kc	7 kc
x 10^2	1.6 kc	1.2 kc	700 c
x 10^3	160 c	120 c	70 c
x 10^5	16 c	12 c	7 c

Tube Complement: Generator:

8 — 6485		1 — 5894
5 — 5965	2 — 6AN8	1 — 6AW8
4 — 12AX7	2 — 12BY7	1 — 6BQ7A
5 — 6AN5	2 — NE51	1 — 12BH7
2 — 5963	1 — 5687	1 — 6U8

Power Supply, 1 — 0C3, 1 — 6AK5, 1 — 6AS7.

Accessories Supplied: Interconnecting cables, Type CAP-35 Power Cord, 2 Type 874-C58 Cable Connectors, spare fuses.

Other Accessories Available: Type 1219-A Unit Pulse Amplifier* for higher power output.

Accessories Required: Trigger source; practically any laboratory oscillator of the appropriate frequency range is adequate; the Type 1210-B Unit R-C Oscillator† is recommended.

Power Supply Input: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles, 385 watts.

Dimensions: Generator, 19 (width) x 14 (height) x 12½ inches (depth) over-all; Power supply, 19 (width) x 10½ (height) x 12½ inches (depth) over-all.

Net Weight: Generator, 30 pounds; power supply, 40 pounds.

Type		*Code Word*	*Price*
1391-AM‡	**Cabinet Model (incl. Power Supply)**	EDIFY	**$1745.00**
1391-AR‡	**Relay-Rack Model (incl. Power Supply)**	EBONY	**1745.00**

* See *Experimenter* for July, 1955, pp. 9–15.
† See *Experimenter* for May, 1955, pp. 1–11.

‡ U. S. Patent No. 2, 548,457.
Licensed under patents of the Radio Corporation of America.

MORE NEW VARIACS®

The new W2-series Variacs are 2-ampere counterparts of the W5 series, previously announced.[1] The new W2-series Variacs are identical in design, construction and appearance to their W5 brothers, differing from the latter only in electrical rating, size, and weight. All current and kva ratings are 40% of the W5 ratings. Panel mounting area, volume, and weight are each about 50% of the measurements of equivalent W5 series models. Figure 1 shows the basic model, Type W2.

The basic, uncased model carries a 2.4-ampere rating, an increase of 20% over the Type V2 which it supersedes. Other features include Duratrak brush track, unit brush, captive counterbalanced radiator assembly and square flange mounting. Mounting holes matching those of the V2 and the earlier Type 200-B are also provided, so that the new unit directly replaces these models in practically all cases.

Entirely new in this size Variac are cased models for fixed installations as well as for portable and bench use. The totally enclosed Type W2M can be wall- or panel-mounted. Standard ⅞ in. diam. knockouts are provided for ½ in. conduit or cable connectors. Portable models include line cord, convenience outlet, line switch, and carrying handle, plus resettable overload protector, first introduced in the W5 series. W2MT is provided with two-wire cord and outlet; the W2MT3 has the new standard three-wire fittings which ground the equipment.

The square-base design makes ganging simple, and assemblies are available both with and without enclosure. A number of variations of the standard design are also possible. For example,

[1]*Experimenter*, December, 1955.

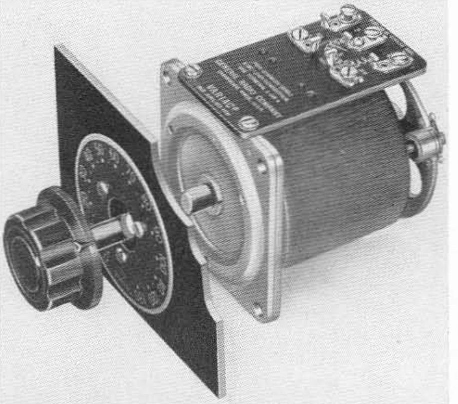


Figure 1. View of Type W2 Variac. Mounting holes are on a 2¾-inch square. Depth behind panel is 3¹⁵⁄₁₆ inches.

Case dimensions, both types are (width) 4⅛ x (height) 5$\frac{9}{16}$ x (depth) 4¼ inches, over-all

Figure 2. Type W2MT, with overload protector.

Figure 3. Type W2M, with conduit knockouts.

units for 360° rotation and two-brush models are available on special order. Motor-driven assemblies will be announced in a future issue of the *Experimenter*, as will the stock availability of units equipped with ball bearings.

NEW 400-CYCLE MODELS

The construction of the two-ampere and five-ampere 400-cycle models, Types M2 and M5, have been revised to include all the features of the 60-cycle models. These 400-cycle models are now identical to the 60-cycle models except for the obvious difference in vertical dimension, made possible by the lower stack height of the high-frequency units.

Fungus-resistant treatment has been added as standard and stock units now pass most commonly encountered military corrosion, salt-spray and fungus specifications, as well as shock, vibration and humidity requirements. Manufacturing economies resulting from the use of parts common to the 60-cycle (W-series) units permit a significant reduction in price, as shown in the following table:

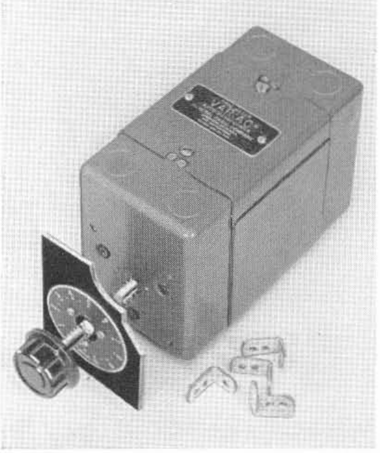
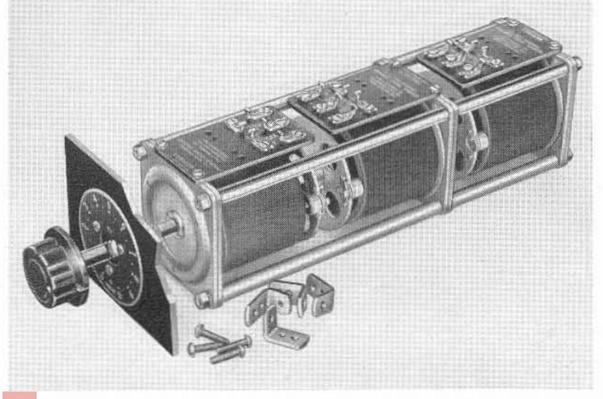


Figure 5 (left) Type W2G2M; (right) Type W2G3



	Old Style	*New Design*
Type M5	$22.50	$18.50
Type M2	15.50	14.50

Even more striking is the comparison with the Type 60-AU, predecessor of the M5, which listed five years ago at $28. These lower prices, accompanied by substantially improved performance, have been accomplished in a period of rising material and labor costs and are the result of a continuous program of careful attention to design, tooling and production methods.

SPECIFICATIONS FOR W2-SERIES VARIACS

			Line-Voltage Connection				*Overvoltage Connection*						
Type	*Mounting*	*Input Voltage*	*Rated Output Current — amp.*	*Output Voltage*	*Maximum Current — amp.*	*Output kva*	*Output Voltage*	*Rated Output Current — amp.*	*60-cps no-load loss — watts*	*Driving torque ounce-inches*	*Net Weight — pounds*	*Code Word*	*Price*
W2	Uncased	115	2.4	0–115	3.1	0.36	0–135	2.4	3.5	5–10	3⅝	BAGAL	**$13.50**
W2M	With case	115	2	0–115	2.6	0.30	0–135	2	3.5	5–10	4⅛	BAGER	**18.00**
W2MT	Portable 2-wire	115	*See Note Below*				0–135	2	3.5	5–10	4¾	BAGIC	**24.00**
W2MT3	Portable 3-wire	115	*See Note Below*				0–135	2	3.5	5–10	4¾	BAGOM	**26.00**

Note 1. MT models are shipped with overvoltage connections and corresponding dial scales, but can be supplied on special order with line-voltage connections and dial scales.
Note 2. The Type W2 dial plate is reversible, with 0–115 on one side, and 0–135 on the other. Angle of rotation is 320 degrees.
Note 3. Replacement brushes for Type W2 Variacs are Type VB-1, 55¢ each.
Note 4. Complete dimension drawings furnished on request.

TYPE M2 AND TYPE M5 VARIACS

	Output Current					
Type	*Rated*	*Max.*	*Depth Behind Panel*	*Net Weight*	*Code Word*	*Price*
M2	**2**	**3**	**2½ inches**	**1⅞ pounds**	BAGGY	**$14.50**
M5	**5**	**7.5**	**2⅝ inches**	**3¼ pounds**	CANNY	**18.50**

GANGED MODELS

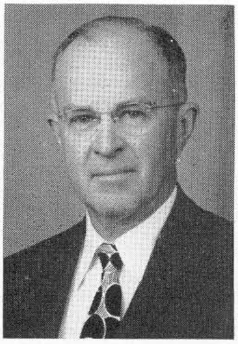
Type	*Description*	*Net Weight*	*Code Word*	*Price*
W2G2	**Two-gang**	**7 pounds**	BAGALGANDU	**$32.00**
W2G2M	**Two-gang with case**	**8 pounds**	BAGALBONDU	**40.00**
W2G3	**Three-gang**	**11 pounds**	BAGALGANTY	**48.00**
W2G3M	**Three-gang with case**	**12 pounds**	BAGALBONTY	**56.00**
M2G2	**2-gang M2**	**3⅝ pounds**	BAGGYGANDU	**33.00**
M2G3	**3-gang M2**	**5½ pounds**	BAGGYGANTY	**49.50**
M5G2	**2-gang M5**	**6¾ pounds**	CANNYGANDU	**41.00**
M5G3	**3-gang M5**	**10¼ pounds**	CANNYGANTY	**61.50**

SECOND INTERNATIONAL CONGRESS ON ACOUSTICS

Cambridge, Mass — **June 17-23, 1956**

General Radio acoustical apparatus will be on display at the exhibit held in Memorial Hall, Harvard University, June 20 and 21, in connection with this Congress.

PRESIDENTS—OLD AND NEW



Errol H. Locke

Charles C. Carey

On December 31, 1955, Errol H. Locke retired as President of the General Radio Company and, on February 16, 1956, Charles C. Carey was elected to succeed him.

Mr. Locke came to the General Radio Company in 1918, three years after its founding, and became Vice-President in 1920. His first association was with commercial and sales matters; later, as Vice-President, his main concern was with production. He was elected President in 1944 and held that post continuously until his retirement. As President, one of his primary interests was personnel policies, a field in which his long experience and deep human sympathies were particularly effective.

Mr. Carey's association with the General Radio Company began in 1927 in the production department. In that same year he became foreman of the winding department. He was appointed assistant to the Vice-President for Production in 1931 and Production Superintendent in 1934. When Errol H. Locke became President in 1944, Mr. Carey succeeded him as Vice-President for Manufacturing and continued in this office until 1956.

CHAIRMAN HONORED

At the annual meeting of the Scientific Apparatus Makers Association in Belleaire, Florida, April 11, Harold B. Richmond, Chairman of the Board of Directors of the General Radio Company received the Scientific Apparatus Makers Award "in recognition of his leadership, vision, and devotion to the growth and progress of the scientific instrument industry." Mr. Richmond's record of service to the Association dates from 1938. He was chairman of its board of directors in 1947, its president in 1938, and is at present a director-at-large. He is the first person in the history of the association to receive this award before retirement.

Harold B. Richmond

AMERICAN SOCIETY FOR TESTING MATERIALS

59th Annual Meeting **Chalfonte-Haddon Hall** **Atlantic City, N. J.** **June 18–21, 1956**

At the apparatus exhibit held in conjunction with this meeting, General Radio will exhibit some of the new items recently announced in the *Experimenter*. Among these are the TYPE 1605-A Impedance Comparator, the TYPE 1230-A D-C Amplifier and Electrometer, and the W-model Variacs. Other equipment in the exhibit includes bridges for measuring impedance, power factor, and insulation resistance; stroboscopes; polariscope; sound- and noise-measuring instruments, and voltage regulators.

Plan to visit the General Radio exhibit in booths 48 and 49. Our engineers will be on hand to discuss your measurement problems with you.

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

TELEPHONE: TRowbridge 6-4400

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the GENERAL RADIO Experimenter

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Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 31 No. 1 JUNE, 1956

A HIGH-PRECISION CALIBRATOR FOR FREQUENCY AND TIME

The TYPE 1213-C Unit Time/Frequency Calibrator is in no sense a simple redesign of its predecessor, the TYPE 1213-AB Unit Crystal Oscillator.[1] It is an all-new design that reflects both the field experience gained from the earlier instrument and the advances in electronic circuit techniques over the past five years. The new calibrator comprises, in a small unit-type case, all the circuits necessary for the frequency calibration of oscillators, receivers, and other wide-range devices up to frequencies somewhat above 1000 megacycles; and for the sweep-time calibration of oscilloscopes at intervals from 0.1 μsec to 100 μsec.

A comparison of the old and new instruments show four important new features of the Time/Frequency Calibrator:

(1) 10-Mc harmonic series.

(2) A crystal mixer good from low frequencies to frequencies above 1000 Mc.

(3) An amplifier for audible beats, which makes possible direct calibration of oscillators up to 1000 Mc.

(4) A video amplifier for the multivibrator output to permit oscilloscope time-axis calibration and to make the output standard-frequency wave-forms available for driving external pulse equipment.

Additional features are ease and resettability of calibration, frequency deviation with no disturbance of calibration, and improved frequency stability and reliability.

[1] R. B. Richmond, "Unit Crystal Oscillator," *General Radio Experimenter*, Feb., 1952.
"Improved Unit Crystal Oscillator," *General Radio Experimenter*, Sept., 1955.

Figure 1. Panel view of the Type 1213-C Unit Time/Frequency Calibrator with Unit Power Supply.

Of particular importance is reliability, which is becoming of more and more concern in these days of increasing electronic complexity. The TYPE 1213-C Unit Time/Frequency Calibrator, containing only seven vacuum tubes, is not in the class with instruments requiring a major reliability analysis; yet it reflects thinking on the subject which will be applied to instruments more than on order of magnitude more complex. The multivibrators, used as frequency dividers in this instrument, represent a new concept of multivibrator reliability in measuring instruments. They are classical Abraham-Bloch[2] multivibrators, designed by analytical procedures to produce maximum immunity to tube-characteristic deterioration. These multivibrators are discussed in some detail in the circuits section of this article.

BLOCK DIAGRAM

The basic circuits used in the Unit Time/Frequency Calibrator are shown in Fig. 2. They consist of:

(1) A 5-Mc crystal oscillator electron-coupled to a 2:1 multiplier.

(2) A 10-Mc buffer stage.

(3) A group of three multivibrators controlled by a panel switch and dividing the 10-Mc crystal controlled frequency by factors of 10, 100, and 1000.

(4) A harmonic generator which will produce a continuous harmonic spectrum of the 10-Mc, 1-Mc, 100-kc and 10-kc signals from the multivibrator.

(5) A crystal mixer either to couple the harmonics out of the instrument on a coaxial lead, or to produce and to detect a beat against a signal fed into the mixer.

(6) An amplifier stage, switched either to amplify the audio beat signal from the mixer or to produce a video signal for oscilloscope calibration.

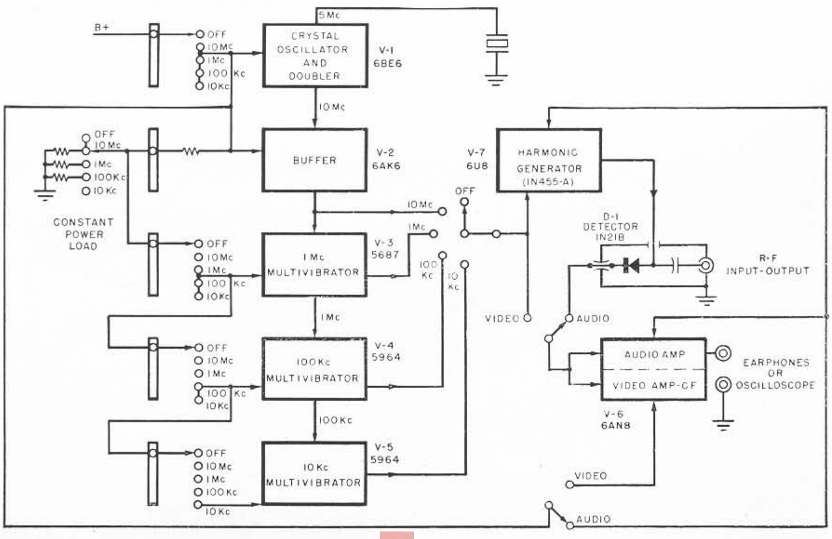
CIRCUITS

Oscillator

A hermetically sealed, AT-cut, 5-Mc quartz crystal is used as a frequency control element for the oscillator. The electron-coupled Gouriet-Clapp[3] oscillator circuit uses the first control-grid-screen-grid space of a pentagrid converter tube to provide the oscillating loop gain. Output is taken from the plate circuit of the pentagrid tube, which is tuned to resonance at 10 Mc.

Buffer

The 10-Mc signal at the plate of the



[2] Abraham, H. and Bloch, E., "Notice sur les Lampes-Valves a 3-Electrode et leurs Applications," *Publication 27 of the French War Ministry*, April, 1918.

[3] Clapp, J. K., "Frequency-Stable L-C Oscillators," *Proc. IRE*, 42, 8; August, 1954; page 1295.

Figure 2. Block diagram of the calibrator, showing the basic circuits.

oscillator drives a pentode buffer. The 45-volt buffer output at 10 Mc drives the 1-Mc multivibrator and either the harmonic generator or video amplifier, depending upon the position of the audio/video selector switch. The buffer output also feeds a germanium diode rectifier circuit, which produces a d-c voltage for audio amplitude control.

Multivibrators

Three multivibrators of a design intended to produce maximum reliability are used to divide the 10-Mc buffer frequency to produce the standard 1-Mc, 100-kc and 10-kc frequencies. These carefully designed and constructed multivibrators will insure long and trouble-free operation without regulated voltage supplies and with no readjustments of the circuit when tubes are replaced. A typical circuit is shown in Figure 3. It will be recognized as the simplest form of the astable multivibrator. The design has been carefully studied and optimized for reliability by:

(1) Exact adjustment of all controllable circuit parameters, and trigger amplitude to the correct values to permit maximum tube degradation before failure.

(2) Choice of the operating point for the tubes so that the multivibrator performance as determined by the conducting-tube plate voltage is least affected by the aging of the tube.

Figure 4 shows the timing action of the multivibrator of Figure 3. Assume that from t_0 to t_1, V_1 is off; and, at t_1, V_1 switches on and quickly by the loop regeneration is brought to and beyond zero bias. (For the purposes of this discussion, neglect the positive grid transient.) Now after time t_1, the plate voltage (E_{b10}) of *V-1* is at a low value depending on the zero-bias plate current and R_L. C_{c2} must discharge through R_{g2} toward E_{bb}, and it will continue to discharge until the cutoff of *V-2* is reached, whereupon the two tubes will again switch, with *V-2* going on and *V-1* off. We can now write down the equation for the timing action determined by the discharge of the grid coupling *RC* circuit and the amplitude of the plate swing.

$$T = R_{g2}\, C_{c2} \log_e \frac{E_{bb} + E_{p10}}{E_{bb} + E_{co2}} \qquad (1)$$

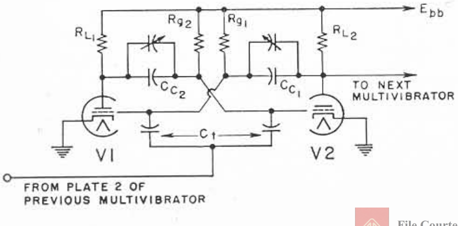
and since $E_{co2} = E_{bb}/\mu_{co2}$,

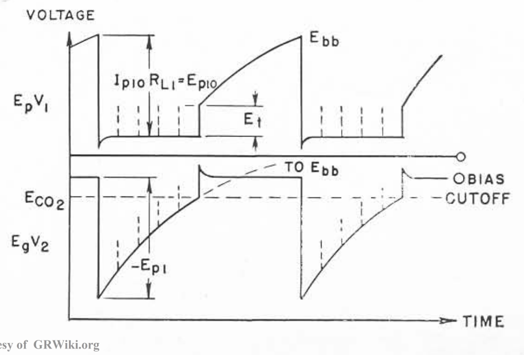
$$T = R_{g2}\, C_{c2} \log_e \frac{1 + \dfrac{E_{p10}}{E_{bb}}}{1 + \dfrac{1}{\mu_{co2}}} \qquad (2)$$

Since $E_{p10} = i_{p10} R_{L1}$ equation (2) shows all of the important circuit variables. The quantity μ_{co2} is a function of tube geometry and does not change appreciably with tube life, so attention need only be given to the *RC* product $R_g C_{c2}$ and i_{p10}.

How are these quantities used to optimize the design of a triggered multivibrator? Consider Figure 5 where the

Figure 3 (below). Schematic circuit diagram of typical 2-tube multivibrator.
Figure 4 (right). Timing diagram for multivibrator of Figure 3 showing typical plate-voltage waveforms.





timing waveform has been linearized to illustrate the triggering principles, so that the time equation is modified as shown in equation (3)

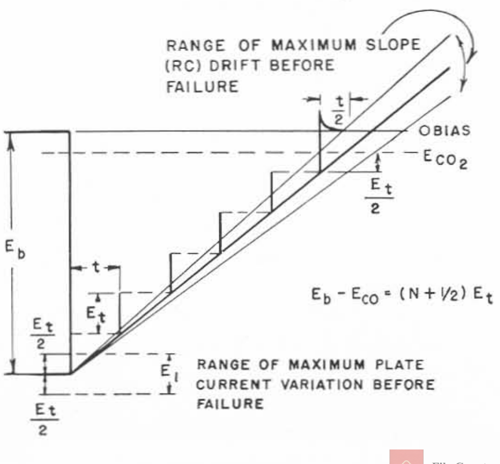
$$T = KRCE_{p1} \qquad (3)$$

A study of Figure 5 and Equation (3) makes it obvious that, for maximum locking range on the nth trigger with arbitrary variations of e_p and the RC slope, the trigger amplitude (E_t) must be set at a value determined by the plate swing as stated in Equation (4)

$$E_t = \frac{E_{p10} - E_{co2}}{n + \frac{1}{2}} \qquad (4)$$

This is the optimum trigger-voltage amplitude, and the intercept of the grid discharge voltage waveform with the cutoff line in the absence of triggering pulses must be at a time of $n + \frac{1}{2}$ units, where the time unit is that established by the interval between trigger pulses. The proof that Equation (4) does provide the optimum trigger amplitude follows. Consider the locking conditions for values of E_t greater than and less than the optimum value given in equation (4); (1) When the plate swing E_{p10} varies through values greater than and less than the design value with the slope constant, and (2) When the range of slope values is greater and lesser than the original slope with E_{p10} held constant. It can be seen that values of trigger voltage greater than and less than that determined by Equation (4) will decrease the locking range of the multivibrator, by having it jump to a lock on the 4th or 6th triggering pulse when E_t is greater, or by having it go out of lock completely when E_t is less.

Figure 5. Linearized timing-waveform diagram for the multivibrator of Figure 3.



There is an inescapable conclusion that follows from this simple analysis. One is allowed a total deviation of $\pm \frac{1}{2} E_t$ in the value of the grid discharge voltage level at the time of the nth trigger pulse at which the multivibrator should switch. Therefore, in a symmetrical multivibrator dividing by 10 (n equals 5 on each half-cycle of the multivibrator), a change of approximately $\pm 9\%$ in the combination of E_{p0} and RC will cause a failure in the count. Since emission varies with time, one must remove any controllable fixed errors in order to transfer all allowable variation to the tube, which is bound to change with time. This is done by using adjustable components to remove any effect due to component tolerances on the R-C time constants. An important fact that must be recognized is that the plate current of vacuum tubes seldom rises with age. Initial adjustment can thus be made to take advantage of this fact by setting the R-C time constant on the long side so that the tolerance for changes in plate current approximates $+3$ and -15%.

The facts presented above apply to all stable multivibrators no matter how operated. When the multivibrator frequency is below 100 kc, techniques of "hard-bottoming"[4] can be applied.

The plate resistors for all multivi-

[4] Harris, C. C., "The 'Hard-Bottoming' Technique in Nuclear Instrumentation Circuit Design," *IRE Transactions on Nuclear Science*, NS-3, 2; March 1956; page 5.

brators of this design are always set at their maximum allowable value. This value is determined by the time necessary to recharge the coupling capacitor after the switching interval in which the tube is turned off. The plate voltage should recover to value near the supply voltage[5]. The largest possible value of plate-load resistance gives the best approach to the "hard-bottomed" characteristic and offers the additional features of minimum plate dissipation for the tube and minimum plate current, which tend to increase tube life.

Experimentally, multivibrators designed on this basis have proved to be extremely reliable. For example, a string of eight such units dividing frequency from 10 Mc have operated a clock with 10-second pulses for over nine months, 6,500 hours, without a failure caused by a vacuum tube.

The three frequency-dividing multivibrators are added serially to the circuit system by the frequency selector switch on the front panel. This switch turns the plate power on and connects the appropriate multivibrator to either the harmonic generator or the video amplifier. Throughout this switching operation, the power dissipated in the unit is held constant by the insertion of dummy load resistors so that the box temperature will remain as nearly constant as possible.

Amplifiers

The audio-video switch selects the two input-output types of operation. When the unit is to be used for time calibration with the switch in the video position, the output of the 10-Mc buffer or of one of the multivibrators is connected to the grid of the video amplifier. This stage is a pentode amplifier-limiter feeding a cathode follower. The cathode follower is connected by the switch to a terminal pair on the panel and provides a low-impedance source to drive external circuits. When the audio-video switch is thrown to the audio position, the following changes in circuitry are effected: (1) the amplifier stage is converted to a two-stage audio amplifier with 5-kc bandwidth and a voltage gain of about 70 db connected to the silicon-crystal mixer output (Figure 6); and (2) the 10-Mc buffer or one of the multivibrator outputs is connected to the harmonic generator.

Harmonic Generator

The harmonic generator consists of two stages, the first a pentode limiter-driver, and the second a triode used to drive the germanium-crystal diode harmonic generator. The plate of the pentode section is tuned when the frequency selector switch is in the 1 and 10 Mc positions, and it acts as an untuned amplifier in the 100-kc and 10-kc positions. The pentode stage between the multivibrators and harmonic generator removes most of the trigger pulse that occurs on the multivibrator waveforms and which would otherwise make the harmonic spectrum nonuniform. The triode harmonic generating stage and its connection to the mixer are shown in Figure 6. The driving waveform switches the plate current off and on, and the impedance discontinuity offered by the crystal diode when the plate current switches on generates a very sharp negative-going spike of voltage. The criterion for the crystal diode used in this application is that the front resistance should be as low as possible. Hence, one of the new "VLI" diodes, the 1N455, is used in

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[5] Shenk, E. R., "The Multivibrator — Applied Theory and Design," *Electronics*, January 1944; page 136.

this application. It is the sharp voltage spike that produces the uniform spectrum of harmonics fed to the mixer.

Mixer

The mixer used in the Unit Time/Frequency Calibrator is a new design combining good high-frequency performance with compactness, accessibility for crystal replacement, and protection for the crystal diode. The coaxial panel fitting serves the double purpose of either coupling the r-f spectrum to external systems as an output connector, or as an input fitting to accept an externally produced r-f signal to be mixed with the standardized r-f spectrum. A built-in coaxial coupling capacitor protects the 1N21B crystal mixer against surges from connecting external circuits. The mixer current is produced by the harmonic-generator waveform, so that with small injected signals, the injected signal does not materially affect the efficiency of the mixer.

The gain of the audio amplifier is controlled in a non-linear fashion by adjustment of grid bias on the second audio stage. Enough bias is applied to cut the tube off for small signals so that undesired beats of harmonics of the standard frequency signal between harmonics of the unknown signal can be rejected.

