the GENERAL RADIO Experimenter

INDEX

TO

GENERAL RADIO EXPERIMENTER

VOLUMES 30 and 31

JUNE, 1955 through MAY, 1957

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

Printed in U.S.A.

INDEX BY TITLE

INDEX BY INSTRUMENT TYPE NUMBER

Type 874-PB Panel Connector - More New Coaxial Parts (September, 1955)
Type 874-PB8 Panel Connector - More New Coaxial Parts (September, 1955)
Type 874-PB9 Panel Connector - More New Coaxial Parts (September, 1955)
Type 874-PB58 Panel Connector - More New Coaxial Parts (September, 1955)
Type 874-PB62 Panel Connector - More New Coaxial Parts (September, 1955)
Type 874-QLJ Adaptor to UG 154/U or A/U Type LC Connector - New Coaxial Elements, Attenuators, Filters, Line Stretchers, Detectors, Adaptors (April, 1956)
Type 874-QLP Adaptor to UG 352A/U Type LC Connector - New Coaxial Elements, Attenuators, Filters, Line Stretchers, Detectors (April, 1956)
Type 874-QU1 Adaptor to 7/8", 50-Ohm, UHF Line - More New Coaxial Parts (September, 1955)
Type 874-QU2 Adaptor to 1 5/8", 50- Ohm, UHF Line - More New Coaxial Parts (September, 1955)
Type 874-R22 Patch Cord - New Coaxial Elements (August, 1955)
Type 874-UB-P2 Balun Terminal Unit - New Coaxial Elements (August, 1955)
Type 874-UB-P3 300-Ohm Balun Terminal Pad - New Coaxial Elements (August, 1955)
Type 874-VQ Voltmeter Detector - New Coaxial Elements, Attenuators, Filters, Line Stretchers, Detectors, Adaptors (April, 1956)
Type 874-W100 100-Ohm Coaxial Standard - New Coaxial Elements (August, 1955)
Type 874-W200 200-Ohm Coaxial Standard - New Coaxial Elements (August, 1955)
Type 907-R X-Y Dial Drive - Synchronous Dial Drives for Automatic X-Y Plotting (G. A. Clemow: August, 1956)
Type 908-R X-Y Dial Drive - Synchronous Dial Drives for Automatic X-Y Plotting (G. A. Clemow: August, 1956)
Type 942-A Output Transformer - High Power with Low Distortion (January, 1956)
Type 980 Decade Capacitors - New Decade Capacitors with Polystyrene Dielectric (July, 1956)
Type 1184-A Television Transmitter Monitor - New Television Transmitter Monitor (C. A. Cady: September, 1956)
Type 1212-P2 One-Megacycle Filter - A Tuned Filter for Use in Capacitance Measurements at One Megacycle (Henry P. Hall: January, 1956)
Type 1213-AB Unit Crystal Oscillator - Improved Unit Crystal Oscillator Now Available (September, 1955)
Type 1213-C Unit Time/Frequency Calibrator - A High-Precision Calibrator for Frequency and Time (R. W. Frank, F. D. Lewis: June, 1956)
Type 1213-P1 Differentiator - A High-Precision Calibrator for Frequency and Time (R. W. Frank, F. D. Lewis: June, 1956)
Type 1214-AS2 Unit Oscillator - A 120-Cycle Source for Electrolytic Capacitor Testing with the Capacitance Test Bridge (August, 1956)
Type 1219-A Unit Pulse Amplifier - New Pulse Amplifier Increases Utility of Unit Pulser (R. W. Frank: July, 1955)
Type 1219-A Unit Pulse Amplifier - Correction (September, 1955)
Type 1220-A Unit Klystron Oscillator - A Low-Cost Microwave Signal Source (Benedict O'Brien, R. A. Soderman: March, 1957)
Type 1230-A D-C Amplifier and Electrometer - A New, High-Sensitivity Electrometer (A. G. Bousquet: March, 1956)
Type 1304-B Beat-Frequency Audio Generator - Recorder Coupling for the Beat-Frequency Audio Generator (July, 1956)
Type 1391-A Pulse, Sweep, and Time-Delay Generator - A Versatile Generator for Time-Domain Measurements (R. W. Frank: May, 1956)
Type 1391-A Pulse, Sweep, and Time-Delay Generator - Double Pulses with (R. W. Frank: April, 1957)
Type 1419-A Decade Capacitor (July, 1956)
Type 1420 Variable Air Capacitor (H. M. Wilson: July, 1956)
Type 1454-A Decade Voltage Divider - An Accurate Voltage Divider for DC and Audio Frequencies (Ivan G. Easton: August, 1955)
Type 1482 Standard Inductor (May, 1957)
Type 1551-A Sound-Level Meter - The Sound-Level Meter as an Audio-Frequency Voltmeter and Amplifier (E. E. Gross: January, 1957)
Type 1552-B Sound-Level Calibrator - An Improved Sound-Level Calibrator (E. E. Gross: June, 1955)
Type 1556-A Impact Noise Analyzer - The Measurement of Impact Noise (Arnold P. G. Peterson: February, 1956)
Type 1570-ALS15 Automatic Voltage Regulator - Militarized Line Voltage Regulator (November, 1956)
Type 1603-A Z-Y Bridge (Ivan G. Easton, Horatio W. Lamson: July, 1955)
Type 1605-A Impedance Comparator - A High-

INDEX BY AUTHOR

the GENERAL RADIO Experimenter

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 8 JANUARY, 1955

THE NEW 970-SERIES POTENTIOMETERS— HIGH-QUALITY PERFORMANCE AT MODERATE PRICES

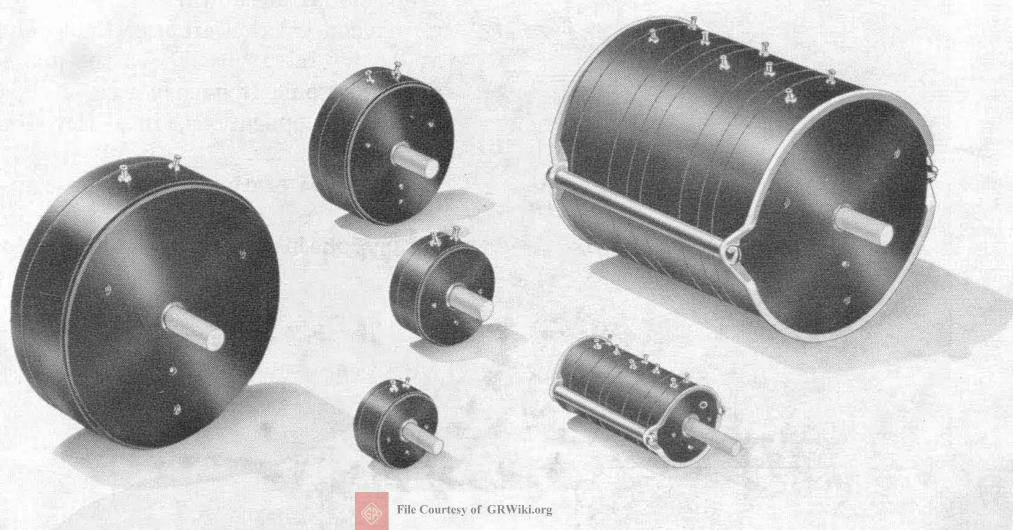
The General Radio Company has been manufacturing wire-wound rheostats and voltage dividers for nearly forty years. These controls are designed for general use in electronic equipment. Their characteristics have not been circumscribed by a need for the lowest possible cost, as in mass-produced radio-receiver volume controls; nor have they been extended to the degree found possible in today's closely machined, but very expensive, ultra-precision potentiometers.

Many years' experience with potentiometers and rheostats have brought out the design features important for applications in General Radio instruments. Concentration on these features has led to designs that satisfy not only our own requirements but those of many customers, who find these medium-priced controls, of good all-round characteristics, to be just right for their applications as well.

It is in this tradition that the new 970 series of variable resistors has been evolved, not to make "just another potentiometer," but to upgrade a distinctive class of controls whose existence has been amply justified.

Contemporary usage demands controls with outstanding mechanical per-

Figure 1. Type 970-Series Potentiometers are available in the four diameters shown here. Ganged units are available on special order.



formance and features that can only be achieved by utilizing to the utmost today's knowledge of materials and manufacturing techniques. To be suitable for general instrument use, however, these devices must also be designed with due consideration for electrical parameters other than resistance, as well as for adaptability and reasonable cost.

The new 970 types meet these objectives. They are quality potentiometers, moderately priced, sturdy and versatile, with resistance-performance specifications approaching the best available, plus a-c performance substantially better than those found in today's high-precision d-c types. This combination of mechanical precision, good electrical characteristics, and general adaptability makes these new components even more useful than earlier models and in a broader field of applications.

The new 970 series of potentiometers progresses through 8 sizes, ranging in diameter from 1¼ inches to 4¼ inches, in power dissipation at 40°C ambient from approximately 2 to 20 watts, and comprises stock resistance values in 1, 2, 5 sequence from 2 ohms to 500,000 ohms. The chart on pages 4 and 5 gives a panoramic view of the series and emphasizes the completeness of the coverage.

Because there is a close family relationship between individual types in the 970 series, a detailed description of any one suffices for all. Figure 2 is an external view of a typical model, illustrating the dust-proof total enclosure and the external hub. When the two setscrews in this exposed hub are loosened, the shaft can be adjusted or removed entirely without opening the enclosure and exposing the interior to dirt or damage. This permits easy phasing and ready substitution of shafts of different lengths or materials.

Removal of a single cover screw makes the interior readily accessible for inspection, even when the control is mounted. Figure 3 is a view of an opened unit arranged so that the salient features can be observed, and shows the simplicity of construction that permits low cost and dependability.

The low capacitance across the winding and between winding and ground is attained by reducing to a minimum the number and size of metal parts. The base and cover cups are phenolic moldings, and the shaft is fabricated from glass-reinforced polyester resin. The thin winding form of phenolic laminate keeps inductance down. Potentiometers of this construction are useful not only at dc, but also throughout the audio and supersonic frequency ranges and, in many applications, into the low radio frequencies.

The brush arm and spring are combined into a single stamping of spring-temper phosphor-bronze, as shown in

Figure 2. External view of a Type 975 Potentiometer.

the photograph. A punched key on this piece engages a milled keyway in the hub, and the two parts are then swaged together. The screw that holds the cover to the base passes through a horseshoe-shaped slot in the brush arm to serve as a rotational stop. Force exerted against the stop is transmitted directly and positively to the hub by the central portion of the arm and does not strain the outer ring, which carries the brush. The entire outer ring serves as an extra-long spring, to make brush pressure uniform, independent of accumulated tolerances.

The hub rotates in a reamed brass insert molded into the cover to form one bearing. The shaft is rigidly held by this hub and a second bearing is provided by a stainless-steel insert in the base. The hub is closely fitted to its bearing, which is approximately in the plane of the brush and therefore contributes to linearity and stability of setting. The shaft bearing, in consequence, can have a slight allowance to accomodate thermal expansion of plastic shafting. Reasonable play in this latter bearing has a negligible effect on the brush position. Stainless steel is used because it wears well with all shaft materials, including such abrasive ones as ceramics and glass fibers. The location of the two bearings, at the extreme ends of the enclosure, provides maximum stability.

The moving contact, which is spot-welded to the spring arm, is a wire whose diameter is chosen to yield fine resolution, small transition from winding to end terminal, and precise angle of electrical rotation. It is made of a heat-hardened precious-metal alloy, selected to be compatible with the resistance alloy used. The non-corrosive and wear-resistant qualities of this alloy contribute to reliability and long life.

The turret terminals are both riveted and soldered to the ends of the winding and to the spring-bronze contact take-off in the cover, so that none of the fixed internal connections depend on pressure alone. The terminals are made of brass, plated with tin alloy for easy soldering, and are hollow to minimize thermal capacity and conductivity. They will, therefore, not loosen in the phenolic when properly soldered.

The resistance cards are accurately wound by skilled workmen, on specially designed winding machines using the best wire alloys available. The standard tolerances for total resistance listed on the chart were chosen because they can

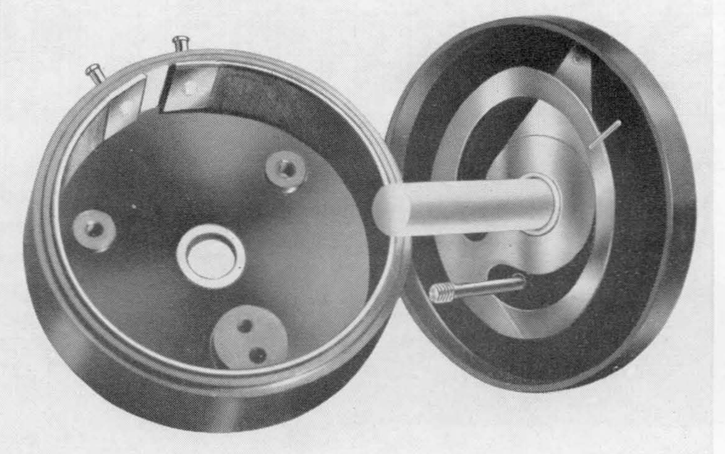
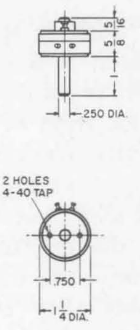
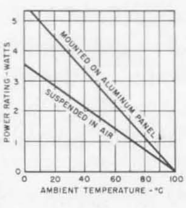


Figure 3. View of an opened unit showing features of design and construction.

TYPE 971

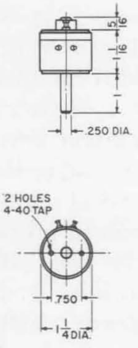


APPROXIMATE WEIGHT	1/2 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±5°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±5%
AVERAGE TORQUE	1 OZ. IN.

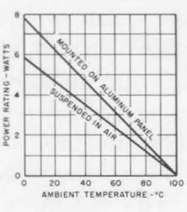


TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
B	2	+.07 %	<1%	±2%
C	5			
D	10	±.002%		
E	20			
F	50		<.5%	
G	100			
H	200			
J	500			
K	1000	+.002%		
L	2000			
M	5000		<.2%	
N	10,000			
P	20,000			

TYPE 972

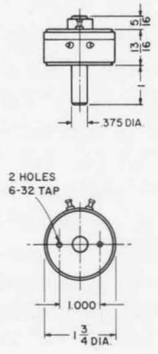


APPROXIMATE WEIGHT	3/4 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±5°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±5%
AVERAGE TORQUE	1 OZ. IN.

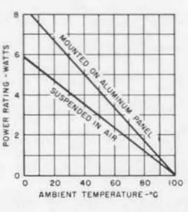


TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
C	5	+.07 %	<1%	±2%
D	10			
E	20	±.002%		
F	50			
G	100		<5%	
H	200			
J	500			
K	1000			
L	2000	+.002%		
M	5000			
N	10,000		<.2%	
P	20,000			
Q	50,000			

TYPE 973

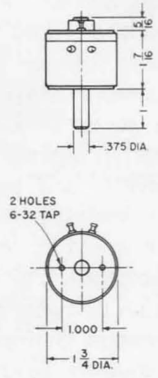


APPROXIMATE WEIGHT	1 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±5°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±5%
AVERAGE TORQUE	1 1/4 OZ. IN.

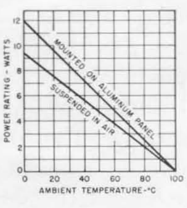


TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
C	5	+.07 %	<.5%	±1%
D	10			
E	20	±.002%		
F	50			
G	100			
H	200			
J	500		<2%	
K	1000			
L	2000	+.002%		
M	5000			
N	10,000		<.1%	
P	20,000			
Q	50,000			

TYPE 974



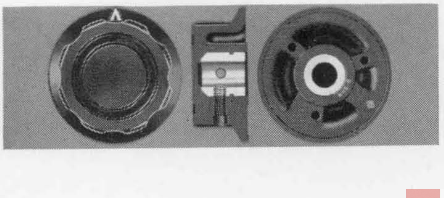
APPROXIMATE WEIGHT	1 3/4 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±5°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±5%
AVERAGE TORQUE	1 1/4 OZ. IN.



TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
D	10	+.07 %	<.5%	±1%
E	20			
F	50	±.002%		
G	100			
H	200			
J	500			
K	1000		<.2%	
L	2000			
M	5000	+.002%		
N	10,000			
P	20,000		<.1%	
Q	50,000			
R	100,000			

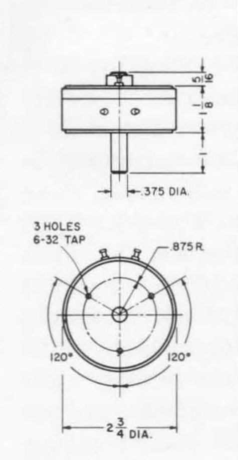
For Prices See Pages 7 and 8.

Knobs Suitable for Use with 970-Series Potentiometers

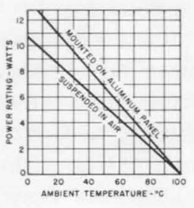


These phenolic knobs are molded in one piece with a brass insert bored for a 3/8-inch shaft. A bushing is furnished with each knob to adapt it to a 1/4-inch shaft. Knob is clamped to shaft by two set-screws spaced 90° apart, except in TYPE KNSP-6, which has 135° spacing.

TYPE 975

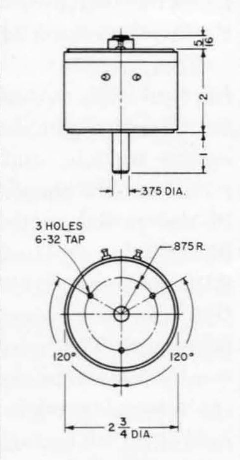


APPROXIMATE WEIGHT	3 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±2°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±2%
AVERAGE TORQUE	3 1/2 OZ. IN.

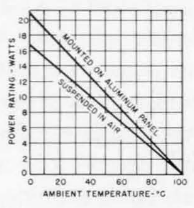


TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
*D	10	+.07 %	<.5%	±1%
*E	20			
*F	50	±.002%		
*G	100			
*H	200			
J	500		<.2%	±.5%
K	1000			
L	2000			
M	5000	+.002%		
N	10,000		<.1%	
P	20,000			
Q	50,000		<.05%	
R	100,000			

TYPE 976

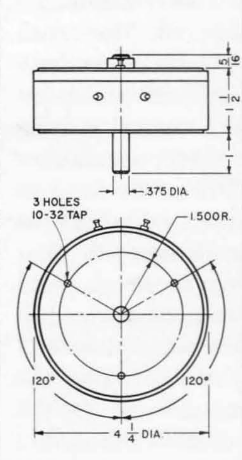


APPROXIMATE WEIGHT	4 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±2°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±2%
AVERAGE TORQUE	3 1/2 OZ. IN.

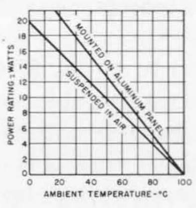


TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
*E	20	+.07 %	<.5%	±1%
*F	50			
*G	100	±.002%		
*H	200			
*J	500			
K	1000		<.2%	±.5%
L	2000			
M	5000			
N	10,000	+.002%		
P	20,000		<.1%	
Q	50,000			
R	100,000		<.05%	
T	200,000			

TYPE 977

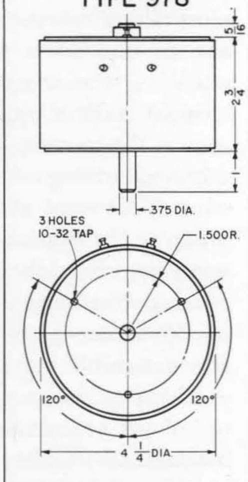


APPROXIMATE WEIGHT	9 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±2°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±2%
AVERAGE TORQUE	10 OZ. IN.

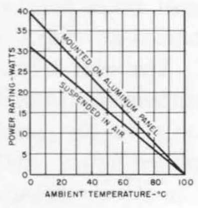


TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
*E	20	+.07 %	<.2%	±.5%
*F	50			
*G	100	±.002%		
*H	200			
*J	500			
K	1000		<.1%	±.2%
L	2000			
M	5000			
N	10,000	+.002%		
P	20,000			
Q	50,000		<.05%	
R	100,000			
T	200,000			

TYPE 978



APPROXIMATE WEIGHT	12 OZ.
EFFECTIVE ELECTRICAL ROTATION	320°±2°
TOTAL MECHANICAL ROTATION	330°±5°
STANDARD RESISTANCE TOLERANCE	±2%
AVERAGE TORQUE	10 OZ. IN.



TYPE LETTER	NOMINAL RESISTANCE OHMS	TEMPERATURE COEFFICIENT OF RESISTIVITY	RESOLUTION	STANDARD INDEPENDENT LINEARITY
*F	50	+.07 %	<.2%	±.5%
*G	100			
*H	200	±.002%		
*J	500			
*K	1000			
L	2000		<.1%	±.2%
M	5000			
N	10,000			
P	20,000	+.002%		
Q	50,000			
R	100,000		<.05%	
T	200,000			
U	500,000			

*NOT USUALLY MANUFACTURED OR STOCKED. INQUIRIES ARE INVITED.

Type*	Recommended for Type	Skirt Diameter inches	5† to 19	Unit Prices‡ 20 to 199	200 to 399	400 to 1999
KNS-6 or KNSP-6	971, 972, 973, 974	1 5/16	$0.60	$0.50	$0.47	$0.44
KNS-8 or KNSP-8	975, 976	1 15/16	.75	.65	.61	.58
KNS-10 or KNSP-10	977, 978	2 3/8	1.05	.95	.90	.85

*KNSP-types have pointer; KNS-types do not. †Minimum quantity sold. ‡Net; no additional quantity discounts be met economically, yet are sufficiently close for most uses. Closer tolerances can be met when required. The brush track on the wound card is carefully cleaned with a special buff which removes the varnish and enamel coating without cutting into the fine resistance wire. To assure stability, the track is made at the edge of the card, where the wires remain tight and maintain their spacing. Furthermore, a thorough cleaning operation can be easily performed on this accessible portion of the element.

Electrical noise is minimized by the use of the precious-metal brush, by the mechanical stability of the winding, and by the maintenance of cleanliness in the dust-proof enclosure. A thorough final cleaning is the last assembly operation before the cover is closed, and every unit must pass an oscilloscope test for traces of noise.