Power Supply

The Unit Time/Frequency Calibrator is designed to work with either the General Radio Type 1203-A or 1201-A Power Supplies. Power requirements are 300 volts, 60 milliamperes, 6.3 volts, 3.15 amperes. The Type 1201-A Regulated Supply is recommended for minimum hum and maximum frequency stability.

Construction

All of the circuits except the harmonic-generator stage are located on a single etched board. This board has an etched ground plane under the crystal oscillator, buffer and audio-video amplifier circuits. Distributed-capacitance loading on the multivibrator is reduced by omitting the ground plane under these circuits. Careful consideration of component layout and shielding on this board insures a good environment for the crystal oscillator free of thermal transients and electrical interference. The multivibrator time constants are controlled by precision components with mica capacitors and glass trimmer capacitors. These components insure good multivibrator performance and long life.

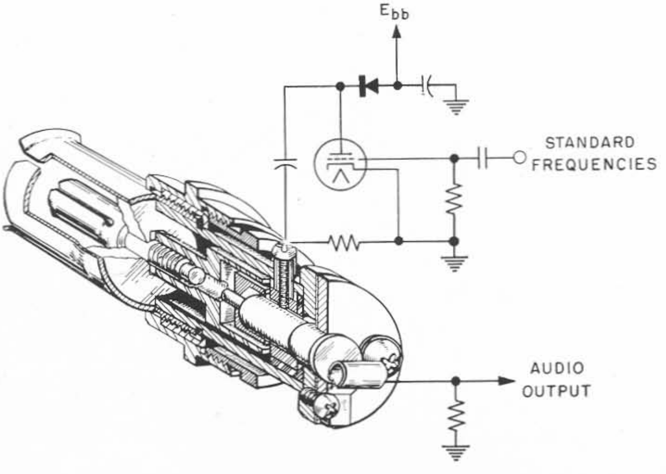


Figure 6. Cutaway view of the crystal mixer, with schematic of triode harmonic-generating stage.

APPLICATIONS

The TYPE 1213-C Unit Time/Frequency Calibrator used with the required power supply and headphones provides all the necessary apparatus for the calibration of radio-frequency oscillators and receivers to frequencies beyond 1000 Mc, and it also provides square-wave markers for oscilloscope sweep-time calibration. A simple plug-in device, the TYPE 1213-P1 Differentiator (supplied as an accessory) converts these square waves to brief pulses. The output pulse has been made powerful enough to trigger most pulse generators and oscilloscope sweeps, thus providing a stable driving source for timing pulse systems for various applications.

The calibration of oscillators in the laboratory is easily carried to frequencies in excess of 1000 Mc by introduction of the oscillator signal at the detector fitting of the calibrator; audible beats are produced as the dial of the oscillator is rotated. The 10-Mc points permit ready identification of calibration points beyond 1000 Mc by a count of the widely spaced beat points on the dial. Below 500 Mc it is possible to add calibration marks at closer intervals by use of the 1-Mc output. The harmonic-generating system is effective in supplying harmonics of 10 Mc to 1500 Mc, and of 1 Mc to 500 Mc, with input signals in excess of 50 mv. The 100-kc and 10-kc multivibrators can be used for oscillator calibration up to 100 Mc and 10 Mc, respectively. Calibration of sensitive receivers is readily carried out by the use of the r-f output harmonic series. With sensitive receivers the harmonics are usable above the frequency limits given for oscillator-calibration operation. When using the calibrator for receiver calibrations, care should be taken that lower harmonics of the 1- or 10-Mc output signal being used do not block the i-f amplifier. It is possible to block the receiver if a sufficiently strong signal of the harmonic spectrum lies within the i-f pass band. A high-pass filter must be used between the 1213-C and the receiver being calibrated to correct this difficulty.

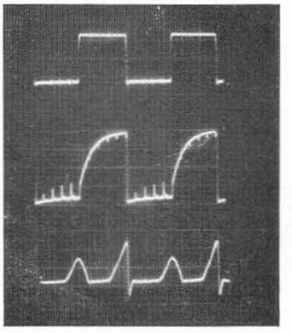
Measurement of frequencies lying near the standard frequency harmonics is facilitated by the inclusion of the "touch-button" crystal-oscillator frequency deviator on the panel. Touching this button reduces the frequency of the crystal oscillator slightly, thus indicating the sign of the difference between the unknown frequency and the standard frequency, without requiring any resetting of the main frequency adjustment control. Calibration of the sweep time of cathode-ray oscilloscopes is easily carried out: TYPE 1213-P1 Differentiator is inserted in the pair of binding posts connected to the video output amplifier; the selector switch is set to timing markers; and the resulting timing pulses are applied to the scope. Pulses are available at intervals of .1, 1, 10, and 100 μsec. The accuracy of the intervals is the same as that of the

Figure 7. Waveforms in the Type 1213-C Unit Time/Frequency Calibrator.

10-kc video-amplifier output (note 100-kc marks)

10-kc multivibrator plate.

1-Mc harmonic generator plate



crystal oscillator. Since it is possible to calibrate the crystal oscillator directly against WWV by use of a radio receiver, the accuracy of these timing markers is much greater than that required for oscilloscopic measurements.

— R. W. Frank
F. D. Lewis

The authors are indebted to W. P. Buuck and A. M. Eames for their many suggestions and contributions during the development of the Unit/Time Frequency Calibrator.

SPECIFICATIONS

Output Frequencies: 10 Mc, 1 Mc, 100 kc, 10 kc.
Output Amplitudes: 10 Mc, 10v peak-to-peak, 30 volts peak-to-peak at lower output frequencies from pulse amplifier; r-f harmonics usable to 1000 Mc from 10-Mc output, to 500 Mc from 1-Mc output, to 100 Mc from 100-Kc output, and 10 Mc from 10-kc output.
Output Impedence: Video cathode-follower, 300 ohms; r-f output obtained from crystal-diode harmonic generator.
Stability: After 1 hour warm-up, drift rate with regulated plate supply is mainly the drift rate of the quartz crystal (approx 1 ppm/°C). With unregulated power supply, an additional variation of ±½ ppm with line voltage change from 105 to 125 volts.
Sensitivity: Usable beat notes can be produced with 50 millivolts signal input to mixer over the harmonic ranges specified under "Output Amplitudes."
Tube Complement: 1-6BE6, 1-5687, 2-5964, 1 6AK6, 1-6AN8, 1-6U8.
Power Supply: 6.3 v a-c, 3 a; 300 v d-c, 60 ma. Type 1203-A or Type 1201-A is recommended.
Accessories Supplied: Type 1213-P1 Differentiator, one coaxial connector, and one multipoint connector.
Mounting: Aluminum panel and sides, finished in black crackle; aluminum cover, finished in clear lacquer. Relay rack panel is available for mounting both calibrator and power supply.
Dimensions: 10½ (width) x 5¾ (height) x 7 (depth) inches, overall. **Net Weight:** 4 lbs, 10 oz.

Type		*Code Word*	*Price*
1213-C	**Unit Time/Frequency Calibrator ***	REBEL	**$195.00**
1203-A	**Unit Power Supply**	ALIVE	**40.00**
1201-A	**Unit Regulated Power Supply**	ASSET	**80.00**
480-P4U3	**Relay-rack panel (for mounting both calibrator and power supply)**	UNIPANCART	**10.00**

* U. S. Patent 2,548,457; licensed under patents of the American Telephone and Telegraph Co.; licensed under patents of the Radio Corporation of America; licensed under patents of G. W. Pierce pertaining to piezo electric crystals and their associated circuits.

VACATION CLOSING

During the weeks of July 23 and July 30, our manufacturing departments will be closed for vacation.

There will be business as usual in the sales-engineering and commercial departments. Orders and 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.

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the GENERAL RADIO Experimenter

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Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 31 No. 2 JULY, 1956

NEW DECADE CAPACITORS WITH POLYSTYRENE DIELECTRIC

Also IN THIS ISSUE

Mica, a natural material, has long been the outstanding dielectric for capacitors and, for many applications, has not been superseded. It is still used almost universally, for instance, for a-c standard capacitors and will undoubtedly continue to be used in this application for a long time. In many respects, however, some of the newer synthetic materials exhibit characteristics superior to those of mica.

Among the materials available in a form economically suited for capacitor manufacture is polystyrene. This material possesses very nearly the ideal characteristics: dielectric constant and low dissipation factor that are invariant with frequency. Measurements from dc to at least several hundred megacycles show substantially constant values of these parameters. Mica, on the other hand, exhibits marked polarizations at frequencies below the audio range. These are manifested by rising values of capacitance and dissipation factor at the low end of the audio range. The relaxation times of these polarizations

Figure 1. View of the Type 980-A Decade Capacitor Unit.

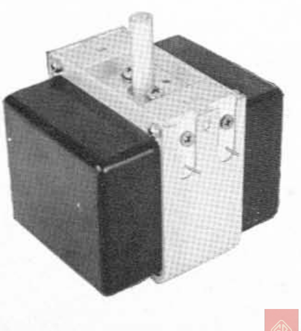


Figure 2. View of the Type 1419-A Decade Capacitor

correspond to frequencies in the tenths and hundredths of cycles per second and appear even in the millicycle and microcycle range. These polarizations are believed to be interfacial, resulting presumably from the laminar structure of the mica.

A thorough discussion of polarization in dielectrics is beyond the scope of this article. These phenomena can be described either in the frequency domain in terms of dielectric constant and loss factor (complex dielectric constant) or in the time domain in terms of the time variation of current resulting from changes in applied d-c voltage. The d-c response is often expressed in terms of "apparent resistance," and in fact most short term insulation-resistance measurements are actually nothing more than a measure of the charging current flowing into the low-frequency polarizations.

Terminology is as yet not well standardized. Terms such as "dielectric absorption," "soakage," "voltage recovery," and "d-c capacitance" have been used. The difficulty is that such terms can be relatively meaningless unless the method of measurement is specified. It is to be hoped that standardization on terminology, specifications, and method of measurement will soon be reached[1] in these areas, which appear to be of growing interest.

Capacitors carefully made of properly processed polystyrene can be shown to be about two orders of magnitude better than an equivalently carefully made mica capacitor. For example, Mr. R. F. Field reports[2] observations of high-quality, silvered-mica capacitors that show rises in capacitance as great as 30%, while similar measurements on the polystyrene units described later indicate rises of only a few tenths per cent. These measurements of discharge current vs. time were taken over a period of weeks and thus correspond, in the frequency domain, to measurements in the microcycle range.

Early Applications

The potentialities of polystyrene as a capacitor dielectric were recognized in the late thirties, and since about 1940 General Radio has carried on a program of development, and manufacture for its own uses, of polystyrene capacitors. Our first commercial application was in tuning networks in the Type 762 Vibration Analyzer, in the frequency range down to 2.5 cycles. In this application other available capacitors were unsatisfactory. Mica was not only out of the question because of cost, size, and weight in the large capacitance values required, but the polarization mentioned above caused anomalous behavior at the low frequencies. Subsequent uses of such capacitors include the Type 1611-A Capacitance Test Bridge. In this instrument, a 1-μf polystyrene capacitor accurate to 0.25% is used as a standard. Field use in many hundreds of these bridges over a period of ten years has shown these capacitors to be entirely satisfactory from the points of view of stability and life expectancy. Capacitors of this type have thus demonstrated their performance and reliability and are now offered for sale in the form of decade units.

These polystyrene-dielectric capacitors, owing to their very low dielectric absorption, are particularly useful in research and development work on computor and integrator circuits, and on low-level a-c amplifiers. Because of their constancy of capacitance and dissipation factor with frequency, they

[1] Sections A and C, Subcommittee XII, ASTM Committee D-9 are interested in this work. The writer will welcome any comments or the participation of anyone interested.

[2] Unpublished data.

make excellent components for measuring circuits, filters, and tuned circuits. They are nearly ideal capacitors for d-c work, because of their high insulation resistance and low dielectric absorption.

TYPE 980 DECADE CAPACITORS

Decades for assembly into other equipment are available in three capacitance ranges, with capacitance at maximum setting of 1.0, 0.1, and 0.01μf.

Each decade consists of four capacitors of magnitudes in the ratios 1–2–2–5. The switch selects parallel combinations to give increments over zero capacitance in all integral values from 1 to 10.

The individual capacitor units are non-inductively wound and carefully heat treated. The tape used is cast of purified high-molecular-weight polystyrene, pre-stretched only in the direction of winding. During heat treatment the units are carried beyond the transition temperature of the polystyrene, and the shrinkage of the tape produces an extremely firm, stable unit, which is insensitive to pressure, and which is stable in retrace capacitance value for temperatures up to 65° C.

The units are hermetically sealed in black-finished brass cans, having Teflon feed-through insulators to assure high resistance even under adverse humidity conditions. No impregnant, which might jeopardize the low-frequency performance, is used.

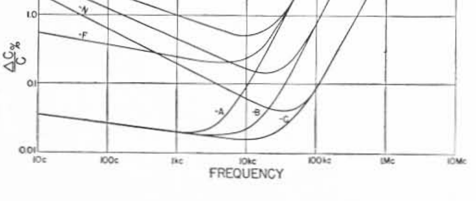
The cased units are mounted to a newly developed cam-type decade switch. The supporting dielectric material of the switch, including the shaft, is heat-resistant cross-linked polystyrene, and Teflon spacers support the rigid-wire leads.

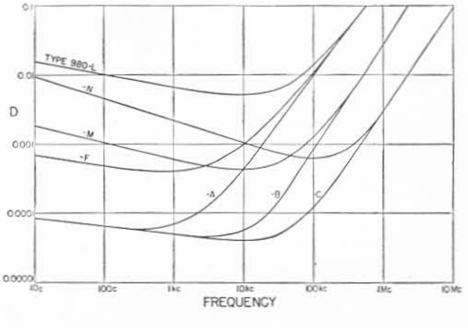
Low-Frequency Performance

The resulting decade capacitor assembly has an insulation resistance greater than 10^{12} ohms under standard laboratory conditions (23° C, 50% RH) when measured at 100 volts. Dissipation factor is typically of the order of 0.0001 in the audio frequency range, and is specified not to exceed .0002 at frequencies down to 100 cycles. A slight rise occurs as frequency approaches zero, as shown in the plot of Fig. 3. Theory [3] indicates that the maximum value of dissipation factor (from dielectric loss) cannot be greater than one-half the value of the rise in capacitance. Measurements indicate that this maximum value is of the order of 0.0005.

[3] The "circular-arc" theory proposed by Cole and Cole.

Figure 3. Typical plots of change in capacitance and dissipation factor as a function of frequency for Type 980 Decade Capacitor Units. Types 980-A, -B, and -C are polystyrene units; Types 980-L, -M, -N, and -F are paper and mica units. Capacitors are adjusted to their rated accuracy at 1 kc.





In addition, at some sufficiently low frequency, the leakage resistance becomes significant in determining dissipation factor. At 10^{-4} cycles, the 10^{12} ohms resistance of one microfarad produces a dissipation factor of 0.001.

One of the most convenient means of measuring d-c performance is by the voltage-recovery method. If a capacitor is charged for a given period of time and then short-circuited through a protective resistor for a period long enough to discharge the high-frequency capacitance, the charges in the long-time polarizations remain. These charges gradually transfer to the high-frequency capacitance and appear as a measurable potential at the terminals. If these capacitors are charged for one hour and then discharged for 10 seconds, the ultimate recovered voltage is 0.1% or less of the original charging voltage. In contrast, even a good mica capacitor may recover 10% or more, while some impregnated paper capacitors may show recoveries approaching the charging voltage.

In terms of frequency characteristic the above performance is equivalent to an increase in capacitance of 0.1% at a frequency of the order of 10^{-4} cycles.

High-Frequency Performance

At frequencies above a few hundred cycles, the dissipation factor of the material seems to reach a "floor" and remains constant, as does the dielectric constant. The terminal values of capacitance and dissipation factor, however, are modified by the residual inductance and series resistance of the capacitors, switch structure, and leads. The capacitance change increases as the square of the frequency, while the dissipation factor change varies as the 3/2 power of frequency. Representative plots of these variations are shown in Fig 3.

SPECIFICATIONS

Accuracy: Capacitance increments are within ± 1% from zero position when measured at 1 kc. The units are checked with the switch mechanism high, electrically, and the common lead and case grounded. The zero capacitance is 10 μμf and must be added to the switch settings to give the total capacitance.

Dissipation Factor: Less than 0.0002 at 1 kc and 23°C, 50% RH

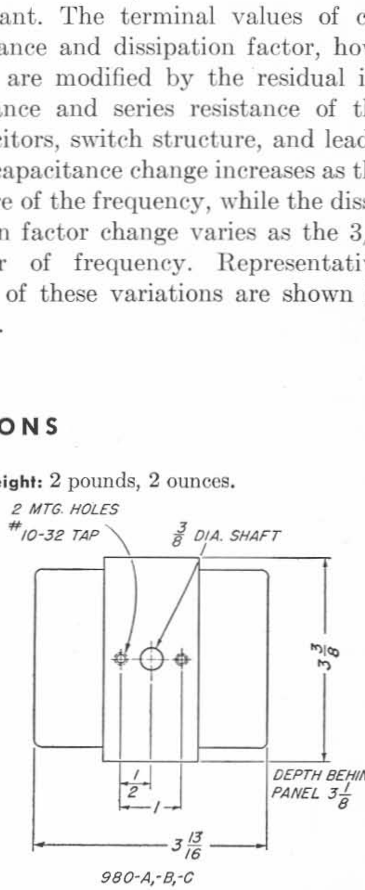
Frequency Characteristics: Figure 3.

Maximum Voltage: 500 volts d-c or peak at frequencies below the limiting frequencies tabulated below. At higher frequencies the allowable voltage decreases and is inversely proportional to the square root of the frequency. These limits correspond to a temperature rise of 40° Centigrade for a power dissipation of 3.5 watts.

Mounting: Machine screws for attaching the decade to a panel are supplied.

Dimensions: See accompanying sketch.

Net Weight: 2 pounds, 2 ounces.



980-A,-B,-C

Type	Capacitance	Dielectric	Frequency Limit in Kc-Max. Volt.	Code Word	Price
980-A	1.0 μf in 0.1 μf steps........	Polystyrene	10	AVAST	$66.00
980-B	0.1 μf in 0.01 μf steps.......	Polystyrene	100	AVERT	51.00
980-C	0.01 μf in 0.001 μf steps......	Polystyrene	1000	AVOID	57.00

TYPE 1419-A DECADE CAPACITOR

A three-dial decade capacitor having a range from .001 μf to 1.11 μf in steps of .001 μf is also available. The individual TYPE 980 decades are mounted on an aluminum panel, in an aluminum cabinet, providing complete electrostatic shielding. A separate ground post is provided, so that the capacitor may be used in either two-terminal or three-terminal applications, with case grounded.

SPECIFICATIONS

Capacitance Range: .001μf to 1.11μf in steps of .001μf. The three decades have steps of .001, .01, and .1μf respectively.

Zero Capacitance: Approximately 35μμf.

Accuracy: Individual capacitors are adjusted to an accuracy of ± 1%. The capacitance at the terminals, less the zero capacitance, is within ± 1% of indicated value for any setting

Dissipation Factor: Dissipation factor caused by dielectric loss is less than 0.0002 at all frequencies above 100 cycles. At high frequencies, series metallic resistance increases the dissipation factor as shown by the curves of Figure 3.

Insulation Resistance: Greater than 1 megamegohm (10^{12} ohms), when measured at 100 volts, 23° C, and 50% RH.

Maximum Voltage: 500 volts d-c or peak.

Frequency Characteristics: The d-c capacitance is equal to the 1-kc value within 0.1%. At high frequencies, series inductance causes capacitance to increase as shown by the curves of Figure 3.

Dielectric Absorption: See Voltage Recovery.

Voltage Recovery: The voltage recovery at the terminals is less than 0.1% of the original charging voltage, after a charging period of one hour and a 10-second discharge through a resistance equal to one ohm per volt of charging.

Mounting: Aluminum panel and cabinet.

Dimensions: (Length) 13 x (width) 4$\frac{5}{16}$ x (depth) 5 inches, over-all.

Net Weight: 8$\frac{3}{8}$ pounds.

Type		*Code Word*	*Price*
1419-A	**Decade Capacitor..............**	BIGOT	**$195.00**

DECADE CAPACITORS WITH MICA AND PAPER DIELECTRICS

The new decade switch is now also used for mica and paper decade capacitors. The new assemblies replace the former TYPE 380, with identical mounting dimensions. A listing of these units is given, with specifications, below. The low-loss switch, plus improvements in the mica capacitors themselves, result in lower dissipation factor than that specified for the superseded TYPE 380 Units.

SPECIFICATIONS

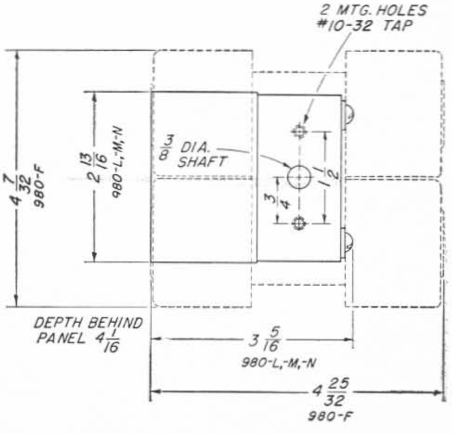
Accuracy: Capacitance increments on all units are within ± 1% from zero position when measured at 1 kc except the TYPE 980-L, which is accurate within ±2%. The units are checked with the switch mechanism high, electrically, and the common lead and case grounded. The zero capacitance of all units is 10μμf and must be added to the switch settings to give the total capacitance.

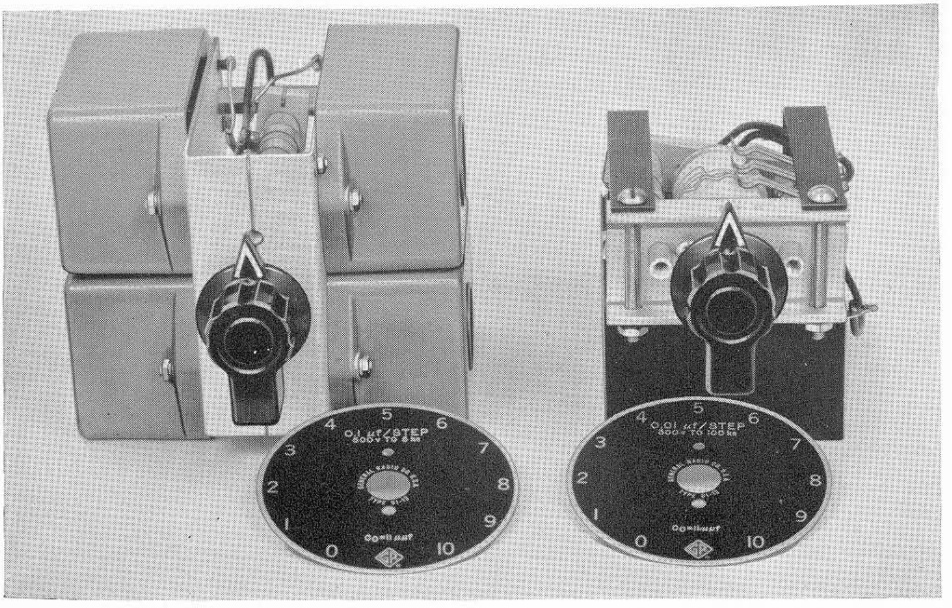
Dielectric: See table.

Dissipation Factor: See table.

Frequency Characteristics: See Figure 3.

Maximum Voltage: 500 volts peak for all units (except 980-L which is rated at 300 volts) at frequencies below the limiting frequencies tabulated below. At higher frequencies the allowable voltage decreases and is inversely proportional to the square root of the frequency. These limits correspond to a temperature rise of 40° Centi-





View of the Type 980-F (left) and Type 980-N (right) Decade Capacitor Units.

grade for a power dissipation of 2.5 watts for the Type 980-F and 3.5 watts for all other units.
Mounting: Machine screws for attaching the decade to a panel are supplied.

Dimensions: See accompanying sketch.
Net Weight: Type 980-F, 3 pounds, 12 ounces; Type 980-L, 1 pound, 10 ounces; Types 980-M and -N, 1 pound, 8 ounces.

Type	*Capacitance*	*Dielectric*	*Dissipation Factor at 1 kc and 23° C*	*Frequency Limit in Kc for Max. Voltage*	*Code Word*	*Price*
980-F	**1.0 μf in 0.1 μf steps**	**Mica**	**Less than 0.0003**	**5**	ACUTE	**$128.00**
980-L	**1.0 μf in 0.1 μf steps**	**Paper**	**Less than 0.010**	**1**	ADAGE	**28.00**
980-M	**0.1 μf in 0.01 μf steps**	**Mica**	**Less than 0.001**	**100**	ADDER	**42.00**
980-N	**0.01 μf in 0.001 μf steps**	**Mica**	**Less than 0.001**	**1000**	ADDLE	**26.00**
980-PI	**Switch only**				SWITCHBIRD	**11.00**

WESCON 1956

The Western Electronic Show and Convention will be held in Los Angeles, August 21–24. Visit us in booths 918 and 919 to see the new GR instruments that you have been reading about in the *Experimenter*, including:

Type 1230-A D-C Amplifier and Electrometer
Type 1605-A Impedance Comparator
Type 1391-A Pulse, Sweep, and Time-Delay Generator
Type 1603-A Z-Y Bridge
Type 874-LBA Slotted Line, with Type 874-MD Motor Drive
Type 907-R and 908-R X-Y Dial Drives

TYPE 1420 VARIABLE AIR CAPACITOR

A NEW, HIGH-QUALITY COMPONENT FOR INSTRUMENT USE

The concept of machining a parallel-plate type of variable air capacitor from solid metal, although not a new one, is unique among contemporary manufacturers. The main features of the new TYPE 1420 Capacitors (Fig. 1) are derived from this technique, which offers advantages, both mechanical and electrical, over more conventional methods.

Certain mechanical advantages are obvious. Machining is inherently a more precise operation than rolling, so that plates can be better controlled in thickness and straightness. Gang milling eliminates the cumulative spacing errors imposed by piece tolerances on a stacked structure, and turning and boring on a single piece insures better concentricity than can be obtained in a composite assembly. The integral-plate construction makes a sturdy structure with high mechanical stability.

Electrical performance gains are equally apparent. The precise machining produces inherently good linearity and control of capacitance magnitude. The homogeneous nature of the conductors yields lower metallic resistance and inductance than even a soldered stack and provides low thermal drift. The ruggedness of the plates minimizes microphonic tendencies.

The General Radio Company, in the light of the advanced state of the arts of aluminum extrusion alloys and cutting tools, undertook the development of a practical capacitor incorporating the foregoing advantages. Although the improved performance for this construction in an instrument-grade capacitor would warrant a cost premium, it was discovered that the proper combination of free-machining aluminum alloy with tungsten-carbide tools in a special machine (Fig. 3) produced superior one-piece plate assemblies at less cost than the conventional punching, stacking and soldering methods.