The excellent linearity of the 970-series potentiometers is attributable not only to the good workmanship exemplified by the quality of the winding and the closely fitted primary bearing, but also to the basic design. It will be noted in the illustrations, for instance, that the peripheral walls of all these controls are smooth cylinders, inside and out, without bosses or change in section thickness. A molding with this uniform geometry has no unequal curing or aging stresses and will therefore remain round and concentric. The resistance element is cemented directly to the true interior surface, and the assembly is baked to cure the cement and to stress-relieve the card. With this construction, the linearity limits on the specification sheet are readily met by all the units without a need for expensive machining operations. The resulting simplicity of manufacture leads to exceptionally low prices for this degree of precision. Every control is tested and graded for linearity, and closer tolerances than those listed are available by selection at slightly increased prices.

The locations of the mounting holes for the Type 970-series potentiometers are the same as those for the equivalent earlier models, and the maximum dimensions are chosen to be within those of the earlier models. The older Type 301 can be replaced by the new Type 973, the Types 214 and 314 by the Type 975, and the Types 371 and 471 by the Type 976. The holes in the bases of the new potentiometers are tapped, while the earlier models required nuts for mounting. The small models mount with two screws, and the large with three screws, as shown in the chart on pages 4 and 5. This installation method offers several distinct advantages. Any panel thickness can be accomodated by simply selecting screw lengths; screws are easier to install than large nuts; countersunk screws may be used when flush panel surface is desired; and multiple screws lock against rotation without keys or pins which require fussy tolerances.

Ganged assemblies are made with nesting phenolic spacer rings and skeleton-proportioned aluminum clamps as shown in Figure 1. The external hubs on each unit are progressively attached to a common shaft in approximate angular location. Accurate tracking is then obtained by rotating the individual potentiometer bodies prior to final tightening of the clamps. The rabbets on each end of the unit casings register with the cylindrical spacers and with the clamps to keep the assembly concentric during this phasing operation. The small amount of metal in the clamps keeps capacitance between units at a minimum. So many combinations of numbers, values and characteristics can be specified for a ganged control that it is not feasible to list stock models, but inquiries will be welcomed on an individual quotation basis. Since best results are obtained when a ganged assembly is adjusted at the factory, ganging hardware will not, at present, be sold separately.

Variations from the standard models can be easily produced. For example, 360° rotation is achieved (at the factory) by removing the cover screw, cementing a bridge between the ends of the windings and then fastening the cover to the base with the same clamp rings that are used on the ends of a ganged assembly.

Intermediate taps can be provided anywhere around the periphery and are brought out to hollow turret terminals installed in the base cup prior to inserting the resistance element. The winding form is provided with a clearance hole in the general area of each tap and, a loop of wire is left in the winding at the measured resistance point. After assembly an enameled conductor is passed through the terminal, through the winding adjacent the loop and is soldered at each end. The only limitation on the number of taps that can be provided in this compact manner is the external spacing of the terminals.

Any reasonable characteristic of resistance change with rotation can be accomplished by tapering and/or stepping the unused edge of the winding form. A variety of shapes have already been cut for use in General Radio instruments as well as for customers, and inquiries for special functions are invited.[1]

For any potentiometer application, whether it be a special model, utilizing the extreme versatility, or a standard model taking advantage of the outstanding catalog specifications, a 970-type potentiometer is offered as the most practical solution evaluated in quality and performance per dollar.

— H. M. Wilson

[1] P. K. McElroy, "The Versatile Voltage Divider".

PRICE LIST FOR 970-SERIES POTENTIOMETERS

Type	*Code Word*	*Unit Price*	*Type*	*Code Word*	*Unit Price*
971-B	ANTRIMBITE	$3.15	973-C	CANDIDCREW	$4.00
971-C	ANTRIMCREW	3.15	973-D	CANDIDDULL	4.00
971-D	ANTRIMDULL	3.15	973-E	CANDIDEARL	4.00
971-E	ANTRIMEARL	3.15	973-F	CANDIDFALL	4.00
971-F	ANTRIMFALL	3.15	973-G	CANDIDGERM	4.00
971-G	ANTRIMGERM	3.15	973-H	CANDIDHUNT	4.00
971-H	ANTRIMHUNT	3.15	973-J	CANDIDJUMP	4.00
971-J	ANTRIMJUMP	3.15	973-K	CANDIDKISS	4.00
971-K	ANTRIMKISS	3.15	973-L	CANDIDLEAP	4.25
971-L	ANTRIMLEAP	3.15	973-M	CANDIDMILK	4.25
971-M	ANTRIMMILK	3.15	973-N	CANDIDNULL	4.25
971-N	ANTRIMNULL	3.15	973-P	CANDIDPARK	4.25
971-P	ANTRIMPARK	3.15	973-Q	CANDIDQUAD	4.25
972-C	BANTERCREW	3.75	974-D	DANCERDULL	4.50
972-D	BANTERDULL	3.75	974-E	DANCEREARL	4.50
972-E	BANTEREARL	3.75	974-F	DANCERFALL	4.50
972-F	BANTERFALL	3.75	974-G	DANCERGERM	4.50
972-G	BANTERGERM	3.75	974-H	DANCERHUNT	4.50
972-H	BANTERHUNT	3.75	974-J	DANCERJUMP	4.50
972-J	BANTERJUMP	3.75	974-K	DANCERKISS	4.50
972-K	BANTERKISS	3.75	974-L	DANCERLEAP	5.00
972-L	BANTERLEAP	3.75	974-M	DANCERMILK	5.00
972-M	BANTERMILK	3.75	974-N	DANCERNULL	5.00
972-N	BANTERNULL	3.75	974-P	DANCERPARK	5.00
972-P	BANTERPARK	3.75	974-Q	DANCERQUAD	5.00
972-Q	BANTERQUAD	3.75	974-R	DANCERRISK	5.00

Price List For 970-Series Potentiometers (*continued*)

Type	Code Word	Unit Price	Type	Code Word	Unit Price
975-J	EAGLETJUMP	$4.75	977-K	GANDERKISS	$6.00
975-K	EAGLETKISS	4.75	977-L	GANDERLEAP	6.00
975-L	EAGLETLEAP	4.75	977-M	GANDERMILK	6.00
975-M	EAGLETMILK	4.75	977-N	GANDERNULL	6.75
975-N	EAGLETNULL	5.25	977-P	GANDERPARK	6.75
975-P	EAGLETPARK	5.25	977-Q	GANDERQUAD	6.75
975-Q	EAGLETQUAD	5.25	977-R	GANDERRISK	6.75
975-R	EAGLETRISK	5.25	977-T	GANDERTICK	7.50
976-K	FANGELKISS	5.50	978-L	HAMPERLEAP	7.00
976-L	FANGELLEAP	5.50	978-M	HAMPERMILK	7.00
976-M	FANGELMILK	5.50	978-N	HAMPERNULL	7.75
976-N	FANGELNULL	6.00	978-P	HAMPERPARK	7.75
976-P	FANGELPARK	6.00	978-Q	HAMPERQUAD	7.75
976-Q	FANGELQUAD	6.00	978-R	HAMPERRISK	7.75
976-R	FANGELRISK	6.00	978-T	HAMPERTICK	8.50
976-T	FANGELTICK	6.50	978-U	HAMPERULNA	10.00

Prices are net f.o.b. Cambridge, Mass., U. S. A. Quantity discounts (see below) apply on quantities of 10 or more identical items, purchased on a single order for single shipment to one destination in U.S.A. only.

Quantity	1 — 9	10 — 19	20 — 99	100 or more
Discount	net	5%	10%	15%

CORRECTION

(November, 1954, Issue)

Current Rating for TYPE M-10 Variac® Autotransformer

The output current for the TYPE M-10 Variac is incorrectly stated on page 7 of the November *Experimenter*. Correct current ratings for this transformer are as follows:

Rated Output Current: 10 amperes
Maximum Output Current (for line-voltage connection only): 13 amperes

Code Words for TYPE M-10 Gangs

The code word listed for TYPE M-10G2 2-Gang TYPE M-10 Variac Assembly should be corrected to read CABINGANDU.

Code Words for TYPE V-2 Gangs

Code words as listed are transposed, correct as follows:

TYPE V-2G2 2-Gang TYPE V-2 Variac Assembly—BEADYGANDU.
TYPE V-2G3 3-Gang TYPE V-2 Variac Assembly—BEADYGANTY.

The R-C Oscillator

The patent number listed on page 4, should read 2,173,427.

GENERAL RADIO COMPANY

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the GENERAL RADIO Experimenter

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 9 FEBRUARY, 1955

A 900–2000 Mc UNIT OSCILLATOR

With the addition of the new TYPE 1218-A Unit Oscillator, the series of GR Unit Oscillators shown in Figure 2 now covers the frequency range from 0.5-2000 Mc. The lowest-frequency unit has two frequency ranges, the others have only one. They all are simple triode oscillators with output adjustable from a low value to about 200 milliwatts. The oscillators are well shielded for use in the measurement laboratory to drive bridges, slotted lines, and other impedance-measuring equipment, and as power sources in general testing and measurement systems. Heater and plate power can be obtained from any available power source but ordinarily one of the small GR Unit Power Supplies will be used. The new oscillator covers the frequency range of 900 to 2000 megacycles, used mostly for aircraft navigation and marine services.

Tube

The oscillator tube used in the Type 1218-A 900–2000 Mc Unit Oscillator is the 5675-type pencil triode shown in Figure 3. This tube has small internal electrodes of conventional cylindrical design, but grid connections are brought out to a large circumferential terminal which requires disc seal construction. The cylindrical plate, grid and cathode electrodes are all located on the plate side of the grid disc, and tuning between plate and grid is possible with a quarter-wave line section at frequencies as high as 2000 Mc. At the same frequency a ¾ wave-length section is required to tune between grid and cathode.

Tuning Elements

Since the high Q of the short coaxial grid plate line determines performance and stability of the oscillator, the longer grid cathode line has been coiled up in a 3½″ diameter circle to save space. It is housed in a shallow cylindrical compartment, which is shown in Figure 4 with the shield cover removed. The mechanical design of the oscillator is

Figure 1. View of the Type 1218-A Unit Oscillator.

Also
IN THIS ISSUE

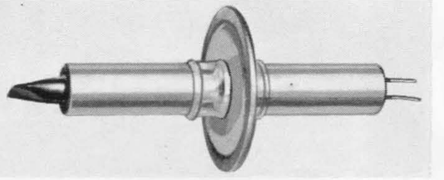


Figure 3. The 5675-type pencil tube used in the Type 1218-A Unit Oscillator.

determined by this construction, which requires a linear motion for plate tuning and a rotational motion for the cathode in a plane perpendicular to the plate line. Of equal importance for the final design was the decision to use sliding contacts in the two tuned circuits. With the new materials and methods now available, reliable sliding contacts can be produced, and f-m noise due to vibration and microphonics is lower in contact-type circuits than in circuits that have closely spaced parts to produce wide frequency ranges.

Output Coupling

A current maximum at all frequencies occurs only at the point of the movable short-circuit in the grid-plate quarter-wave line. Coupling to the load is accomplished at this point, and means are provided for adjusting the coupling in the movable plunger.

Drive Mechanism

The complete oscillator is shown in Figure 1. Like all other Unit Oscillators, it consists of a casting with large round shields and an L-shaped bracket that carries the frequency dial. The TYPE 874 Output Connector and a knob for fine tuning are located on top of the casting. Figure 4 and Figure 5 show how some of the mechanical problems have been solved. The ¼″ wide berillium copper band and the rack and pinion visible in Figure 5 provide the linkage between the main frequency dial, which is rotated through 200° by 8 turns of the vernier dial, the short-circuit plunger of the plate grid line, which moves linearly by 1¾″, and the contact arm on the grid cathode line which rotates 200°. With these drives the oscillator can be tuned to audio beats.

Power Supply

Like all other Unit Oscillators, the new TYPE 1218-A works best from a 300-volt power supply with about one half this voltage on the plate of the oscillator tube. The large plate series resistor required for this operation helps to stabilize the oscillator and protects the tube from overloads. To avoid complications in the r-f output circuit, the B supply is grounded at the plate potential of the oscillator tube. To reduce undesirable fm when commonly available 6.3 volt a-c heater power is used, a rectifier and filter for the cathode heater voltage have been included.

Figure 2. Group of Unit Oscillators covering a frequency range of 0.5 to 2000 megacycles. The lengths of the bars in front of the units indicate their frequency coverage on a logarithmic scale.

OPERATING CONSIDERATIONS

Several modes of operation which have not been possible on previous Unit Oscillators have been provided. A 3-position switch selects the desired operation, and allows the application of external control or modulating voltages at a telephone jack. Schematic diagrams corresponding to the switch positions are shown in Figure 6.

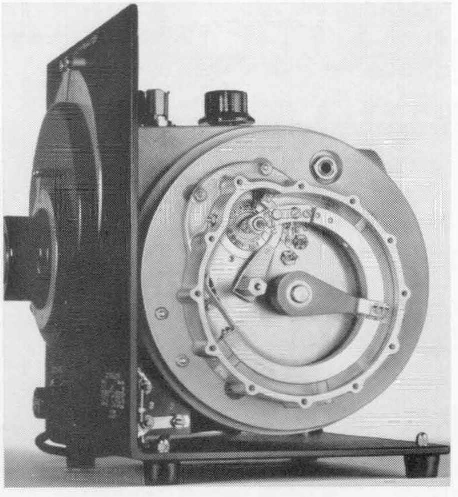


Figure 4. View of the right-hand end of the oscillator assembly with cover removed to show the cathode line.

Normal Operation

Normal operation is obtained in the first switch position labeled CW. Figure 6a shows that the plate circuit can be opened at the ground point by plugging in at the panel jack and that a control voltage can be inserted in series with the plate voltage. As with all other Unit Oscillators, audio voltage can be applied here to obtain sinusoidal amplitude modulation to allow the use of high-gain audio amplifiers after an r-f detector.

No control voltage is required for CW operation, unless it is desired to change the amplitude or to hold the oscillator output constant as the frequency is varied. To accomplish this, a voltage derived from an output monitor can be inserted at the panel jack. While a feedback system of this sort can be set up using the 874-VR Voltmeter Rectifier and an amplifier, automatic output control is so useful and almost indispensable for some applications, that an amplitude-regulating power supply has been developed for this purpose and will be announced in a few months.

Square-Wave Modulation

Amplitude modulation, obtained by superimposing a-c voltages on the d-c plate voltage of the oscillator tube, introduces undesirable frequency modulation, which increases rapidly with carrier frequency. Square-wave modulation that turns the oscillator on and off eliminates this difficulty. Ordinarily considerable square-wave power is required to turn the oscillator off completely or to give large output if the d-c plate voltage is eliminated. To obtain satisfactory operation with low power, the circuit is changed in the SQUARE WAVE position of the selector switch as shown in Figure 6b. A large resistor is inserted in the grid circuit, which makes the oscillator un-

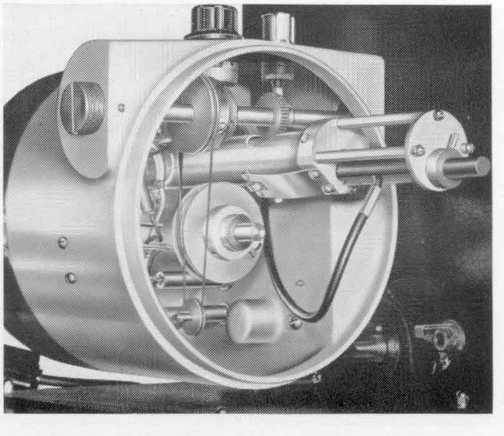


Figure 5. View of the left-hand end of the oscillator casting with cover removed showing the drive mechanism.

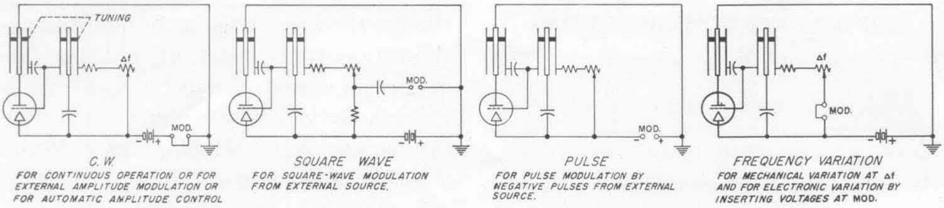


Figure 6. Schematic diagrams of oscillator for various modulation conditions.

stable so that it can be triggered with relatively low power. Good square-wave modulation from about 100 to 5000 cycles can be obtained, with square wave input as shown in Figure 7. Figure 8 shows the output produced if sine waves are applied in the SQUARE WAVE position of the selector switch.

Pulse Modulation

For pulse modulation, the d-c plate supply is removed in the PULSE position of the selector switch, and pulses are applied to the cathode. This circuit is shown in Figure 6c. For full output, 150 volts are required. The build-up time of this Unit Oscillator varies from about 3 to 10 microseconds, depending on carrier frequency and load. The decay time is of the order of 0.5 microseconds. While this performance is not adequate to reproduce faithfully short pulses, it is possible to obtain reasonably good output pulses down to about 1 microsecond. If a monitoring scope is available, the input pulse can be adjusted to equal the observed rise time and the desired pulse length. Characteristic 1 and 5-microsecond output pulses, obtained with input pulses of 6 and 10 microseconds, at 1500 Mc, are shown in Figures 9 and 10. A Type 1217-A Unit Pulser with a suitable amplifier was used as the modulating source.

Frequency Increments

Small frequency variations, of the order of 20 kc to 100 kc, can be obtained by varying mechanically the resistance in the grid circuit. The 1000-ohm resistor, Δ f, at the top of the main casting, has been provided for this purpose. In series with this variable resistor is a fixed resistor of 2000 ohms and a telephone jack that is normally closed. This circuit is shown in Figure 6d. Increasing the grid circuit resistance beyond 3000 ohms tends to make the oscillator unstable, but bias voltages with low internal impedance can be introduced at the telephone jack to change the frequency by about 0.1%. Since both sides of the bias voltage are high against ground, the modulator jack on the front panel cannot be used for this purpose, and a second jack, shown in Figure 4, has been provided. The circuit can be used for electronic frequency control in

Oscillograms of modulation waveforms. Repetition rate is 1000 cycles per second. Upper trace is the input waveform; lower trace the output.

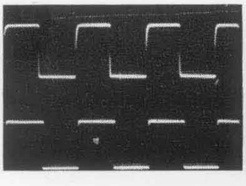


Figure 7. Square-wave modulation. The rise and fall time is faster in the r-f output than in the input.

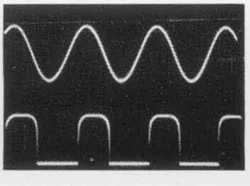


Figure 8. Sine-wave input, square-wave output.

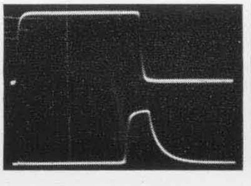


Figure 9. 6μsec input pulse, 1μsec output pulse.

Figure 10. 10μsec input pulse, 5μsec output pulse.

a closed-loop system as well as for frequency modulation.

ACCESSORIES

The TYPE 1218-A Unit Oscillator is well suited for use as a generator in measurements with the TYPE 1602-B Admittance Meter and the Type 874-LBA Slotted Line. In conjunction with the TYPE 874-MR Mixer Rectifier and the TYPE 1216-A Unit I-F Amplifier, it functions as the heterodyning oscillator in a u-h-f detector assembly. With the addition of a TYPE 874-GA Adjustable Attenuator and the Type 874-VR, -VI Voltmeter, the oscillator becomes a standard-signal generator.

Amplitude modulation to 100% with negligible fm, and pulsing with a high degree of carrier suppression can be obtained with the TYPE 1000-P7 Balanced Modulator. In addition, the extensive line of General Radio TYPE 874 Coaxial Elements is available for adapting the oscillator to other uses in the laboratory. — EDUARD KARPLUS

SPECIFICATIONS

Frequency Range: 900–2000 Mc.

Frequency Control: 6″ dial with direct reading frequency calibration over 200°. Slow motion drive, 8 turns.

Frequency Calibration Accuracy: ± 1%.

Frequency Drift: Approximately 0.1% per day.

Output Power: At least 200 milliwatts into a 50-ohm load. Maximum power can be delivered to load impedances normally encountered in coaxial systems.

Output Connector: TYPE 874 Coaxial Connector; adaptors to other types of coaxial connectors are available.

Modulation: Sinusodial amplitude modulation in the plate circuit; automatic output control with amplitude-regulating power supply; square-wave modulation in the grid circuit; pulse modulation in the plate circuit; frequency variation in the grid circuit. For general use, square-wave modulation is recommended.

Power Supply Required: 300 v, 30 ma, d c; 6.3 v, 0.135 a, a c or d c. TYPE 1203-A Unit Power Supply is recommended for operation from 50-to-60-cycle power line of 115 volts. TYPE 1202-A Unit Vibrator Power Supply is recommended for operation from a 6 or 12-volt storage battery.

Tube: TYPE 5675 UHF triode.

Mounting: The oscillator is housed in an aluminum casting and is shielded with two spun-aluminum covers. The assembly is mounted on an L-shaped panel and chassis finished in black crackle lacquer. TYPE 480-P7U1 adaptor panel is available to mount the oscillator in a relay rack. See page 8.

Accessories Supplied: TYPE 874-R22 Patch Cord, TYPE 874-C Cable Connector, TYPE 874-PB Panel Connector, multipoint connector, and telephone plug.

Accessories Available: Unit Power Supplies; Unit Oscillators and Unit Pulser for modulation; TYPE 1000-P7 Balanced Modulator; TYPE 874 Coaxial Elements, including adaptors, attenuators, volt-meters, filters, mixers, and lines. See the General Radio catalog and recent issues of the EXPERIMENTER for details.

Dimensions: Width, 12½ × height, 10⅜ × depth, 9½ inches overall.

Net Weight: 14¾ pounds.

Type		*Code Word*	*Price*
1218-A	**Unit Oscillator**	CARRY	**$465.00**

U. S. Patent Nos. 2,125,816 and 2,548,437.

NEW ADAPTABILITY FOR UNIT INSTRUMENTS

General Radio Unit Instruments are rapidly becoming recognized as a convenient and inexpensive solution to the problem of equipping the electronics laboratory with basic measuring equipment—power supplies, generators, amplifiers and detectors. They are particularly useful in the educational laboratory, because they can be assembled like building blocks into combinations for particular purposes, thus giving the student an understanding of the elements of which more specialized instruments are composed, while their modest prices provide a welcome relief to the strain on the departmental budget.

For the industrial organization, Unit Instruments perform reliably and at low cost many of the everyday jobs of the electronic engineering laboratory, and their simplicity of operation combined with compact construction makes them equally well suited for many production tests.

Two new developments, described on the following pages, bring to the Unit line a still greater flexibility of application. The Type 1202-A Unit Vibrator Power Supply, operating from batteries, provides power for Unit Instruments in the field, where a-c power lines are not available; and the Type 480 Panels permit permanent installation on relay racks in the laboratory.

THE UNIT VIBRATOR POWER SUPPLY

Design Considerations

Most of the Unit instruments are normally supplied with heater and plate voltages at the multipoint connector of a Type 1203-A Unit Power Supply, which operates from a 115-volt 50-60 cycle power line. Two of the Unit instruments include their own supply for direct power-line operations.

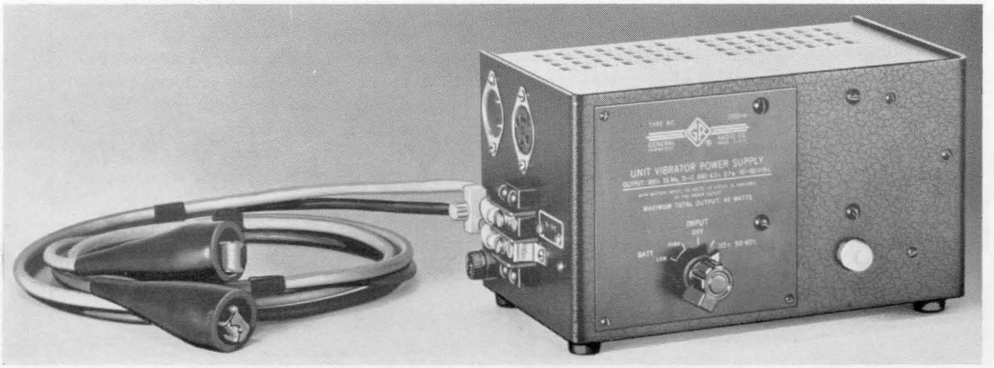
The new vibrator power supply is designed to meet the exact needs of both Unit-line groups when operated from either a 6-volt or a 12-volt storage battery. There is a multipoint connector for heater and plate supply; there is a power outlet for 115-volt a-c supply. This latter feature extends the usefulness of the new supply to field operation of many instruments other than that of the Unit line, such as megohmmeters, vacuum-tube voltmeters, oscillators, etc. Power can be taken simultaneously from both outlets to supply, for example a Type 1216-A I.F. Unit Amplifier and a Type 1209-A U.H.F. Oscillator for antenna measurements.

To avoid duplication of facilities, the new vibrator supply can also be operated from a 115-volt, 50-60 cycle line.

Alternate Methods

Commercial equipment for supplying higher-voltage a-c or d-c power from storage batteries has been available for some years. A survey of the equipment on the market with the requirements of the Unit Instruments in mind made it quite evident that a supply designed especially for these instruments was necessary. In some instruments, the heater must not be grounded, in one, the heater voltage is rectified. Therefore, any supply that requires that the heaters be connected direct to the battery is not adequate. This is even more evident for 12-volt-battery operation. Some Unit Instruments require a grounded plate supply; in others, the plate supply must not be grounded. The plate and heater circuits of the supply must be isolated from each other and from ground and, therefore, from the battery as is done in the Type 1202-A Vibrator Supply. Any method that involves the generation of 115 volts a-c from the battery to feed a Type 1203-A Supply which in turn supplies the plates and heater circuits of the Unit instrument requires unnecessary duplication of equipment and substantially greater conversion inefficiency with consequent extra drain on the storage battery. A single supply is lower in cost and more efficient than two in tandem.

View of the Type 1202-A Unit Vibrator Power Supply.



Design Features

The TYPE 1202-A Vibrator Supply incorporates filtering for "hash" and r-f to an adequate degree. The frequency at the 115-volt outlet and at the heater supply outlet for battery-input operation is 115 cycles and the wave-shape is approximately square. With power-line input, the heater-supply frequency and wave-shape is 50-60 cycles sine-wave. There are two switch positions for battery operation to allow for diverse battery and load conditions.

Selenium rectifiers are used in the plate supply system for greater overall efficiency and less drain on the battery. The 6-foot battery cable has heavy-duty insulation to withstand the severe mechanical treatment that can be expected out of doors and at the battery of a car. It is fitted with extra-large battery clips. The leads are color-coded because the supply must be connected with due regard to the ground connection at the battery.

The complete supply is housed in a standard General Radio Unit Instrument cabinet that is about one fifth of a cubic foot in volume.

—A. G. BOUSQUET

SPECIFICATIONS

Input: Six-volt storage battery or twelve-volt storage battery or 115-volt, 50- to 60-cycle power line. Instrument is shipped with connections for 6-volt operation unless 12-volt supply is specified on the order.

Output: 300 volts at 55 ma d-c; 6.3 volts at 2.7 amperes a-c. With battery input, 115 volts at 115 cycles is also available. The maximum output is 40 watts.

Vibrator: A 6-volt vibrator is supplied with the instrument. It is used for both 6-volt and 12-volt operation.

Output Connectors: A standard multi-point connector is mounted on one side of the cabinet for plugging in instruments of the unit line. A standard a-c outlet on the other side of the cabinet for connection to instruments that normally plug into a power line.

Accessories Supplied: Spare fuses, a mating multipoint connector, a power line cord and a heavy cable for battery connection.

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

Dimensions: (Width) $10\frac{1}{8} \times$ (height) $5\frac{3}{4} \times$ (depth) $6\frac{3}{8}$ inches overall.

Net Weight: $11\frac{1}{2}$ pounds.

Type		*Code Word*	*Unit Price*
1202-A	**Unit Vibrator Power Supply**	AURAL	**$125.00**

RELAY-RACK MOUNTING FOR UNIT INSTRUMENTS

An important feature of Unit Instruments is their small size, which for general use on the laboratory bench, is a considerable advantage. They can be stacked one on another, for instance, to require as little bench space as possible. Where permanent installation for long periods is desired, however, relay rack mounting reduces the need for bench space to a minimum. In order to provide as much flexibility in use as possible, we are therefore making available

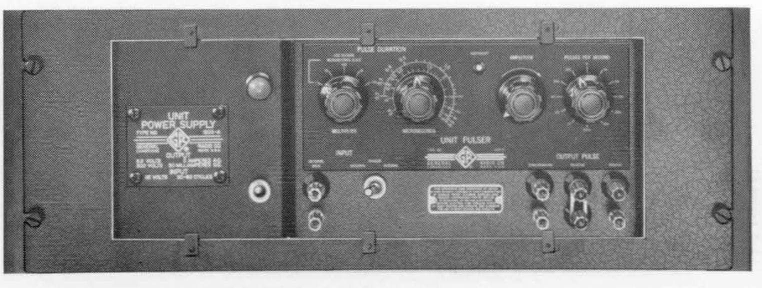


Figure 1. View of the Type 1217-A Unit Pulser and the Type 1203-A Unit Power Supply mounted in a Type 480-P4U3 Relay-Rack Panel.

relay-rack adaptor panels in which Unit Instruments can be mounted.

Each panel has a cut-out opening in which one or more Unit Instruments can be mounted. No alteration of the Unit Instrument is necessary; each instrument fastens into the hole in the panel with simple hardware to produce a secure, neat, flush-mounting. Ample clearance around instruments is provided, so that systems can be set up in any convenient arrangement. Most instruments can be mounted with a power supply in a single rack; one, the TYPE 1218-A Unit Oscillator, because of its size, requires separate panels for oscillator and power supply. All necessary mounting hardware is supplied.

— S. P. BALDWIN

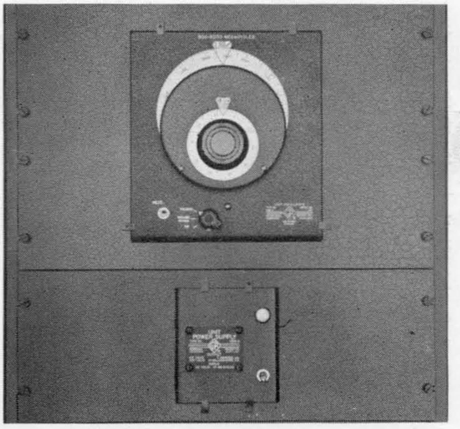


Figure 2. View of the Type 1218-A Unit Oscillator and the Type 1205-A Unit Power Supply mounted in the Type 480-P7U1 and the Type 480-P4U1 Relay-Rack Panels, respectively.

Type	*Type Numbers of Unit Instruments Panel will handle*	*Code Word*	*Price*
480-P4U1	1214 or 1203	UNIPANARCH	**$12.50**
480-P4U2	1204, 1206, 1212, 1213, 1216, or 1217	UNIPANBOLT	**12.50**
480-P4U3	1203 and any of above	UNIPANCART	**12.50**
480-P4UC1	1203 and 1208	UNIPANDOCK	**15.00**
480-P4UC2	1203 and 1209	UNIPANFORT	**15.00**
480-P4UC1	1203 and 1211 or 1203 and 1215	UNIPANGOLF	**16.00**
480-P7U1	1218 only	UNIPANHUMP	**14.00**

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1000 NORTH SEWARD STREET
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CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
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the GENERAL RADIO Experimenter

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Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 10 MARCH, 1955

A STANDARD SIGNAL GENERATOR FOR THE 900- TO 2000-MC RANGE

The new Type 1021-AW Standard-Signal Generator covers frequencies between 900 and 2000 megacycles, which include the important band of 960 to 1220 megacycles used for DME and safety beacon transmissions in aircraft navigation.

The total range covered by the popular Type 1021 line of signal generators is now 40[1]- to 2000 megacycles, covered in three units, as shown in Figure 2.

The tuned circuit of the Type 1218-A Unit Oscillator, which was described last month, forms the basis of the Type 1021-AW 900-2000-Mc Standard Signal Generator shown in Figure 1. The new oscillator unit is shown at the right. The power supply and the cabinet are the same as used already on two lower-frequency signal generators which were announced March 1950.[2] These two older oscillator units are tuned by wide range butterfly circuits.

In external appearance and in operation the three oscillator units shown in Figure 2 are very much the same. They all are triode oscillators with slow-motion drives and large direct-reading frequency dials. Output can be adjusted from 1 μv to 1 volt with the second

[1] The range of the v-h-f model, Type 1021-AV has been extended down to 40 Mc in order to include television i-f frequencies. See page 4.

[2] Eduard Karplus, Ervin E. Gross, "A Standard-Signal Generator for Frequencies Between 50 and 920 Mc," *General Radio Experimenter*, Vol. XXIV, No. 10, 1950.

Figure 1. Panel View of the Type 1021-AW Standard-Signal Generator.

SEE THE LATEST
at the
RADIO ENGINEERING
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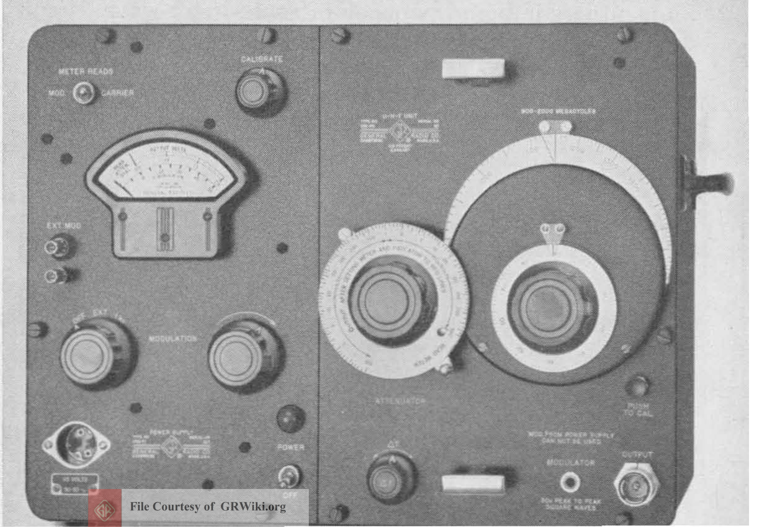
page 10



large dial on the front panel, which controls the coupling in a calibrated mutual-inductance-type attenuator. The output level and the output impedance are established by a diode voltmeter and a termination resistor as shown schematically in the lower part of Figure 3. The output meter, which is located in the power-supply compartment, can be calibrated in terms of an accurately known 60-cycle voltage.

Modulation

Unlike the two lower-frequency generators, which are amplitude modulated by sinusoidal voltages, the new high-frequency unit is designed for amplitude modulation by square waves from an external source. Square-wave modulation, which effectively eliminates incidental frequency modulation, has many advantages in high-frequency measurements, and, in addition, is particularly desirable in this generator, which has a high-Q tuned circuit between the oscillator and the attenuator.

Tuning

The frequency-determining element of the oscillator is a quarter-wave line between plate and grid of a pencil-type triode, and output from the oscillator is obtained by a coupling loop located in the movable shorting plunger of the line. The attenuator must be coupled to an element that carries high current

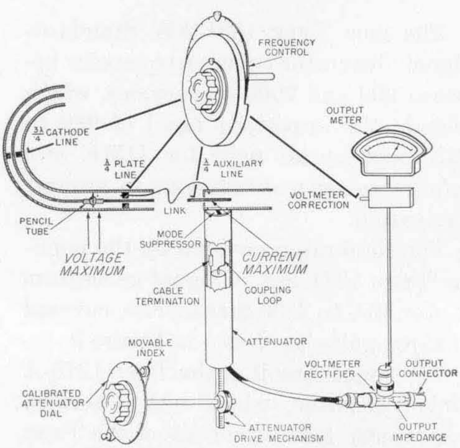
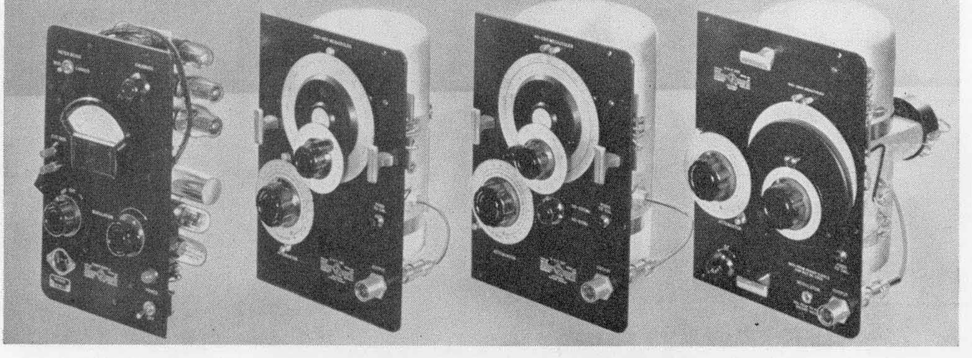


Figure 3. Functional schematic diagram of the new oscillator unit, Type 1021-P4.

at all frequencies and is stationary in space. This is made possible by a quarter-wave circuit with movable center

Figure 2. View of the power supply unit and the three oscillator units that make up the Type 1021 series of signal generators. Oscillator units are interchangeable mechanically.



conductor as shown schematically in the upper part of Figure 3. This auxiliary circuit is electrically coupled to the oscillator by a link line and ganged to it by joining the movable center conductor to the movable short circuit of the oscillator.

Metering

Since the resonant frequency of the diode-type output indicator is only twice the maximum frequency of the signal generator, a frequency correction for the voltmeter error is required. The correction, which varies from about 10% at 1000 Mc to 30% at the high end of the frequency range, is obtained automatically by the potentiometer mounted on the rear end of the main shaft.

Stability

Tuning a 1000-Mc oscillator to produce an audio beat note requires high precision, and maintaining the beat note requires unusual stability. The sliding contacts of the new oscillator perform well under these critical conditions. Compared to tuning systems which depend on close mechanical spacings, the new oscillator is remarkably free from noise modulation caused by microphonics and vibrations. A variable resistor in the grid circuit of the oscillator tube is used for fine frequency adjustment. The heater voltage is rectified and filtered to reduce modulation by power frequency components.

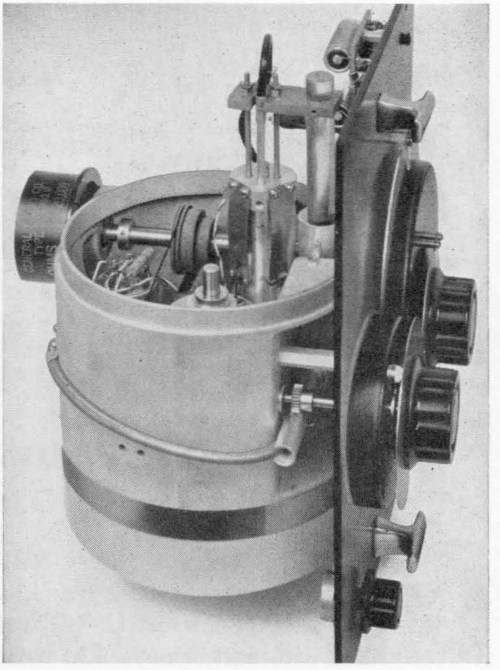


Figure 4. Interior view of the oscillator unit with shield cover removed.

R-F Filtering

The power supply leads are filtered by small inductors imbedded in Carbonyl powder.

SPECIFICATIONS

Frequency Range: 900–2000 Mc

Circuit: Grid separation triode oscillator. Line sections with sliding contact shorts are used to tune plate and cathode.

Frequency Control: A 6″ dial with direct-reading frequency calibration over 200°. Slow-motion drive, 8 turns.

Frequency Calibration Accuracy: ± 1%.

Frequency Drift: Under 0.1% per day.

Output Voltage: Continuously adjustable from 0.5 μv to 1.0 volt open circuit.

Output Impedance: 50 ohms ± 10%.

Output Voltage Accuracy: Over-all accuracy of output voltage is better than ± 20%.

Modulation: Square-wave modulation from 100-10,000 cycles with external modulator. 30 volts peak to peak is required. 10,000-ohm input impedance.

Leakage: Stray fields and residual output voltage cannot be detected with a receiver having 2 μv sensitivity.

Terminals: Type 874 Coaxial Terminals are provided.

Power Supply: 115 or 230 volts, 50 to 60 cycles, power input approximately 50 watts.

Tubes: One Type 5675 u-h-f medium-mu triode (pencil tube) in 1021-P4; one each 6X5GT, 6K6GT, Amperite 6–4; two OC3.

Accessories Supplied: one TYPE 874-R22 3-foot Patch Cord (50 Ohms); one TYPE 874-C58 Coaxial Cable Connector; one TYPE 874-PB58 Panel Connector; one TYPE CAP-35 Power Cord, and one telephone plug.
Other Accessories Available: Not supplied, but available on order are TYPE 874-GF 20-db Attenuator Pad; TYPE 874-GG 10-db Attenuator Pad; TYPE 874-K Coupling Capacitor; and TYPE 1000-P7 Balanced Modulator.
Mounting: The aluminum cabinet has a black wrinkle finish. The left-hand side houses the TYPE 1021-P1 Power Supply; the right-hand side houses the TYPE 1021-P4 U-H-F- Unit. Panels are black crackle-finished aluminum.
Dimensions: (Height) $14\frac{3}{8} \times$ (width) $20\frac{1}{4} \times$ (depth) $10\frac{9}{16}$ inches, over-all.
Net Weight: $37\frac{1}{2}$ pounds.

Type		*Code Word*	*Price*
1021-AW	**Standard-Signal Generator, 900-2000 Mc....**	EAGLE	**$845.00**
1021-P4	**Oscillator Unit only *.......................**	EXALT	**650.00**

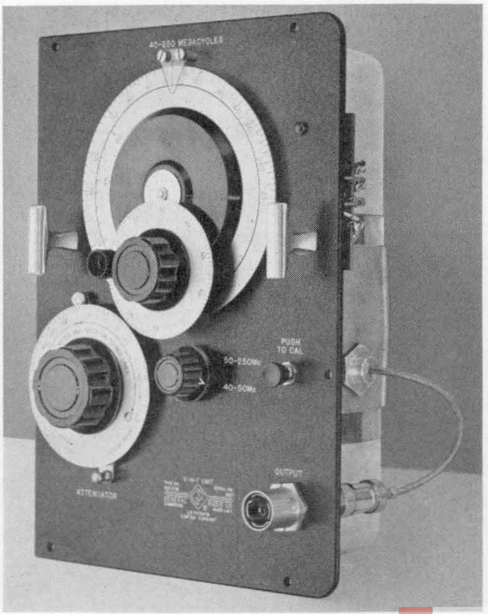
* The oscillator unit, TYPE 1021-P4, is available separately for those who use a single power supply and cabinet with interchangeable oscillators.

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

40- TO 50-MC ADDITION TO RANGE OF TYPE 1021-AV STANDARD-SIGNAL GENERATOR

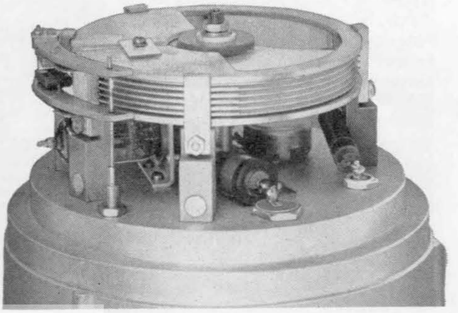
For some time, orders for TYPE 1021-AV Standard-Signal Generators and for TYPE 1021-P3 Oscillator Units have been filled with instruments that cover 40 to 50 megacycles in addition to the previous range of 50 to 250 megacycles. The range switch and the second calibration of the main dial of the new TYPE 1021-P3B Oscillator Unit can be seen in Figure 1. Most of the commonly used i-f frequencies in television receivers lie in the new range.

Figure 1. Panel view of the Type 1021-P3B Oscillator Unit.



To obtain the added range, two 35 $\mu\mu$f capacitors are connected across the high-voltage points of the butterfly-type tuning circuit. The capacitors are mounted on two curved arms which can be seen in Figure 2. The arms are moved up and down by a cable actuated by the new panel switch. With this added capacitance, the minimum frequency of the butterfly circuit is changed from 50 to 40 Mc, and good output can be obtained over a small part of the tuning range. At higher settings, losses in the added capacitance increase rapidly.

Figure 2. Interior view, showing the location of the two padding capacitors, which are switched into circuit for the 40- to 50-megacycle range extension.



While the 40- to 50-Mc range is readily installed in a new instrument, addition of the switch in older oscillators is not practical. This range can be obtained, of course, by shunting a 70-$\mu\mu$f low-loss capacitor across the gap of the butterfly circuit. To preserve the original calibration, the mounting screws of the butterfly circuit should not be disturbed, and clamps should be used to add the shunting capacitors.