The design of the TYPE 1420 Variable Air Capacitor, delineated in Fig. 2, takes further advantage of the machining process to provide a number of extra features. Because the stator (1) is plunge cut, the resulting plates are completely joined on their outer pe-

Figure 1. View of the three stock models of Type 1420 Variable Air Capacitor

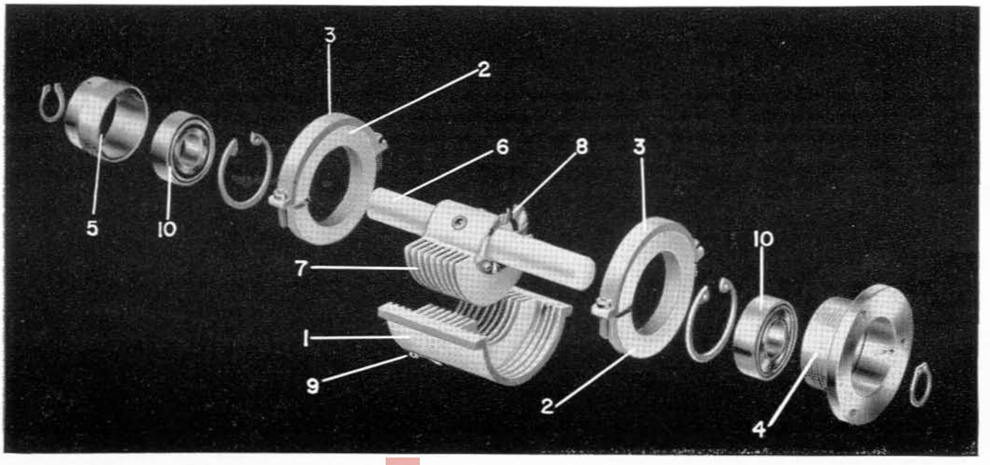
ripheries. This eliminates irregularities in the capacitance-vs.-rotation curve which might otherwise be caused when the rotor passes the vicinity of a stator supporting post or strut, helps to minimize resistance and inductance, and makes the part rigid enough to serve as the supporting frame for the whole capacitor. Use of the stator as a frame is accomplished by concentrically boring out all but 1/32 in. of the four plates on each end of the piece. Precisely fitted polystyrene insulators (2) are matched to these bored ends and held by clamps (3). The vestigial plates in both stator and clamps lock the insulators axially.

Polystyrene is an ideal dielectric material for the insulators of an air capacitor, because of its low dielectric constant and extremely low losses. Although it is thermally and mechanically unsuitable in most structures, the insulators in the Type 1420 are machined from a cast bar of cross-linked polystyrene for thermal adequacy and are stressed entirely in compression over a wide area to eliminate crazing or other structural failure.

These insulators have tapped center holes and are slit, to mate with and to clamp on to, threaded bearing cages (4) and (5), thereby permitting micrometer adjustment and subsequent locking of the ball bearings (10), which support the shaft (6). The shaft is of glass-reinforced polyester, filled with long axial fibers, similar to a modern fishing rod, and is of exceptional strength and stability as well as being good electrically. The use of an insulating shaft isolates the rotor for three-terminal connections and takes the ball bearings out of any electrical path. It is well known that the erratic conductivity of ball bearings produces electrical noise even when well shunted by parallel sliding contacts.

The rotor (7) is simply and firmly attached to the shaft by setscrews transverse to a closely fitted through hole. The concentricity of the rotor is insured, because the plates are milled and turned on a centered arbor held by the setscrews exactly as the shaft is secured in assembly. The front end bearing cage (4) has a flange by which the capacitor is mounted, and the rear cage (5) has a thin-walled, perforated extension to which a rotor connection may be soldered. Electrical connection to the stator is normally made by a solder lug (9) which is affixed adjacent to the rotor terminal to aid in providing short leads to associated circuitry.

Figure 2. Exploded view of a Type 1420 Variable Air Capacitor with elements identified. In order to show the split-spring ring contact, the rotor is reversed in this view.



A coin-silver, split-spring ring (8) is attached permanently to the rotor with drive pins and has two independent sliding contacts brushing the rear bearing cage. In the General Radio Type 1606-A R-F Bridge, a special reversed version is used, in which the rotor brush makes contact with the front bearing housing to provide a grounded rotor.

The rotor, stator, and clamp blanks are cut off from shaped extruded rods (Fig. 4). The aluminum alloy is identical in these parts to eliminate differential expansions and consequent thermal capacitance drift. The bearing cages are of brass, bright-alloy plated, and the full size (standard inch series 3/8″) ball bearings are double shielded, packed with wide-temperature-range lubricant and are suitable for continuous motor drive. In the Type 1606-A R-F Bridge these capacitors have passed all the environmental tests of MIL-T-945-A.

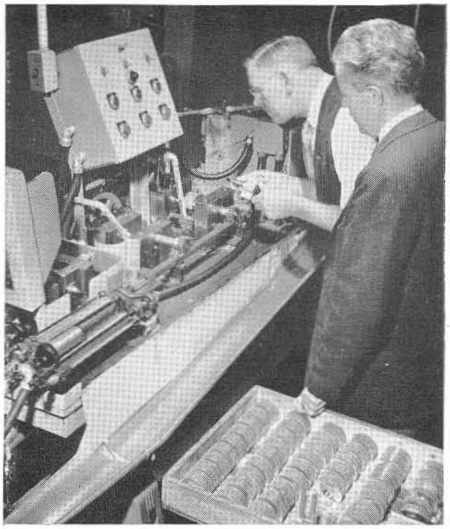


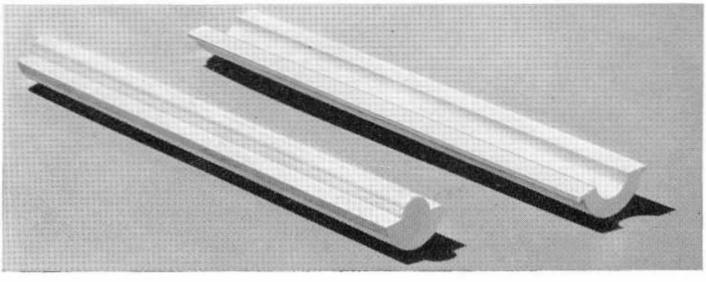
Figure 3. Designed and built in General Radio's tool department, this machine automatically mills the rotors and stators from the aluminum extrusions shown in Figure 4.

An interesting application of the Type 1420 Capacitor is shown in Fig. 5. This small, plug-in, general-purpose variable capacitor is shielded and equipped with a coaxial connector. The design takes advantage of the good high-frequency characteristics of the Type 1420, as well as its compactness, ruggedness and reliability.

The General Radio Company has had several years experience in the manufacture and use of these milled plate capacitors in proprietary instruments. They are now being offered for sale as a catalog component in the belief that many customers will have applications ideally suited to their many features.

— H. M. Wilson

(Below) Figure 4. Extruded aluminum stock from which rotor and stator are milled. (right) Figure 5. View of the Type 874-VC Variable Capacitor, a shielded unit of the 1420-type, used as a tuning element in coaxial circuits.



SPECIFICATIONS

Capacitance Range:

	Nominal Max.	Nominal Min.	Range for Linear variation
H	250	16	216 ± 5μμf
G	130	14	108 ± 5μμf
F	70	13	54 ± 5μμf

The rotor-to-ground capacitance is about 2μμf, and the stator-to-ground capacitance is about 6μμf, for all sizes. The data in the above table are for the capacitor used as a two-terminal device, with rotor grounded. If stator is grounded, maximum and minimum capacitance values will be decreased by about 4μμf.

Linearity: The variation of capacitance with angle of rotation is guaranteed linear within ± 0.2% of full scale. The angular range of linear variations is 160°.

Typical linearity is better than ± 0.1%.

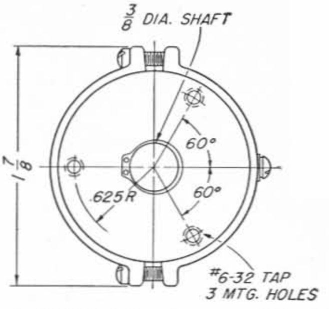
Dielectric Losses: For the grounded-rotor connection, the dielectric losses correspond to a D_oC_o product of less than .01 x 10^{-12}. The rotor-to-ground capacitance has a D_oC_o product of 0.1 x 10^{-12}. This loss component is in parallel with the main capacitance only for the ground-stator connection.

Insulation Resistance: Greater than 10^{11} ohms under standard ASTM laboratory conditions (23° C, 50% RH).

Depth behind panel

F 1¾
G 2⅛
H 2⅞

Shaft Dia. ⅜



Temperature Coefficient of Capacitance: Approximately + .003% per degree C.

Shock and Vibration: Will pass shock and vibration tests of MIL-T-945-A.

Maximum Voltage: 70 volts peak.

Inductance: Approximately 0.006 micro-henry.

Torque: 2 ounce-inches maximum.

Net Weight: Type 1420-F, 4 oz; -G, 4½ oz; -H, 5½ oz.

Dimensions: See sketch.

Type		*Code Word*	*Price*
1420-F	**70 μμf, max**	MARRY	**$20.00**
1420-G	**130 μμf, max**	MATIN	**21.50**
1420-H	**250 μμf, max**	MAXIM	**22.50**

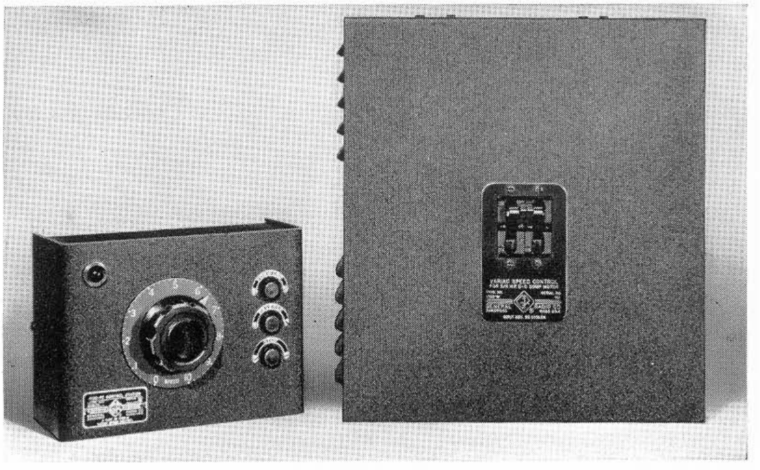
CLOSE-OUT SALE OF TYPE 1702-M MOTOR CONTROL

¾-hp, push-button-controlled model

We have on hand a number of our ¾-hp, Type 1702-M Variac® Speed Controls, complete with push-button control stations. This model, which originally sold for $350.00, has been discontinued as a result of the introduction of the new Type 1702-BW, which can be used with a drum-type controller to accomplish the same purpose at a lower price.

These controls are brand new and carry our standard new-equipment guarantee. To close out our stock, they are now offered at $175.00 each, just one-half the original price. Circuit and characteristics are identical with those currently supplied on newer models, and the unit is an exceptional bargain at this price, which is well below that of current models.

This control will operate a 115-volt, d-c, shunt or compound motor from a 115-volt, 60-cycle, a-c line. Motor speed is continuously adjustable and is controlled by a Variac® autotransformer. A description will be found on page 3 of the *Experimenter* for December, 1953.



View of the Type 1702-M Variac Motor Speed Control. The small control unit shown at the left can be mounted in any location convenient to the operator.

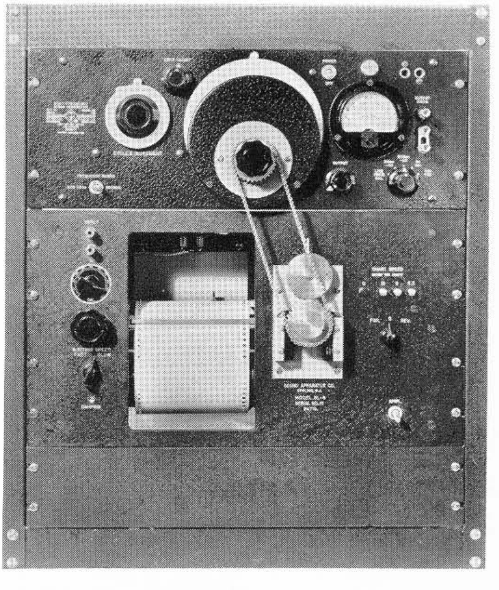
SPECIFICATIONS

Horsepower: ½ and ¾.
Input: 105 to 125 volts, 60 cycles, or 105 to 120 volts, 50 cycles, 10 amperes.
Input Power: 1150 watts, full load; 65 watts, standby.
Electrical Output: Armature supply, 0 to 115 volts, 6.5 amperes, dc; field supply, 115 or 75 volts, 0.4 ampere.
Motor Speed Range: 0 to rated or 0 to 1.15 rated.
Dynamic Braking: Automatic in stop position.
Armature Overload Protection: Circuit breaker at 7.5 to 9 amperes.
Control Station: Remote.
Main Cabinet Dimensions: 13½ x 15 x 6½ inches.
Code Word: WISTY
Price: $175.00.

RECORDER COUPLING FOR THE BEAT — FREQUENCY AUDIO GENERATOR

The Sound Apparatus Company, Stirling, New Jersey, has recently completed the development of its Model SL-4 Recorder. It is designed for the plotting of frequency response curves of electro-acoustical apparatus. With it, response curves of loud-speakers, microphones, filters, equalizers, transformers can be automatically plotted in a very short time. A General Radio Type 1304-B Beat-Frequency Audio Generator is especially recommended by the manufacturer as the generator for driving the equipment under test. Its frequency control dial is attached by a low-backlash chain drive to the motor in the recorder which operates the paper drive. Complete information about the recorder can be obtained from its manu-

Figure 1. View of the Sound Apparatus Company's Model SL-4 Recorder coupled to the General Radio Type 1304-B Beat Frequency Audio Generator.



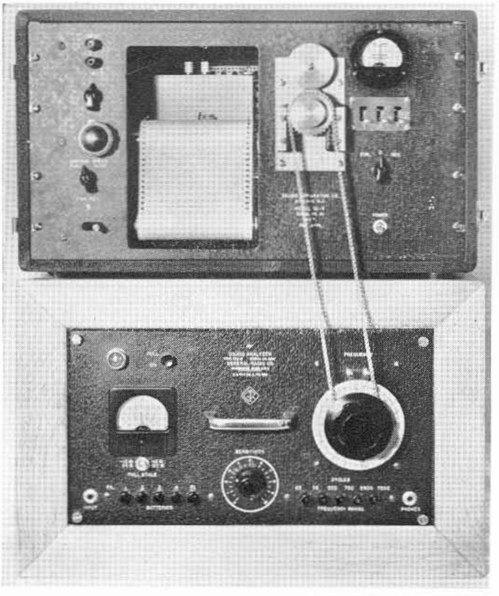


Figure 2. The recorder coupled to the General Radio Type 760-B Sound Analyzer.

facturer. He is equipped to provide the coupling means between the recorder drive and the oscillator.

Here is another application in which the beat-frequency type of oscillator is ideal because the entire audio spectrum may be swept with one rotation of the frequency control dial, eliminating the need for the frequency multiplier adjustments necessary with R-C type oscillators.

Figure 1 shows the Sound Apparatus Model SL-4 Recorder coupled to the Type 1304-B Beat-Frequency and Figure 2 shows the same recorder arranged to drive the Type 760-B Sound Analyzer.

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VOLUME 31 No. 3 AUGUST, 1956

MOTOR DRIVES FOR W-SERIES VARIACS®

Also IN THIS ISSUE

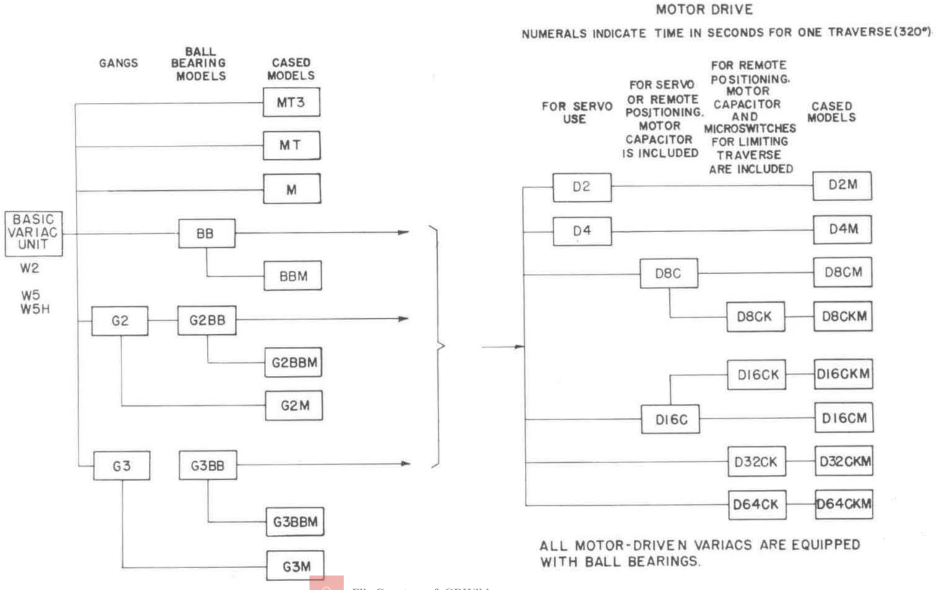
Motor drives in a wide variety of speeds, suitable for servo work as well for remote positioning applications, are now offered for the recently announced Types W5 and W2 Variacs. These drives, together with the several models and ganged assemblies previously announced,[1,2] make the W-series Variacs an extremely flexible and versatile product line. The completeness of the line is best illustrated by the "genealogy" shown in Figure 1. Careful design planning and extensive production tooling make it possible to assemble the many variations shown from a limited number of stocked parts and subassemblies. The prices are consequently determined on a production basis, rather than on the "special-order" basis that might ordinarily be expected.

Mechanical Design

An extremely simple and straightforward design has been adopted to

[1] "Type W5 Variac®, *General Radio Experimenter*, 30, 7; December, 1955; pp 1–11.
[2] "More New Variacs®", *General Radio Experimenter*, 30, 12; May, 1956; pp 13–15.

Figure 1. "Family tree" of W-model Variac® Autotransformers. Type numbers are formed by adding in sequence the appropriate letter and numeral combinations. For examples, see Figure 4.



provide motor drive. The gear reducer motor, with a suitable mounting plate, is "ganged" to the unit to be driven, much as another Variac would be. The construction is shown in Figure 2. Drive is from the base end of the Variac, making possible a rigid mechanical assembly and minimizing insulation problems. Ball bearings are used on all motor-driven Variacs.

Gear coupling between motor shaft and Variac shaft was chosen for a number of reasons.

1. The problem of alignment between shafts is reduced as compared to a rigid direct coupling.

2. The problem of phase shift in a flexible coupling is eliminated, simplifying the servo-drive problem.

3. With a choice of gear ratios several drive speeds can be provided from a given motor.

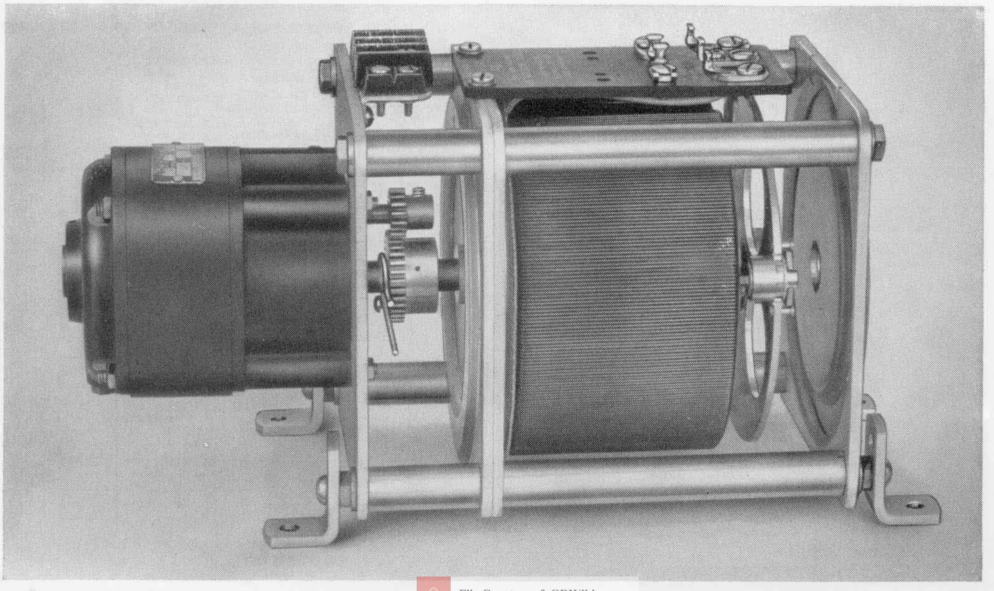
Mounting slots in all motor plates permit proper motor location for the selected gear and close adjustment of the gear and pinion mating. Motor leads are brought out to a terminal strip attached to the motor plate.

Motor

To make available a wide range of drive speeds, three different motor speeds will be stocked. Gear reducers assembled to the basic motors produce output shaft rates of approximately one second, four seconds, and sixteen seconds per revolution. These speeds, in conjunction with the additional choice of reduction available in the coupling gears, provide Variac traverse rates of 2, 4, 8, 16, 32, or 64 seconds, full scale.

The two fastest drives (2 and 4 seconds) are intended for servo operation, as in the GR Type 1570-A Automatic Voltage Regulator. For such applications the motor chosen has low moment of inertia and high angular acceleration. The low angular momentum eliminates any need for limit switches, ordinarily used to de-energize the motor. A simple mechanical stop is used, arranged so that stalled torques are not transmitted to the Variac. Enough elastic deformation is provided by the Variac shaft to prevent impact damage to the gear train. Both motor and gear train will withstand stalled

Figure 2. View of a motor driven Type W5 Variac.



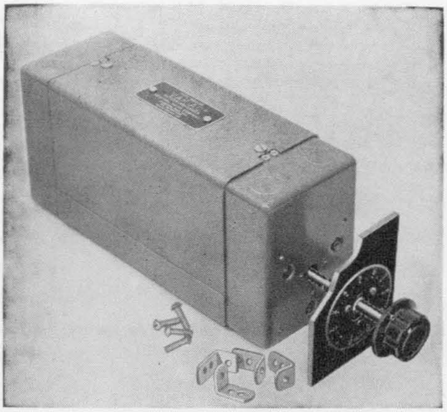


Figure 3. View of cased model of motor-driven Variac. Appearance is identical with that of a ganged model with case.

conditions indefinitely and will take, without damage, thousands of full-impact stops. Since, for servo-operation, it is assumed that the proper motor capacitor will be included in the servo amplifier, no capacitor is furnished.

The same type of low-inertia motor is used also for the medium-speed drives (8 and 16 seconds), in whose applications fast starting is not ordinarily essential, but fast stopping with minimum overshoot is desirable. With the motors selected, stopping is fast enough so that for most applications no dynamic braking is required.

This motor can be used for either servo or remote positioning applications, and so a motor capacitor is furnished. Microswitches for limiting traverse are optional.

The third motor, for 32- and 64-second traverse and remote-positioning applications, has a higher torque, exceeding the capabilities of the mechanical stop, so that microswitches are mandatory. Motor capacitor is furnished.

Table I summarizes the mechanical specifications for the three motors.

Enclosures

Motor-driven assemblies are available open or completely enclosed. The structural similarity to a ganged Variac is extended to the method of enclosure. Neat, economical enclosure is provided by making use of already available cases and methods. Figure 3 shows a typical enclosed assembly.

TABLE I

		STANDARD EXTERNAL GEARING					
STANDARD MOTOR	A	2:1	4:1				
	B			2:1	4:1		
	C					2:1	4:1
SECONDS FOR 320°		2	4	8	16	32	64
OUNCE-INCHES TORQUE		30	60	120	240	240	480
VARIAC	2	x	x	xo	xo	xo	xo
W — or M — * Model 115 or 230 volts	2G2	x	x	xo	xo	xo	xo
	2G3		x	xo	xo	xo	xo
	5	x	x	xo	xo	xo	xo
	5G2		x	xo	xo	xo	xo
	5G3		x	xo	xo	xo	xo
STOP		MECHANICAL		OPTIONAL		MICROSWITCH	
CAPACITOR		NO		YES		YES	

x Servo applications only xo Either servo or remote positioning * 60-cycle motor, 400-cycle Variac

Although the many possible assemblies and variations as shown in Figure 1 are not stocked assembled for immediate shipment, inventory will be carried of basic ball-bearing Variacs, as well as motor drive, micro-switch assembly and enclosure parts. Under normal conditions, therefore, any of the combinations shown can be shipped, in moderate quantities, within a few weeks of order.

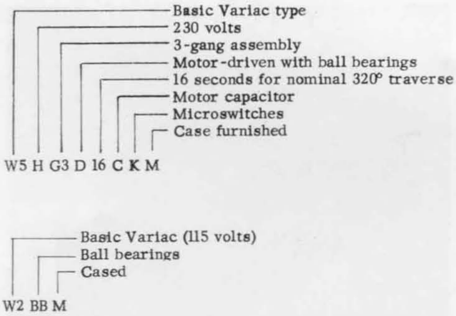


Figure 4. Two examples of how Variac type numbers are formed.

SPECIFICATIONS

Motor: 2-phase, 115 volts, 60 cycles
Winding Impedance: at 60c, 1300 + j2200 ohms, each winding; d-c resistance, 575 ohms, each winding.
Capacitor: 0.8 to 0.9 μf, oil-filled, 300 v wkg.
Normal speed, rotor: 1350 rpm

Moment of Inertia, rotor: 0.1 ounce-in.^{2}
Stalled rotor torque: 2 ounce-inches
Theoretical acceleration: 7680 radians/sec.^{2}
Variac Moment of Inertia: Type W2, 0.95 ounce-in.^{2}
Type W5, 3.08 ounce-in.^{2}

PRICES

Refer to Table I for available models
Refer to Figure 3 for type numbering system

Variac or Variac Assembly with ball bearings		Price
W2	**BB***	**$18.50**
W2G2	**BB***	**39.00**
W2G3	**BB***	**57.00**
W5	**BB***	**23.00**
W5G2	**BB***	**49.00**
W5G3	**BB***	**71.00**
W5H	**BB***	**25.00**
W5HG2	**BB***	**53.00**
W5HG3	**BB***	**77.00**

MOTOR-DRIVEN ATTACHMENTS

		Unit Price
Motor Drive Only	**(D)**	**$75.00†**
Capacitor	**(C)**	**n/c**
Microswitches	**(K)**	**7.00**
Case	**(M)**	**8.00**

* Motor-driven Variacs need not include the BB designation in the type number, since all motor-driven models are equipped with ball bearings.

† In lots of 5 or more. For quantities less than 5, an additional set-up charge of $6.00 is added and is prorated over the quantity ordered.

NATIONAL ELECTRONICS CONFERENCE

Hotel Sherman — Chicago

October 1–3, 1956

Visit the General Radio exhibit in booths 142 and 143 to see the latest in electronic test equipment. The motor-driven Variacs® and the X-Y dial drives described in this issue will be on display, as will the new Type 1230-A D-C Amplifier and Electrometer, the Type 1605-A Impedance Comparator, the Type 1213-C Time/Frequency Calibrator, the Type 1391-A Pulse, Sweep and Time-Delay Generator, and other important new instruments.

SYNCHRONOUS DIAL DRIVES FOR AUTOMATIC X-Y PLOTTING

Automatic sweeping techniques continue to increase in importance in electronic measurement systems. The improved reliability of data and the conservation of man-hours, together with the design of new recorders and sweeping devices, have stimulated greater use of this test method. Basically, the independent variable, whether it be frequency, voltage or other quantity, is varied at a controlled rate over a fixed range while the output characteristic of the device under test is observed or recorded. In particular, the measurement of the frequency response of a device or system lends itself readily to this technique.

The output amplitude as a function of frequency can be displayed on a cathode-ray oscilloscope by use of the methods previously described for General Radio's Type 1750-A Sweep Drive[1] and Type 908-P1 and P2 Synchronous Dial Drives.[2] When permanent and more precise recordings of the data are required, however, the use of a two axis plotter is desirable. A d-c voltage proportional to the independent variable is fed in to drive the X axis, while the output characteristic as a d-c signal is used to drive the Y axis of the recording pen. For most plots a single trace is sufficient, and it is desirable to use sweeping rates considerably slower than those used in CRO presentation. A synchronous sweeping rate is not always required but is often valuable because it furnishes a standard, reproducible, common time base.

The new General Radio X-Y Dial Drives are designed to sweep standard GR 4-inch (Type 907-WA) and 6-inch (Type 908-WA) Gear Driven Precision Dials for front-of-panel mounting. The 4-inch model is shown in Figure 1 and the 6-inch model in Figure 6. The synchronous motor in the drive rotates the dial at a uniform rate, which, in turn, rotates a potentiometer providing an output voltage proportional to the dial position. The motor can be switched off and disengaged from the dial to permit manual operation of the instrument by means of a knob mounted on the potentiometer shaft. The potentiometer remains engaged with the dial regardless of the method of operation, thus facilitating adjustments of zero position before the recording is made.