SPECIFICATIONS

Same as for Type 1021-AV except:
Carrier Frequency Range: 40–250 Mc in two bands.

Type		*Code Word*	*Price*
1021-AV	**Standard Signal Generator, 40 to 250 Mc....**	EVENT	**$595.00**
1021-P3B	**Oscillator Unit only......................**	EVOKE	**$400.00**

U. S. Patent Nos. 2,125,816, 2,367,681 and 2,548,457.

THE TYPE 1803-B VACUUM-TUBE VOLTMETER

General Radio's moderately priced vacuum-tube voltmeter, the TYPE 1803-A[1], has proved to be a remarkably reliable and trouble-free instrument. Our service department records do not show a single instance of failure of one of these voltmeters during the one-year guarantee period. A new model now available, the TYPE 1803-B, combines the basic features of the older instrument with several new operating conveniences, which will still further widen its usefulness in the laboratory.

Years of experience with the TYPE 1800-A Voltmeter[2] have proved the desirability of having both a-c and d-c voltage ranges on a voltmeter, and so d-c ranges are an important new feature on the TYPE 1803-B. Another new feature is the inclusion of a 10:1 multiplier for audio and ultrasonic frequency a-c voltages, which is permanently attached to the voltmeter cabinet. The multiplier also provides convenient binding posts that can be used for a-c voltage measurements when the probe is suitably connected to the multiplier. In addition, storage space has been provided inside the cabinet for the probe cable.

[1] C. A. Woodward, Jr., "The TYPE 1803-A Vacuum-Tube Voltmeter", *General Radio Experimenter*, Vol. XXIV, No. 11, April, 1951, pp. 1–5.
[2] C. A. Woodward, Jr., "A New Vacuum-Tube Voltmeter", *General Radio Experimenter*, Vol. XXII, No. 4, September, 1946, pp. 1–8.

A-C Voltage Measurement

The ranges provided are 1.5 5, 15, 50, and 150 volts for full-scale deflection of the indicating meter.

Experience has also shown that there is a demand for a multiplier to make it possible to measure voltages in excess of 150 volts, particularly over the audio-frequency range. This demand is

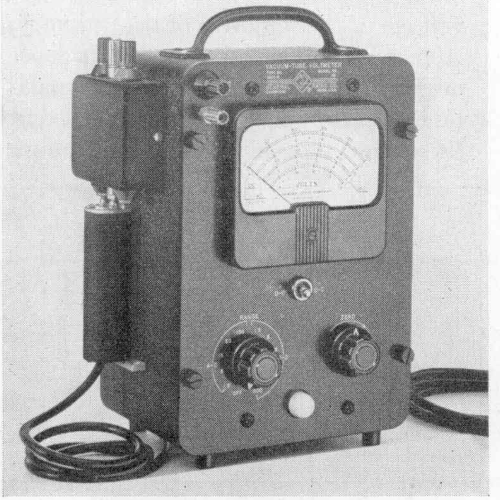


Figure 1. View of the Type 1803-B Vacuum-Tube Voltmeter.

met, not by providing a multiplier as a separate accessory, which may be misplaced or unavailable when needed, but by permanently attaching a 10:1 multiplier to the side of the voltmeter cabinet. This multiplier is a resistive voltage divider that has been compensated to have a response flat within ±2% up to 40 kilocycles.

The multiplier also serves as a storage device for the probe, which can be plugged into either of two positions. When the probe is plugged into the forward jacks on the bottom of the multiplier, the voltmeter reads one tenth of any voltage applied to the X10 binding posts on the top of the multiplier. When the probe is plugged into the rear jacks, the voltmeter reads directly the voltage applied to the DIRECT binding posts on the top of the multiplier.

The frequency response is shown in Figure 2. The resonant frequency of the probe input circuit is about 410 megacycles.

D-C Voltage Measurement

Six d-c voltage ranges have been provided, 1.5, 5, 15, 50, 150, and 500 volts full scale.

It is felt that a 500-volt range should make it possible to measure the output voltage of the majority of the ordinary, laboratory, d-c power supplies. In most modern power supplies, high-capacitance electrolytic capacitors are used in the output filter circuit. The maximum d-c working voltage of these capacitors is less than 500 volts. Therefore, if the power-supply output voltage is greater than 500 volts, the capacitors must be connected in series. The voltage across each capacitor can be measured and the readings added to obtain the total output voltage.

The input resistance to the d-c voltmeter is 111 megohms for all ranges. However, by the removal of a soldered connection inside the instrument, connection is made directly to the grid for the 1.5, 5, 15, 50-volt ranges. The effective input resistance then depends upon the applied voltage and is between 1000 and 30,000 megohms or higher. The input resistance for 150 and 500-volt ranges remains 111 megohms.

A polarity switch is provided so that voltage of either + or − polarity may be applied to the high input terminal.

Meter Scales

The meter face, shown in Figure 3, has four scales. The two outer scales are linear and are used for measurement of all d-c voltages and all a-c voltages above 5 volts. The two inner scales are non-linear and are used only for measurement of a-c voltages of less than 5 volts.

General Construction

The basic construction features of the TYPE 1803-A have been retained in the TYPE 1803-B Vacuum-Tube Voltmeter. The instrument is of light, yet rugged

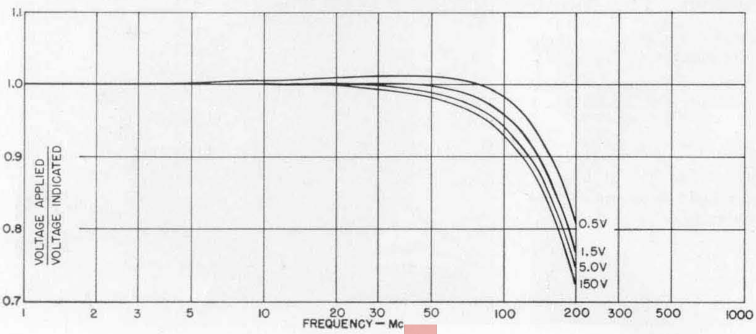


Figure 2. High-frequency correction for the Type 1803-B Vacuum-Tube Voltmeter.

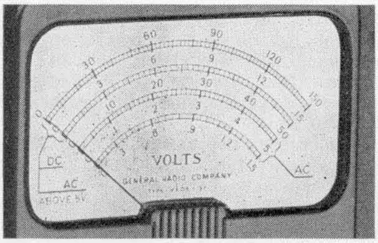


Figure 3. Meter scales

construction. The cabinet is made of heavy gauge aluminum with all joints welded. Rubber feet are provided to support the instrument with the panel either vertical or horizontal, and a simple carrying handle is located on the top.

The a-c voltage-multiplier housing is attached to the left-hand side of the cabinet where it provides a convenient means of storage for the probe. The binding posts on the top of the multiplier housing provide for direct application of applied a-c voltage to the probe and for a 10:1 reduction in the voltage before it is applied to the probe terminals.

The input terminals for d-c voltage measurement are located at the top left-hand corner of the panel.

The power cord is permanently attached to the voltmeter chassis and is led out through a notch in the cabinet edge. When the probe is attached to the multiplier, the probe cord can be stored inside the cabinet. The cord is led out through a slot in the bottom of the cabinet, and, for storage purposes, the cord is pushed through the slot into the cabinet where it folds into the space provided for it. The probe cable is completely shielded.

Circuit

The circuit of the Type 1803-A has proved to be so free of defects that it has been adopted without change for the a-c voltage measuring circuit for the Type 1803-B.

An elementary schematic diagram of the circuit is shown in Figure 5.

For d-c measurements the voltage is applied to the d-c input terminals which are connected to a 111-megohm divider, consisting of two highly stable, deposited-carbon-film resistors. For the 1.5-volt to 50-volt ranges, the voltage is then applied through a ripple filter to the grid of the active amplifier triode. The grid of the inactive amplifier triode is connected to ground through a resistor. For the 150-volt and 500-volt d-c ranges, the voltage applied to the active grid is reduced 10:1 by the divider.

The balanced amplifier circuit insures good zero and calibration stability with changes in line voltage. A change in line voltage of 10 volts causes a zero shift of only .01 volt or less on the 1.5-volt ranges.

— C. A. Woodward, Jr.

SPECIFICATIONS

Voltage Ranges: 0.1 to 150 volts, a-c, in five ranges (1.5, 5, 15, 50, and 150 volts, full scale). A multiplier is attached for increasing the range to 1500 volts at audio and ultrasonic frequencies. 0.02 to 500 volts, d-c, in six ranges (1.5, 5, 15, 50, 150, and 500 volts, full scale).

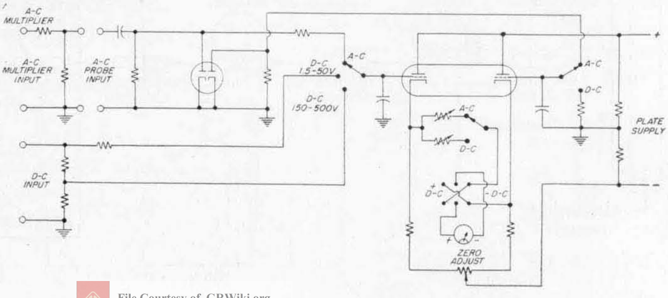


Figure 4. Elementary schematic circuit diagram of the voltmeter.

Accuracy: AC, ±3% of full scale, subject to frequency correction above 50 megacycles. Correction curve supplied in instruction book (see Figure 2). Use of the multiplier imposes an additional error of ±1%.

DC, ±3% of full scale for the 1.5, 5, 15, 50-volt ranges; ±4% of full scale for the 150 and 500-volt ranges.

Waveform Error: The instrument is calibrated to read the r-m-s value of a sine wave on all a-c ranges. On the higher ranges, the instrument is peak responding, and the reading corresponds to either the r-m-s value 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 lower ranges, the response departs from peak and approaches r-m-s response. When the multiplier is used, the voltmeter is not peak responding. The multiplier is adjusted so that the voltmeter reads one-tenth of the r-m-s value of a sine-wave voltage applied to the multiplier.

Frequency Error: The plot of Figure 2 gives the frequency correction for several different voltage levels. At low voltages, the transittime and resonance effects tend to cancel, while at higher voltages, the error is almost entirely due to resonance. The resonant frequency is about 410 Mc.

At low frequencies, the response drops off because of the increasing reactance of the series capacitance of the input circuit. At 40 cycles per second, the drop is 2% or less.

The response of the multiplier is flat within ±2% up to 40 kc.

Input Impedance: The equivalent a-c input circuit is a resistance in parallel with a capacitance. At low frequencies, the equivalent parallel resistance is 7.7 megohms. At high frequencies, this resistance is reduced by losses in the shunt capacitance. The equivalent parallel capacitance at radio frequencies is 10 $\mu\mu$f. At audio frequencies, the capacitance increases to 11.5 $\mu\mu$f. The multiplier input impedance is a resistance of approximately 9 megohms in parallel with 11 $\mu\mu$f.

The d-c input resistance is 111 megohms. By removal of an internal connection, open-grid input can be obtained for the 1.5, 5, 15, and 50-volt ranges.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. The power input is about 11 watts.

Tubes: 1-6AL5 1-6SU7-GTY 1-6X4. All are supplied.

Dimensions of Cabinet: (Width) 8¼ × (depth) 6½ × (height) 11¾ inches over-all.

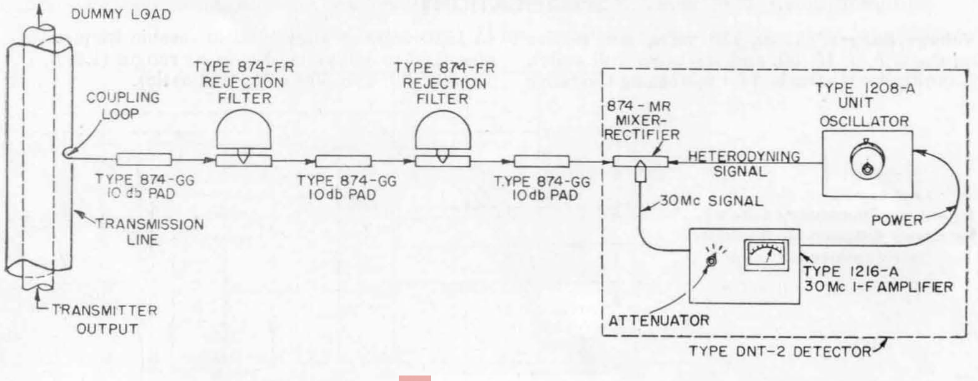
Net Weight: 9½ pounds.

Type		*Code Word*	*Price*
1803	Vacuum-Tube Voltmeter..................	ABOOM	$180.00

HARMONIC MEASUREMENTS ON VHF-TV TRANSMITTERS

The Federal Communications Commission has recently inserted in its rules a maximum permissible harmonic content of the visual and aural transmitter outputs of television transmitters. For VHF stations, all harmonics up to the tenth, but below 1000 Mc, in the signal at the transmitter output terminals, must be at least 60 db below the level of the fundamental. As a result, many television broadcasters will be faced with the problem of measuring

Figure 1. Block diagram of the system for measuring transmitter harmonics. The two rejection filters are isolated by the 10-db pad, which also makes the impedance level 50 ohms.



the harmonic content of their transmitters.

In general, this problem can be solved by terminating the output transmission line in a dummy load and coupling a small amount of the r-f power from the line to a selective calibrated detector by means of a coupling loop or probe. The receiver is tuned first to the fundamental and then to the various harmonic frequencies, and the relative amplitudes of the components determined.

If a directional coupler is used to couple to the transmission line, it is not necessary to replace the antenna with a dummy load.

One relatively simple method of making the measurement is to use a General Radio Type DNT-2 Detector[1] in combination with two Type 874-FR Rejection Filters for the fundamental frequency, three 874-GG 10-db Pads, and a small single-turn coupling loop fitted with a coaxial connector for sampling the field in the main transmission line. A block diagram of this arrangement is shown in Figure 1. The calibrated attenuator and meter in the i-f amplifier are used to determine relative signal levels. An initial measurement is made of the fundamental level with the rejection filters out of the circuit. The filters are then inserted and tuned to produce a minimum detector indication. The detector is next tuned to the various harmonic frequencies in turn and the relative signal levels are measured with the calibrated detector. At frequencies between 54 and 530 Mc, the detector can be used with the mixer operating on the fundamental of the local-oscillator frequency. At frequencies above 530 Mc, the second harmonic of the local oscillator can be used and the difference in conversion efficiency must be determined. This is easily done by measuring the same harmonic by both fundamental and second harmonic operation in the overlapping frequency region.

Since the rejection filters are designed to have a flat response characteristic in a 50-ohm system up to the tenth harmonic of the rejection frequency, or 1000 Mc, and, since the sensitivity of the detector is reasonably constant with frequency when the source impedance is 50 ohms[1], the relative levels of the harmonics with respect to the fundamental are equal to the differences in the signal levels measured by the detector, corrected for the frequency response of the coupling device. Therefore, if the coupling-loop frequency response is known, the measurement can be made without requiring a signal generator for calibration of the frequency response of the entire system.

If a small coupling loop is used, the voltage induced in it with a constant current flowing in the main transmission line will be directly proportional to the frequency. If the effective source impedance of the loop is small compared to 50 ohms at the highest frequency measured, or is constant with frequency, the voltage developed across

[1] Soderman, R. A., "A Sensitive, High-Frequency, General-Purpose Detector", *General Radio Experimenter*, Vol. XXVIII, No. 12, May, 1954.

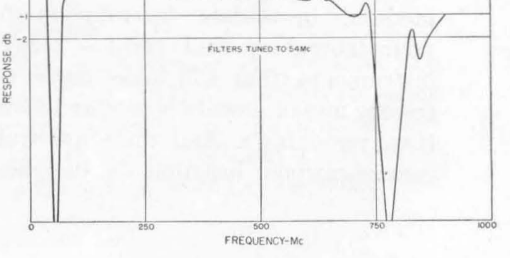


Figure 2. Insertion loss of a Type 874-FR Rejection Filter.

the 50-ohm input to the detector will also be directly proportional to frequency. Therefore, the true level of the second harmonic will be 6 db lower than indicated by the detector; the third harmonic will be 9 db lower; the fourth, 12 db; the fifth, 14 db; etc.

A loop-type of directional coupler can also be used as a coupling device if its coupling element is short compared to a wavelength at the highest harmonic frequency. Most couplers also have a response which increases linearly with frequency.

The Type 874-FR Rejection Filters are tunable series-resonant circuits each of which attenuates the fundamental about 35 db when properly adjusted, and which have a relatively flat pass-band response up to the tenth harmonic of the fundamental. A typical response curve is shown in Figure 2.

If the range of levels to be measured is beyond the linear range of the detector (80 db), additional pads can be inserted when the fundamental level is measured. The 10-db pad shown between the filter and the mixer in the detector is used to keep at a minimum the variations with frequency of the local-oscillator voltage applied to the mixer crystal.

The Type DNT-2 Detector consists of an untuned mixer, a local oscillator and a 30-Mc i-f amplifier with a calibrated output meter and a calibrated attenuator. Since only the fundamental is rejected in the above procedure, all harmonics are impressed across the mixer, and since the mixer will produce a 30-Mc output whenever the frequency difference between a harmonic of the signal and a harmonic of the local oscillator is 30 Mc, numerous responses can be obtained in the frequency range covered by the local oscillator. The desired responses can be easily identified by tuning the local oscillator to a frequency 30 Mc above or below the frequency of the desired harmonic. A low-pass filter inserted between the second rejection filter and the second pad (see Figure 1) is recommended to eliminate spurious responses and to simplify the identification of harmonics.

The method outlined makes possible simple measurements, with an accuracy of about 3 db, of the harmonic content of VHF-TV transmitters with compact equipment, most of which is suited to a variety of other common measurements. Actual field measurements indicate that the method is practical and convenient.

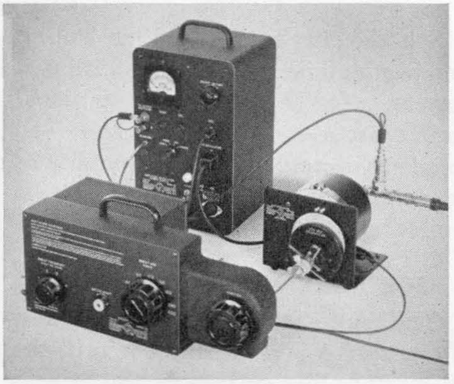
A detailed description of the equipment, with prices, is available on request.

— R. A. Soderman

SEE THE LATEST*

At the 1955 Radio Engineering Show, General Radio presents a display of modern, up-to-date instruments for your laboratory and plant — today's instruments, that will make basic, necessary measurements better, and faster than yesterday's. And these are truly general-purpose instruments, designed, not for a single job, but for many — adaptable, flexible, and fitted to a variety of applications. These instruments have G-R's built-in quality: the accuracy and stability and durability that results from good basic design

* And, for old timers, an anniversary showing of some of the earliest.



The new Type 1750-A Sweep Drive and Type 1263-A Amplitude-Regulating Power Supply, driving a Type 1209-A Unit Oscillator.

carefully selected components, and rugged construction based on 40 years of manufacturing experience.

Be sure to drop in at the General Radio booth — 251 to 255 Instruments Avenue — to talk over your measurement problems with our engineers and to see the new products listed below.

SWEEP DRIVES

Automatic presentation of data is the modern time saver in the multitudinous series of measurements encountered in circuit development and component design. The General Radio solution is not a battery of individual sweep generators, but simple, precise motor drives that can be used with the oscillators already in your laboratory, drives that can be quickly and conveniently adjusted to sweep wide ranges or narrow ones.

The synchronous dial drives described previously[1] do this job for audio frequencies, making possible the display of amplitude-frequency plots on a recorder or oscilloscope, by driving the beat-frequency oscillator dial. The new Type 1750-A Sweep Drive and the Type 1263-A Amplitude-Regulating Power Supply bring this same convenience and adaptability to the v-h-f and u-h-f ranges.

[1] Littlejohn, H. C., "Motor Drives for Precision Dials and Beat-Frequency Oscillators", *General Radio Experimenter*, Vol. XXIX, No. 6, November, 1954.

SLOTTED-LINE DRIVE

The new Type 874-LBA Slotted Line will be shown with a motor-drive attachment that sweeps the probe over any desired portion of its total travel, so that standing-wave ratio can be determined directly from an oscilloscope screen.

BRIDGES

The determination of impedance is a basic measurement in the laboratory and in the plant, and General Radio brings you two additions to its already extensive line of impedance bridges.

Z-Y Bridge

The new Type 1603-A Z-Y Bridge measures, either as an impedance or as an admittance, literally any impedance, irrespective of phase angle, between zero and infinity. Connect a "black box" to the terminals of the bridge and balance the bridge to a null; the dial settings will then tell you either its impedance or its admittance. The uses of the bridge are legion. Lines, transformers, resistors, capacitors, inductors, resonant circuits, filters, transducers — all of these can be measured, plus the conductivity of solutions. Negative parameters can be measured as well as positive; motional impedance diagrams of transducers can be determined.

R-F Bridge

For radio frequencies, we have the new Type 1606-A Radio-Frequency Bridge, a more compact, modern successor to the widely used Type 916-A. Frequency range, 400 kc to 60 Mc.

Limit Testing

For the measurement, selection and matching of components to close tolerances, a precise bridge is needed. The Type 1604-B Comparison Bridge is designed for just this purpose and has an accuracy of 0.1%. Try it and see for yourself.

POTENTIOMETERS

You read about the new 970 series of potentiometers in the January issue of the *Experimenter*. See them here and inspect them. You'll like their simple, well-thought-out design, modern in every detail. They're used in new General Radio instruments. They have to be good.

STANDARD-SIGNAL GENERATORS

The new Type 1021-AW Standard-Signal Generator, described in this issue, will be on display, as will the new Type 1021-P3B Oscillator Unit for the Type 1021-AV Standard-Signal Generator. You can see its construction and better appreciate its many features.

U-H-F DETECTOR

The Type 1216-A Unit I-F Amplifier is an indispensable item for the laboratory where v-h-f and u-h-f measurements are made. A null detector and a voltmeter for relative signal levels, it can be used to measure attenuation, crosstalk, and signal strength.

PULSES

See the Type 1217-A Unit Pulser, compact and inexpensive, but with performance far beyond what you would expect from its size and price — an excellent example of the high quality at moderate prices that General Radio builds into its Unit Instrument line.

FOR CONSTANT LINE VOLTAGE

The Automatic-Voltage Regulator, Type 1570-A is an excellent remedy for fluctuating line voltage in the laboratory. You'll always see it in GR displays, because it's just as useful in keeping a display running properly under the constantly changing load conditions encountered in shows. With its 6 KVA capacity, it really fills the bill.

40 YEARS OF ELECTRONICS— OLD TIMERS' DISPLAY

Founded in 1915, the General Radio Company celebrates this year its 40th Anniversary. Throughout the past 40 years General Radio has been supplying the basic standards and measuring instruments to the electronics industry.

We have arranged a display of General Radio products built in the first few years of the Company's existence, which will bring back fond memories to those who are old timers in the industry.

CORRECTION

In the February issue of the *Experimenter*, page 8, the relay-rack panel for either Type 1203 and Type 1211 Unit Instruments or for Type 1203 and Type 1215 was incorrectly listed. The correct type number is 480-P5UC1.

GENERAL RADIO COMPANY

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the GENERAL RADIO Experimenter

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME XXIX No. 11 APRIL, 1955

A NEW SYSTEM FOR AUTOMATIC DATA DISPLAY

Today's shortage of new engineers points up the increasing importance of more efficient use of our available engineering man-hours. Just as improvements in tooling have extended the productivity of the factory worker, so will improvement in the tools of the research worker enable him to do more work in less time. Automation in production has its counterpart in new techniques for automatic data presentation designed to save time for the engineer and to augment his productivity.

One of the simplest and most useful improvements in measuring techniques is the replacement of point-by-point measurements by data displayed as continuous functions of the independent variable. Very commonly, the independent variable is frequency, and sweep oscillators to serve as generators for these measurements are coming into widespread use. These sweep techniques are helping the development engineer to simplify measurements, are suggesting new solutions to complicated problems, and are speeding up adjustment and testing of components and circuits in production. Sweep oscillators for these uses change frequency as a function of time and provide a voltage that is a known function of that frequency

Figure 1. View of the new General Radio Sweep Drive and Amplitude-Regulating Power Supply set up to sweep a Type 1209-B Unit Oscillator.

See also "Automatic Sweep Drive for the Slotted Line," page 10.

Also

IN THIS ISSUE

to serve as a horizontal deflection voltage for a graphic recorder or cathode-ray oscilloscope.

Electronic or mechanical sweep oscillators covering various frequency ranges are available on the market. To avoid flicker when used with CRO display, they employ relatively fast repetition rates, usually related to the power-line frequency. The frequency of the electronic type is varied by a voltage-sensitive element in the frequency-determining circuit. In mechanical types, the frequency is similarly varied by a displacement-sensitive element. Large fractional variation in frequency is difficult to obtain with either of these systems. Although the electronic types are quiet, and insensitive to shock and vibration, they are limited in sweep range and are not suitable for high frequencies. Mechanical types, on the other hand, can be made to cover all frequencies, although the types using small vibrator-driven circuit elements usually suffer from similarly restricted sweep ranges. At audio frequencies, where very wide ranges must be considered, slow mechanical dial drives are sometimes used in connection with synchronized recorders. A speed of 3 decades in 2½ minutes is common. General Radio's previously announced synchronous dial drives[1] are suitable for this service and provide speeds as fast as 6⅔ seconds per octave to permit oscilloscope displays of data at audio frequencies.

At high frequencies, where the required sweep range is usually smaller, speeds should be high enough to give a continuous trace on an oscilloscope with a long-persistence screen, but not so high that extraneous transient effects occur when the performance of a high-Q circuit is being observed.

Intermediate between the speeds of 30 or 60 cycles per second, which do not produce flicker on a 'scope, and the lower speeds of the audio recorder, are the speeds around 1 cycle per second, which are fast enough to produce a satisfactory trace on a cathode-ray tube

[1] Littlejohn, H. C., "Motor Drives for Precision Dials and Beat-Frequency Oscillators", *General Radio EXPERIMENTER*, Vol. XXIX, No. 6, November 1954, pp. 1–3.

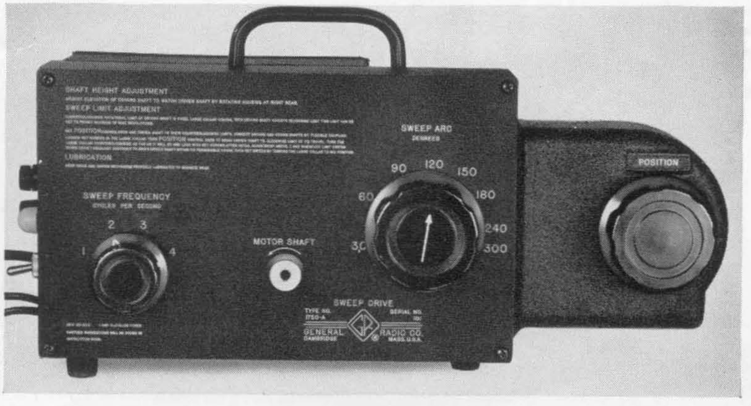


Figure 2. Front panel view of the Type 1750-A Sweep Drive, showing the SWEEP FREQUENCY, SWEEP ARC, and POSITION controls.

with a long-persistence screen and to permit observation of pattern changes without excessive delay. Most conventional oscillator dials can be turned back and forth at these speeds without damage to the oscillator. The new General Radio Sweep Drive shown in Figure 1 is designed to perform this function.

The new drive is unique because it adapts manually operated equipment to automatic sweep applications. It can be attached to the tuning knob of any oscillator to operate as an artificial hand, turning the oscillator dial back and forth over the desired frequency range and supplying a horizontal sweeping voltage proportional to shaft angle.

A very important requirement of any sweep generator is that the output voltage be constant with frequency, since any variation shows up as a part of the displayed curve. The problem of maintaining an adequate degree of flatness of output increases with the range to be covered, and, for wide sweep ranges, output regulation is usually necessary. General Radio Unit Oscillators cover very wide frequency ranges and are therefore particularly suitable for use with the Sweep Drive. Since they use separate power supplies, they are easily adaptable to output regulation. The new Type 1263-A Amplitude-Regulating Power Supply is designed primarily for use with these oscillators to maintain constant output.

TYPE 1750-A SWEEP DRIVE

The new sweep drive shown in Figure 2 can be attached to shafts, knobs or dials to drive them in reciprocating motion at speeds between 0.5 and 5 cycles per second. Two independent controls are provided to adjust the sweep arc and the center position of the sweep while the drive shaft is in motion. The sweep arc is adjustable between 30 and 300 degrees, and the position control has a range of nine full turns of the drive shaft between adjustable stops.

The height of the drive shaft is adjustable from 2½ to 4⅞ inches above the bench. The drive shaft can be coupled directly to shafts whose diameters are ¼ inch and ⅜ inch, and a universal clutch is provided for attachment to knobs and dials up to 4 inches in diameter.

Mechanical System

The diagram of Figure 3 shows the operation of the drive. The Sweep Drive is powered by a 5000-rpm universal motor, operated with fixed field supply and adjustable armature supply, (SWEEP FREQUENCY control) as in the General Radio Type 1701-AU Variac® Speed Control. A crank is driven through two belts to provide

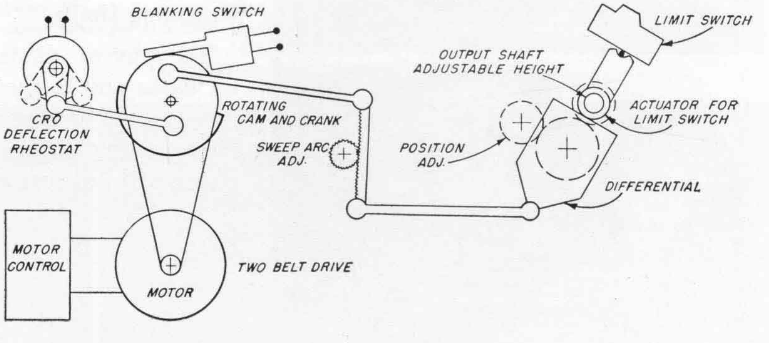


Figure 3. Elementary mechanical diagram of the Sweep Drive.

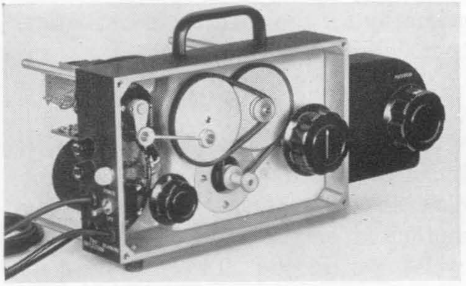


Figure 4. View from front with panel removed. The potentiometer that supplies the horizontal sweep voltage can be seen in the upper left-hand corner.

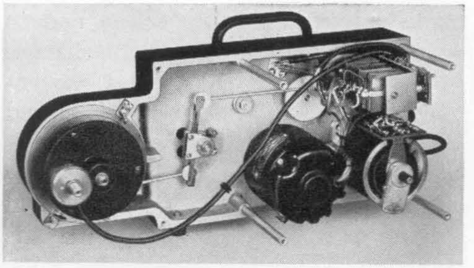
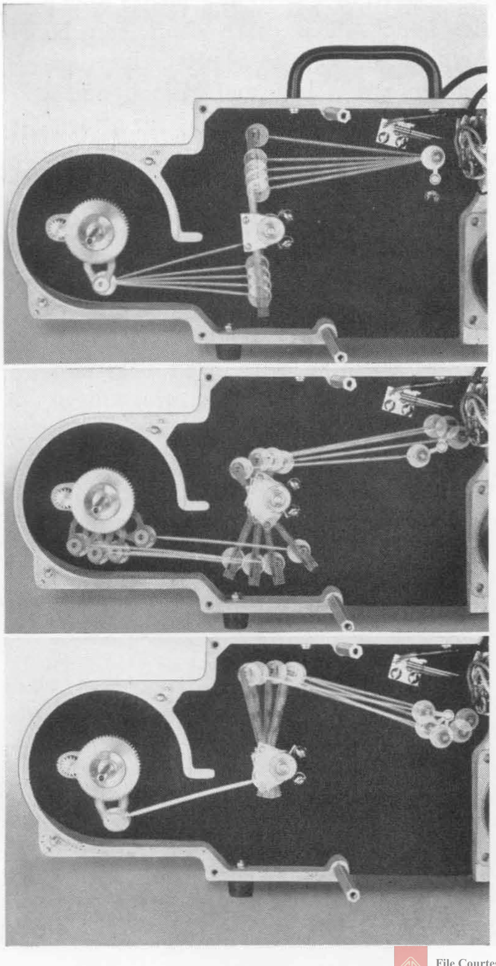


Figure 5. Rear view with cover removed, showing motor, motor control circuits, driving crank, and adjustable rack.

Figure 6. Multiple exposure views showing the action of the sliding rack. The upper view shows the driving mechanism at rest in the center of its stroke, and the range over which the rack can be adjusted by means of the position control. The center view shows the drive in motion at maximum sweep arc, and the lower view similarly shows the operation at minimum arc.



the necessary speed reduction. Operated from the crank through a connecting rod is a rack, adjustable in position by the SWEEP ARC control. At the opposite end of the adjustable rack is a second connecting rod, which operates through a differential (the POSITION control) to turn the output shaft.

Figure 4 shows the motor shaft, pulleys, and belts through which the speed reduction is obtained. In Figure 5, a view from the rear of the assembly, the motor, main driving crank, and sliding rack are visible. Figure 6, a series of multiple exposure photographs, shows the sliding rack in different positions and illustrates how the sweep arc is changed by adjustment of the point at which the rack pivots. At the left is the differential. In Figure 7, are shown the output coupling shaft, with its two flexible couplings, and details of the universal clutch.

Operating Limits

To prevent damage to the driven oscillator and to the sweep drive itself, speeds must be kept at safe values. The forces acting on the driven device increase with the moment of inertia of the moving parts and with their angular acceleration. The accelerating forces increase 1000:1 when the controls are changed from 30° and 0.5 cycles per second to 300° and 5 cycles per second. In any specific application, the sweep arc is determined by the requirements of the measurement to be made. The highest speeds should be used only with small-angle sweeps, with the speed being decreased correspondingly as the arc increases.

In reciprocating motion, forces vary harmonically and reverse gradually two times each cycle. In practice, small clearances between the shafts and bearings prevent a gradual reversal. This small play, which can never be eliminated, is the cause of backlash in manual operation and of pounding in the motor drive. The rated maximum torque of the drive shaft is 24 ounce-inches. No definite limit can be specified for the accelerating forces. Their effect can be estimated by the amount of pounding they cause. As a protection of the driven device, excessive force (about five times rated torque) will cause slipping in the POSITION control.

For additional protection, a built-in limit switch disconnects and brakes the motor when the preset limits of shaft travel are accidentally exceeded. The two limits can be set apart by nine full turns of the output shaft, which is useful

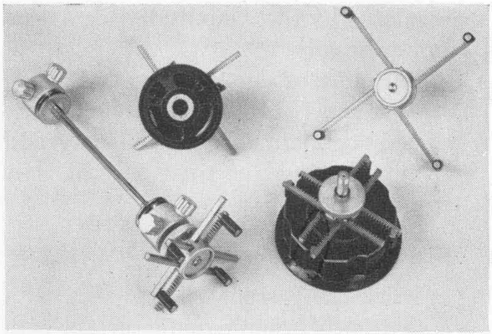


Figure 7. View of the coupling attachments furnished with the Sweep Drive. At left is the coupling shaft, to which has been attached the universal clutch. The other views show the clutch and the clutch attached to a knob.

when the drive is coupled to the slow-motion drive shaft of an oscillator.

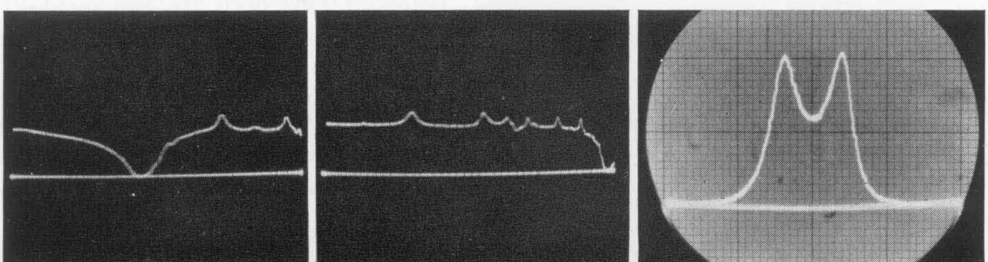
Use With Unit Oscillators

Current models of General Radio Unit Oscillators can all be used with the Sweep Drive. These oscillators are:

Type No.	*Frequency Range*
1211-A	0.5 to 5 Mc and 5 Mc to 50 Mc
1215-B	50–250 Mc
1209-B	250–920 Mc
1208-B	65–500 Mc
1218-A	900–2000 Mc

The last two models, TYPES 1208-B and 1218-A have sliding contacts in the tuned circuit, and, while not recommended for high-speed sweeping over long periods, they are satisfactory for use at low speeds with the Sweep Drive. The TYPE 1208-B, however, cannot be

Figure 8. Oscillograms of typical amplitude-frequency characteristics as displayed by the Sweep Drive. Left, Characteristic of a Type 874-FR Rejection Filter tuned to 76 Mc; sweep range is 48 to 260 Mc. Center, characteristic of same filter for the 250- to 900Mc range. Right, characteristic of a television front-end tuner set to channel 7; sweep range is 160 to 200 Mc. Vertical scale is square law for all of these oscillograms.



regulated by the Amplitude-Regulating Power Supply.

The older models, the TYPES 1208-A, 1209-A and 1215-A, were originally designed for manual operation only and therefore should be used only at slow speeds.

Use With Other Oscillators

When the Sweep Drive is used with oscillators of other manufacture, or with other General Radio oscillators, the same precautions should be taken. Sweep arcs should be held within safe limits, and speeds should be adjusted to conform to the mechanical limitations of the oscillator.

Calibration

The horizontal deflection voltage for the oscilloscope is obtained from a potentiometer, driven by a fixed crank, which can be seen in Figure 4. This voltage is proportional to the angle through which the oscillator shaft is turned. Owing to the geometry of the various linkages involved, the relation is closely linear in one direction but does not repeat on the return trace. A blanking contact is provided to suppress the return trace and to replace it by a zero reference axis.

The frequency distribution on the oscilloscope screen repeats the frequency distribution of the swept oscillator, but the actual frequencies corresponding to ordinate lines on the screen depend upon the settings of the arc and position controls. Accuracies comparable to the calibration accuracy of the swept oscillator are readily obtained by transferring the oscillator calibration to the screen. To facilitate this transfer, the end of the motor shaft has been extended through the panel of the sweep drive. With power on, and with the speed control at zero, an oscillator coupled to the output shaft can be set manually to a desired frequency by rotation of the motor shaft. The spot on the oscilloscope indicates the ordinate at which this frequency appears.

Applications

The flexibility of this new sweep drive, the fact that it can be used with manual-drive oscillators, and the consequent wide sweep ranges that can be obtained open up many new applications for sweep techniques. While the obvious uses are those involving the sweeping of an oscillator to display amplitude-frequency characteristics, the drive is not limited to these. It can be used in the display of any electrical quantity as a function of shaft angle, or of any other quantity, mechanical, for instance, that can be converted to an electrical voltage.

— EDUARD KARPLUS

TYPE 1263-A AMPLITUDE-REGULATING POWER SUPPLY

In sweep techniques, it is essential that the amplitude of the applied signal remain constant as a function of frequency. Since General Radio Unit Oscillators, like most high-frequency oscillators do not meet this condition when operated from a power supply with fixed-plate voltage, the Amplitude-Regulating Power Supply has been designed to maintain constant oscillator output.

The Type 1263-A Amplitude-Regulating Power Supply compares the d-c potential developed by the oscillator output rectifier with a d-c reference potential and applies a correction to the oscillator plate supply to minimize the difference. A maximum of 300 volts at 30 milliamperes is available for the oscillator plate. The d-c reference potential is adjustable from zero to 2.5 volts, which corresponds to an r-f output of zero to 2 volts with the Type 874-VR Voltmeter Rectifier. With an oscillator capable of producing at least 2 volts output with a 300-volt, 30-milliampere plate supply at all frequencies within its range, this power supply will maintain any preset level within 2 per cent over the entire frequency range.

Speed of Response

In sweep applications, rapid variations of the oscillator output are likely to occur, particularly in the u-h-f range. The Type 1263 Amplitude-Regulating Power Supply will change the plate current supplied at a rate of 3 milliamperes per millisecond or faster. For an oscillator requiring 30 milliamperes at 300 volts, this corresponds to a change of 30 volts per millisecond. Such an oscillator must not be swept at a speed that requires a rate of plate-supply variation exceeding this value. General Radio Unit Oscillators can be swept through their entire ranges in a sinusoidal manner at rates up to one cycle per second. With the Type 1750-A Sweep Drive, the maximum speed recommended for mechanical reasons is, incidentally, also one cycle per second for full-range sweeping. Fractional parts of the oscillator ranges can, of course, be swept at correspondingly more rapid rates.

Blanking

Phone-tip jacks on the panel permit connection to be made to an external contactor to cut off the oscillator plate supply. This connection is useful for blanking the oscillator output in sweep applications to eliminate the return sweep and to provide a reference base line on the cathode-ray oscilloscope. The Type 1750-A Sweep Drive is provided with a blanking contactor.

Calibration

An internal d-c vacuum-tube voltmeter, calibrated in terms of r-f output voltage, indicates the voltage at the output rectifier. The meter scale is quasi-logarithmic and covers an output voltage range of 0.1 to 2. An internal calibration means permits the meter to be standardized with a particular output rectifier. The calibration and zero adjustments are convenient, thumb-set controls on the panel of the instrument.

Circuit

The elementary schematic diagram (Figure 10) illustrates the principle of operation of the Type 1263-A Amplitude-Regulating Power Supply. The output rectifier develops a negative d-c potential proportional to the r-f amplitude at the oscillator output. This potential is applied to the voltmeter amplifier and to one grid of the first dif-

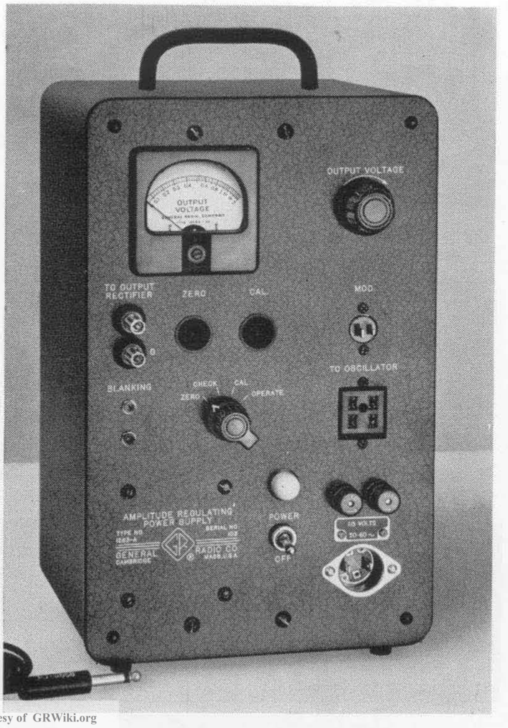


Figure 9. Panel view of the Type 1263-A Amplitude-Regulating Power Supply.

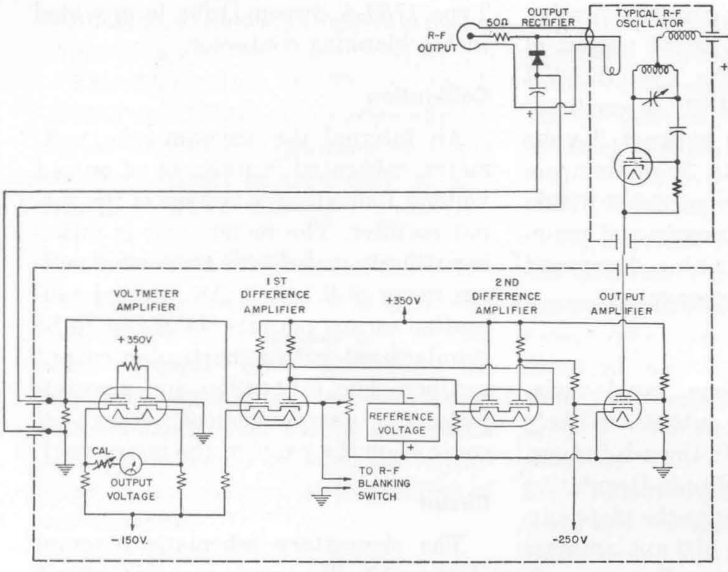


Figure 10. Elementary schematic circuit diagram of the Power Supply connected to an oscillator.