These drives are readily mounted in place of the existing manual gear drive on the GR oscillators listed on the next page.

The drives may be used with other equipment when the Type 907-WA or Type 908-WA Dial is installed.[3]

[1] Eduard Karplus, "A New System for Automatic Data Display", *General Radio Experimenter*, 29, 11, April, 1955.
[2] H. C. Littlejohn, "Motor Drives for Precision Dials and Beat-Frequency Oscillators," *General Radio Experimenter*, 29, 6, November, 1954.

[3] See latest General Radio Catalog.

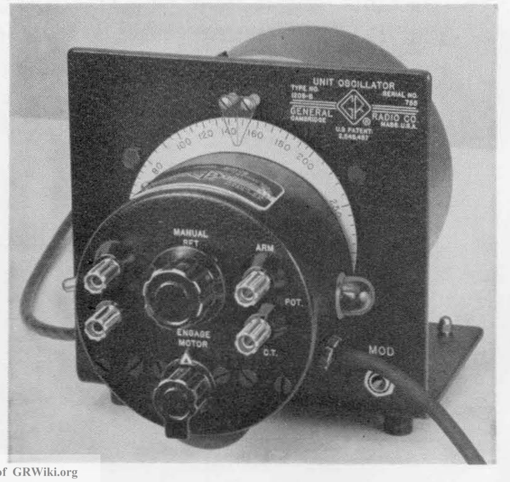


Figure 1. View of the Type 908-R144 X-Y Dial Drive installed on a Type 1208-B Unit Oscillator.

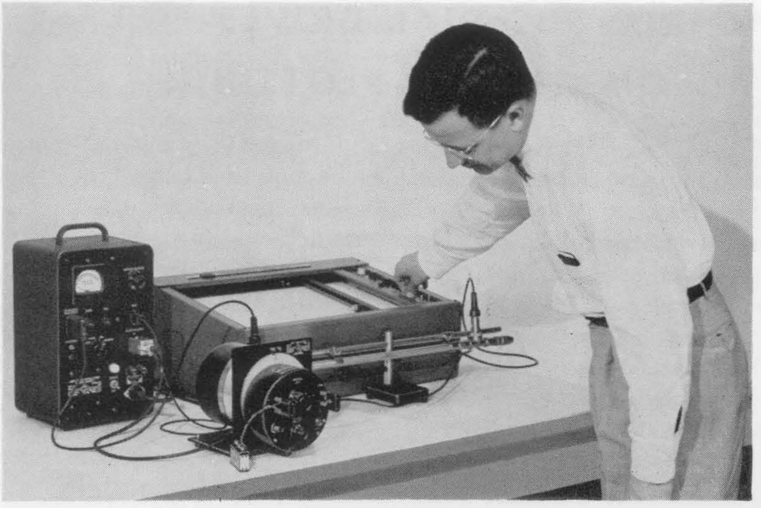


Figure 2. Assembly of equipment for plotting frequency characteristic of a Type 874-F185 Rejection Filter. The Type 1215-A Unit Oscillator is driven by the Type 908-R96 X-Y Dial Drive; oscillator amplitude is held constant by the Type 1263-A Amplitude-Regulating Power Supply. The recorder is a Variplotter, Model 1100-A, manufactured by Electronic Associates.

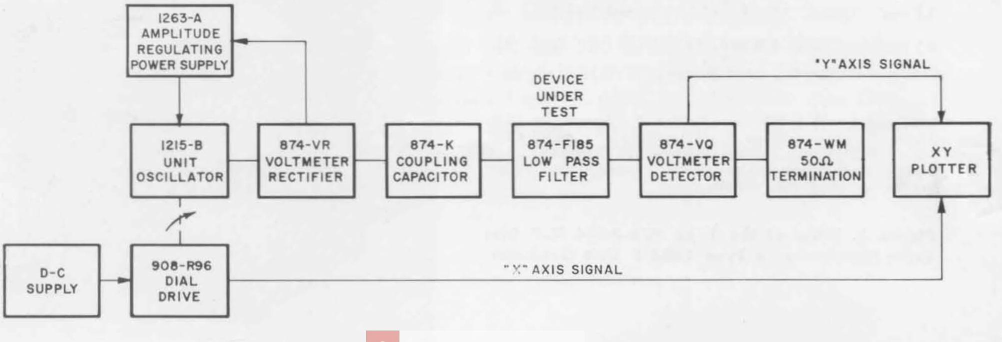
Type No.		*Frequency Range*
1304-B	Beat Frequency Audio Generator	20–40,000 cycles
*1210-B	Unit Oscillator	20–500,000 cycles
1211-B	Unit Oscillator	0.5–50 Mc
1215-B	Unit Oscillator	50–250 Mc
*1208-B	Unit Oscillator	65–500 Mc
*1209-B	Unit Oscillator	250–920 Mc
1218-A	Unit Oscillator	900–2000 Mc

(* Instruments marked require the Type 907-R Drive while those not marked require the Type 908-R Drive.)

The amplitude of the signal from the oscillator must be held constant if the final recording is to be a direct indication of relative response. The General Radio TYPE 1263-A Amplitude Regulating Power Supply, when used with the TYPES 1211-B, 1215-B, 1209-B or 1218-A Unit Oscillators, will provide a constant output voltage. The TYPE 1304-B Beat-Frequency Audio Generator and 1210-B Unit R-C Oscillator contain built-in, automatic-voltage-control circuits. A system response can, of course, be recorded and compared with a recording of a varying input signal if it is impracticable to maintain a constant input signal.

Fig. 2 shows a set-up in which the regulated output of a TYPE 1215-B oscillator is being swept over the range of 50 to 250 Mc and fed into a TYPE 874-F185 Low-Pass Filter. The rectified output from the filter and the dial position voltage are plotted by an X-Y recorder with the results shown in Fig. 4. Figure 3 is a block diagram of the system. It may be of interest to note that one can prepare suitable calibrated coordinate paper on the recorder by first manually positioning the dial to a specific frequency and then traversing

Figure 3. Block diagram for equipment shown in Figure 2.



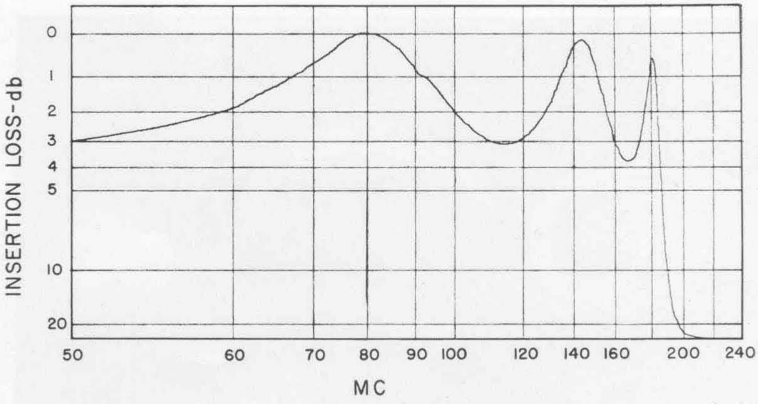


Figure 4. Plot obtained on recorder for the measurement shown in Figure 2 and 3. Horizontal and vertical coordinates were drawn by recorder.

the pen in the Y direction. After this procedure has been completed for principal values of frequency, suitable values of the Y axis voltage are fed in and the pen traversed along the X axis. If this grid is drawn on tracing paper prints can be made to provide specialized plotting paper.

The Type 1304-B Beat-Frequency Audio Generator has been designed with a logarithmic dial, thus conveniently permitting the use of commercially available audio-frequency semi-log paper. This feature is a great advantage in amplitude frequency tests on lines, amplifiers, loudspeakers, filters, equalizers, transducers and other networks.

An interesting application of the sweep technique in the audio range is shown in Figure 7. While some tape recorders record and play back at the same time, the leakage of the bias signal between the two heads may influence the apparent output response level. To obtain the most reliable results, the input signal should first be recorded and then played back on a subsequent rerun. Since the oscillator is being driven synchronously, it is possible to insert a frequency marker on the original signal fed to the tape recorder, which can be used to key the recorded sweep of the oscillator with the output signal from the tape recorder.

To provide greater versatility in the use of these dial drives, two speeds are offered in each of the two sizes. The higher-speed models operate with a self-reversing synchronous motor while the lower-speed models are driven by counterclockwise (increasing frequency

Figure 5. View of the Type 1304-B Best-Frequency Audio Generator and X-Y Dial Drive, with Moseley Model 60 Logarithmic Amplifier and Model 3 Autograph X-Y Recorder, arranged to measure the audio network shown in the foreground. The logarithmic amplifier, whose d-c output is proportional to the logarithm of the a-c input, permits the use of an amplitude scale linear in db.

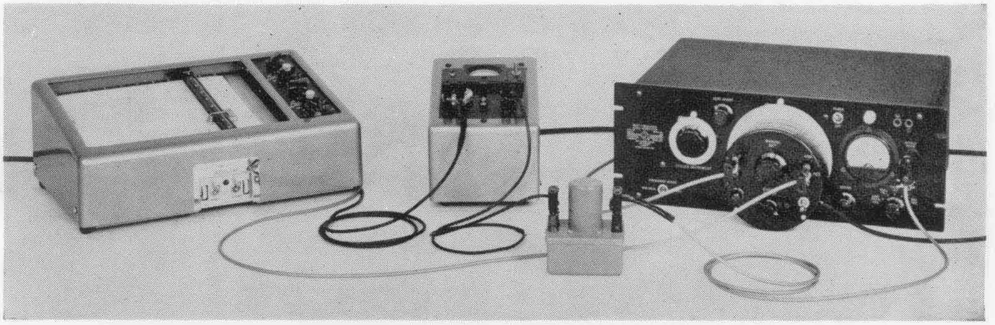


Figure 6. Close-up view of the Type 908-R X-Y Dial Drive installed on the Type 1304-B Beat-Frequency Audio Generator. This generator is ideal for audio-frequency plotting, because it covers the entire audio range in a single sweep of the dial and its output voltage is constant to ± 0.25 db.

on GR oscillators) motors. On these lower-speed units, a friction clutch is supplied to prevent damage if the motor is permitted to run after the dial has reached its stop.

To accommodate the wide range of d-c voltage ranges that may be desired from the position potentiometer, binding posts are provided for the insertion of a selected d-c supply. Binding posts are also available for the position signal. The direct-coupled, manual-drive knob can be used to center the potentiometer about any dial setting.

These drives find many important applications in both laboratory development and production testing, because they offer advantages of a rapid, reliable, semi-automatic test uncomplicated by the tedious task of reading, logging and plotting point by point values. It can produce an accurate graphic performance record that is easily compared with acceptance standards and one which can be reproduced for record files, certification reports and customer's information.

— G. A. Clemow

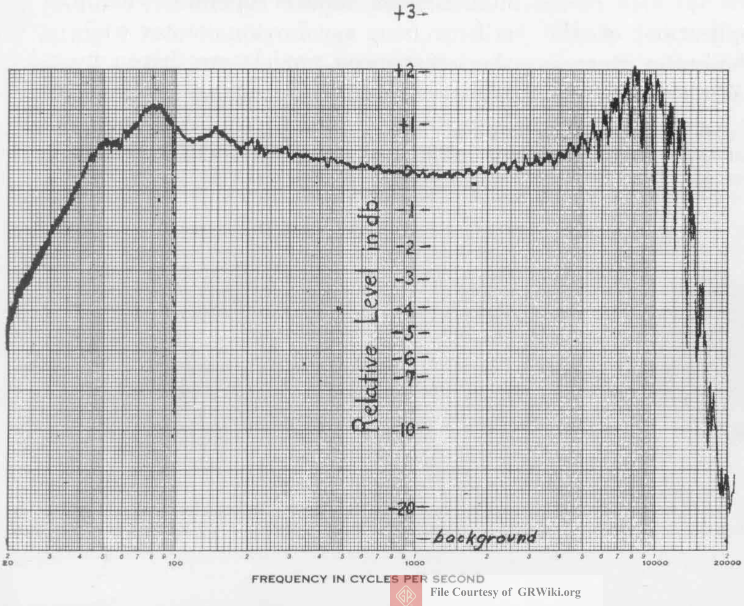


Figure 7. Graphic record of the frequency response of a tape recorder. The test voltage source was the Beat-Frequency Audio Generator shown in Figure 6. The vertical line at 100 cycles is the frequency calibration reference.

SPECIFICATIONS

Power Supply: Motor: 105–120 volts, 50–60 cycles, 3 watts. Potentiometer, see below.
Dimensions: 907-R, 4 (diameter) x 3⅞ (deep) inches.
908-R, 5¾ (diameter) x 3⅞ (deep) inches.

Weight: 907-R, one pound, 11 ounces.
908-R, two pounds.
Note: Data are for 60-cycle operation. Multiply speeds by ⅚ for 50-cycle operation.

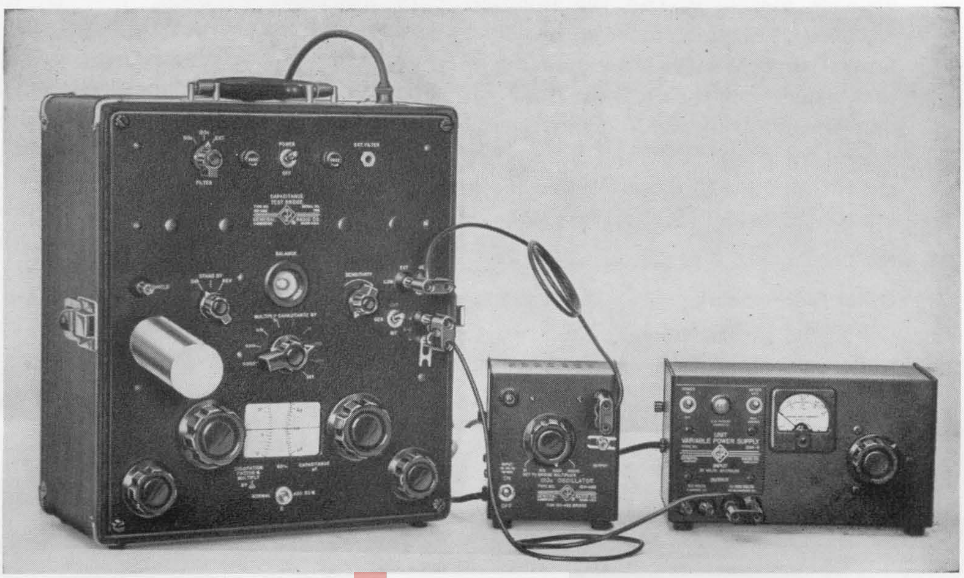
Type	*Dial*	*Pinion Speed*	*Dial Speed*	*Rotation*	*Center-tapped Potentiometer Resistance*	*Max Potentiometer Current*	*Resolution*
907-R18	907	½ RPM	18°/min	CCW	20 kΩ	10 ma	0.4°
907-R144	907	4 RPM	144°/min	Self-reversing	20 kΩ	10 ma	0.4°
908-R12	908	½ RPM	12°/min	CCW	50 kΩ	10 ma	0.2°
908-R96	908	4 RPM	96°/min	Self-reversing	50 kΩ	10 ma	0.2°

Type		*Code Word*	*Price*
907-R18	**X-Y Dial Drive**	EARLY	**$55.00**
907-R144	**X-Y Dial Drive**	EDUCE	**55.00**
908-R12	**X-Y Dial Drive**	EGRET	**55.00**
908-R96	**X-Y Dial Drive**	EJECT	**55.00**

A 120-CYCLE SOURCE FOR ELECTROLYTIC CAPACITOR TESTING WITH THE CAPACITANCE TEST BRIDGE

In most applications of electrolytic capacitors, a significant 120-cycle ripple component is superimposed on the applied unidirectional voltage. For this reason it has become widely accepted standard practice to test such capacitors at that frequency rather than at the more readily available 60 cycles. To meet this requirement, a modification of the 60-cycle Type 1611-A Capaci-

Figure 1. View of the Capacitance Test Bridge (left) with 120-cycle oscillator (center) and Unit Variable Power Supply (right) for furnishing the d-c polarizing voltage.



tance Test Bridge has been available for some time.[1] The modification as shown in the schematic diagram (Figure 2), consists primarily of the addition of terminals for connection of an external generator and of providing 120-cycle tuning for the internal detector. Switching is provided so that either the standard circuit or the special configuration can be used.

Because the input impedance to the bridge varies between 1 ohm and 1000 ohms, most available audio oscillators are not capable of delivering enough voltage directly to the bridge over its entire range for adequate sensitivity of balance. A multiwinding impedance-matching transformer is frequently required to deliver adequate energy to the bridge, particularly for the 1000 multiplier setting, and, in any event, a transformer is required to isolate the a-c source from the d-c polarizing voltage.

A recent modification of the TYPE 1214-A Unit Oscillator, the TYPE 1214-AS2 120-cycle Oscillator, has a power output approaching the maximum that the bridge arms will withstand. This inexpensive oscillator provides the 120-cycle source, the impedance matching, and the isolation. An output transformer is provided, tapped to provide optimum match to the bridge for each of the four applicable multipliers. A panel switch selects the proper tap, and the engraving corresponds to the multiplier markings of the bridge, X1, X10, X100, and X1000.

Other Frequencies

For the measurement of electrolytic

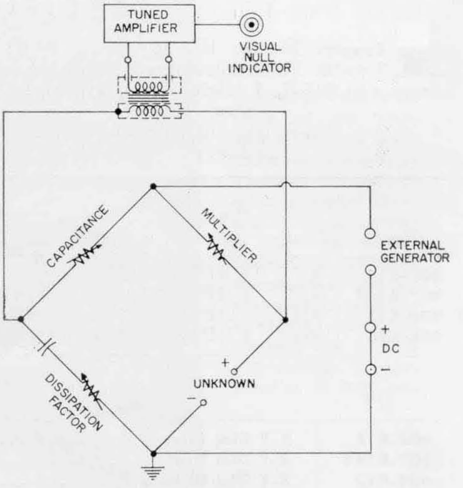


Figure 2. Elementary schematic of the bridge.

capacitors over a range of low audio frequencies, it is convenient to make use of the impedance-matching transformer and switching provided in the new oscillator. Accordingly, a jack is provided on the panel of the oscillator by means of which an external source can be connected.

The bridge circuit is designed for optimum sensitivity at 60 cycles, and substantially the same performance is obtained at 120 cycles. As the measuring frequency is raised, however, the bridge sensitivity factor decreases and above about 400 cycles is inversely protional to frequency. Figure 3 shows the variation of the bridge sensitivity factor[2] S for the different settings of the CAPACITANCE dial. The sensitivity factor is independent of multiplier setting, but the voltage applied to the bridge varies with ratio arm setting, as

[1] "Electrolytic Capacitor Testing at 120 Cycles", *General Radio Experimenter*, Vol. 28, No. 6, November, 1953, p. 8.

[2] Defined as $S = \dfrac{\frac{Za}{Zb}}{1+\frac{Za}{Zb}}$ d, where d is the precision of setting of the reactive balance

shown in the following table.

Bridge Multiplier	Approx. Voltage (rms) Applied to Bridge
× 1	18
× 10	6
× 100	2
× 1000	0.6

The upper frequency limit for satisfactory operation is thus a function not only of available detector sensitivity and applied voltage but also of the magnitude of the capacitance being measured and of the accuracy of measurement desired. With the internal detector, measurements can be made at 1 kilocycle on even the highest multiplier with a resolution of about 1%. If higher resolution is desired, a more sensitive detector can be connected externally to the external-filter jack of the bridge. For best results the external detector should have a 20-db discrimination to harmonics and noise.

Dissipation Factor

The dissipation factor range of the bridge is directly proportional to frequency. At 60 cycles the range is 0.6 (60%), at 120 cycles 1.2 (120%) and at 400 cycles 4.0 (400%). This variation is compatible with the normal tendency of high-value electrolytic capacitors to show dissipation factors rising with frequency as a result of fixed series resistance.

The effective accuracy of dissipation factor measurement decreases at the high frequencies. In addition to the problem of residual phase-angle errors within the bridge, the problem of making a satisfactorily low resistance connection to the capacitor under measurement is a serious one. For example, at 10,000 μf and 1000 cycles a series resistance of 0.001 ohm in lead or connection produces a dissipation factor of 0.6 (60%). For such an extreme case the limitation on accuracy is external to the bridge; for less extreme combinations of frequency and capacitance the accuracy of dissipation factor is $\pm 2\%$ of dial reading $\pm .0005$ $(f/60)$.

Applied Voltage

The a-c voltage applied to the capacitor under test is always somewhat lower than the voltage applied to the bridge, shown in the table above, since the ratio arm is in series with the unknown. The d-c polarizing voltage should normally be greater than the peak value of a-c test voltage. The voltages applied by the Type 1214-AS2 Oscillators are safely below ordinary voltage ratings for any given range. If, however, reduced test voltage is desired for capacitors of very low d-c rating or for any other reason, an adjustable resistor may be connected (in series or shunt) between the oscillator and the bridge to set to an arbitrarily specified level.

— I. G. Easton

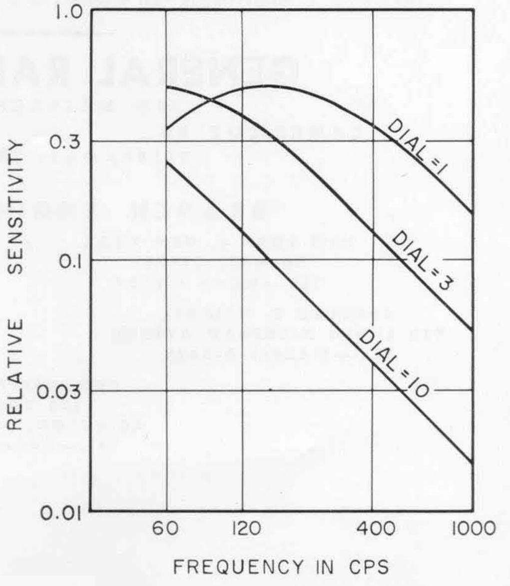


Figure 3. Variation of bridge sensitivity with frequency for different settings of the CAPACITANCE dial.

SPECIFICATIONS FOR TYPE 1214-AS2 UNIT OSCILLATOR

Frequency: 120 cycles ±2%.

Output Impedance: Four impedances to match the impedance of the TYPE 1611-AS2 Capacitance Test Bridge at four multiplier positions.

Output: At least 200 milliwatts into matched load.

Controls: Output impedance switch and power switch.

Distortion: Less than 3% into a matched load.

Terminals: The output terminals are jack-top binding posts with standard ¾-inch spacing; a ground terminal is provided, adjacent to one of the output terminals. Jack is provided for connecting external oscillator.

Power Supply: Unlike most instruments of the Unit line, the power supply is built into the instrument; 115 volts, 40–60 cycles; power consumption is about 16 watts.

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

Tube: One 117N7-GT, which is supplied with the instrument.

Mounting: Aluminum panel and sides finished in black-crackle lacquer. Aluminum dust cover finished in clear lacquer. Relay-rack adaptor panel available.

Dimensions: (Height) 5¾ x (width) 5 x (depth) 6¼ inches, over-all, not including power-line connector cord.

Net Weight: 4½ pounds.

SPECIFICATIONS FOR TYPE 1611-AS2 CAPACITANCE TEST BRIDGE

Capacitance Range: 0 to 11,000 μf at 60 cycles. 1 μf to 11,000 μf at 120 cycles or other external frequency.

Dissipation-Factor Range: 0 to 60% at 60 cycles. Range proportional to frequency. (0 to 120% at 120 cycles.) Dial readings must be multiplied by the ratio $\frac{f}{60}$ for frequencies other than 60 cycles.

Accuracy: Capacitance ±1%. Dissipation factor $\pm$(2% of dial reading $+0.05\% \times \frac{f}{60}$ dissipation factor).

Detector Filter: Tuned to 60 or 120 cycles, selected by switch. Jack provided for use of an external filter for other frequencies.

External Generator: Required for frequencies other than 60 cycles. TYPE 1214-AS2 Oscillator described below is recommended for 120-cycle measurements.

Polarizing Voltage: Terminals are provided for connecting an external d-c polarizing voltage. The maximum voltage that should be impressed is 500 volts.

One of the terminals is grounded so that any a-c operated power supply with grounded output can be used. The terminal capacitances of the power supply do not affect the bridge circuit.

Power Supply Voltage: 105 to 125 (or 210 to 250) volts, 60 cycles. **Power Input:** 15 watts.

Accessories Supplied: TYPE CAP-35 Power Cord and spare fuses.

Mounting: Portable carrying case of luggage-type construction. Case is completely shielded to insure freedom from electrostatic pickup.

Tube Complement: One each 6X5-GT/G, 6SJ7, and 6U5.

Net Weight: 30½ pounds.

Dimensions: (Width) 14½ x (depth) 16 x (height) 10 inches, over-all, including cover and handles.

Type		*Code Word*	*Price*
1214-AS2	Unit Oscillator (including power supply)........	ABBOT	$95.00
1611-AS2	Capacitance Test Bridge......................	FAVOR	$545.00

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

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CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
TEL.—WAbash 2-3820

SILVER SPRING, MARYLAND
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TEL.—JUniper 5-1088

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VOLUME 31 No. 4 SEPTEMBER, 1956

NEW TELEVISION TRANSMITTER MONITOR

A Major Advance in Station Instrumentation

Also IN THIS ISSUE

Monitoring equipment for radio and television broadcasting stations must meet or exceed FCC requirements, but reliability and easy maintenance are equally important. Beyond this, the well-designed and properly used monitor can function as a general test instrument for transmitter operations and maintenance, and these test facilities should be easily available and convenient to use. Finally, obsolescence must be considered and the monitor should be designed not merely to meet today's minimum requirements of accuracy and dependability, but to anticipate those of tomorrow.

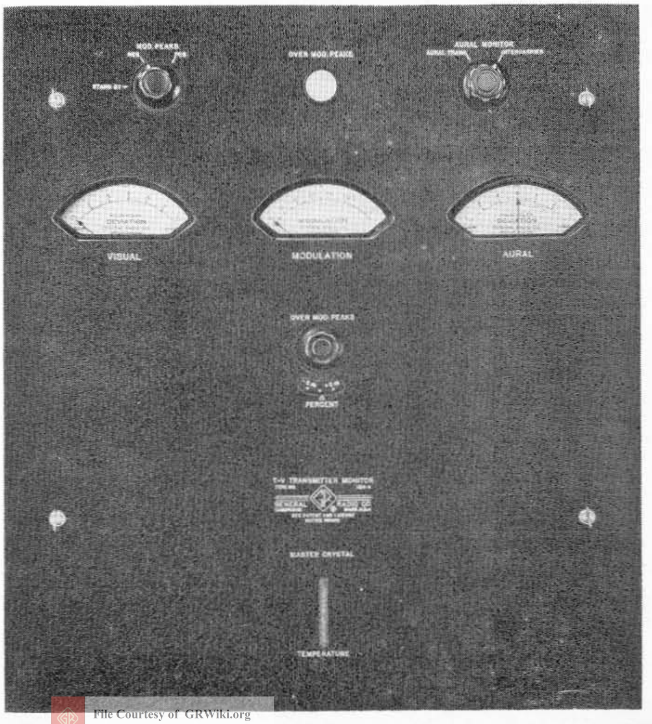


Figure 1. Panel view of the Type 1184-A Television Transmitter Monitor

The General Radio Company has been concerned with instrumentation for the broadcasting station for thirty years, which provides a fund of field experience unmatched in the industry. General Radio monitors are used by twice as many AM broadcasting and TV stations as all other makes combined.

The design of the new General Radio TYPE 1184-A Television Transmitter Monitor is based upon the field experience with its predecessors and incorporates many features specifically requested by transmitter engineers.