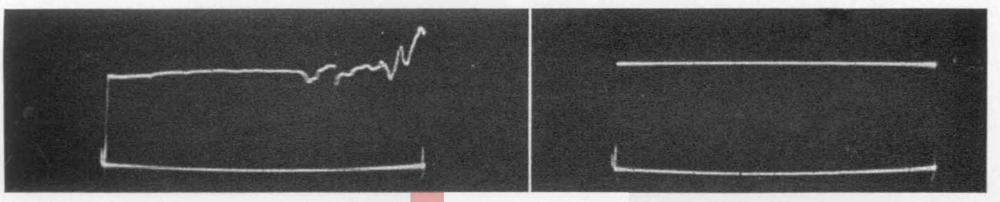
ference amplifier. A negative adjustable reference potential is applied to the other grid of the first difference amplifier. An increase in the negative potential with respect to the reference potential is amplified by the two difference amplifiers and appears as a negative-going potential at the output amplifier grid. This reduces the plate current supply to the oscillator. Conversely, a decrease in output produces an increase in plate current supplied. A closed-circuit feed-back system is thereby established, which holds the output closely to a preset level.

The Amplitude-Regulating Power Supply also furnishes power for the plate and cathode heater of the oscillator. Direct current is used for the heater supply, in order to minimize frequency modulation from hum. The Type 1263-A Amplitude-Regulating Power Supply is designed primarily for use with General Radio Unit Oscillators. Other oscillators can be operated from this instrument if their power requirements are within the allowable range and if a d-c connection can be made to the cathode circuit for applying plate current control. The following oscillators are suitable for use with this power supply:

Type No.	*Frequency Range*
1211-A	0.5–5 and 5–50 Mc
1215-B	50–250 Mc
1209-B	250–920 Mc
1218-A	900–2000 Mc

The earlier "A" models of the Types 1215 and 1209 oscillators will operate satisfactorily with the Amplitude-Regulating Power Supply if the modulation phone plug provided is removed or adapted to connect to the screw-type

Figure 11. Output amplitude characteristic as a function of frequency for the Type 1209-B Unit Oscillator (250–920 Mc), unregulated (left), and (right) when operated from the Amplitude-Regulating Power Supply.



terminals provided on these instruments. The TYPES 1208-A and 1208-B, however, cannot be used with this power supply.

The General Radio TYPE 874-VR Voltmeter Rectifier is the recommended output rectifier. It is equipped to plug directly into the output connector of General Radio Unit Oscillators and provides a matched source for 50-ohm coaxial cable.

— W. F. BYERS

SPECIFICATIONS

Type 1750-A Sweep Drive

Reciprocating Output Shaft

Center Position: Adjustable within 9 turns.
Sweep Arc: Adjustable 30–300 degrees.
Torque: Rated max. 24-ounce inches.
Sweep Speed: Adjustable 0.5–5 cycles per second. Moment of inertia limits the speed at which a load can be driven.
Height of Shaft: Adjustable from 2½–4⅞ inches over bench.
Flexible Coupling: 5¾ inches long.
Provision for Coupling: Shaft diameters, ¼ and ⅜ inches; knobs and dials, 1 to 4 inches.

Limit Switch: One limit fixed, second limit adjustable within 9 turns.

Sweep Voltage: 2.5 volts peak to peak, ungrounded.

Blanking: Shorting contact closed during clockwise rotation of driven shaft, ungrounded.

Input Power: 115 volts, 50–60 cycles, 60 watts.

Dimensions: 17½″ wide, 9″ high, 8¼″ deep.

Weight: 22½ pounds.

Type 1263-A Amplitude-Regulating Power Supply

General: For use with an oscillator whose output can be controlled by varying plate voltage applied. D-C connection to oscillator cathode must be available for applying modulation.

Plate Supply: 0–250 volts at 25 milliamperes with 105 to 125 line volts (or 210 to 250), as required to maintain preset output level. Up to 300 volts at 30 milliamperes is available above 115-volt line (or 230).

Heater Supply: 6 volts dc at 0.5 amperes at 115/230 volt line (5.4 volts at 0.7 ampere).

R-F Output Regulation: An output control permits the regulating level to be set from 0.2 to 2 volts. The output of an oscillator that is capable of delivering a minimum of 2 volts into 50 ohms within stated plate supply limitation will be regulated within ± 2 per cent of the preset level over its frequency range. Output change with rated line-voltage variation is less than 20 millivolts.

Response Time: Plate voltage is changed at a rate of 30 volts per millisecond.

Output Meter: An internal d-c vacuum-tube volt-meter is provided, which is calibrated in terms of the r-f voltage at the external output rectifier. An internal calibration means is provided for standardization of this meter with the rectifier.

Power Input: 55 watts maximum at 115/230 volts, 50–60 cycles.

Blanking: Phone-tip jacks are provided to which connection to a contactor in the TYPE 1750-A Sweep Drive can be made for cutting off the oscillator plate supply. This connection is useful for blanking the oscillator output, to eliminate the return sweep and to provide a reference base line on the CRO display.

Terminals: A Jones-type socket is provided for direct plug connection to General Radio Unit Oscillators. A detachable cable terminating in a phone plug is provided for connection to the modulation jack on a Unit Oscillator. Binding posts provide connection for external output rectifier and provide monitoring points for checking the dynamic regulation, in sweep applications, by means of a CRO.

Vacuum Tubes: The following tubes are supplied: 3 12AX7; 1 6V6-GT; 1 0A2; 1 6X4.

Accessories Supplied: Power cord, cable for connecting to modulation jack on unit oscillators, multipoint connector plug, spare fuses.

Other Accessories Required: TYPE 874-VR Voltmeter Rectifier, TYPE 274-NF Patch Cord and TYPE 874-Q6 Adaptor for connecting output rectifier.

Dimensions: Panel, (height) 13¼ x (width) 8¼ inches; depth behind panel, 7¼ inches.

Net Weight: 18½ pounds.

Type 874-VR Voltmeter Rectifier

Maximum Voltage: 2 volts.

Resonant Frequency: Approximately 3800 Mc.

By-Pass Capacitance: Approximately 300 $\mu\mu$f; shunt capacitance of crystal, approximately 1 $\mu\mu$f.

Dimensions: 3¾ x 2½ inches.

Net Weight: 5 ounces.

PRICES

SWEEP DRIVE SYSTEM

Type		*Code Word*	*Price*
1750-A	**Sweep Drive** *	STUDY	**$400.00**
1263-A	**Amplitude-Regulating Power Supply**	SALON	**250.00**
874-VR	**Voltmeter Rectifier** †	STANPARGAG	**30.00**
274-–NF	**Patch Cord**	STANPARGAG	**2.00**
874-Q6	**Adaptor** †	COAXCLOSER	**2.25**

* Patent Applied for.
† U. S. Patents 2,125,816 and 2,548,457

UNIT OSCILLATORS

Type	*Frequency Range*	*Code Word*	*Price*
1211-A	**0.5 to 5 Mc**	ATLAS	**$295.00**
1215-B	**50 to 250 Mc**	ADOPT	**190.00**
1209-B	**250 to 920 Mc**	AMISS	**235.00**
1218-A	**900 to 2000 Mc**	CARRY	**465.00**

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

AUTOMATIC SWEEP DRIVE FOR THE SLOTTED LINE

An important branch of high-frequency measurements where automatic operation will be welcomed is in slotted-line measurements of standing-wave ratio and impedance. This method of measurement has the important advantage of accuracy, but a serious disadvantage is the time consumed in making the measurements by manual operation. The probe carriage must be moved to locate a voltage minimum, whose position and magnitude are then recorded. Next, the position and magnitude of the voltage maximum must be located and recorded. From these data, the impedance can be calculated. Even when only the magnitudes are wanted, as in the measurement of VSWR, a

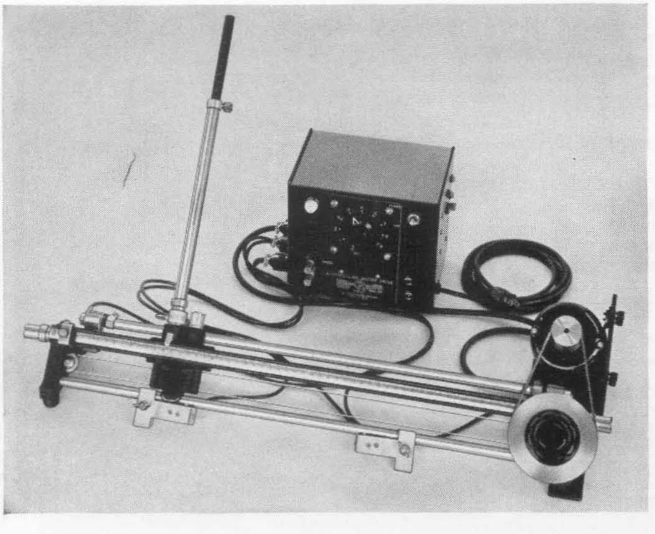


Figure 1. View of the Type 874-LBA Slotted Line with the Type 874-MD Slotted-Line Motor Drive installed. The circuits for motor control, relays, and sweep are housed in the cabinet. The microswitches for reversing the direction of travel can be seen attached to the front supporting rod.

new voltage maximum and a new minimum must be found for each measurement. In the adjustment of a matching transformer, for instance, this procedure must be followed for each change in setting of any element in the transformer.

The new General Radio TYPE 874-LBA Slotted Line[1] and the TYPE 874-MD Slotted-Line Motor Drive brings to these measurements the same speed and accuracy of automatic data presentation that is obtainable for amplitude-vs-frequency measurements with the equipment described in the previous article. The motor drive provides an automatic cyclic sweep of the probe carriage along the line, as well as a linear horizontal sweep voltage, so that the standing-wave pattern can be displayed on a cathode-ray oscilloscope.

This automatic display of the standing-wave pattern, greatly speeds up the process of measurement, because the VSWR and the position of the voltage minimum can both be read directly from the oscilloscope screen. Thus, the accuracy of the slotted-line method of measurement can be utilized in production-line tests and adjustments, where a number of similar units are to be adjusted for identical performance. The motor drive is equally useful in the laboratory, where the time required for measurements and adjustments on equipment under development can be shortened many-fold, because the effects of circuit changes and adjustments are shown immediately on the oscilloscope. Even when the problem is the adjustment of VSWR of an antenna or other network at a single frequency, substantial savings in time are realized.

[1] Soderman, R. A., "Improved Slotted Line", *General Radio Experimenter*, Vol. XXIX, No. 7, December, 1954.

The motor-drive attachment consists of the following items:

1. A 1/50th hp. d-c motor, which is mounted on a bracket at the right-hand end of the slotted line.
2. A Variac® Speed Control.
3. A pulley that mounts on the drive shaft of the slotted line.
4. A V-belt for coupling the motor to the drive shaft.
5. Two microswitches, mounted on movable brackets, which clamp on one of the supporting rods of the slotted line. These determine the travel of the carriage.
6. A linear potentiometer, wound on a rod with a sliding contact element that attaches to the carriage. This potentiometer attaches to the rear supporting rod of the slotted line and provides the horizontal-sweep voltage for the oscilloscope.

The motor-control circuits, the relay and relay rectifiers, and the sweep circuits are all housed in the motor-control unit shown in Figure 1. The motor, microswitches, and sweep potentiometer are connected to the control unit by means of cables, which terminate in multipoint connectors. The entire unit can be assembled and installed on any TYPE 874-LBA Slotted Line in less than 5 minutes.

Motor Drive Unit

The details of the drive can be seen in Figure 1. The motor is mounted on a bracket at the right-hand end of the line and drives the probe carriage through a V-belt and pulley. The pulley has two grooves; one of large diameter, as shown in Figure 1, for the high speeds used in oscilloscope presentation, and another, of small diameter, for the very slow sweeps that are needed when a meter-type standing-wave indicator is to be used. The pulley is equipped with a knob, so that manual operation is also possible.

Speed Control

Power is supplied to the motor through a Variac Speed Control similar to the General Radio TYPE 1701-AK. Field voltage is fixed, while armature voltage is supplied from a Variac® and is controlled by a knob on the front panel. With the high-speed pulley, maximum speeds range from one sweep per second for the entire 47 centimeters of line to 5 sweeps per second for very short sweeps. On the low-speed pulley, one sweep in not less than 20 seconds for the whole line can be obtained.

Reversing Mechanism

The motor-drive unit is designed to cycle the probe carriage automatically between two positions on the line. The reversing mechanism is a latching relay whose coils are alternately energized by two microswitches, one for each end of the sweep range. These are mounted on moveable brackets, which clamp on one of the supporting rods of the slotted line. A foot on the base of the carriage casting strikes a roller on a spring, accuating the microswitch and reversing the polarity of the applied armature voltage. The motor reverses very rapidly, as shown by the oscilloscope picture of the speed characteristic of the carriage in Figure 2. The use of a latching relay rather than a single relay or a stepping relay prevents improper reversal caused by double action of a microswitch. The relays are operated on dc to avoid the malfunctioning that may occur at high speeds when ac is used.

The microswitch brackets can be unlocked by means of wing nuts and slid to any desired position on the line, and thus, by proper positioning of the brackets, any particular part of the standing-wave pattern can be swept over. These adjustments can be made while the carriage is in motion. The minimum carriage travel at low speeds, when the two microswitch brackets are as close as possible, is 1 cm, and the maximum travel at low speeds is 47 cm.

Horizontal Sweep Voltage Output

The horizontal deflection of the oscilloscope is proportional to the position of the carriage on the line. The voltage required to drive the horizontal deflection amplifiers is derived from a linear voltage divider wound on a rod and a sliding contact element mounted on the back of the carriage. The rod is mounted above the rear supporting rod of the slotted line by means of two clamps. The two ends of the potentiometer are connected to an ungrounded 7-volt d-c supply, which is housed in the motor-control cabinet. One end of the potentiometer is connected to the ungrounded sweep binding post, which is also located on the control unit. The palladium contact element on the carriage is grounded to eliminate the necessity for an additional connection to the moving carriage. The sweep voltage appearing between the sweep terminal

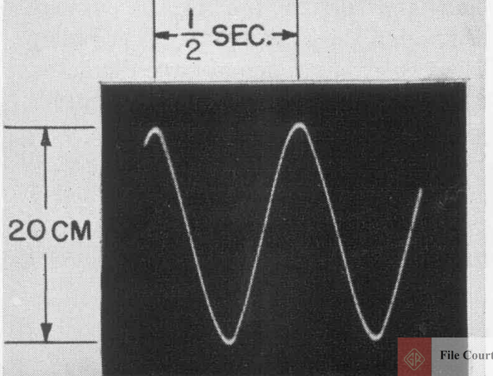


Figure 2. Displacement- vs.-time characteristic of the carriage.

and ground varies from zero to about 7 volts for a full traverse of the line.

Since the controlling element is attached directly to the carriage, the sweep voltage is closely proportional to the position of the carriage, independent of the speed or direction of sweep. All backlash in the driving mechanism is eliminated, and hence both forward and reverse traces can be utilized.

Presentation

The standing-wave pattern appearing on the oscilloscope depends on the type of modulation of the r-f source used and the type of amplifier in the oscilloscope. The preferred arrangement is 100% square-wave modulation and an oscilloscope with d-c amplification. The sensitivity of the oscilloscope amplifier should be at least 10 millivolts (rms) per inch. Two traces appear on the oscilloscope, one a baseline representing zero voltage on the line and the other representing the variation in voltage along the line. The actual voltage at any point in the line is a function of the distance between the two traces at that point. The VSWR can then be easily determined by measuring the amplitudes of the voltage minima and maxima. In this presentation the position of the baseline does not shift as the VSWR is changed, and hence the oscilloscope screen is easy to calibrate and read. Under good conditions a VSWR of 1.01 can be measured on the oscilloscope.

The position of a voltage minimum can be determined with reasonable accuracy on the oscilloscope if a grid-type overlay is used. If the impedance or the phase of the reflection coefficient at a certain point is desired, a short or open circuit can be placed at the point in question and the position of the voltage minimum on the oscilloscope noted. The horizontal gain and centering controls are then adjusted to make the distance between two adjacent minima some exact multiple of 5 on the grid with one minimum positioned exactly on a reference line. When the unknown is connected, the shift in position of the minimum in wavelengths, as well as the VSWR, can be determined on the oscilloscope. Thus, the magnitude and phase of the reflection coefficient at the load, as well as the impedance, can be obtained. Figure 3 shows a typical trace obtained on the oscilloscope when this method is used.

If desired, the vertical grid on the overlay can be calibrated to read VSWR directly when the vertical gain and centering are adjusted to set the baseline and voltage maximum at certain levels. The VSWR is then read directly off the grid at the voltage minimum.

In the frequency range between 900 and 2000 megacycles the TYPE 1218-A Unit Oscillator, with square-wave modulation, is recommended for use as the generator. With oscillators not designed for square-wave modulation, such as the TYPE 1209 and 1215 Unit Oscillators, either of two other methods will give completely satisfactory results.

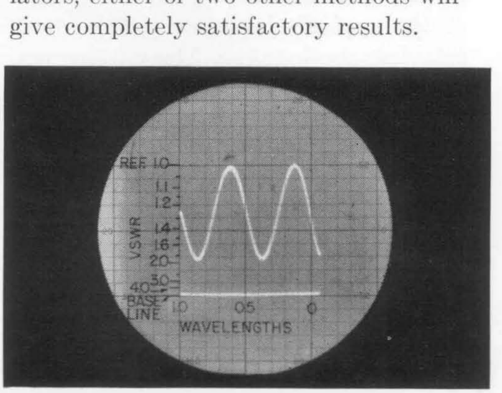


Figure 3. Typical standing-wave pattern obtained when generator is square-wave modulated. The direct-reading scales are on transparent overlays mounted on the face of the oscilloscope tube.

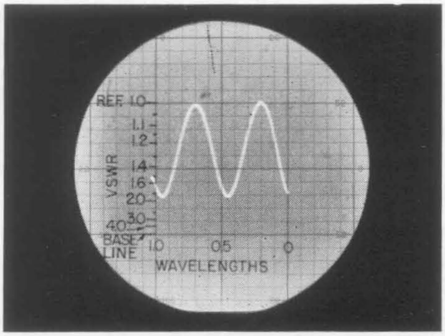


Figure 4. Standing-wave pattern obtained with generator unmodulated. Baseline is not shown.

The first method uses an unmodulated generator and an oscilloscope with d-c amplifier. The output of the probe crystal is applied directly to the oscilloscope vertical amplifier. The oscilloscope pattern is shown in Figure 4. The baseline, however, is not obtained simultaneously with the standing-wave pattern, but appears when the generator voltage is removed. This is only a minor inconvenience, however, because the baseline can be easily established for reference when needed. An important advantage of this method is that it requires a minimum of equipment.

The second method uses a sine-wave-modulated generator, in the circuit of Figure 5. The two crystal diodes in a clamping circuit suppress the lower-half of the typical sine-wave pattern and establish the baseline. The pattern obtained is shown in Figure 6.

Applications

The combination of the Type 874-MD Slotted-Line Sweep and Type 874-LBA Slotted Line make possible tremendous savings in time and convenience, whether measurements are to be made in the laboratory or on the production line. A high degree of measurement accuracy is obtainable with a minimum of effort.

One of the most valuable applications of the motor-driven line is for measurements of the VSWR and angle of the reflection coefficient of a number of similar units. For these measurements the unit under test can be plugged into the line and the VSWR and position of the minimum easily determined. In some cases limit lines can be drawn on the oscilloscope face. When the element under test has to be adjusted to a specific value, the method is even more advantageous.

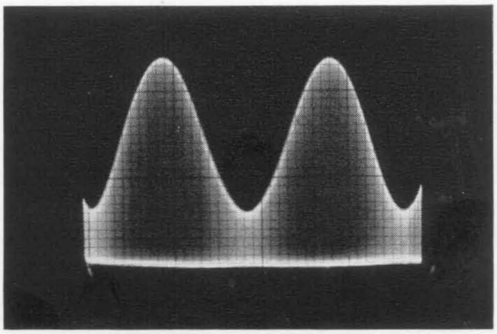
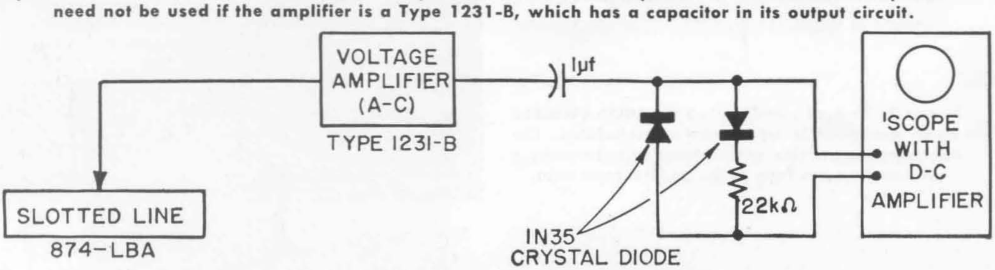


Figure 6. Standing-wave pattern obtained with sine-wave modulation and the circuit of Figure 5. The direct-reading scales shown in Figures 3 and 4 could be used equally well with this pattern.

Figure 5. Circuit for obtaining oscilloscope pattern when generator is sine-wave modulated. The amplifier is necessary to raise the voltage to the point where the diodes operate. The 1-microfarad capacitor need not be used if the amplifier is a Type 1231-B, which has a capacitor in its output circuit.



In adjustments of matching transformers for a particular VSWR or a VSWR as close to unity as possible, the motor-driven line has many advantages, one of which is that the standing-wave pattern can be seen continuously as adjustments are made.

Even for such single-frequency measurements as the adjustment of the VSWR of an antenna, valuable time savings are possible through the use of the sweep drive.

— R. A. SODERMAN

SPECIFICATIONS

Length of Sweep: Adjustable, 1 cm to 47 cm.
Sweep Speed Range: For complete sweep (47 cm), from one sweep in 20 seconds to better than one per second; for shorter sweeps, up to 5 per second.
Maximum Sweep Output Voltage: 7 volts.
Power Supply: 115 volts, 50 to 60 cycles.
Net Weight: 16¾ pounds.

Type		*Code Word*	*Price*
874-MD	**Slotted-Line Motor Drive**	STORY	**$220.00**
874-LBA	**Slotted Line**	COAX RUNNER	**220.00**

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

NEW MODELS OF UNIT OSCILLATORS

The v-h-f and u-h-f Unit Oscillators, TYPE 1215-B, 50 to 250 Mc, and 1209-B, 250 to 920 Mc, replace the older A-models of the corresponding type numbers. Changes and improvements in the new models have been made to make them more easily adaptable to sweep applications with the TYPE 1750-A Sweep Drive and the TYPE 1263-A Amplitude-Regulating Power Supply and with the TYPE 908-P1 and -P2 Synchronous Dial Drives.