This new instrument is more than a monitor. It provides for many operational tests that will speed and improve adjustment, maintenance, and trouble-shooting in both aural and visual transmitter circuits. Continuous audible monitoring against loss of either carrier, and continuous meter monitoring of FM noise on the visual carrier, are typical of the additional functions provided in this new instrument.

It provides maximum protection against obsolescence.

The TYPE 1184-A Monitor is designed *beyond* mere legal minimum requirements for today's use. Thus protected against early obsolescence, this new instrument promises *long-term* value that far outweighs initial cost considerations.

It is easy to keep in operation. The TYPE 1184-A Monitor expresses a wholly new concept in mechanical design that gives convenience never before attained in an instrument of this type. Every operation in the installation, use, and maintenance of this new monitor can be handled from the front.

OUTSTANDING FEATURES

Intercarrier Monitoring

The new color TV standards [1] specify tolerances [2] for both the visual transmitter and intercarrier frequencies, thus requiring monitoring facilities for both. In addition, a complete intercarrier sound-detection system has been included within the monitor. This permits monitoring that simulates actual receiver operation and makes possible the correlation of transmitter performance with receiver listening tests.

Residual F-M Noise on Visual Carrier

No convenient method has hitherto existed for direct measurement of the

Figure 2. Front panel removes easily, and entire chassis pulls forward on slides for access to adjustments, test points, and tubes, with monitor operating.

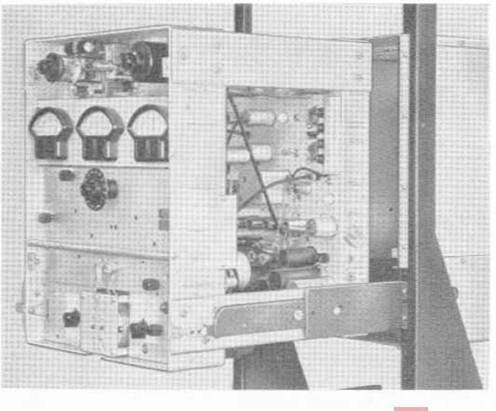
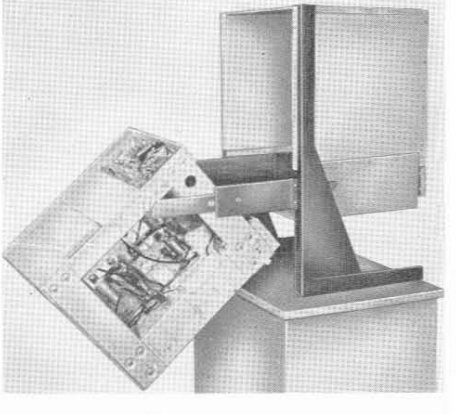


Figure 3. For access to rear or bottom, chassis tilts into this position and is held by latches. Monitor is still operating.



residual f-m noise on the visual transmitter carrier. In monochrome operation, noise of this type caused trouble in some types of receivers. With the introduction of color, this condition is more serious because of the distinct possibility of over-modulation on certain saturated colors unless video modulators are prevented from doing so by adequate limiters properly adjusted. Since a noise burst will appear in intercarrier-sound-detection receivers whenever either carrier frequency momentarily goes to zero, as when the visual transmitter is modulated to full 100% in the negative (white) direction, it becomes important to be able to monitor this characteristic. Circuits for this purpose are provided in the monitor.

Construction

In any instrument as complex as a monitor, facility and ease of service are of paramount importance.

All major circuits in the monitor can be checked for proper operation by means of a panel selector switch. Input-level adjustments are located directly behind a quickly removable panel plate. The panel itself has only those controls which are necessary to operate the monitor.

By pulling forward on a handle, one can slide the entire monitor out of the relay rack, where it will lock upon two metal slides in an extended *operating* position. All tubes, internal circuit adjustments, cables, and plugs are within easy reach. The entire front shelf of the monitor can be serviced from this position. The rear of the monitor is readily accessible as shown in Figure 3.

All adjustments and test points are clearly marked in recognizable colors and the color code indicates the relative importance of the particular adjustment. Thus, a red-circled control is vital

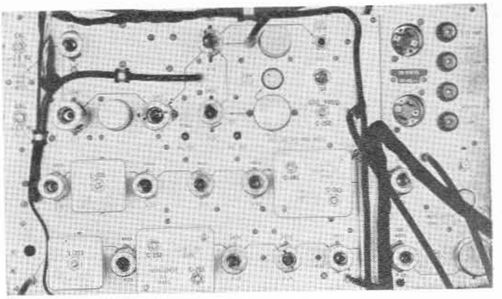


Figure 4. For convenience in maintenance signal paths are indicated by flow lines, adjustments are color coded, and test points are clearly marked.

to the operation and should not be touched without full knowledge of its function. An amber-circled adjustment is intended as a caution sign and implies that some auxiliary measurements may be required in obtaining proper results. A green-circled control is one which may be adjusted readily and does not require any external equipment in establishing its correct setting.

Another assist is given the operator by having "flow lines" or "circuit tracings" outlined upon the top of each shelf. It is thus possible to proceed from a functional block diagram directly to the instrument itself and to follow the circuit progression quite readily. Highly detailed schematic wiring diagrams need only be referred to for isolated trouble-shooting in localized spots.

The monitor offers minimum resistance to vertical air flow. This not only prevents overheating of the monitor itself but also does not obstruct the air flow and thus overheat units placed above or below the monitor. Hence the monitor's location in the rack is entirely optional, and a height can be chosen that gives the best visibility.

Precision Temperature-Controlled Oven

A new, precision, temperature-controlled, crystal oven has been designed.

This new unit uses a vacuum flask as the insulating enclosure. Its low thermal losses permit operation with an *average* power of two watts of heat input at normal room temperature. This makes possible a very simple control circuit without relays or the contact-resistance problems usually associated with sensitive thermostats.

BASIC PRINCIPLES

The monitor operates on the same basic principles as its General Radio predecessors.[2, 3, 4] It employs a single master-reference frequency, a harmonic of which is heterodyned with both visual- and aural-carrier frequencies to generate two beat frequencies, 4.35 Mc and 150 kc, respectively, which are used in direct monitoring of each carrier separately. This is illustrated in Figure 5. A third beat frequency of 4.5 Mc is also produced by mixing aural- and visual-carrier frequencies and is used in intercarrier monitoring.

Block Diagram

In the center portion of Figure 6 is shown the block diagram of the direct-monitoring systems. Two additional circuit groups permit the measurement of residual f-m noise on the visual carrier, shown to the left, and provide for intercarrier monitoring, shown to the right.

For direct aural-carrier frequency monitoring, the 150-kc signal (which contains the frequency-modulation components present on the aural carrier) operates an I-F limiter-amplifier, which drives a pulse-counter discriminator. The d-c component of the output of this discriminator is proportional to the average center frequency of the aural-transmitter carrier frequency.

The 4.35-Mc signal is used for direct visual-carrier frequency monitoring. Since this signal is not frequency modulated, a narrow-band frequency meter can be advantageously used, both for maximum sensitivity and to remove unwanted video modulation components. A second heterodyne process converts the 4.35-Mc signal to 1750 cycles. A limiter-amplifier operating at this frequency feeds a pulse-counter discriminator whose d-c output is a measure of the frequency of the visual-transmitter carrier frequency. This dual

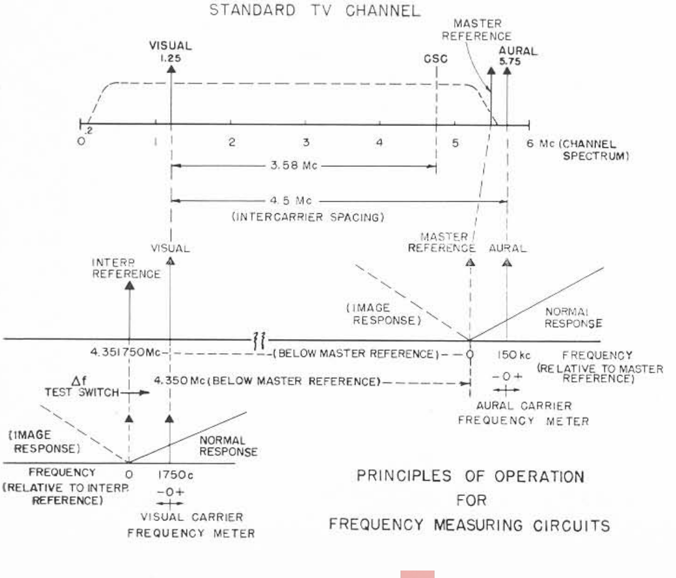


Figure 5. Frequency diagram showing principles of operation.

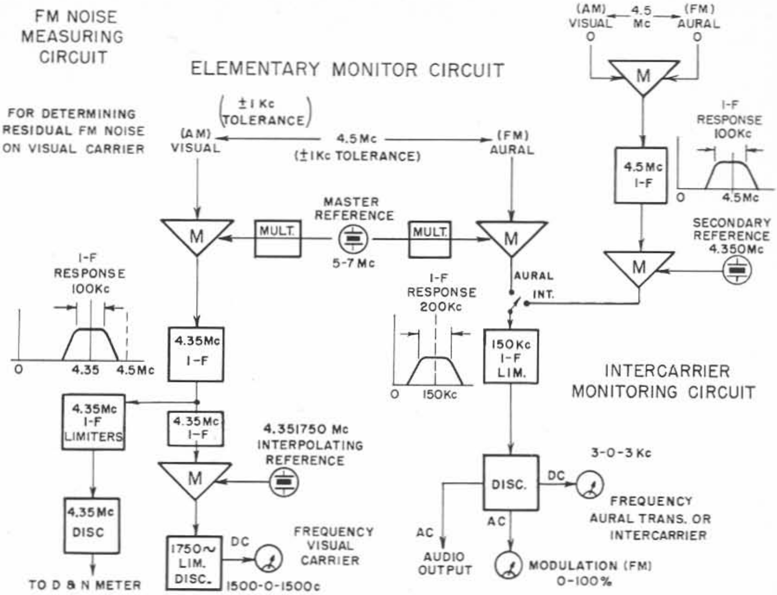


Figure 6. Functional block diagram of the monitor.

conversion step is illustrated at the left of Figure 6.

The 4.35-Mc IF signal is also used to operate a second limiter-amplifier, where the residual amplitude-modulated video components are removed from the signal. It then passes to a tuned-circuit discriminator, the output of which operates an external Distortion and Noise Meter.

The 4.5-Mc intercarrier signal operates a separate I-F limiter-amplifier and is then heterodyned down to 150 kc by means of a secondary reference crystal operating at 4.35 Mc. The resultant 150-kc beat is then available at a panel switch for selectively operating the aural-monitoring circuits from this signal or, alternatively, from the other 150-kc signal derived directly from the aural transmitter signal.

DESIGN FEATURES

Discriminators

For determining the center frequency of the aural carrier, a meter-discriminator of high stability is required. For frequency-modulation detection a highly linear discriminator is needed. Heretofore, both of these functions were combined in a single circuit. In the new monitor, two separate discriminators are used, each one optimized for its particular function.

The meter-discriminator is shown in Figure 7. LRC (on the right) comprise a low-Q series circuit operating above the series resonant frequency. The d-c voltage E_1 developed across C-4 is inversely proportional to frequency in the region near 150 kc. The left section, consisting of C-1, the two rectifiers, and C-2, is the conventional pulse-counter circuit, and hence the voltage E_2 is directly proportional to frequency. This gives twice the sensitivity of either circuit acting alone, and, because the d-c meter responds to the differential, small changes in amplitude of the 150-kc driving signal are canceled out at the zero-current position. Since this corresponds to center scale (3–0–3 kc), maximum accuracy is obtained at the point of maximum use.

The problems involved in this metering circuit can be shown by noting that the meter actually operates over a range of 150 ± 3 kc; hence, the meter scale is only ± 2% of the *operating* frequency. If it must remain stable to, say, one division (i.e., 100 cycles), the over-all circuit stability must be ± 100/150,000 or ± 0.067%. To achieve this stability requires minute attention to such details as component drift and temperature coefficients. Fortunately, the differential characteristics of the circuit aid in this respect. In this circuit, stability is of paramount importance and every practical means has been used to make it outstandingly good.

An additional advantage of this metering circuit is that no fragile ballast tubes are required to regulate the heaters of d-c amplifier tubes. The rectifiers used are crystal diodes, which have been stabilized against thermal and aging effects by appropriate circuit design.

Audio Discriminator

For frequency-modulation detection, the discriminator must be extremely linear and free of residual noise. Stability is required only to meet the needs of a modulation meter. This discriminator is based upon the well-known pulse-counter types,[5] as shown in Figure 8. The inherent linearity of these types is well known, but I-F filtering problems are severe, and sensitivity is usually low. Both of these problems are minimized by a balanced pulse-counter discriminator, which uses transformer output coupling and provides good sensitivity and simple filtering.

Each diode produces, on each half cycle, a current pulse through a resistance, R, as shown in the lower portion of Figure 8. This action is analogous to that of two pulse counters in series. The pulses occur at a uniform rate of 150 kc in the absence of frequency modulation of the 150-kc driving waveform. A d-c component is developed across the resistance R, but no use is made of this, and, obviously, the transformer cannot pass dc. The 150-kc fundamental component is balanced in the transformer, leaving only relatively small-amplitude even harmonics. These are high enough in frequency to be well above the transformer pass band and are therefore highly attenuated.

When the 150-kc input signal is frequency modulated, the current pulses through the resistance R are time modulated, i.e., they occur at a nonuniform rate. The deviation is proportional to the frequency modulation present. The a-c components in the audio range, represented by the time-rate-of-change of these current pulses occurring in the transformer primary, are a measure of the modulation present. These are passed through the transformer and constitute the demodulated audio signals. Only a small amount of

Figure 7. Elementary circuit of balanced discriminator used for center-frequency meter.

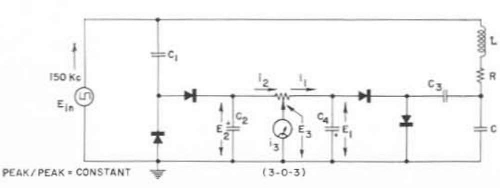
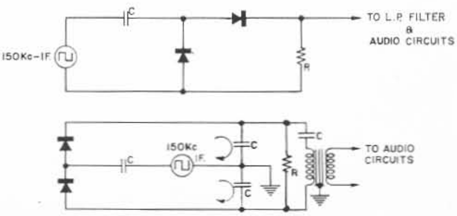


Figure 8. Discriminator used for f-m detection. At top, simple prototype; below, balanced circuit used in monitor.



filtering is necessary in the audio circuits that follow.

Precision Temperature-Controlled Crystal Oven

The heart of a frequency monitor is the quartz crystal employed to establish a reference frequency. The new unit developed specifically for this monitor is an example of simplicity in control.[8]

The circuit is shown in Figure 9. The main heater current is controlled by a small thyratron, which is turned on or off by a mercury-column thermostat. A cut-off, a-c, bias voltage is applied to the thyratron control-grid through the thermostat contacts, which close at 60° C. To prevent overshoot of the oven temperature, a small heater, or anticipator winding, is placed around the thermostat bulb.[6]

This control circuit is remarkably free from troubles due to contact resistances associated with the thermostat.

Figure 10 is a cross-section drawing of the crystal-oven detail. An outer aluminum cylinder surrounds the glass vacuum flask which has a balsa-wood plug at the open end. The heater is wound on a metal disc attached to this plug and all leads are brought out

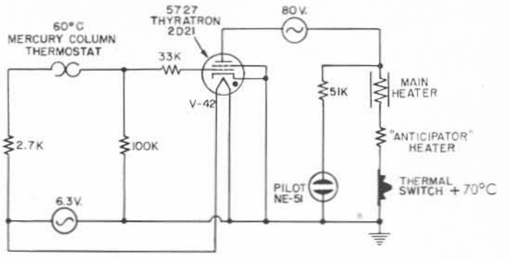


Figure 9. Schematic of control circuit for crystal oven.

through it. The heat loss by conduction along the wires is thus minimized, and a mechanical mount is made available for all internal parts. Included within the glass flask are the thermostat, quartz crystal mount, and two air-trimmer capacitors which are externally adjustable by means of insulated control rods.

The control characteristics of this oven are shown in Figure 11. In these tests, the ambient temperature was rapidly changed over a wide range, by means of rapid forced-air circulation. It represents an extreme condition not likely to be encountered in normal environments. For normal, slowly varying temperatures, the oven will maintain constant internal temperature at all times within a few hundredths of one degree C.

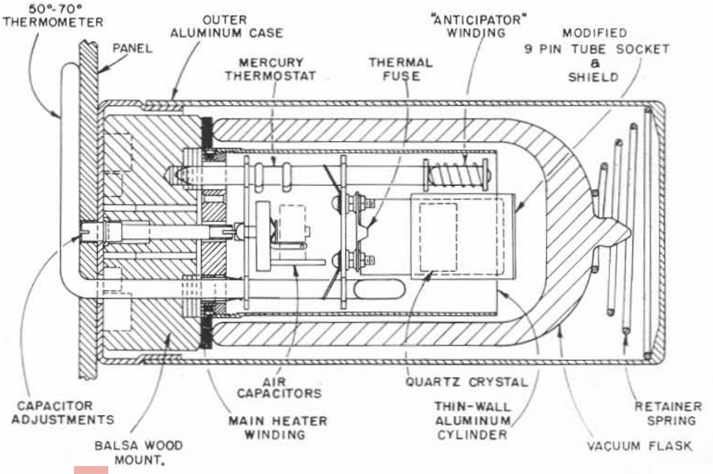


Figure 10. Cross-section of precision temperature-controlled oven.

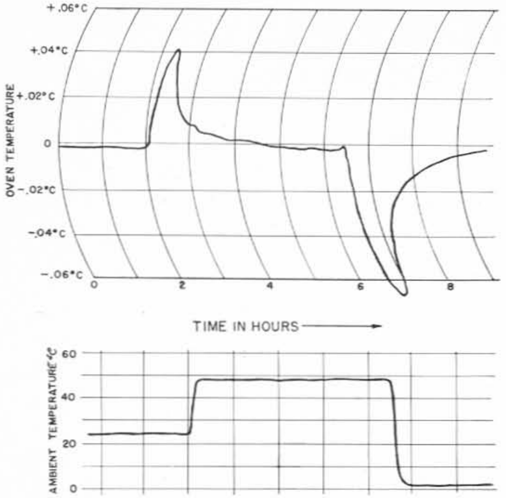


Figure 11. Control characteristics of the crystal oven.

A new AT-cut plated crystal is used, to provide the exceptional frequency stability necessary to meet the stringent requirements of u-h-f monitoring.

Power Supply

Particular consideration was given to the design of the power-supply section of this monitor. It is recognized that spare tube stocks are maintained, and replacements are always on hand. Metallic rectifiers may have longer life, but, when operated continuously, their ultimate replacement must be expected. Spare parts such as these are usually not immediately available and therefore become inconvenient to replace in this class of service.

As shown in Figure 12, two thyratrons are operated in a full-wave rectifier circuit. Control of the d-c output voltage is obtained by variation of the conduction time of each thyratron, through a d-c voltage applied to the thyratron grids. To improve the thyratron grid-control characteristics, a fixed a-c bias voltage is applied through two phase-shift networks. A conventional regulator circuit, as is commonly used with the series tube type of regulator, is used to develop the necessary d-c control voltage. A 5651 voltage-reference tube and a triode d-c amplifier are included.

In order that the ripple frequencies be isolated from the d-c regulator circuit, the ripple filter is placed between the transformer center tap and ground. Ripple frequency components are present only on the transformer secondary and are isolated by adequate transformer shielding.

General

Every effort has been made to reduce the effects of tube replacements, and to obtain normal operation throughout the entire life of the tubes. Special selection of tubes is unnecessary.

This monitor was designed with the assistance of Messrs. H. P. Hall and F. D. Lewis. Special credit is due Mr. W. F. Byers for his many valuable design contributions and to Mr. S. Samour for his untiring efforts in the making of experimental model and tests. Mr. H. G. Stirling was reponsible for the design-drafting detail.

— C. A. Cady

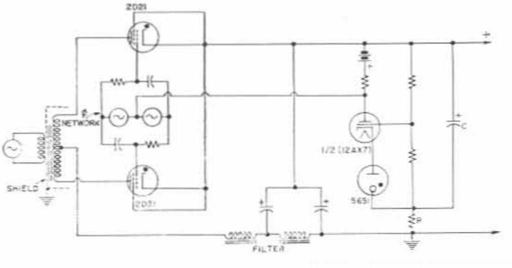


Figure 12. Elementary schematic of regulated thyratron power supply.

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SPECIFICATIONS

Frequency Range: 50-890 Mc (tv channels 2 to 83).

RF Input:

1. Impedance: Low-impedance loop coupling.
2. Level: Intended for use with standard RETMA transmitter monitoring outputs (10 volts, 50Ω).
3. Max Sensitivity: One volt, for all functions except the measurement of residual AM noise on the aural transmitter, which requires a minimum of 4 volts r-f input.
4. Adjustments: Input levels for both aural and visual transmitter are adjustable from the front of the instrument.
5. Indication: Both aural and visual transmitter input levels can be checked by direct indication on a front panel meter.

Frequency: *Crystal Stability* — master reference, ±1.4 ppm/30 days or ±0.35 ppm/10 days; secondary reference, ±5 ppm/30 days (=21.5 cycles) interpolating reference oscillator, ±5 ppm/30 days (=22.5 cycles).

Accuracy:

	Aural	*Visual*	*Inter-Carrier*
Meter Scale	3-0-3 kc	1.5-0-1.5 kc	3-0-3 kc
Metering Accuracy	±200c	±30c	±200c
Overall Accuracy	VHF 500c/30 days UHF 500c/10 days		250c for 30 days

Image Frequency Check: A checking device is incorporated to insure that the transmitter frequency is on the correct side of zero beat.

Aural Modulation (FM): *Meter Scale,* 0 to 100% + 3 db, full scale; *Meter Ballistics,* as required by FCC specifications; *Meter Calibration,* 100% = 25 kc deviation; selector switch for 100% = 50 kc to permit wide-deviation type tests; *Polarity Response,* panel switch for positive or negative peaks, for both meter and flashing lamp; *Peak Indicator,* flashing lamp indicates peaks in excess of dial setting; *Dial,* calibrated from 0 to 100% and to +3 db above 100%; *Meter Frequency Response,* ±0.25 db from 50 to 15,000 cycles, ±0.5 db from 30 to 20,000 cycles; *Peak Indicator Frequency Response,* 0.5 db from 100 to 15,000 cycles.

Fidelity Measurements:

Aural F-M Transmitter: *Audio Outputs* (at low frequencies with 100% modulation), 10.8 volts into 100 kΩ or 0 dbm at 600 Ω. *Residual Distortion* (50 to 15,000 cycles), 0.15% for 25 kc modulation deviation, and 0.25% for 50 kc deviation; *Residual FM Noise,* −70 db below 25 kc modulation deviation; *Audio Response,* follows 75-μsec de-emphasis curve within ±0.5 db from 50 to 15,000 cycles, ±3 db from 15 to 30 kc; *A-M Noise Reference Level* (at low frequencies), 4 volts into 100 kΩ; *Residual Noise, AM,* −70 db below carrier level.

Visual A-M Transmitter: *Noise (FM) Measuring Output* (at low frequencies and 25 kc deviation), 1.5 volts into 100 kΩ load, 75-μsec de-emphasis circuit included; *Residual (FM) Noise,* −65 db below 25 kc deviation with normal video modulation on transmitter (−70 db without video modulation).

Intercarrier Measurements: Same as for aural transmitter, except *Residual (FM) Noise* is −63 db below 25 kc deviation of aural transmitter with video modulation applied to visual transmitters.

External Connections:

1. Frequency Meters:
Visual Transmitter, GR TYPE MEDS-41-3, 0-200 μa dc, 510 Ω, one side grounded.
Aural Transmitter, GR TYPE MEDS-72, 0-100 μa dc, 510 Ω, one side grounded.
2. *(FM) Modulation Meter:* GR TYPE MEDS-28, 0-600 μa dc, 680 Ω, neither side grounded.
3. *Modulation-Peak Indicator:* 3 watt-115 v lamp, one side grounded.
4. *Audio Monitoring Output:* Unbalanced — 600 Ω, 100% modulation = 0 dbm.
5. *Audio Measurement Output:* Intended for use with the TYPE 1932-A Distortion and Noise Meter (100 kΩ unbalanced input); 10.8 volts output at low frequencies; behind-the-panel test jack for connecting on a temporary basis;

rear jack provided for permanent wiring to rack-mounted Distortion and Noise Meter.

6. *Power Cables:* standby line, for master crystal oven; power line, for monitor circuits.

Power Supply:

1. Standby Operation:
   15 watts, with master crystal oven operating.
   115/230 volts; 50-60 cycles.
2. Normal Operation:
   Max demand 265 watts, with all thermostats on.
   Min demand 240 watts, with all thermostats off.
   115/230 volts; 50-60 cycles.
   (155 watts during 30 second initial warm up).

Mounting: 19-inch rack-panel mounting. Front panel removable for access to controls. All controls available from front. Instrument mounted on slides for access to all parts. Designed for vertical-air-flow cabinet racks.

Panel Finish: GR black crackle; also available in certain other colors to match station equipment.

Dimensions: (Width) 19 x (height) 21 x (depth) 16 inches, over-all.

Net Weight: 75 lbs.

Type		*Code Word*	*Price*
1184-A	**Television Transmitter Monitor**	GIANT	**$2650.00**

U. S. Patents Nos. 2,548,457 and 2,362,503. Licensed under patents of the American Telephone and Telegraph Company, patents of the Radio Corporation of America; and patents and patent applications of G. W. Pierce pertaining to piezo-electric crystals and their associated circuits.

THE NEW TYPE 1800-B VACUUM-TUBE VOLTMETER — STABLE AND ACCURATE

The Type 1800-B is a precision Vacuum Tube Voltmeter designed for a wide range of applications. It combines the accuracy of a laboratory instrument with the durability necessary for everyday laboratory and production-line use.

Its accuracy is better than ±2% on all a-c and d-c voltage ranges, and its completely shielded diode probe is designed for use into the u-h-f range. The design and construction of this instrument insures that the high accuracy of the new voltmeter will be sustained throughout years of service. This important stability has been achieved through three means: advanced circuit design, thorough power supply regulation, and the use of long-term-stable precision components.

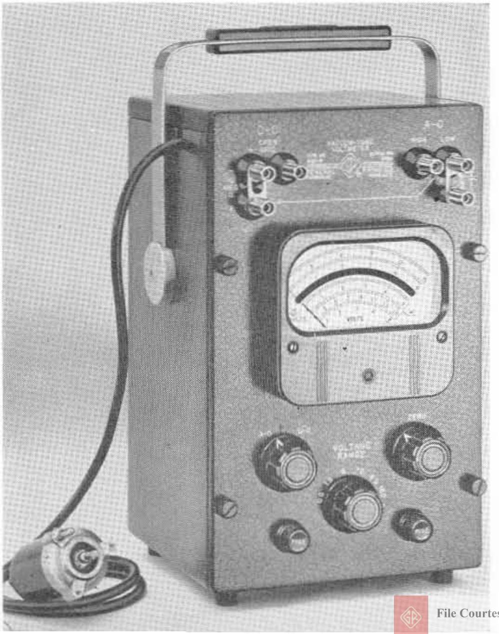

Figure 1. View of the Type 1800-B Vacuum-Tube Voltmeter. It is similar in appearance to its predecessor, the Type 1800-A, but includes a panel switch for d-c polarity selection.

Each increasingly higher voltage range is obtained by an increase in degeneration that decreases the sensitivity of the d-c amplifier, rather than by use of the conventional voltage divider to feed a constant-gain amplifier. As a result, the circuit is substantially independent of drift in tube transconductance on all but the 1.5- and 0.5-volt ranges, and even there a simple adjustment compensates for tube drift. On a-c ranges maximum stability is insured through the use of an internal balancing diode, a feature not often found in voltmeters, but which is essential to first-class performance. These refinements in circuit design coupled with thorough, two-stage power supply regulation, make the meter independent of line-voltage fluctuations. Once the zero is set on the 0.5-volt range, no further adjustment is required for this or any other range. The use of precision wirewound resistors insures that the accuracy of the instrument will be maintained indefinitely.