External changes consist of:

1. Replacement of screw terminals for modulation by a telephone jack.

2. Addition of back-of-panel stops to the main dial, which operate even when the slow-motion drive is removed to permit mechanical coupling to the main shaft.

3. Modification of the slow-motion drive to permit gear disengagement when the Synchronous Dial Drive is used.

4. Replacement of the edge-riding indicator by a transparent plastic type to reduce acoustic noise when the shaft is motor driven.

5. Rotor has been firmly keyed to shaft in order to eliminate possible slippage when the shaft is motor driven.

The new TYPE 1208-B Unit Oscillator also incorporates all these changes except the ball bearings, which cannot conveniently be installed in this instrument. Since the tuned circuit employs sliding contacts, these, rather than bearings, will be the limiting factor in mechanical life for sweep applications. Although, for convenience, the jack for introducing a modulation voltage has been installed, the oscillator cannot be used with the TYPE 1263-A Amplitude-Regulating Power Supply, because the polarity of the modulating voltage required is reversed from that used in the other two oscillators.

Prices and other specifications are unchanged from those of previous models.

Type		*Code Word*	*Price*
1215-B	**Unit Oscillator, 50-250 Mc**	ADOPT	**$190.00**
1209-B	**Unit Oscillator, 250-920 Mc**	AMISS	**235.00**
1208-B	**Unit Oscillator, 65-500 Mc**	AMEND	**190.00**

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

HOLLAND-BELGIUM REPRESENTATION

It is with great regret that we announce the retirement of Mr. A. A. Posthumus, Baarn, Holland, as our exclusive representative for Holland, Belgium and their colonies, after an association of more than thirty years.

The efficient, business-like and meticulous services always rendered our valued clients by Mr. A. A. Posthumus will be continued by our new representatives, the able and well-known firm of Groeneveld, van der Poll & Co's, De Ruyterkade 41–43, Amsterdam, Holland, whose experience in the importation of technical electrical equipment extends back to 1887.

EGYPTIAN REPRESENTATION

We take pleasure in announcing the appointment of Moustapha Ezzat Abdel Wahab & Company, 106, Mohamed Bey Farid Street, P.O. Box 1537, Cairo, as our exclusive representatives for Egypt.

Dr. M. A. El-Said, one of Egypt's foremost electronics authorities, will act as technical consultant to the firm in connection with the application and sale of all General Radio products. Dr. El-Said has a long background of experience in this field and has spent much time in our main engineering laboratories in Cambridge, Mass., U. S. A.

This appointment was effective on January 24, 1955 upon the resignation of Messrs. Casdagli & Company.

PHOENIX—BOSTON—BETHESDA—DAYTON

In April and May, General Radio products are on display in the Southwest, in the Midwest, and on the Eastern Seaboard. If you are attending any of the following meetings, General Radio engineers extend to you a cordial invitation to visit the GR booth and to talk over your measurement problems.

Seventh Region IRE Conference
Hotel Westward Ho, Phoenix, Arizona
April 28 and 29

New England Radio-Electronics Meeting
Sheraton Plaza, Boston, Mass.
April 29 and 30

Fifth Annual Research Equipment Exhibit
and Instrument Symposium
National Institutes of Health, Bethesda, Maryland
May 2 to 5

National Conference on Airborne Electronics
Dayton Biltmore Hotel, Dayton, Ohio
May 9 to 11

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

TELEPHONE: TRowbridge 6-4400

PRINTED IN U.S.A.

the GENERAL RADIO Experimenter

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VOLUME XXIX No. 12 MAY, 1955

UNIT R-C OSCILLATOR—20 CYCLES TO 500 KC

Since Van der Pol's pioneering work on R-C oscillator circuits,[1] commercial instruments using various circuit configurations have found widespread use. To the many standard features that have made the R-C oscillator so generally accepted, the new TYPE 1210-B Unit R-C Oscillator adds two new ones — square-wave output and sweepability. Taken in conjunction with those already inherent in R-C circuits, these features make this versatile instrument fully capable of meeting today's exacting standards.

The first of these new features makes possible both low-frequency and high-frequency square-wave tests of transient behavior, and the second permits the recording of frequency characteristics, either on level recorders or on cathode-ray oscillographs. Both of these uses reflect the modern need for reducing time in obtaining data, the first because one measurement yields information about both amplitude and phase characteristics, and the second because automatic data-taking eliminates laborious point-by-point measurements.

The TYPE 1210-B Unit R-C Oscillator is the latest addition to the General Radio line of Unit Instruments. Generating frequencies from 20 cycles to 500 kilocycles, it extends the coverage of the Unit Oscillators to the unbroken

[1] Van der Pol, Balth., "Relaxatietrillingen", *Tijdschr. v. h. Ned. Rad. Gen.*, Vol. 3, 1926, p. 25. Van der Mark, J. and Van der Pol, Balth., "The Production of Sinusoidal Oscillations with a Time Period Determined by a Relaxation Time", *Physica*, 1, April, 1934, pp. 437–448.

Figure 1. Panel view of the Type 1210-B Unit R-C Oscillator and the Type 1203-A Power Supply. The oscillator plugs into the power supply and can be secured to it with a bolt and butterfly nut to form a rigid assembly.

frequency range from 20 cycles to 2000 Mc.[2]

As in other Unit Instruments, standardized cabinet design has led to economy, simplicity of construction, small size and efficient space utilization. The Type 1210-B Unit R-C Oscillator is, therefore, inexpensive, economical of laboratory bench space, and handy to use.

Frequency-Determining Circuit

Figure 2 is a simplified schematic diagram. The heart of the oscillator is an *R-C* voltage-divider network with its output amplified and returned to its input. The two equal variable capacitors (C) are mounted on the same shaft and are controlled by a 4-inch dial which spans a little more than a decade in frequency. The deposited-carbon-film-type resistors (R) are equal, and decade frequency ranges are obtained by switching them in pairs. At the operating frequency, the phase shift through the *R-C* network is zero, the output voltage (e_2) is one-third the input voltage (e_1), and the input impedance of the network is slightly more than twice the value of R. At frequencies either side of the operating frequency, the phase shift in the *R-C* network departs from zero, and the attenuation increases. When the amplifier has a gain of three and introduces no phase shift, the circuit oscillates at a frequency inversely proportional to the *R-C* product.

$$f = \frac{1}{2\pi RC}$$

Level Control

To insure that the oscillation level is held constant in spite of changes in frequency and in line voltage, an a-v-c system is used. The speed and nature of its response is very important and, in the Type 1210-B Oscillator, this response has been made both rapid and critically damped. To produce the a-v-c voltage, the output from a cathode-follower circuit is rectified and compared with a stabilized reference voltage. The resultant d-c error voltage is then applied to the grid of the amplifier system.

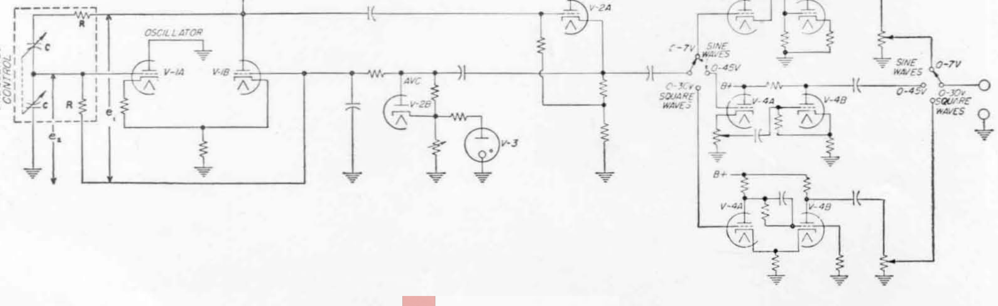
Output

The oscillator provides three different outputs that contribute to its versatility and usefulness. A three-position switch selects any one of the following:

1. *A low-impedance low-voltage output from a cathode-follower type of amplifier.* This output has good waveform over its entire range of 0–7 volts for load impedances of 500 ohms and higher and has an effective output impedance of approximately 50 ohms. The output terminals connect directly to the 5000-ohm output control, which is calibrated in decibels. This calibration is useful

[2] See *General Radio Experimenter* for May, 1950; January, 1953; September, 1953; and February, 1955.

Figure 2. Simplified schematic diagram of Type 1210-B Unit R-C Oscillator. The three output connections are shown as separate circuits for clarity, but are actually set up by switching.



with high-impedance loads and is reliable even at the lowest voltage levels, since the output is less than 3 millivolts when the control is at its extreme counter-clockwise position. Distortion s less than 1% over most of the frequency range.

2. *A high-impedance high-voltage output from a cathode-follower-driven triode amplifier.* This output delivers up to 45 volts open-circuit behind an impedance of 12.5 kilohms. Output impedance is constant, regardless of attenuator setting. Distortion can be as much as 5% on open circuit, but decreases to about 2.5% as the output is shunted down by the load.

3. *A square-wave output from a Schmitt[3] circuit.* This output furnishes square waves of 30-volt peak-to-peak amplitude (open circuit) behind 2500 ohms with 0.25 μsec rise-time and with roughly 1% overshoot. The rise time can be reduced to about 0.15 μsec by loading down the output with a resistance of 1000 ohms.

Output and distortion characteristics are shown in Figure 3.

Power Supply

In Figure 1, the oscillator is shown in combination with the Type 1203-A Unit Power Supply. This combination is satisfactory for all but the most exacting uses, since the a-v-c system incorporated in the oscillator maintains constant output under conditions of fluctuating line voltage. Frequency changes up to ±0.25% for ±10% changes of line voltage can occur at high frequencies, however, and, if these are bothersome, the Type 1201-A Unit Regulated Power Supply[4] can be substituted for the Type 1203-A with an improvement to ±0.1% or better. When the oscillator is to be used in the field, the Type 1202-A Unit Vibrator Power Supply[5] can be used to supply power from a 6-volt or 12-volt storage battery or, in the laboratory, from 115 volts a-c.

Relay-Rack Mounting

When the oscillator is to be permanently mounted in the laboratory, it becomes a rack-mounting instrument in combination with the Type 480-P4U3 Relay-Rack Panel.[6]

[3] Schmitt, O. H., "A Thermionic Trigger," *Jour. Sci. Insts.*, XV, 1, January, 1938, pp. 24–26.

[4] To be announced in a forthcoming edition of the *General Radio Experimenter*.

[5] Bousquet, A. G., "The Unit Vibrator Power Supply", *General Radio Experimenter*, Vol. XXIX, No. 9, February, 1950.

[6] Baldwin, S. P., "Relay-Rack Mounting for Unit Instruments", *General Radio Experimenter*, Vol. XXIX, No. 9, February, 1955.

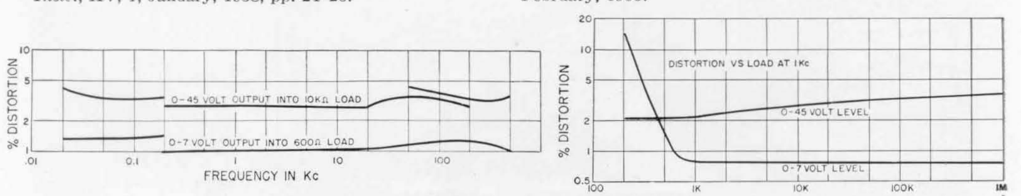
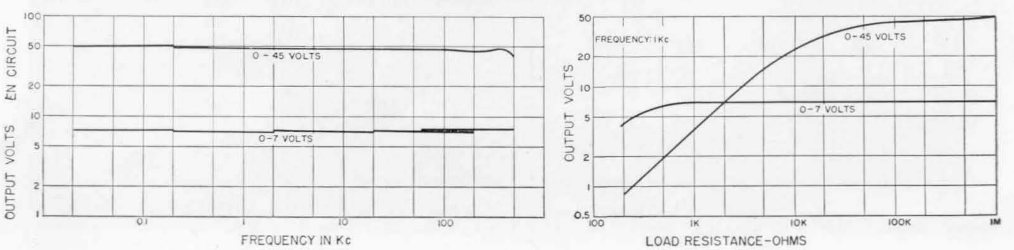


Figure 3. Output and harmonic distortion characteristics of the Unit R-C Oscillator as functions of frequency and load.



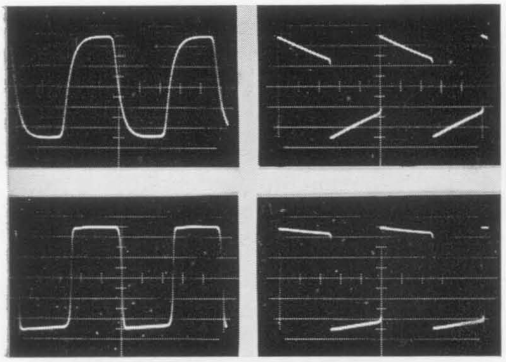


Figure 5. Oscillograms showing the square-wave outputs at extremes of the range of the Type 1210-B Unit R-C Oscillator and Type 1206-B Unit Amplifier. At the left, the lower trace is the square-wave output from the oscillator at 200 kilocycles per second, and the upper trace is the corresponding output from the amplifier. At the right, the lower trace is the 20-cycle square-wave output from the oscillator and the corresponding output from the amplifier above. Note particularly the fast rise time of the output of the Unit R-C Oscillator.

USE WITH OTHER UNIT INSTRUMENTS

1. High-Power Output

The versatility of General Radio Unit Instruments in making available useful combinations is well illustrated by the assembly of the TYPE 1210-B Unit R-C Oscillator and TYPE 1206-B Unit Amplifier[7] shown in Figure 4. The frequency range of the Unit Amplifier was established with this application in mind, and the combination constitutes a high-power R-C oscillator at low cost. The frequency characteristic, as indicated by the oscillograms of Figure 5, is adequate not only for sine-wave outputs over the entire frequency range of the TYPE 1210-B Unit R-C Oscillator but for most square-wave uses as well. At frequencies up to 50 kc, the full 3-watt output of the TYPE 1206-B can be obtained with low distortion, and, at 500 kc, the available power is still more than 0.1 watt. Within the available-power limits the frequency characteristic is flat within 2 db over the entire frequency range from 20 cycles to 500 kc.

[7] Hall, Henry P., "A Laboratory Amplifier for Audio and Ultrasonic Frequencies", *General Radio Experimenter*, Vol. XXVIII, No. 6, November, 1953.

2. Square-Wave Modulator

The amplitude of the square-wave output of this oscillator is sufficient to modulate the TYPE 1218-A Unit Oscillator recently announced.[8]

[8] Karplus, Eduard, "A 900-2000 Mc Unit Oscillator", *General Radio Experimenter*, Vol. XXIX, No. 9, February, 1955.

Figure 4. Panel view of Type 1210-B Unit R-C Oscillator and Type 1206-B Unit Amplifier with Type 1203-A Unit Power Supplies. The combination of these instruments delivers up to 3 watts of power with good waveform.

3. Pulse Trigger

The high-level output is sufficient to trigger the Type 1217-A Unit Pulser[9] continuously over a frequency range extending from the lower limit of the oscillator (20 cycles) to the upper limit of the pulser (100 kc).

4. Bridge Generator

The wide frequency range of this oscillator makes it particularly useful as a bridge generator in conjunction with the Type 1212-A Unit Null Detector[10] as the balance indicator.

SWEEP AND RECORDING APPLICATIONS

The frequency range from 20 cycles to 200 kc is covered in four continuous decade bands. A fifth decade band from 50 kc to 500 kc completes the range. The use of the Type 907-LA Precision Dial for the frequency control not only provides high-resolution manual tuning with a slow-motion control, but also the additional features that make possible the conversion of the simple oscillator to a sweep-type instrument.

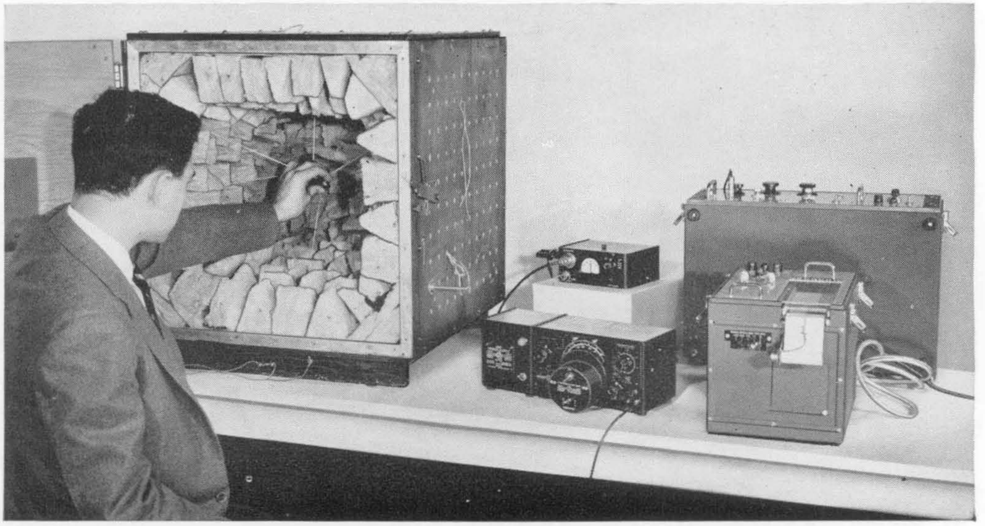
The dial is gear-driven, with a small pinion mounted on the knob shaft engaging an internal annular gear attached to the tuning shaft. The knob is easily detached, with its shaft and gear, by the removal of two mounting screws, and replaced by the Type 908-P1 or Type 908-P2 Synchronous Dial Drive.[11] These drives are powered by small synchronous motors that automatically reverse when their motion in one direction is stopped mechanically. In combination with mechanical stops they therefore make simple, inexpensive sweep drives to cover pre-set angular

[9] Frank, R. W., "Pulses in a Small Package," *General Radio Experimenter*, XXVIII, 10, March. 1954.

[10] Richmond, Robert B., "Type 1212-A Unit Null Detector", *General Radio Experimenter*, Vol. XXVII, No. 9, February, 1953.

[11] Littlejohn, H. C., "Motor Drives for Precision Dials", *General Radio Experimenter*, Vol. XXIX, No. 6, November, 1954.

Figure 6. Setup for recording the frequency response of a small loudspeaker. The Type 1210-B Unit R-C Oscillator is swept over the frequency range of 2 kc to 20 kc by the Type 908-P1 Dial Drive. The output of the oscillator is amplified by a Type 1206-B Unit Amplifier which drives the loudspeaker. The loudspeaker is mounted in one wall of a small anechoic chamber. With the chamber completely closed, the output of the speaker is picked up by a condenser microphone, shown here as it is being put in place by the operator. This microphone is part of the Type 1551-P1 Condenser Microphone System. The signal from the microphone is amplified by the Sanborn Model 150-1400 Log Audio Preamplifier, shown in the upper right, and recorded on the Sanborn Model 151-100A Recorder Assembly, right front.



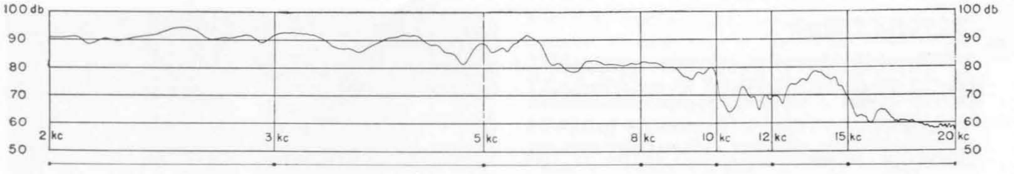


Figure 7. The recording, taken with the setup of Figure 6, showing the frequency response of the small loudspeaker. The chart speed was 5 mm/sec. Both lower and higher speeds are available on this type of recorder.

ranges of the tuning dial at constant speeds determined by the line frequency and their particular gear ratios.

Pen Recorders

Frequency characteristics obtained with sweep generators can be displayed either on pen-type recorders or on cathode-ray oscilloscopes, the method of deriving the horizontal deflection differing for the two types of device.

Pen-type recorders are generally driven horizontally by constant-speed motors, so that information is recorded as a function of time. A mechanical tie from this motor to the sweep-generator tuning shaft supplies synchronization, so that the record becomes, in effect, plotted as a function of frequency.

With the TYPE 908-P1 Synchronous Dial Drive, which has an appropriate speed for a pen-type recorder, the mechanical link between recorder and generator can be eliminated by taking advantage of the constant-speed features of the respective drive systems. The Sanborn Model 151–100A Recorder Assembly,[12] for instance, has a synchronous motor drive. Figure 6 shows the TYPE 1210-B Unit R-C Oscillator and TYPE 908-P1 Synchronous Dial Drive set up with this recorder to take the frequency characteristic of a small loudspeaker.

The gain of the system is first adjusted so that the deflection is adequate and the signal level corresponding to the deflection jibes with the vertical coordinate markings on the recording paper. The recorder is then set in motion and the TYPE 908-P1 Synchronous Dial Drive started at the desired frequency. Marks are made on the recording paper at appropriate frequencies by operation of a pushbutton provided on the recorder for that purpose, as the dial passes these frequencies. The black

[12] Sanborn Company, Cambridge, Mass.

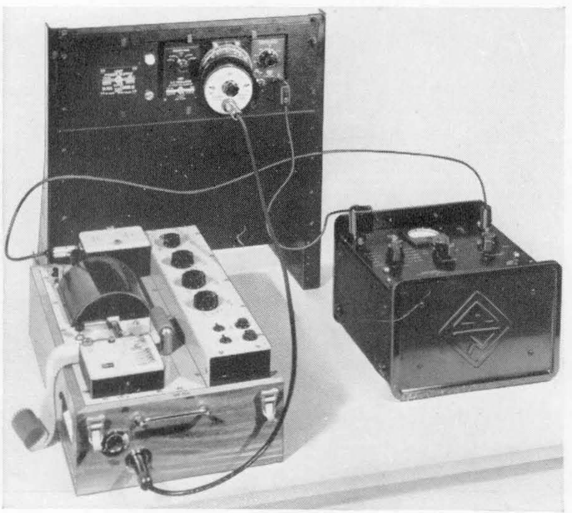


Figure 8. A setup for recording the frequency response of the Type 1550-A Octave-Band Noise Analyzer on the Bruel & Kjaer Model BL-2304 Level Recorder with the Type 1210-B Unit R-C Oscillator applying the signal to the analyzer. The recorder and oscillator are mechanically coupled by the flexible shaft and coupler so that the motor in the recorder drives the chart paper and the frequency control of the oscillator simultaneously. The Type 1210-B Unit R-C Oscillator is shown mounted on a small relay rack with a Type 480-P4U3 Relay-Rack Panel.