The TYPE 1800-B is an extremely versatile test instrument. In addition to performing reliably all the normal routine voltage measurements, many features not found in other instruments have been included to make this vacuum-tube voltmeter suitable for tackling especially difficult measurements. The following list of features highlights the remarkable versatility of the TYPE 1800-B:

1. Excellent high-frequency range through use of a convenient diode probe. VHF voltages may be accurately measured *without* need of special grounding devices, probe disassembly, or external capacitors.

2. Completely shielded probe affords normal accuracy even in the presence of strong r-f fields.

3. Thoroughly shielded amplifier circuit and well-filtered probe eliminate any possibility of "beats" in the measurement o' voltages at frequencies near power-line frequency or its harmonics.

4. The probe cap may be simply bolted to the ground plane of the test circuit, eliminating the possibility of error through ground lead inductance and pickup from electromagnetic fields.

5. The probe may be conveniently plugged into standard ¾-inch jack-top binding posts, and additional a-c terminals are provided on the panel so that test leads may be used rather than the probe, if so desired.

6. A storage space is provided for the probe under a hinged cover at the top of the instrument.

7. A TYPE 874 coaxial fitting and 50-ohm termination are provided. These permit the probe to be used on coaxial lines.

8. High input impedance — resistive component 25 megohms at low frequencies. Open grid connection available for dc provides input impedances in the kilo-megohm range.

9. Panel can be grounded without grounding any of the input terminals. This is an important safety feature; it allows a-c or d-c voltages to be measured between two points, both above d-c ground, without the panel becoming "hot".

10. A polarity switch is provided for d-c measurements. This switch permits either positive or negative voltages to be read without the need of reversing the test leads.

11. An illuminated meter scale eliminates reading difficulties caused by light reflection from the meter glass.

12. The meter's knife edge pointer and mirror insure ease and precision of reading.

13. The carrying handle detents into a right angle position so that the instrument panel may be supported at the most convenient angle for easy reading.

The features outlined above are a few of the items specifically engineered into the TYPE 1800-B to make it the most convenient and useful Vacuum-Tube Voltmeter on the market. The specifications shown below detail the performance of this instrument.

— C. A. WOODWARD, JR.

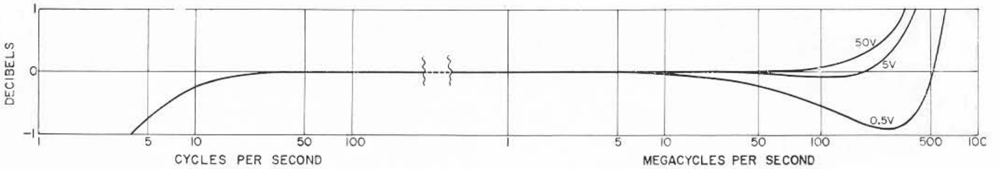

Figure 2. Plot of frequency range for one-db error on three voltage ranges as indicated; error is result of combined transit-time and resonance effects.

SPECIFICATIONS

Voltage Range: 0.1 to 150 volts, ac, in six ranges (0.5, 1.5, 5, 15, 50, and 150 volts, full scale); 0.01 to 150 volts, dc, in six ranges (0.5, 1.5, 5, 15, 50, and 150 volts, full scale).

Multipliers: Multipliers are available for increasing the range to 1500 volts.

Accuracy: DC, ±2% of full scale; AC, ±2% of full scale for sinusoidal voltages, subject to frequency correction (see curve). Because of the change in resistance of the meter movement, the sensitivity of the lowest two ranges changes slightly with temperature and upon warming up of the instrument. The total warm-up decrease in sensitivity is about 1% of the indicated value on the 1.5-volt range and 3 to 4% of the indicated value on the 0.5-volt range. About one-half of this drift occurs in the first hour. The calibration is set to be correct after complete warm-up.

Waveform Error: On the higher a-c voltage ranges, the instrument operates as a peak voltmeter, calibrated to read r-m-s values of a sine wave, or 0.707 of the peak value of a complex wave. On distorted waveforms the percentage deviation of the reading from the r-m-s value may be as large as the percentage of harmonics present. On the lowest range the instrument approaches r-m-s operation.

Frequency Error: At high frequencies, resonance in the input circuit and transit-time effects in the diode rectifier introduce errors in the meter reading. The resonance effect causes the meter to read high and is independent of the applied voltage. The transit-time error is a function of the applied voltage and causes the meter to read low. The curves of Figure 2 show the frequency range for 1-db resultant error. It will be noted that at low voltages the transit-time and resonance effects tend to cancel, while at higher voltages the error is almost entirely due to resonance. The resonant frequency with cap on but plug removed is about 1050 Mc. Correction curves are supplied.

At a frequency of about 15 cycles, the meter indication begins to fluctuate as it tends to follow the voltage change within each cycle.

Input Impedance: At low frequencies the equivalent parallel resistance of the a-c input circuit is 25 megohms. At higher frequencies this resistance is reduced by losses in the shunt capacitance. The equivalent parallel capacitance at radio frequencies is 3.1 μμf with the probe cap and plug removed. At audio frequencies this capacitance increases slightly. The probe cap and plug add approximately 1.2 μμf.

On the d-c ranges two values of input resistance are provided, 10 megohms and open grid.

Power Supply: 105 to 125 or (210 to 250) volts, ac, 50 to 60 cycles. The instrument incorporates a voltage regulator to compensate for supply variations over this voltage range. The power input is less than 25 watts.

Tube Complement:

2—9005	1—6SL7-GT
1—6SU7-GTY	1—6AT6
1—6C4	1—6X5-GT
1—3-4	2—991

Accessories Supplied: Type CAP-35 Power Cord, spare fuses, Type 274 and Type 874 terminations, and 50-ohm coaxial terminating resistor for probe.

Mounting: Black-crackle-finish aluminum panel mounted in a shielded walnut cabinet. The cable and probe are stored in the cabinet. The carrying handle can be set as a convenient support for the instrument when placed on a bench with the panel tilted back.

Dimensions: (Width) 7⅜ x (depth) 7½ x (height) 11⅛ inches, over-all. **Net Weight:** 13¾ pounds.

Type		*Code Word*	*Price*
1800-B	**Vacuum-Tube Voltmeter**	DUCAT	**$415.00**

U. S. Patent No. 2,548,457. Licensed under patents of the Radio Corporation of America.

GENERAL RADIO COMPANY

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TELEPHONE: TRowbridge 6-4400

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VOLUME 31 No. 5 OCTOBER, 1956

A NEW TYPE OF VARIABLE DELAY LINE

With the introduction of the new delay line described in this article, the realization of the complete line of General Radio components and instruments for pulse work is brought one step nearer. At the present time, complete data are available on only one model, the Type 314-S86, but the design of a complete series of variable delay lines with maximum delays of 100, 200, 500, and 1000 millimicroseconds and characteristic impedances of 100, 200, 500, and 1000 ohms is now under way. For a given maximum delay, one or more lines will be offered to fulfill a customer's impedance or size requirements. The bandwidths per unit delay of the larger size units, in general, will be greater than those of the small units, and each delay line will be designed for optimum transient response.

These variable delay lines find general application as wide-band phase-shifting devices and can be used also as components in pulse and video-frequency systems, such as computers, radar and beacon systems, and TV equipment; in short, wherever it is desired to delay a wide-band signal without introducing phase distortion. It is probable that some particular impedance levels and delay times will be more useful than others, and inquiries from customers are invited concerning their preferred values of delay, impedance and bandwidth, even though these values may not be listed above.

In many applications, the most important attribute of an electromagnetic delay line is a satisfactory transient response. Since a good transient response results from the proper combina-

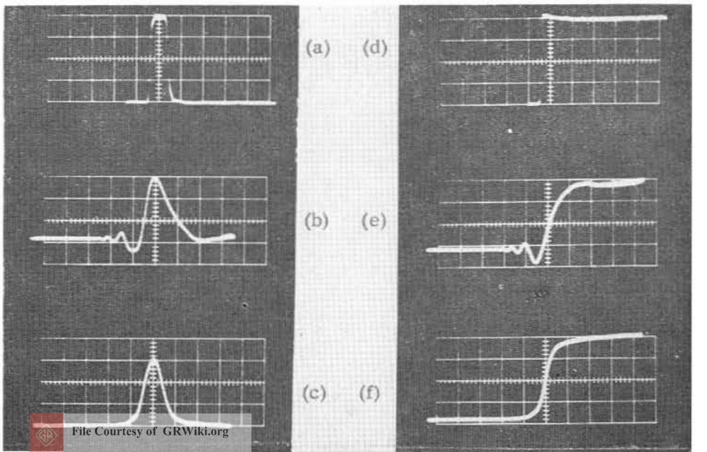


Figure 1. Pulse and step responses of 1-μsec delay, 500-ohm, variable delay lines. (a) pulse input, (b) pulse out of uncompensated line, (c) pulse out of skewed-winding line, (d) step input, (e) step out of uncompensated line, (f) step out of skewed-winding line. Scope photos taken on Tektronix 541, 0.1 μsec/cm sweep.

tion of a constant time delay (linear phase characteristic) with an adequate frequency response, delay lines exhibiting reasonable behavior with step or short-pulse excitation are usually well suited for other delay applications.

In the course of the development of the variable delay lines described here, a method of analysis was developed which sheds light on several properties of distributed-winding delay networks, including (1) the variation of time delay with frequency and (2) end effects. Further investigation along these same lines has already led to some interesting data on losses in distributed delay networks and, it is hoped, may lead to accurate methods for the calculation of such losses.

Because of the experience of the General Radio Company in the manufacture of wire-wound resistors and the availability of machines and components, it was possible to fit the design of the variable delay line into the same general form as that of a wire-wound potentiometer, with its obvious advantages of convenience, small size, and economy. Hence the inductance coil was developed on a card-type mandrel for winding on our standard winding machines.

When the first experimental variable delay lines of this type were constructed on potentiometer forms with copper wire instead of resistance wire and with the addition of a sheet copper-foil ground capacitance, the pulse and step responses of these lines (see Figure 1(b) and 1(e)) were very disappointing. After much experimental and analytical work, the present model variable delay line has been designed with skewed winding for constant delay as a function of frequency, and with tapered capacitance strips to reduce mismatch caused by end effects. The responses shown in Figure 1(c) and 1(f) are characteristic of the performance of these new delay lines.

The Delay Equalization Problem

The most important factor affecting the transient response of a delay line is almost certainly the degree to which the delay time remains constant as a function of frequency. This is another way of saying that the phase response of the network should be a linear function of frequency. Although networks providing constant time delay are reasonably well known in lumped-circuit theory and practice,[1, 2] relatively little has been realized in the design of delay networks using distributed parameters.[3, 4] The principal difficulty in the design of distributed-winding delay lines arises from the presence of high, positive, mutual inductance between the turns of a coil that has a reasonable Q. The mutual inductance between the two representative turns as their axial

[1] A. H. Turner, "Artificial lines for video distribution and delay," *RCA Review*, vol. X, no. 4, pp. 477–489; December, 1949.
[2] E. L. Ginzton, W. R. Hewlett, J. H. Jasburg, J. D. Noe, "Distributed Amplification," *Proc. IRE*, vol. 36, pp. 956–969; July, 1948.
[3] H. E. Kallman, "Equalized delay lines," *Proc. IRE*, vol. 34, pp. 646–657; September, 1946.
[4] J. P. Blewett and J. H. Rubel, "Video delay lines," *Proc. IRE*, vol. 35, pp. 1580–1584; December, 1947.

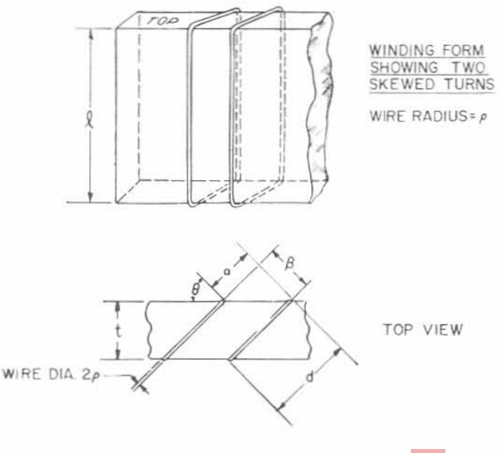


Figure 2. Diagram of two turns on form of rectangular cross section.

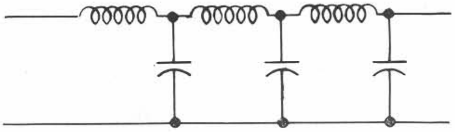


Figure 4. Simplified equivalent circuit of a distributed-parameter delay line, in which each turn is one section of a ladder network.

separation is increased is shown in Figure 3a. Because of the progressive phase shift along the coil of a distributed delay line at a given frequency, it is possible that two turns having a fairly large mutual coupling can carry currents which are not of the same phase. The phase shift thus produces a reduction in the effective inductance of the coil as the frequency is increased.[3,4] The decrease in effective inductance results from the reduction of the in-phase component of the current in a given turn with respect to a reference turn. Thus if a distributed-parameter delay line is constructed with a constant-pitch winding over distributed ground capacitance strips, the time delay, $T_d = \sqrt{LC}$, decreases as the frequency is increased. This problem is obviously not encountered in lumped-parameter networks since there is phase shift only between sections, and mutual inductance between these sections can be adjusted at will. It is instructive to consider the distributed-parameter delay line as a ladder network (see Figure 4) of series L and shunt C elements, each C being the capacitance of the turn to ground and each L being the effective inductance of only one turn, taking into account mutuals to all other turns. Calculation of the effective inductance per turn for a line made with rectangular turns in the distributed winding has been accomplished by considering that each turn is long compared with its width (i.e. it is wound on a thin mandrel). The calculated effective inductance versus phase change per turn of such a constant-pitch distributed-parameter delay line for one particular geometrical arrangement is shown as the curve of a conventional-type winding, $\Theta = 0°$, in Figure 5. Since, in the simple ladder network of Figure 4, the time delay is approximately $T_d = \sqrt{LC}$, it is apparent that satisfactory performance with respect to a constant-time delay characteristic can be obtained with this uncorrected delay line only for low values of delay or phase shift per turn.

Some of the previously proposed modifications of this simple distributed-parameter delay line have produced a form of bridged-T network section by the addition of longitudinal capacitance between turns.[3, 4, 5] However, there are

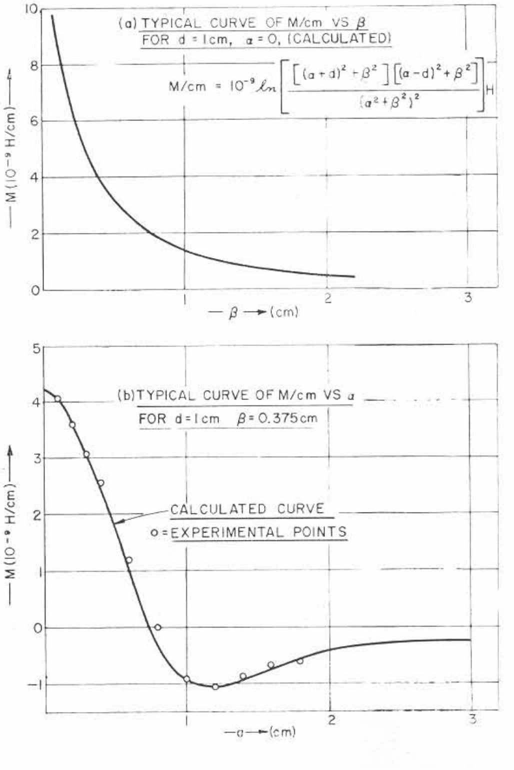


Figure 3. Curves showing variation of mutual inductance, M, between two rectangular turns as (a) their axial separation, β, is varied, and (b) their displacement, d, is varied. (See Figure 2).

limitations and some disadvantages to these modifications. Patch-type compensation causes a large variation of the impedance which is usually within the bandpass of the line. In addition, adequate compensation by means of patches alone cannot be applied easily to low-impedance lines. The use of aluminum paint of high dielectric constant is limited to even higher-impedance lines with relatively low delays per unit length of coil. A direct solution would produce a more nearly constant effective inductance.

Skewed-Winding Delay Equalization

The delay equalization method devised for the new General Radio delay lines uses skewed turns to provide a more nearly constant effective inductance of the distributed winding. As can be seen from Figure 5, skewing the turns of the winding produces an effective inductance which remains nearly constant up to a critical value of phase change per turn. In effect, skewing offers a new means of control over the mutual inductance between turns of a distributed winding delay line. (See Figure 3b). Since the delay $T_d = \sqrt{LC}$ in the ladder network of Figure 4, the delay can thus be made constant without resorting to bridged-T circuit modifications. This simplification allows construction of delay-equalized lines with distributed windings to work at low characteristic impedances without attendant difficulties in getting the large bridging capacitors needed at such low impedances by the other method of equalization. Another advantage of a skewed coil is that a higher Q is obtained for a given inductance and mandrel size.

Several forms of skewed winding have been used experimentally for delay equalization, as shown in Figure 6. For delay lines requiring the use of skewing for equalization of delay, the D-shaped turn on a flat mandrel card appears to be the most satisfactory, since it produces a smooth winding of constant characteristic impedance, which can then be curved to fit the housing of a standard wire-wound potentiometer.

Design Features

The use of silver wire in the winding provides a reliable contact surface for

[5] W. S. Carley, "Distributed-constant delay lines with characteristic impedances higher than 5000 ohms," *IRE Convention Record*, part 5, Circuit Theory, pp. 646–657; September, 1946.

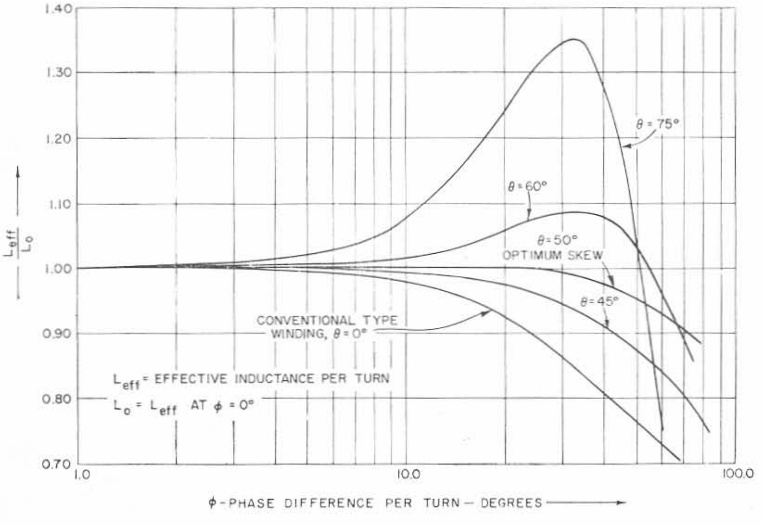


Figure 5. Curves showing effect of various skew angles on the effective inductance per turn versus phase difference per turn.

the moving contact, independent of whether the brush is moved frequently or allowed to stay in one position, as it will be when the line is used as a screwdriver-set unit. The moving contact is made of precious-metal alloy, selected to be compatible with the silver-alloy wire.

Manufacturing processes have been sufficiently refined so that the "baseline ripple," caused by variation of characteristic impedance along the delay line, has been reduced to 5% or less of the signal amplitude. This feature alone is of considerable value in computer and pulse-coding applications. End reflections have been minimized by the use of tapered capacitance elements at the ends of the winding, keeping the impedance relatively constant and resulting in a high degree of freedom from unwanted variations or reflections at points near the ends. Materials used for construction have been selected so that reliable operation is assured even with wide variations of temperature or humidity, and epoxy-type cement is used to insure a permanent bond of all the parts.

Methods of Application

A common method of obtaining variable delay is shown in Figure 7a. However, this method does not allow matching of the input and output, and in fact, the impedance of the output must be much greater than Z_o. Otherwise, large reflections from the slider are sent back to the source.

A recommended circuit is shown in Figure 7b where the source is fed into the slider. The source sees one-half the characteristic impedance of the line and maximum power transfer is obtained when the source impedance is $\frac{Z_o}{2}$ and the load impedance Z_o. For equal input and output impedances of $\frac{Z_o}{2}$, a resistor of $\frac{Z_o}{2}$ can be connected in series with the load. This method permits power transfer without the introduction of reflections.

If the load impedance is capacitive, as is the input of a tube, reflections can be minimized by a half section of low-pass filter consisting of the tube input capacitance and an added inductor as shown in Figure 7c.

In some cases there may be unwanted voltage loss with the method of Figure 7b. It presents, however, an easy method of obtaining power transfer or of matching without producing reflections.

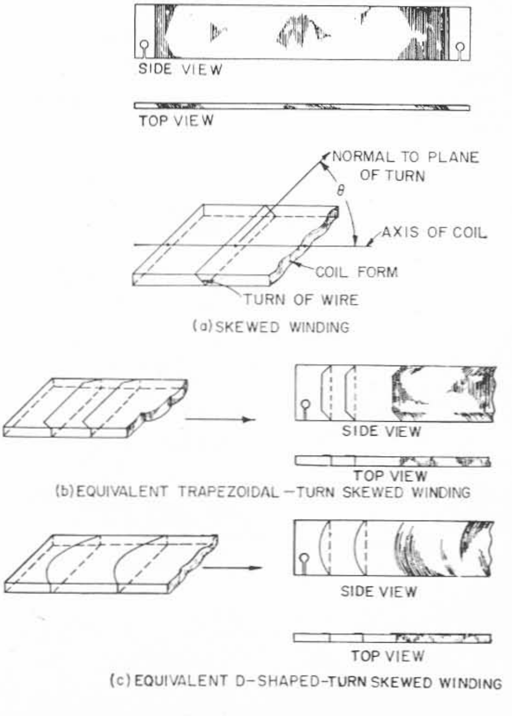


Figure 6. Diagrams showing arrangement of skewed windings on forms of rectangular cross section; (a) rectangular turns, (b) equivalent trapezoidal turns, (c) equivalent D-shaped turns.

These variable delay lines can also be used as adjustable-length shorted transmission lines by shorting the slider to ground as in Figure 7d. For example, if a positive pulse is fed into the line, a negative pulse will be returned, delayed by twice the delay-time setting.

Variable Delay Line Specification

Most engineers who have used delay lines in one form or another are aware of the difficulty with which the specification of a delay line unit is accurately set down. Part of this difficulty arises from the multiplicity of uses for which delay lines are needed. For example, in some applications it may make little difference whether there is overshoot or ringing in the output signal along with the desired pulse. However, the engineer with these moderate requirements can almost certainly use an equivalent higher-quality delay line which exhibits no ringing or overshoot. In any case, he must know the impedance level, maximum delay time, and attenuation or loss in the line in order to judge its suitability for his application.

The principal difficulties in the specification of variable delay lines arise in the matters of phase distortion, attenuation, and bandwidth. The oscilloscope photographs of Figure 1 contain much of the information necessary to specify these quantities. The response to short pulse excitation indicates pulse stretching or bandwidth, pulse dissymmetry or phase distortion, and pulse amplitude or attenuation.

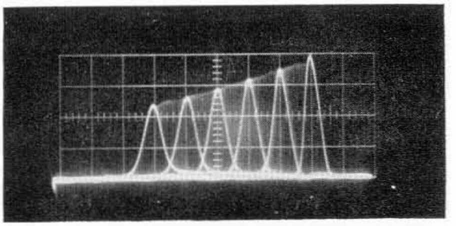


Figure 8. Oscillogram showing pulse shape and pulse amplitude as delay setting is varied. Tektronix 541 Oscilloscope, 53K/54K Pre-Amplifiers; sweep, 0.1 μsec/cm; time scale reads from right to left.

The step response shows rise time or bandwidth, final level or attenuation, and wave shape indicating phase distortion. All scope photographs must have the time scale specified, and the scope should have a much faster rise time than the delay line under test.

A type of oscilloscope photograph which has been found useful for simultaneous determination of the pulse response, impedance uniformity, and end effects is shown in Figure 8. These photographs were obtained by taking a continuous exposure while the slider was slowly moved from minimum to maximum delay. Slightly greater exposure at any point recorded the delayed pulse at that point.

The following information will be supplied for the new General Radio Delay Lines.

1. Impedance, Z_o, and tolerance (at low and intermediate frequencies).
2. D-C resistance.

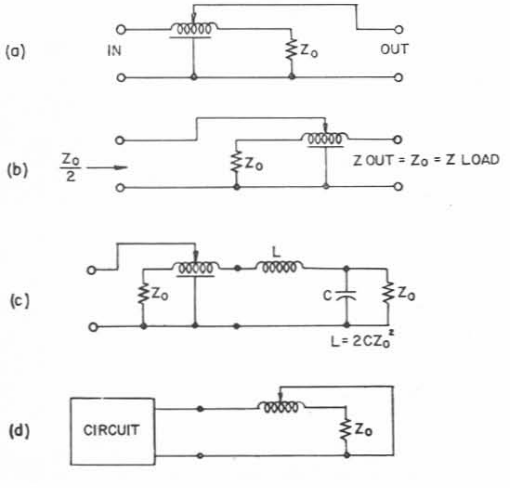


Figure 7. Methods of connection for a variable delay line.

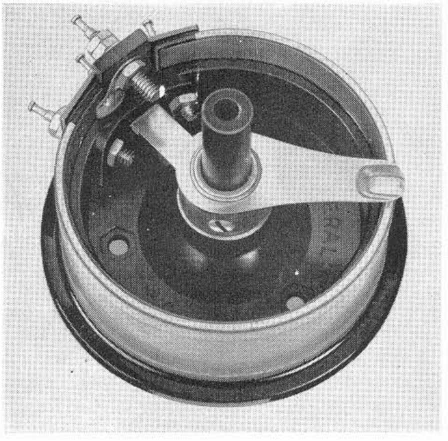


Figure 9. Type 314–S86 Variable Delay Line. $Z_0 = 200$ ohms, maximum time delay, 0.5 μsec (500 millimicroseconds).

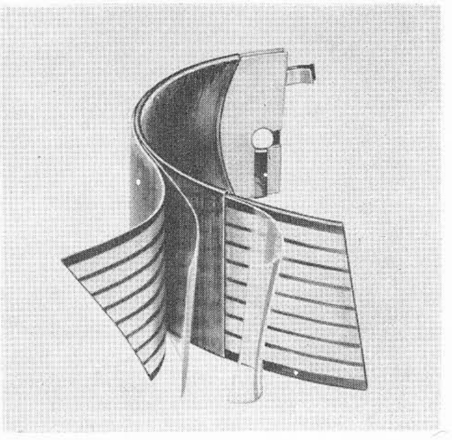


Figure 10. Photograph of skewed-turn delay-line winding opened out to show ground capacitance strips and D-shaped skewed turns.

3. Maximum delay time and tolerance.

4. Departure from constant time delay at several frequencies.

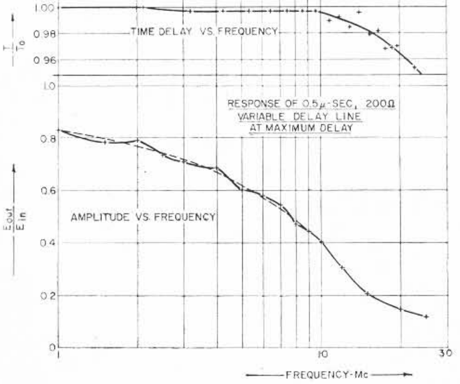
5. Frequency response of amplitude at several frequencies.

6. Rinse time for step input at maximum delay setting.

7. Oscilloscope photographs (not drawings) of waveforms of

a. Short pulse response at maximum delay.

Figure 11. Time delay and amplitude versus frequency with resistive termination as measured at full delay on 0.5-μsec, 200-ohm variable delay line with skewed winding (See Figure 9).



b. Step response at maximum delay.

c. Envelope of response to short pulse over entire delay span.

There may be additional quantities which extend or supersede the quantities mentioned above, but until the time when the specification of variable delay line units is further standardized, the information listed above should provide a reasonable basis in choosing a suitable delay line.

Type 314–S86 Variable Delay Line

The Type 314-S86 Variable Delay Line shown in Figure 9 is the type on which much of the development work for these new lines was done. Figure 10 is an exploded view of the winding. This delay line has a characteristic impedance of 200 ohms and a maximum delay of 500 millimicroseconds. The time delay and the amplitude response versus frequency are shown in the curves of Figure 11. The resultant pulse and step responses are shown in the oscillogram of Figure 12.

A primary reason for the development of these new delay lines has been

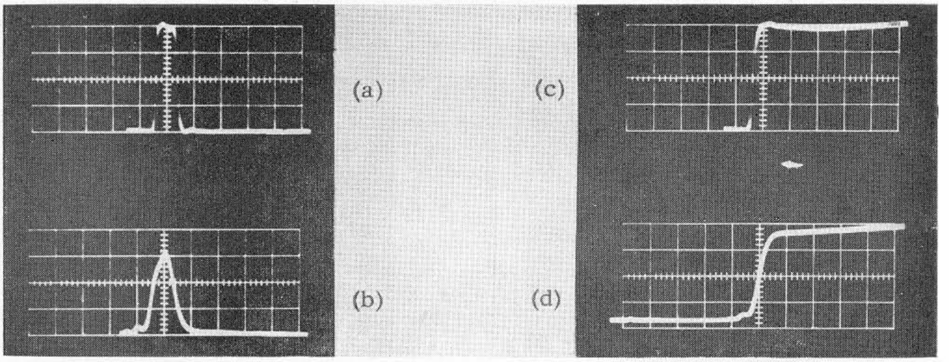


Figure 12. Pulse and step response of 0.5-μsec, 200-ohm variable delay line with skewed winding; (a) pulse input, (b) pulse output at 0.5-μsec delay, (c) step input, (d) step output at 0.5-μsec delay. Scope photos taken on Tektronix 541, 0.1-μsec/cm sweep.

the requirement of quality fixed and variable delay lines in our newer type pulse equipment. Now that manufacturing techniques allow quantity production, these variable delay lines can be offered as a catalog item.

— F. D. Lewis
— Robert M. Frazier

SPECIFICATIONS

Characteristic Impedance: 200 ohms ± 15% at frequencies up to 4.5 Mc.

D-C Resistance: Not over 20 ohms.

Maximum Delay: 0.5 μsec ± 10%
The following quantities refer to maximum delay setting.

Delay vs. Frequency (with respect to delay at 1 Mc): ± 1% up to 10 Mc; ± 2% at 15 Mc; ± 4% at 20 Mc; see Figure 11.

Amplitude Response vs. Frequency: Down 9% (0.8 db) at dc; down 20% (2 db) at 1 Mc; down 30% (3 db) at 6 Mc; down 60% (8 db) at 10 Mc; down 90% (10 db) at 25 Mc; see Figure 11.

Pulse and Step Response: See Figure 12.

Dimensions: Dia., 3 3/16″; depth behind panel, 1½″; shaft dia., 3/8″. Knob is furnished.

Net Weight: 6 ounces

Type		*Price*
314-S86	**Variable Delay Line**	**$60.00**

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE
CAMBRIDGE 39 MASSACHUSETTS
TELEPHONE: TRowbridge 6-4400

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MILITARIZED LINE VOLTAGE REGULATOR

Also IN THIS ISSUE

Where circuit reliability is of prime importance, the need for adequate line-voltage regulation has long been recognized. Not only can vacuum-tube life be extended by operation of the heaters at a slightly reduced but constant voltage,[1] but also performance can be improved by eliminating large plate-supply variations. In many applications, proper power-supply design and the use of a line-voltage regulator can eliminate the need for inefficient, and often less-reliable, series-tube plate-supply regulators. For such applications, the servo-controlled Type 1570-A Line Voltage Regulator[2] with its advantages of high accuracy, no distortion, large power rating, high efficiency, and excellent transient response, has become well established.

The importance of longer tube life and increased circuit reliability has created a demand for such a regulator built to military specifications. In the past few years, the General Radio Company has designed and built a number of specialized regulators for a variety of military end-use applications. A new regulator (Figure 1), the Type 1570-ALS15 is now offered, which incorporates the best of the de-

[1] W. S. Bowie, "The Effects of Heater Cycling and Heater Voltage," *1956 I. R. E. Convention Record*, Part 6.

[2] M. C. Holtje, "An Accurate, High-Speed, Automatic Line-Voltage Regulator," *General Radio Experimenter*, Vol. 29, No. 2, July, 1954.

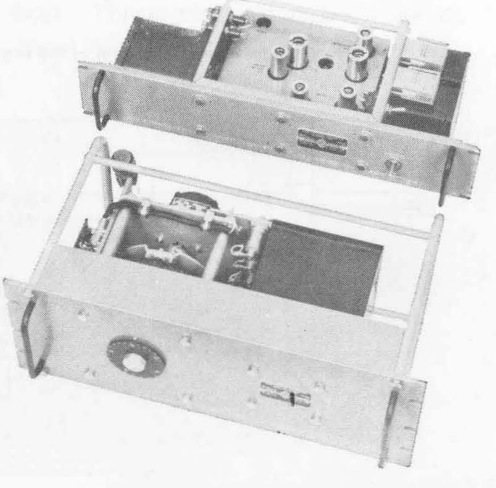


Figure 1. View of the militarized voltage regulator. Regulator unit is in the foreground, control unit at the rear.

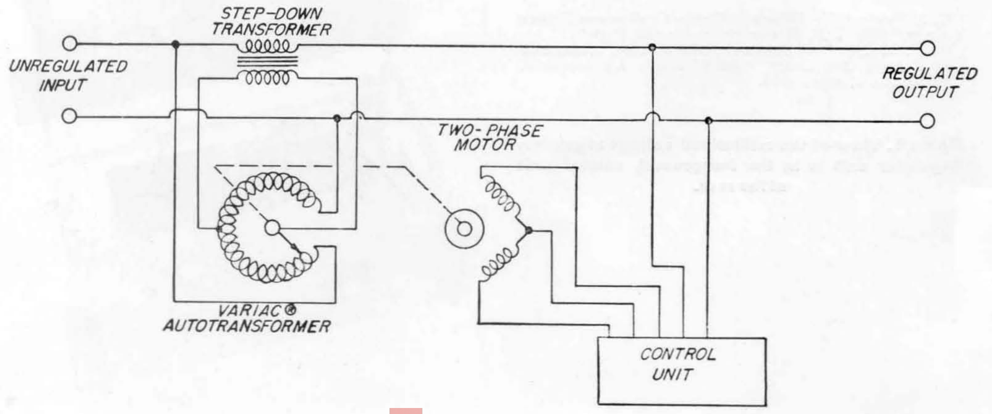
sign and performance features of these special units. In addition to the obvious military environmental requirements of shock, vibration, temperature, humidity, etc., the unit is designed with particular emphasis on flexibility, ease of maintenance, reliability, and long life.

Basically, the regulator (Figure 2) 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. The "buck-or-boost" circuit, which is often used for manual line-voltage correction, is shown at the left of Figure 2.

For flexibility and ease of maintenance, this 6-kva regulator has been built in two units (Figure 1). The larger unit contains a special motor-driven Variac and a hermetically sealed "buck-or-boost" transformer. The smaller unit contains the electronic circuitry for sampling the output voltage and controlling the two-phase servo motor on the Variac to maintain the output voltage constant well within 0.25%. Thus, with different combinations of Variacs and "buck-or-boost" transformers, regulators of different ratings can be assembled using the same electronic control circuit. This not only provides design flexibility, but also simplifies service problems, since only one type of control circuit, interchangeable for all regulators, is required. Furthermore, when service of the electronic circuitry is required, only the small control unit need be removed. The larger unit with all its power wiring can stay in service supplying uninterrupted (but unregulated) power, while the control unit is being replaced or repaired. Manual control of output voltage is possible during these intervals by means of the Variac dial on the front panel.

Ease of maintenance was a prime consideration in the original design of this regulator. Tubes can be replaced without the removal of any covers other than tube shields. Removal of a single dust cover (Figure 3) exposes all other components. Component wiring is accomplished with an etched circuit to provide a high degree of uniformity between units. Each component is marked with its magnitude and rating and is identified by a component number permanently etched on the mounting board. The removal of the bottom cover plate (Figure 4) exposes all etched wiring. The complete circuit diagram is silk screened on the inside of this plate.

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



For protection against the effects of moisture and fungus growths, the etched board is sealed with a fungus-resistant varnish.

Reliability and long life have been assured by conservative ratings and the use of the best materials and components in simple circuits that have proved reliable in long field experience.

Figure 5 is an elementary circuit diagram of the control unit. A d-c voltage proportional to the average amplitude of the a-c output voltage is produced by a full-wave silicon rectifier with a resistive load. The magnitude of the load resistance is chosen to minimize the effect of temperature, and the change in the average value of the rectifier output is less than 0.1% for temperatures up to 135°F (75°C). A ripple filter is included, which provides infinite rejection at the 120-cycle ripple frequency and has negligible phase shift below 5 cycles per second.

The filtered voltage, which is proportional to the a-c output voltage, is compared with a standard voltage from a 5651WA voltage reference tube to obtain a difference, or error, voltage. For maximum stability, a 0A2WA regulator tube is used to provide constant current to the reference tube. These tubes were developed for military use where a voltage reference free from the usual voltage jumps was required.

The error voltage is amplified by a differential amplifier (Figure 5) which uses 5751 tubes operating very conservatively, at constant heater voltage (the unit operates on its own regulated output), to give the longest possible life. Appropriate lead and lag networks are used for optimum regulator performance. This amplified error voltage is applied in push pull to a thyratron (2D21WA) 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 changes 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.

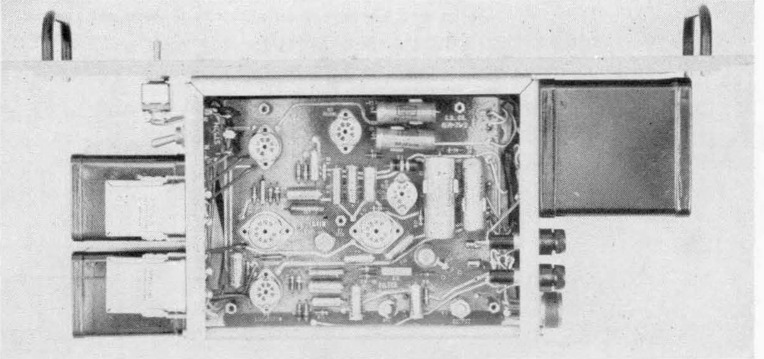


Figure 3. View of the top of the control unit with dust cover removed, showing component identification. Tubes are replaceable without removal of dust cover.

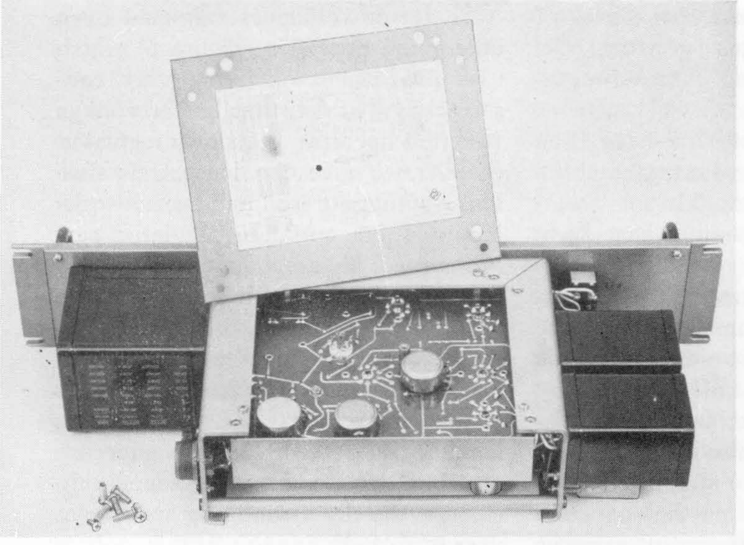


Figure 4. View of the bottom of the control unit with dust cover removed, showing the etched circuit and circuit diagram.

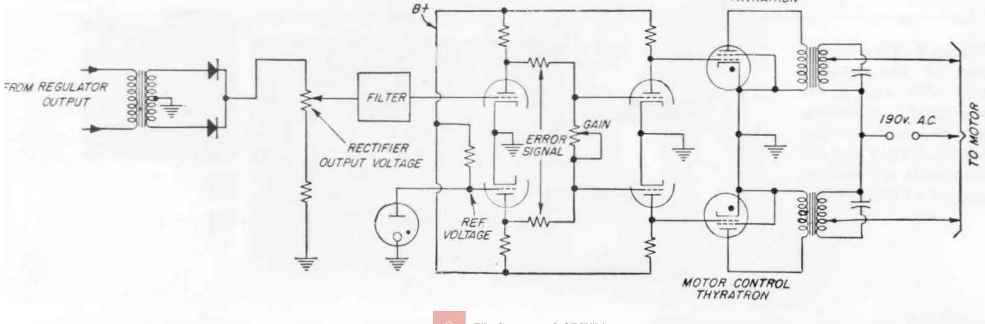
For maximum versatility, a switch is provided inside the control unit for 50-cycle operation of the regulator. In the 50-cycle switch position, the range of operation is 45 to 55 c; in the 60-cycle position, it is 55 to 65 c. Space is also provided for the installation of a separate output-voltage-sampling transformer to permit control of 400-cycle power, although 50- or 60-cycle power must be available to operate the control unit.

The motor-driven Variac is a special ball-bearing model similar in design to the new motor-driven "W" type recently announced.[3] A front-panel dial on the Variac shaft indicates the input line voltage. This dial also indicates the reserve working range of the regulator and permits manual adjustment in case of a control-unit failure. An additional carbon brush to make contact with the radiator in place of the usual metal take-off ring minimizes friction and gives long life in a service demanding continual motion of the Variac brush.

The Variac motor is a two-phase induction motor. Long trouble-free life has been assured by the use of a thyratron motor control circuit rather than relays with their contact maintenance problems. This circuit also results in a superior proportional-type control rather than the usual on-off control.

[3] "Motor Drives for W-Series Variacs®," *General Radio Experimenter*, Vol. 31, No. 2, August, 1956.

Figure 5. Elementary circuit diagram of the control unit. To preserve simplicity, the lead and lag networks and the thyratron bias circuits are not shown.



The motor windings are completely encapsulated to prevent deterioration from moisture or fungus growths, and the output shaft is stainless steel to resist corrosion.

As the brush moves across the Variac winding, it is in contact with more than one turn at a time, thus providing a commutating action and, therefore, a smooth change in output voltage. While this commutating action is necessary for the normal operation of the Variac, the shorting action of the brush causes current surges which can be detected as small radio-frequency noises on the power line. Although, in most applications, this noise is completely insignificant, a noise-reducing filter is provided and is mounted on the Variac terminal board. Further noise reduction is provided by five through-pass capacitors located on the main terminal board at the rear of the regulator, which by-pass the Variac connections at the "buck-or-boost" transformer and the input and output connections to the regulator. This filtering is adequate to meet critical military interference specifications.

To provide adequate strength for military shock and vibration requirements, the regulator unit is built on a seven-inch, U-shaped, extruded-aluminum channel. The smaller control unit mounts on a $\frac{3}{8}''$ aluminum panel. Both units will withstand the standard 1200-ft-lb shock test, and they show no significant mechanical resonances up to 55 cycles per second.

The regulator is designed to meet or to exceed the general requirements of MIL-E-4158A. It will operate at full load over the ambient temperature range from −29°C to +52°C (−20° to +125°F) and for non-operating storage from −54°C to +54°C (−65° to +130°F). With special motor lubricants, operation is possible at far lower temperatures. Higher-temperature operation is possible at lower power rating or with restricted duty cycle. Operation is possible with relative humidity up to 100 percent, including condensation caused by temperature changes.

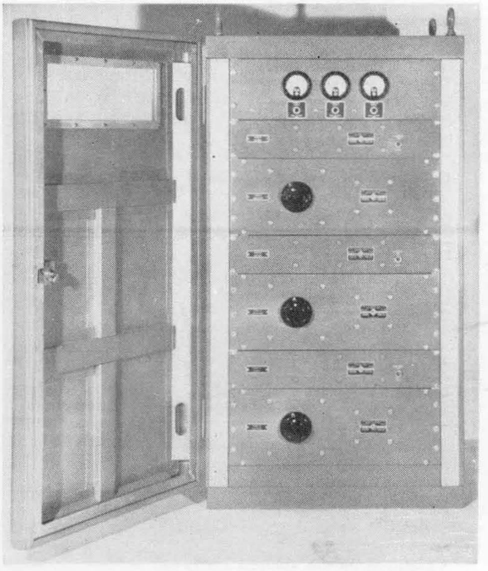


Figure 6. View of a three-phase, 18 KVA assembly of General Radio militarized regulators as used by Raytheon Manufacturing Company to provide constant line voltage for radar stations.

While these military specifications are generally more severe than those encountered in most industrial applications, the increased reliability and ease of maintenance may often justify the use of the militarized regulator in critical industrial applications. This is particularly true for applications at high ambient temperatures or for portable installations where mechanical shock or vibration is encountered.

— M. C. Holtje

SPECIFICATIONS

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.

Output Voltage: Adjustable over a range of ±10% from a base value of 115 volts by means of a screw-driver adjustment on panel.

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

* Instruments are shipped connected for ±10% range unless 20% range is specified in order.
† Slightly less for very small voltage corrections.

Tube Complement: 2-5751, 1-5651WA, 1-0A2WA, 2-2D21WA

Waveform Distortion: None.

Accessories Supplied: Spare fuses.

Waveform Error: The average value of the output voltage is held constant, and a d-c power supply with resistive load 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.

Ambient Temperature: Full ratings apply up to 55°C.

Frequency: From 55 to 65 cycles or from 45 to 55 cycles, as selected by a switch.

Power Consumption: No Load 35 watts
Full Load 100 watts

Mountings: Relay Rack.

Dimensions:

	Regulator Unit	Control Unit
Height	7 in.	3½ in.
Width	19 in.	19 in.
Weight	50 lb.	13¾ lb.

Type		*Code Word*	*Price*
1570-ALS15	**Automatic Voltage Regulator**	CLOTH	**$625.00**

Quantity prices on request.

VARIAC® RATINGS VS. DUTY CYCLE

One of the important advantages of Variac® autotransformers with *Duratrak* contact surface is their ability to operate under short-period overloads without damage. For short-time operation, rated current can be multiplied by a factor that varies between 1 and 10, depending upon the time that the load is applied, as shown in Figure 1. The same properties that prevent deterioration under these high overloads also permit substantial increases in rating for intermittent operation, with the magnitude of the increase depending upon the duty-cycle ratio. If the total number of duty cycles comprise only a relatively short operating period, the current can be further increased to that determined by the short-time rating factor shown in Figure 1.

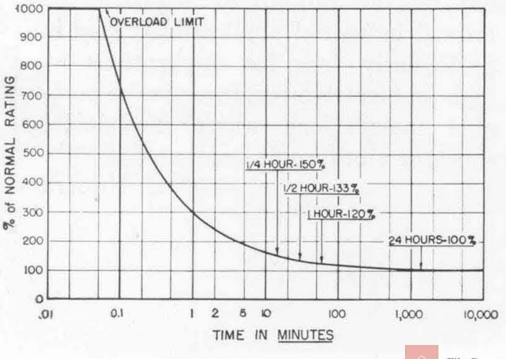


Figure 1. For short-time overloads, the normal Variac current may be exceeded as shown in this curve.

If duty-cycle ratio is defined as the ratio of off-plus-on time to on time, the Variac rated current may be multiplied by the square root of this ratio. The following examples will illustrate the calculation of permissible overload for the Type W5 Variac, whose rated current is 6 amperes.

Example 1

Duty cycle: 15 seconds on, out of every 4 minutes (240 seconds).

$$\sqrt{\text{duty cycle ratio}} = \sqrt{\frac{240}{15}} = 4$$

Up-rated current = 6 x 4 = 24 amperes.

15-second short-time overload (Figure 1 = 500% = 30 amperes. Since this is greater than that calculated from the duty-cycle ratio, the latter controls, and the permissible current is 24 amperes.

Example 2

Duty cycle: 30 seconds on, 8 minutes off.

$$\sqrt{\text{duty-cycle ratio}} = \sqrt{\frac{510}{30}} = 4.2$$

Up-rated current = 4.2 x 6 = 25.2 amperes.

30-second short-time overload (Figure 1) = 380% = 22.8. This figure, being lower than that calculated from the duty-cycle ratio, is the limiting value, and therefore, the permissible current is 22.8 amperes.

Example 3

Duty cycle: 6 seconds on each minute, repeated for one-half hour, maximum.

$$\sqrt{\text{duty-cycle ratio}} = \sqrt{\frac{60}{6}} = 3.16$$

Short-time rating (Figure 1) for 30 minutes = 133%

Up-rated current = 6 x 3.16 x 1.3 = 24.6 amperes.

6-second short-time overload (Figure 1) = 725% = 42.7 amperes.

Permissible current is 24.6 amperes.

— Gilbert Smiley

NEW SALES ENGINEERS

LOS ANGELES

Alan O. Abel has been transferred to the Los Angeles Office of the General Radio Company. Mr. Abel, a B.S. from Purdue University in Electrical Engineering and an M.B.A. from the Harvard Graduate School of Business Administration, has been a Sales Engineer at the Cambridge Office for the past two years.

Frank J. Thoma, of Los Angeles, has joined the staff of the Los Angeles Office as a Sales Engineer. Mr. Thoma holds a B.S. degree in Electrical Engineering from the University of Illinois. He was previously associated with the Sangamo Electric Company and later with Edward S. Sievers as a Sales Engineer for Weston instruments.

PHILADELPHIA

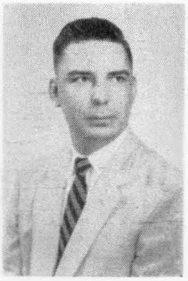
John E. Snook, who joined the Sales Engineering staff at Cambridge in 1955, has been transferred to the Philadelphia (Abington, Pennsylvania) Office. Mr. Snook received his

ALAN O. ABEL

FRANK J. THOMA

JOHN E. SNOOK

JOHN C. HELD



B.S. in Electrical Engineering from Pennsylvania State University in 1950, and for the succeeding five years, was with Sylvania Electric Products at Williamsport, Pennsylvania.

WASHINGTON

John C. Held joined the staff of the Washington (Silver Spring, Maryland) Office on May 1. Mr. Held, a graduate of George Washington University, was for five years an engineer at the Naval Research Laboratory and for the past year and a half has been a manufacturers' representative in the Washington area.

NEW YORK OFFICE MOVES TO RIDGEFIELD

The Metropolitan New York Office of the General Radio Company is now located at

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Telephone service includes both New York City and local numbers:

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The new office is staffed by the same capable General Radio engineers that operated our former West Street Office, George G. Ross and C. William Harrison, who can supply technical and commercial information on all General Radio products.

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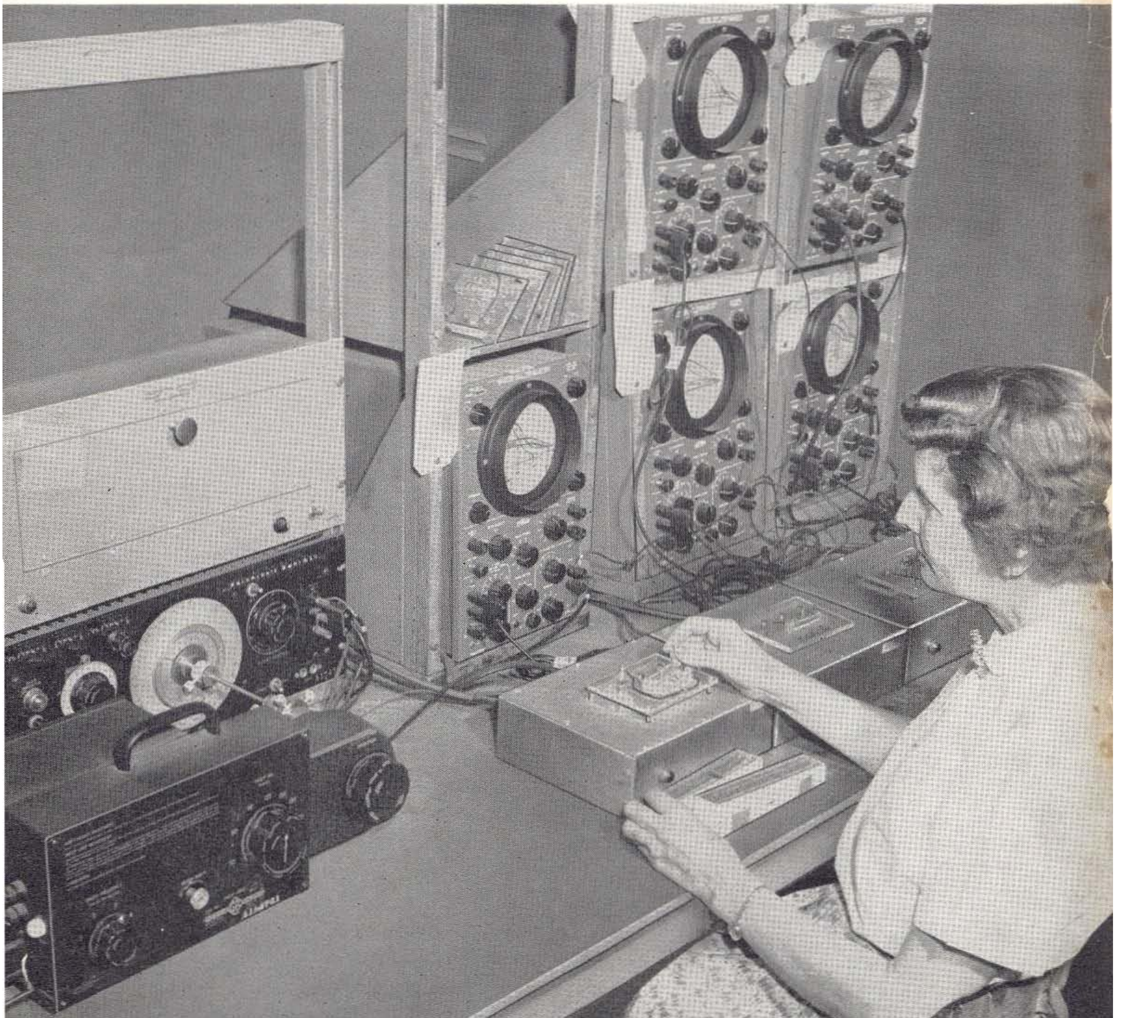

Photo Courtesy Philco Corporation

In This Issue

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Sweep Drives

THE GENERAL RADIO EXPERIMENTER

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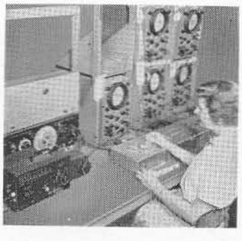
COVER



Testing encapsulated R-C networks for frequency response at Philco Corporation. This test used the General Radio Sweep Drive and Beat-Frequency Generator (left foreground) to present the over-all frequency characteristic on a cathode-ray oscilloscope. The lines drawn on the face of the oscilloscope indicate the test limits.

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RESPONSE OF PEAK VOLTMETERS TO RANDOM NOISE

Random-noise signals are used in a great variety of electrical, acoustical, and vibrational tests.[1] In these applications a measure of the amplitude of the random-noise signal is usually necessary. Voltmeters with either r-m-s or average response are the most satisfactory types for this measurement, and it has been assumed that peak-responding voltmeters could not be used, because the observed results could not easily be related to those obtained with the other types.

The popular peak-responding voltmeters, such as the General Radio Types 1800 [2] and 1803 [3] can, however, measure random noise satisfactorily. To show this, some of the important characteristics of random noise and of peak voltmeters will be considered, and comparisons will be made of predicted and actual performance.

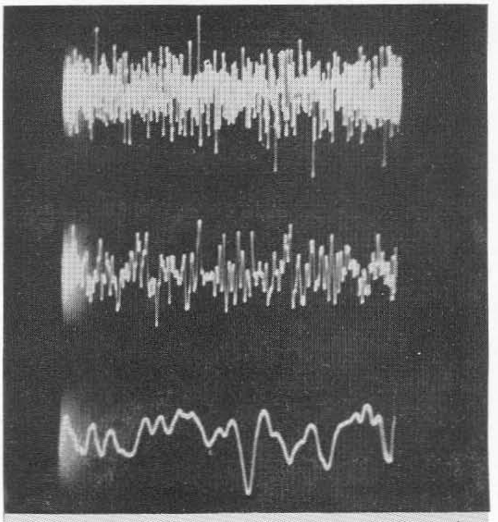


Figure 1. Oscillograms of three different samples of the output voltage from the Type 1390-A Random-Noise Generator. Sweep speeds are in the ratios 1:4:20, top to bottom. A single sweep was used for each oscillogram.

CHARACTERISTICS OF RANDOM NOISE

A random-noise signal is, in some respects, a difficult one to measure, because it is characterized by randomness rather than regularity, as shown in Figure 1. Consequently, noise is ordinarily described by statistical means, and a random noise can be defined as a noise that has a normal distribution of amplitudes. This concept is illustrated graphically by the curve of Figure 2. The probability that a voltage between any two limits will be observed is given by the area under the normal curve between those two limits. Expressed in other terms, if the output

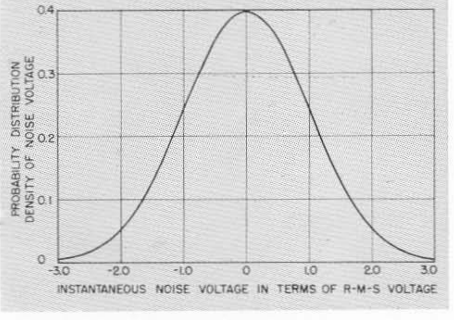


Figure 2. Normal distribution curve of a truly random noise.

[1] Arnold Peterson, "A Generator of Electrical Noise", *General Radio Experimenter*, *26*, 7, December 1951; pp. 1–9.
[2] C. A. Woodward, Jr., "The New Type 1800-B Vacuum-Tube Voltmeter", *General Radio Experimenter*, *31*, 4, September 1956; pp. 10–12.
[3] C. A. Woodward, Jr., "The Type 1803-B Vacuum-Tube Voltmeter", *General Radio Experimenter*, *29*, 10, March 1955; pp. 5–8.

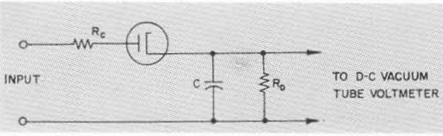


Figure 3. Elementary circuit of a peak-responding diode rectifier.

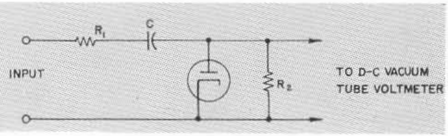


Figure 4. Practical form of the circuit of Figure 3.

voltage is observed over long periods of time, the fraction of the total time the voltage is between the two voltage limits is given by the corresponding area under the probability curve. For example, the instantaneous voltage will be greater than the r-m-s value in the positive direction about 16% of the time. Similarly, it will be greater than two times the r-m-s value in the positive direction about 2.3% of the time. In these two examples, the upper voltage limit was taken as infinity. Naturally, in an electronic system, the usual limitations of amplifiers upset this idealized distribution. In particular, the maximum instantaneous voltage that is obtainable is limited, and some dissymmetry is often introduced, so that the noise is not strictly random. Furthermore, the noise source itself may have similar limitations. But, in general, noise does not have a well-defined peak value, so that the usual simplified concept of the operation of a peak voltmeter cannot be applied to the measurement of noise.

BASIC CIRCUIT OF THE PEAK VOLTMETER

The widely used peak-type voltmeter ordinarily consists of three elements: a diode rectifier, a capacitor, and a d-c voltmeter system, as illustrated in Figure 3. The diode makes it possible for the capacitor to acquire a d-c charge when an a-c voltage is applied to the circuit, and the d-c voltmeter indicates the resulting voltage across the capacitor. In this circuit, the resistance R_C represents the total charging resistance, which includes the effective resistance of the rectifier when it is conducting and the resistance of the source. The resistance R_D is that tending to discharge the capacitor C. The capacitor is charged when the voltage at the input is in such a direction and of such a magnitude that the diode conducts. The net voltage available for supplying charge to the capacitor is reduced as the capacitor voltage increases; and, finally, when the voltage across the capacitor is sufficiently high, no further increase in the voltage across the capacitor occurs. At this point, the charge supplied to the capacitor during the voltage peaks must, on the average, equal the charge that leaks off. How closely the voltage across the capacitor approaches the peak value of the applied wave is dependent upon the charging resistance and the discharging resistance.

A more practical form of circuit developed by Tuttle[4] for a peak-reading voltmeter is that shown in Figure 4. As far as the peak-reading characteristics of this circuit are concerned, the analysis is essentially the same as for the simpler circuit. Here, the effective charging resistance is that of the diode, the source, and any other series resistor, for example, that shown as R_1. The discharge resistance is the parallel combination of the shunt resistor R_2 and the back resistance of the diode, all in series with the resistance R_1. The series resistance has a further effect on the actual d-c voltage supplied to the d-c voltmeter, but this effect is taken care of in the calibration of the voltmeter by a sine-wave signal.

CALCULATION OF RESPONSE

In order to calculate the response of these peak-type voltmeters to any input wave, certain simplifying assumptions are usually made. For input voltage above a few volts it is assumed

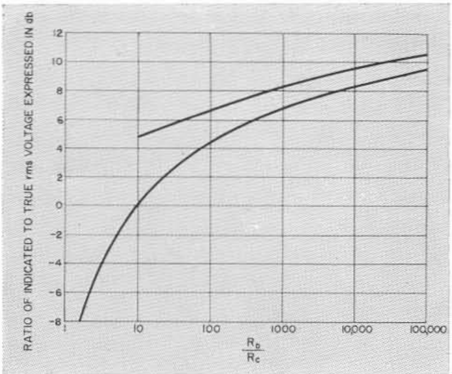


Figure 5. Previously published data of the response of a peak voltmeter to random noise (upper curve, reference (5); lower curve, reference (6).

that the rectifier is a perfect switch but with constant forward resistance and constant reverse resistance. It is also assumed that the discharge time is very long compared to the period of the applied wave. On the basis of these assumptions, the response for a sine-wave signal can be readily calculated, and this response is ordinarily used as the basis for the calibration of the meter. The calibration is usually made experimentally in terms of the r-m-s value of the applied sine wave. This type of calibration will be assumed for the subsequent discussion of response to random noise.

The response to random noise has been calculated on the basis of the above assumptions,[5, 6] but no correct numerical values appear to have been published. The results published previously are shown in Figure 5. These differ by such large factors that one wonders which is correct. Strangely, neither of them is. Beranek[5] analyzed the problem correctly on the basis of the procedure given above and obtained the equation

$$\frac{1}{E_b}\int_{E_b}^{\infty} EP(E)\,dE - \int_{E_b}^{\infty} P(E)\,dE = \frac{R_C}{R_D}$$

where E_b is the average voltage across the capacitor C, E is the instantaneous value of the input voltage, $P(E)$ is the probability distribution of the instantaneous amplitudes of the input wave, R_C is the total resistance through which the capacitor is charged, and R_D is the total resistance through which the capacitor discharges. He also assumed that the reactance of the capacitor was small compared to R_C and R_D for all frequencies of the input wave. Errors apparently occurred in

[4] W. N. Tuttle, "The Type 726-A Vacuum-Tube Voltmeter", *General Radio Experimenter, 11*, 12, May, 1937; pp. 1–6.
[5] L. L. Beranek, "Acoustic Measurements," John Wiley & Sons, N. Y., 1949, pp. 475–479.
[6] B. M. Oliver, "Some Effects of Waveform on VTVM Readings", *Hewlett-Packard Journal, 6*, 10, June 1955.

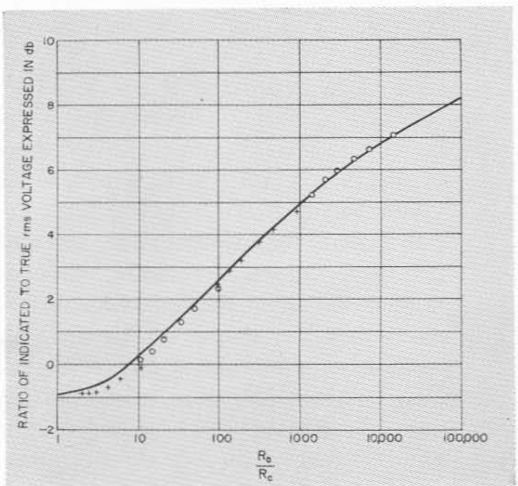


Figure 6. Response of peak voltmeter to random noise. Curve is calculated, points are experimental data.

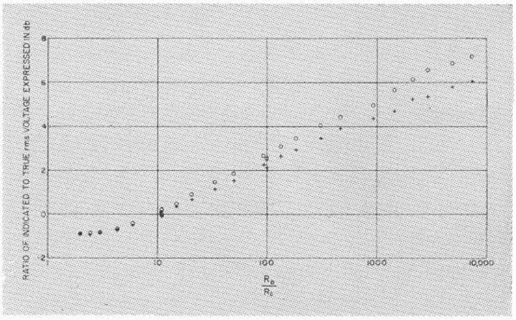


Figure 7. Experimental data for Figure 6, showing spread between positive and negative halves of wave.

the calculation [5], however, and the published curves are not correct. The other analysis [6] involved two important simplifying assumptions beyond those already stated. The first was the assumption that the voltage developed across the capacitor did not affect the charging current, and the second was that, for a sine wave, the indicated voltage was equal to the peak value. The first assumption makes the analysis incorrect for large values of the ratio of discharge and charge resistances, and the second makes the analysis incorrect for small values of this ratio.

This problem was reviewed some time ago, and new data were calculated from Beranek's formula. These are shown in Figure 6 as the solid curve. Also on this curve are plotted a number of points which show the results of an experimental test in which the Type 1800 Vacuum-Tube Voltmeter was used to measure the output of the Type 1390-A Random Noise Generator at a noise level of 3 volts r-m-s. In order to obtain the series of points shown on the figure, resistors ranging in value from 10,000 to 100,000 ohms were put in series with the high terminal of the probe of the voltmeter. Various resistors were also put in parallel with the 125-megohm resistor shunting the diode. For each point, the reading was calibrated in terms of the r-m-s value of a sine wave to give the same reading obtained for the noise. The data are plotted as a function of the ratio of the discharge to the charge resistance. It is seen from this figure that the observed values agree very well with the theoretically calculated curve. At low values of the ratio the response is similar to that of an average meter, and, as the ratio increases, the response increases gradually. Much of the departure of the observed points from the calculated curve can be accounted for by the resistance of the diode, which was neglected in the calculation of R_D/R_C for the experimentally observed points.

DISSYMMETRY OF NOISE WAVE

The actual noise wave measured was somewhat dissymmetrical, and this characteristic is a common one for noise signals. The dissymmetry is not indicated on the usual r-m-s or average-type meter, but it is observable on a cathode-ray oscillograph display of the wave. It can be measured on the peak-type voltmeter by noting the indication for both the positive and negative halves of the wave, and the results of these two sets of measurements are shown in Figure 7. When the voltmeter is operating as a good peak voltmeter, that is, with a discharge resistance many times the charge resistance, the dissymmetry is readily measured, as shown by the example of Figure 7. When the charge resistance is about equal to the discharge resistance, however, the instrument responds essentially to the average value, and the dissymmetry cannot be measured.

The meter used for obtaining the reference r-m-s reading was a full-wave type, and the calculations were based on a symmetrical distribution. Consequently, for comparison with the calculated curve in Figure 6, the average of the two observed readings for each value of the ratio was used.

EFFECT OF VOLTAGE LEVEL

At the voltage level used for the experimental points of Figures 6 and 7, the diode behaved essentially as a switch with a discontinuity in its characteristic, as assumed in the analysis. At low voltage levels, however, the diode rectifies mainly by virtue of the curvature of its characteristic. The voltmeter is then no longer peak-indicating, but rather it approximates an r-m-s indication. The transition between these two modes of operation occurs between about one tenth of a volt and one volt.[7] This transition is shown in the experimentally determined curves of Figure 8 and Figure 9. These curves show the ratio of the applied r-m-s noise voltage to the observed voltage. The behavior is shown here as a correction factor to be applied to the reading of the voltmeter to obtain the r-m-s value of the applied noise voltage. Two curves are shown for each voltmeter. One is for no added series resistance, and the other is for 100,000 ohms series resistance.[8] If intermediate values of resistance are used, the correction factor can be easily interpolated between these two with the aid of the curve of Figure 6 to supply the limiting value.

When no series resistance is used, the indicated voltage is highly dependent on the high instantaneous voltages that occur occasionally. For example, for a random noise at an r-m-s voltage of about 10 volts, the actual d-c voltage developed across the capacitor in the TYPE 1800-B Vacuum-Tube Voltmeter is about 3½ times the

[7] C. B. Aiken, "Theory of the Diode Voltmeter", *Proc. IRE*, *26*, 7, July 1938; pp. 859–876.
[8] The 100,000 ohms series resistance affects the sine-wave calibration of the meter by only about 1%. Ibid., p. 876.

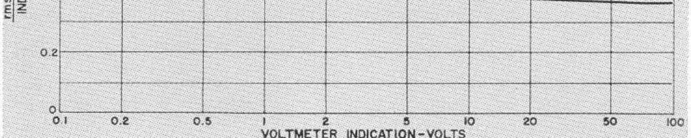


Figure 8. Correction for Type 1800 Vacuum-Tube Voltmeter indication to obtain r-m-s value of random noise.

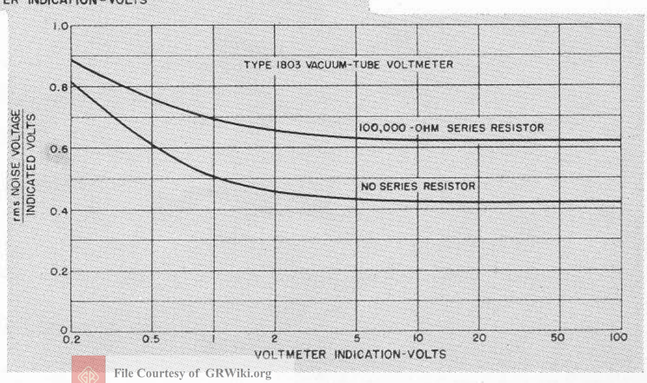


Figure 9. Correction for Type 1803 Vacuum-Tube Voltmeter indication to obtain r-m-s value of random noise.

r-m-s value of the noise. Instantaneous voltages that are still higher must, therefore, occur occasionally to supply the charge for the capacitor. For a normal distribution, the noise voltage is higher than this value only about 0.02% of the time. This direct measurement can, therefore, be a useful indication of the higher voltages existing in the noise; for example, to determine the extent of peak clipping.

A good measure of the r-m-s value can usually be obtained from the reading of a peak voltmeter when it is possible to use a high resistance in series with the diode. The indicated value then depends on a larger sample of the instantaneous voltage. When a 100,000-ohm series resistor is used, the r-m-s value of random noise can be obtained by applying to the meter indication the correction shown in Figure 8 or Figure 9. The one disadvantage of using a series resistor is that it reduces the frequency range over which the voltmeter response is essentially uniform.

FREQUENCY CHARACTERISTIC

One of the important advantages of the peak-type voltmeter with its attached probe is its excellent frequency characteristic, for example, the Type 1800-B Vacuum-Tube Voltmeter can be used to hundreds of megacycles. When measurements must be made up to those frequencies, the probe must be attached at the point where the measurement is desired in order to obtain this good frequency response, and no series resistance should be used. If, however, measurements of audio-frequency noise are being made, high resistances can be inserted in series with the probe terminal without seriously affecting the response to the audio voltage. Thus, for example, if 100,000 ohms is inserted in series with the high terminal right at the probe, the response is down about 10 per cent at 130 kc. If 50,000 ohms is used, the corresponding frequency is raised to 250 kc; or if ½ megohm is used, the 10-per cent point occurs at about 30 kc.

CONCLUSION

The peak-reading voltmeter can be more useful in the measurement of random noise than has heretofore been believed.

The correction curves of Figures 8 and 9 make it possible to relate the meter indications to the true r-m-s amplitude of random noise. These data should prove useful when r-m-s or average meters are not available or where, for some reason, their use is not feasible. In addition, the use of the voltmeter directly, i.e., without a series resistor, yields information about instantaneous peak voltages that cannot be obtained with other types of meters.

— Arnold P. G. Peterson

AUTOMATIC DATA DISPLAY

CRO—RECORDER—X-Y PLOTTER

The several automatic dial drives described in recent issues of the *Experimenter* [1, 2, 3, 4, 5] have greatly simplified the problem of automatic display and recording as a routine laboratory operation. They attach to existing oscillators and make possible both oscilloscope and graphic display without necessitating the use of specialized sweeping equipment. They combine the features of economy and simplicity with the ability to produce highly satisfactory results.

To facilitate a selection of the best drive for a given application, the several drives and their uses have been tabulated below, together with the General Radio oscillators with which they can be used, listed in the order of increasing frequency range.

GENERAL RADIO SWEEP DRIVES

Frequency Range	*Oscillator Type No.*	*Drive Type No.*	*CRO* [10]	*Graphic Recorder*	*X-Y Plotter*
10 c to 100 kc	1302-A	1750-A	x	x	x
20 to 20,000 c 20 kc to 40 kc	1304-B	908-P2	x		
		908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
20 to 20,000 c 20 kc to 40 kc	1303-A	908-P2	x [6]		
		908-P1		x	
		1750-A	x		
20 to 200μ 0.2 to 2 kc 2 to 20 kc 20 to 200 kc 50 to 500 kc	1210-B	908-P1		x	
		908-P2	x [6, 7]		
		907-R18		x	x
		907-R144		x	x
		1750-A	x		
0.5 to 5 Mc 5 to 50 Mc	1211-B [8]	908-P2	x [6]		
		908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
5 to 15 kc 15 to 50 kc 50 to 150 kc 150 to 500 kc 0.5 to 15 Mc 15 to 50 Mc	1330-A	908-P1		x	
		907-R18		x	x
		907-R144		x	x
50 to 250 Mc	1215-B [8]	908-P2	x [6]		
		908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
250 to 920 Mc	1209-B [8]	908-P2	x [6]		
		908-P1		x	
		907-R18		x	x
		907-R144		x	x
		1750-A	x		
900 to 2000 Mc	1218-A [8]	908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
300 to 5000 Mc	Type 874-LB Slotted Line with appropriate oscillator	874-MD	x [9]		x

[1] H. C. Littlejohn, "Motor Drives for Precision Drives and Beat-Frequency Oscillators", *General Radio Experimenter*, 29, 6; November, 1954, pp. 1–3.

[2] Eduard Karplus, "A New System for Automatic Data Display", *General Radio Experimenter*, 29, 11; April, 1955, pp. 1–6.

[3] R. A. Soderman, "Automatic Sweep Drive for the Slotted Line", *General Radio Experimenter*, 29, 11; April, 1955, pp. 10–15.

[4] G. A. Clemow, "Synchronous Dial Drives for Automatic Plotting", *General Radio Experimenter*, 31, 3; August, 1956, pp. 5–9.

[5] W. F. Byers, "The Type 1263-A Amplitude-Regulating Power Supply", *General Radio Experimenter*, 29, 11; April, 1955, pp. 6–10.

[6] Horizontal deflection voltage not provided; synchronous drive.

[7] Horizontal deflection voltage can be furnished with the Type 1210-P1 Detector and Discriminator.

[8] Oscillator must be powered by the Type 1263-A Amplitude Regulating Power Supply.

[9] Displays VSWR directly on CRO.

[10] Oscilloscope should have long-persistence screen.

THE TYPE 1750-A SWEEP DRIVE

(see cover)

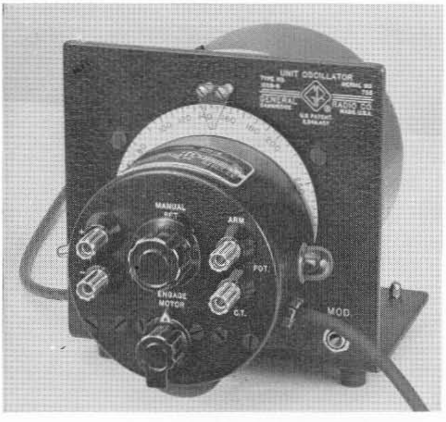
Of all the drives, the Type 1750-A is the most flexible in application, because it fits any knob or dial and is easily adjustable, while operating, both in sweep arc and sweep rate. Speed range is 0.5 to 5 cps over arcs from 30° to 300°. This drive is fully described in the *Experimenter* for April, 1955.

Type		*Code Word*	*Price*
1750-A	**Sweep Drive (115 volts, 50–60 cycles)..........**	STUDY	**$440.00**

AMPLITUDE-REGULATING POWER SUPPLY

Where indicated in the table (with Types 1211-B, 1215-B, 1209-B, and Type 1218-A Unit Oscillators) the Type 1263-A Amplitude-Regulating Power Supply is necessary to hold the oscillator output constant. This, with other accessories, is listed below.

Type		*Code Word*	*Price*
1263-A	**Amplitude Regulating Power Supply..........**	SALON	**$280.00**
874-VR	**Voltmeter Rectifier..........................**	COAXRECTOR	**30.00**
874-VQ	**Voltmeter Detector..........................**	COAXVOQUER	**30.00**
274-NF	**Patch Cord..................................**	STANPARGAG	**1.50**
874-Q6	**Adaptor.....................................**	COAXCLOSER	**2.25**
874-WM	**50-ohm Termination........................**	COAXMEETER	**12.50**

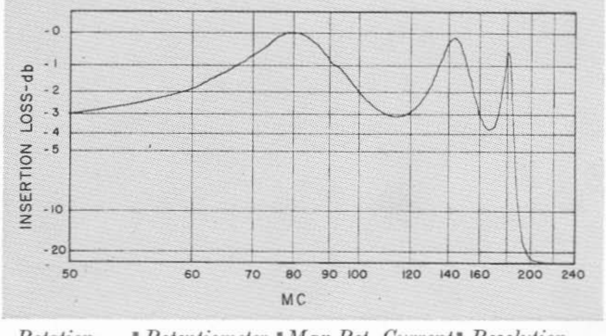


THE TYPE 907-R and TYPE 908-R X-Y DIAL DRIVES

These drives are designed to fit the General Radio Type 907-WA (4-inch) and Type 908-WA (6-inch) Gear Drive Precision Dials for front-of-panel mounting. Oscillators using these dials are listed in the table for the R-type drives. The drive replaces the knob on the front of the dial and is easily installed. Its synchronous motor rotates the dial at a uniform rate. A potentiometer is rotated simultaneously, providing an output voltage proportional to dial position, which can be used to drive the X-axis of a plotter. A complete description and specifications will be found in the *Experimenter* for August, 1956. Two speeds are available in each size.

(Above) View of Type 907-R-144 X-Y Dial Drive, installed on a u-h-f Unit Oscillator.

(Right) Plot of the frequency characteristic of a Type 874-F185 Filter obtained on an X-Y plotter with the X-Y Dial Drive shown above.

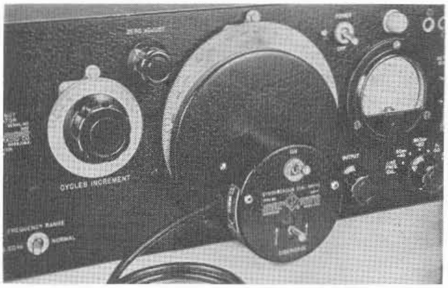


Type	*Dial*	*Speed*	*Rotation*	*Potentiometer*	*Max Pot. Current*	*Resolution*
907-R18	907	18°/min	CCW	20 kΩ	10 ma	0.4°
907-R144	907	144°/min	Self-reversing	20 kΩ	10 ma	0.4°
908-R12	908	12°/min	CCW	50 kΩ	10 ma	0.2°
908-R96	908	96°/min	Self-reversing	50 kΩ	10 ma	0.2°

Type		Code Word	Price
907-R18	X-Y Dial Drive..................................	EARLY	$55.00
907-R144	X-Y Dial Drive..................................	EDUCE	55.00
908-R12	X-Y Dial Drive..................................	EGRET	55.00
908-R96	X-Y Dial Drive..................................	EJECT	55.00

THE TYPE 908-P1 and TYPE 908-P2 SYNCHRONOUS DIAL DRIVES

Simplest and least expensive of the dial drives, these synchronous units will fit both the Type 907-WA and the Type 908-WA Gear-Drive Precision Dials. They do not include the potentiometer for supplying a horizontal deflection voltage. Adjustable stops are provided for limiting travel. Drives are self reversing. The faster model, Type 908-P2, can be used for oscilloscope display if a simple discriminator is provided to supply the X-axis original. The Type 908-P1 is recommended for use with a graphic recorder. A complete description with specifications was published in the *Experimenter* for November, 1954.

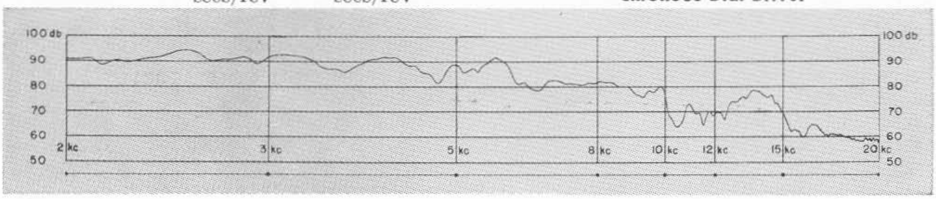


Speed:

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

(Above) View of the Type 908-P1 Synchronous Dial Drive installed on a Type 1304-B Beat-Frequency Audio Generator.

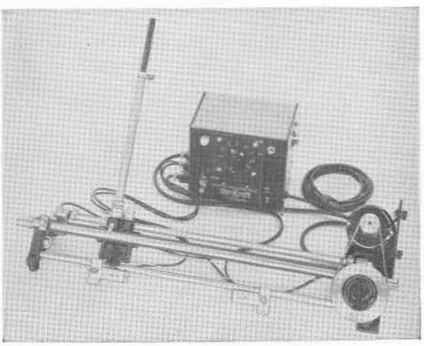
(Below) Record of the frequency response of a small loudspeaker in an anechoic chamber. Oscillator was driven by the Type 908-P1 Synchronous Dial Drive.



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

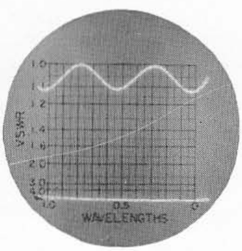
SLOTTED LINE MOTOR DRIVE

The slotted-line motor drive, designed to drive the probe carriage of the General Radio Type 874-LBA Slotted Line, makes possible the display of VSWR directly on an oscilloscope. Its use greatly speeds up slotted line measurements. See the *Experimenter* for April, 1955, for complete details.



View of the Type 874-LBA Slotted Line with the Type 874-MD Motor Drive.

VSWR pattern, as displayed on scope, obtained with the motor-driven slotted line.



Type		Code Word	Price
874-MD	Slotted-Line Motor Drive..	STORY	$290.00

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extends to all *Experimenter* readers its best wishes for a Merry Christmas and a Happy New Year.

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