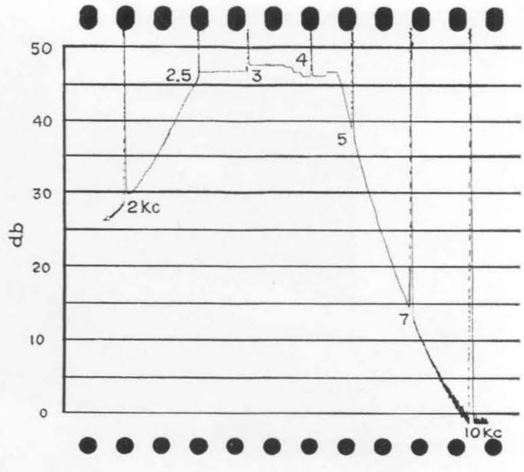


Figure 9. Record taken on the Bruel & Kjaer recorder, with the setup of Figure 8, of the response of one of the filters in the Octave-Band Analyzer. A 50-db recorder range was used to show the filter "skirts". If a detailed record of the response in the pass band were desired, a smaller recorder range could have been used. The record has been given frequency markings by the method provided in the recorder. Since the recorder and the oscillator are mechanically coupled together, only one or two of these need be recorded. Others can be put in according to the scale on the frequency dial of the oscillator, or the chart paper can be printed with a scale corresponding to the dial markings.

dots printed by this means are visible at the bottom of the record of Figure 7, which has had both horizontal and vertical coordinates inked in for clarity. This system provides maximum flexibility, because the generator and recorder need have no particular physical placement with respect to each other and may, in fact, be widely separated.

A more common arrangement is the direct mechanical link illustrated in Figure 8. This picture shows the Bruel and Kjaer Model BL-2304 Level Recorder,[13] with the Model BL-3005 Coupler and Model BL-3003 Flexible Cable recently developed by Bruel and Kjaer to drive a General Radio Type 907 or Type 908 Precision Dial.

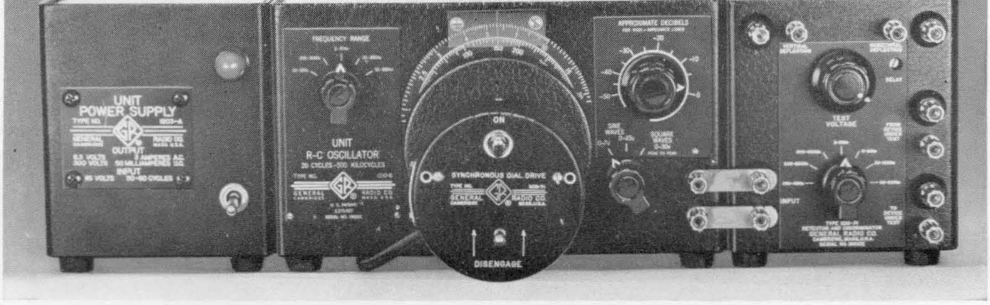
The complete combination with the Unit R-C Oscillator is set up to record the frequency characteristic of one of the filters in the Type 1550-A Octave-Band Analyzer. The record itself is shown in Figure 9. This system requires physical proximity of the generator and recorder, but compensates for this lack of flexibility by making possible the starting and stopping of the record without loss of synchronism between generator and recorder.

Cathode-Ray Oscillograph

Probably today's most common device for displaying frequency-dependent phenomena is the cathode-ray oscillograph. Long-persistence phosphors make the cathode-ray oscillograph entirely practical for use with the Type

[13] Brush Electronics Company, Cleveland, Ohio.

Figure 10. Combination of Type 1210-P1 Detector and Discriminator with Type 1210-B Unit R-C Oscillator. The Type 1210-P1 can be attached to the right-hand end of the oscillator by similar means to that used to attach the Type 1203-A Unit Power Supply to the left-hand end of the oscillator to form a complete rigid assembly. When it is desired to mount this combination in a relay rack the oscillator and power supply mount in a Type 480-P4U3 Relay-Rack Panel, and the detector unit in a separate Type 480-P4U1 Relay-Rack Panel.



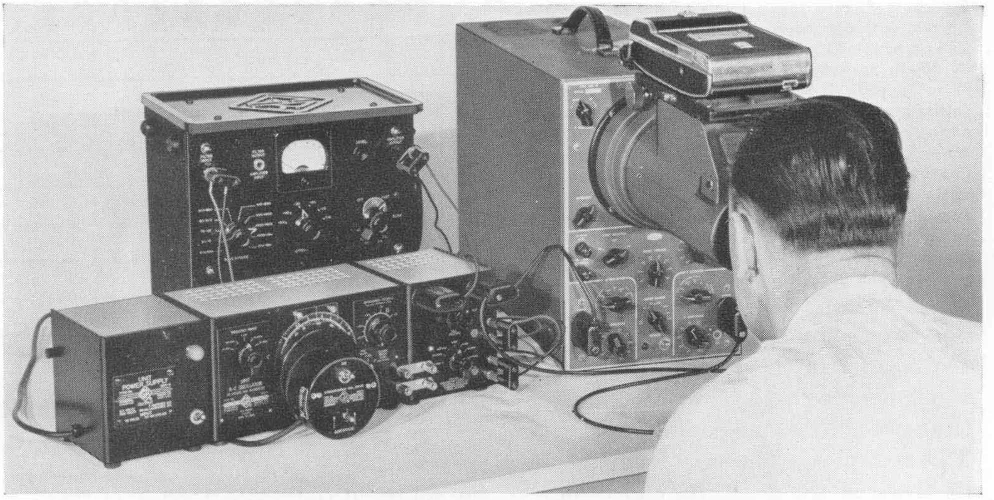


Figure 11. A setup for observing and recording the response of the octave-band analyzer on a DuMont Cathode-Ray Oscillograph. The Type 1210-B Unit R-C Oscillator, which is driven by the 908-P2 Dial Drive, supplies the signal to the analyzer, and the Type 1210-P1 Detector and Discriminator, shown attached to the oscillator, supplies the deflecting voltages to the oscillograph.

1210-B Unit R-C Oscillator and the Type 908-P2 Synchronous Dial Drive, which is faster than the Type 908-P1 and, therefore, better adapted to cathode-ray work.

With this combination, a discriminator circuit is used to produce a horizontal-deflection voltage proportional to frequency. The Type 1210-P1 Detector and Discriminator, shown in Figure 10, incorporates both this discriminator circuit for the horizontal sweep and a detector unit to furnish vertical drive for the oscillograph.

Figure 11 shows a setup using the combination of Type 1210-B Unit R-C Oscillator, a Type 908-P2 Synchronous Dial Drive, and a Type 1210-P1 Detector and Discriminator to display a frequency characteristic on a cathode-ray oscillograph. Figure 12 is a photograph of the oscillograph trace for the same filter as that shown in the record of Figure 9. The difference in shape is attributable to the fact that the vertical

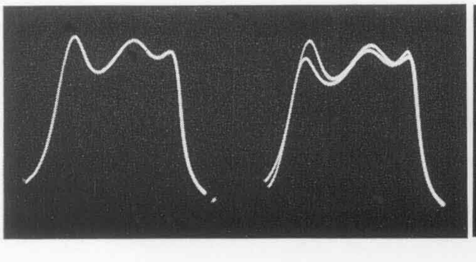


Figure 12. The oscillogram taken with the arrangement of Figure 11, showing the response of one filter of the octave-band analyzer. The vertical deflection is proportional to the output of the filter, and the horizontal deflection is proportional to frequency. The behavior of the response in the pass band is clearly shown. The response in this instance changes so rapidly with frequency that there is an appreciable effect on the trace compared to the steady-state response as indicated in the right-hand picture, which shows the traces for both directions of sweep. This effect can readily be taken into account if measurements for a number of instruments are to be made on the trace, by first checking the response at the critical points for one sample curve.

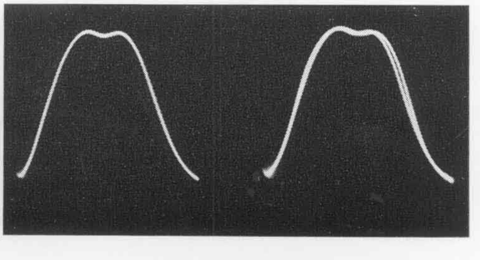


Figure 13. Photographs of a cathode-ray oscillograph display for the response of a tuned i-f stage at 455 kc made with a setup similar to that of Figure 12. The picture at the right shows both traces and illustrates how closely the two traces can be brought into coincidence by the adjustment provided in the Type 1210-P1. Because these four oscillograms were photographed through a mirror, frequency increases from right to left.

deflection in Figure 9 is logarithmic, in Figure 12 linear.

Figure 13 shows a similar curve for a 455 kc i-f transformer. With narrow-band sweeping of this type, the rate of sweep and reversal is fast enough to make possible adjustments without irritating delay in presentation of the resultant changes in characteristics of sharply tuned circuits.

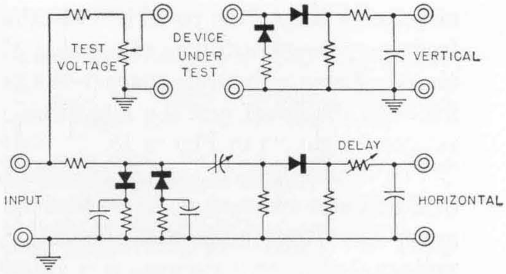


Figure 14. Elementary schematic circuit diagram of the Type 1210-P1 Detector and Discriminator.

DETECTOR AND DISCRIMINATOR UNIT

TYPE 1210-P1 Discriminator and Detector is housed in a small unit-instrument cabinet, identical in size with the Unit Power Supply, as shown in Figure 10. No power supply is required.

The circuit that provides the horizontal sweep is shown in the lower part of the elementary schematic diagram of Figure 14 and consists of a balanced diode limiter, a resistance-capacitance discriminator, which has seven different time constants selected by the lower panel switch, a detector, and an adjustable filter at the output. These elements combine to give a d-c output voltage that increases with increasing frequency of the applied signal.

The heart of this section is the R-C discriminator, whose a-c output increases as the frequency of the applied signal increases. This output must then be rectified to supply a d-c signal to drive the oscillograph. Reasonably good linearity is obtained over a 10:1 frequency range by using a germanium-junction diode as the rectifier. At the high-frequency end of the range the rectification is improved through the use of a point-contact rectifier in series with the junction rectifier. When the discriminator is operated at frequencies above the values covered in the normal linear range, the output produces an approximately logarithmic frequency scale for a range of 3 to 1 in frequency. This characteristic is obtained when the

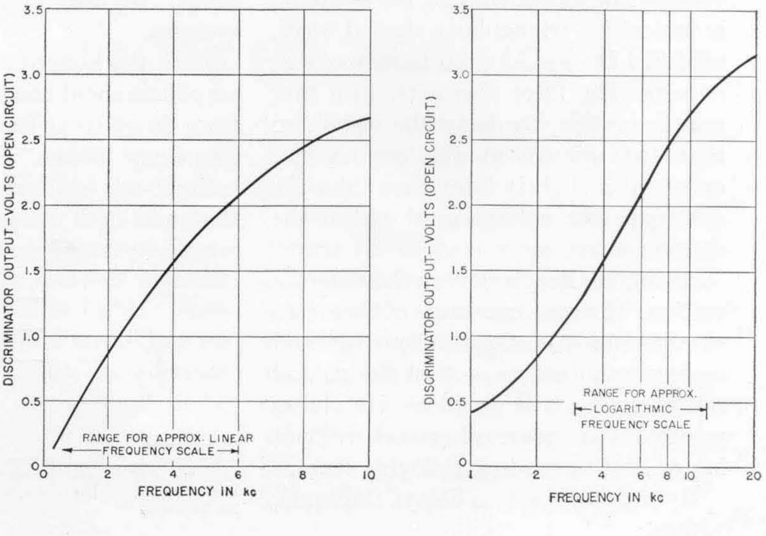


Figure 15. Typical plots of the linear (left) and logarithmic (right) response ranges of the discriminator output.

selector switch on the panel is set to the frequency range next lower than that of the oscillator. Typical characteristics for both the linear and the logarithmic ranges are shown in Figure 15.

The limiter acts to reduce the effect of the sudden reversal at the ends of the sweep on the horizontal deflection voltage.

The filter, which is necessary to reduce the a-c component in the detected discriminator voltage, is designed to work down to 200 cps. This lower limit is based on providing a filter that does not seriously affect the sweep voltage but at the same time covers almost the entire range of the oscillator.

The upper part of Figure 14 shows the detector for the output of the network under test. It provides a d-c voltage that is proportional to the a-c output, and a filter is also included to reduce the a-c component of the rectified output. This detector is essentially linear for applied voltages greater than 2 volts, rms, and square law for applied voltages less than 0.5 volt, rms.

Both filter networks affect the signals fed to the oscillograph, because the signals are not really direct-current values. The sweep voltage, for example, is basically a triangularly shaped wave, modified by the filter to have rounded corners. The filter also acts, to a first approximation, to delay the signal, so that the voltage at the oscillograph occurs at a slightly later time than the corresponding voltage produced at the discriminator.

A similar effect occurs in the detector section. The time constants of these two circuits must be carefully balanced against one another so that the go and return traces will lie as accurately as possible upon each other and will not lag or lead to produce a double trace.

By making the two delays the same, one can usually bring the two patterns into good coincidence. Since this delay is dependent on the oscillograph loading of the filter system, an adjustment is included so that the delay can be set to the optimum value for a given test.

An additional effect, encountered in all sweep systems, is important. The instantaneous response of a network to a sweeping signal as it sweeps through a given frequency is not the same as for a steady-state signal of that frequency.[14] For many of the systems that one wishes to display, this effect is, fortunately, either small or can be taken into account. It is most serious when the response of the system under measurement varies rapidly with frequency, and it can be described as a delay and a modification of the response. As a result of this behavior, the response may also be different for the two directions of sweep.

The horizontal-axis amplifier in the oscillograph used with this sweep system should have sufficient sensitivity so that an input of 0.2 volt produces at least 1 cm deflection of the spot. This sensitivity is necessary for displays that cover a relatively narrow frequency range, as for example, receiver i-f systems.

Both the horizontal and vertical-axis amplifiers should be uniform in response from dc up to at least the lower audio-frequency range. There are many cathode-ray oscillographs on the market that meet both this requirement and the sensitivity requirement given above.

— A. G. Bousquet
— A. P. G. Peterson
— D. B. Sinclair

[14] Marique, J., "The Response of RLC Resonant Circuits to EMF of Sawtooth Varying Frequency", *Proceedings Institute of Radio Engineers*, Vol. 40, No. 8, August, 1952, pp. 945–950.

SPECIFICATIONS

Frequency Range: 20 to 500,000 cycles in five ranges, 20-200 cycles, 200-2000 cycles, 2-20 kilocycles, 20-200 kilocycles and 50-500 kilocycles.

Frequency Controls: A range-selection switch and a 4-inch precision gear-driven dial. The frequency dial has two scales, 2-20 and 50-500. The dial is driven by a slow-motion knob that covers each decade in approximately 4½ turns.

Frequency Accuracy: ± 3%.

Output Control: Logarithmic, calibrated 0-50 db.

Output System: A 3-position panel switch selects square-wave output, sine-wave low-impedance output or sine-wave high-impedance output.

Low-Impedance Output: 0-7 volts; constant within ± 1 db up to 200 kilocycles; output impedance, 50 ohms; distortion less than one percent from 200 cycles to 20 kilocycles, no load; less than 1.5% over entire frequency range. With 600-ohm load, at 1 kilocycle, distortion is less than 1.5%. Hum is at least 60 db below output voltage level.

High-Impedance Output: 0-45 volts; constant within ± 1 db from 200 cycles to 200 kilocycles. Distortion, less than 5 percent from 200 cycles to 200 kilocycles at no load and is reduced under load. Output impedance, 12,500 ohms. Hum is at least 50 db below maximum output voltage.

Square-Wave Output: 0-30 volts peak-to-peak; approximately ¼-microsecond rise time; about 1% overshoot; hum is at least 60 db below output voltage level; output impedance, 2500 ohms.

Output Terminals: Two jack-top 274-type binding posts, one grounded to panel.

Tubes: One 6BQ7-A, two 12AU7 and one OB2; all tubes are supplied with the instrument.

Power Supply: The Type 1203-A Unit Power Supply is recommended for operation from a 115-volt, 50-60-cycle power line. The Type 1204-B Unit Variable Power Supply can also be used. The Type 1202-A Unit Vibrator Power Supply is available for operation from either a 6-volt or a 12-volt storage battery or from a 115-volt, 50-60 cycle power line. A matching multi-point connector is supplied for connection to any other adequate supply. Power requirements are 6.3 volts ac or dc at one ampere and 300 volts dc at 50 ma.

Accessories Supplied: Multipoint connector.

Mountings: Black-crackle-finish aluminum panel and sides; aluminum cover finished in clear lacquer. Accessory panel is available for relay-rack mounting; see price list below.

Dimensions: (width) 10½ × (height) 5¾ × (depth) 7 inches over-all.

Net Weight: 6¼ pounds.

Type		*Code Word*	*Price*
1210-B	**Unit R-C Oscillator**	ABAFT	**$140.00**
1203-A	**Unit Power Supply**	ALIVE	**40.00**
1210-P1	**Detector and Discriminator**	DUDAD	**75.00**
480-P4U3	**Relay-Rack Panel**	UNIPANCART	**12.50**
480-P4U1	**Relay-Rack Panel**	UNIPANARCH	**12.50**
1206-B	**Unit Amplifier**	ARBOR	**85.00**
908-P1	**Synchronous Dial Drive**	SYNDO	**27.50**
908-P2	**Synchronous Dial Drive**	SYNKA	**27.50**

RECORDER COUPLING FOR PRECISION DIALS

In the previous article, mention is made of a means for coupling the Bruel and Kjaer Model BL-2304 Level Recorder to General Radio Type 907 and Type 908 Gear Drive Precision Dials. The Model BL-3005 Coupler and the Model BL-3003 Flexible Cable[1] have been developed by Bruel and Kjaer for use with General Radio instruments that are equipped with these dials. Figure 1 shows this coupling system attached to the General Radio Type 1304-B Beat-Frequency Audio Generator.[2]

With the setup shown, the speed of driving the frequency-control of the oscillator is selected by one set of gears in the recorder, and the speed of the recording paper is separately selected by the gear-shift mechanism on the recorder. By selecting a shaft speed of 7.5 rpm and a paper speed of 1 mm/

[1] The recorder and the attachments are available from the Brush Electronics Company, 3405 Perkins Avenue, Cleveland 14, Ohio.

[2] Woodward, C. A., "The Type 1304-B Beat-Frequency Audio Generator", *General Radio Experimenter*, Vol. XXIX, No. 1, June 1954, pp. 1–6.

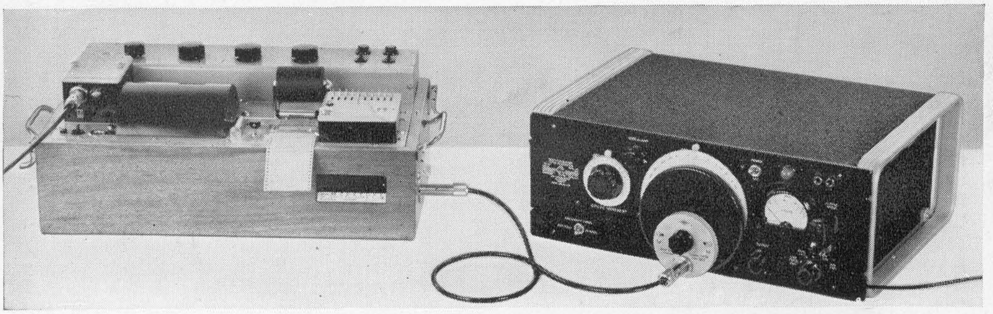


Figure 1. View of the General Radio Beat-Frequency Audio Generator coupled to the Bruel and Kjaer Model BL-2304 Level Recorder by means of the new coupler and flexible cable.

second, one can use, in the recorder, BL-3602 Chart Paper, which has the correctly spaced logarithmic frequency scale for the Audio Generator already printed on it. A number of multiples of these speeds are also available, if it is desired to cover the frequency range at a faster or slower rate.

The coupling device includes a friction clutch so that the knob visible on the front can be used to override the drive and to set the dial to the desired point. The clutch also eliminates the possibility of damage when the drive is in motion as the dial hits a stop.

Because of the ability of the beat-frequency type of oscillator to scan rapidly frequencies from 20 to 20,000 cycles, the combination shown in Figure 1 is particularly valuable for studying such devices as audio-frequency networks, transducers, filters, amplifiers, and preamplifiers.

The very versatile Type 1303-A Two-Signal Audio Generator can also be used in such a setup, and the line of General Radio Unit Oscillators covering the frequency range from 20 cycles to 2000 Mc can also be driven by the recorder through the coupling means now available. For the higher frequency units, the signal must be rectified before recording because the recorder will work directly with signals only up to 200 kc. When these Unit Oscillators are used, it will also be generally desirable to use the TYPE 1263-A Amplitude-Regulating Power Supply [3] to maintain a constant signal level at the input of the device under test.

[3] Karplus, E., and Byers, W. F., "A New System for Automatic Data Display", *General Radio Experimenter*, Vol. XXIX, No. 11, April 1955, pp. 6–9.

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the GENERAL RADIO **Experimenter**

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 30 No. 1 JUNE, 1955

1915-1955

Also IN THIS ISSUE

The 40th birthday is a minor milestone, not calling forth the same fervor of festivity as the 25th or the 50th. Yet it has a unique significance. A man, lacking the dignity of a full half century, still hopes that he is not really old yet knows he is no longer young. He is old enough to have a past but young enough to have a future. It is the age where he longs to be young again, knowing what he knows now.

Unlike a man, a company is self-renewing and can face the future with the vigor of youth and the experience of maturity; so, as General Radio celebrates its 40th anniversary this month, we recall the past in its significance for the flowering of the present and the fruition of the future.

The electron was less in the public mind than the atom now is when the youthful Melville Eastham started a company intended to apply the com-

View of the Combined Plants of the
GENERAL RADIO COMPANY
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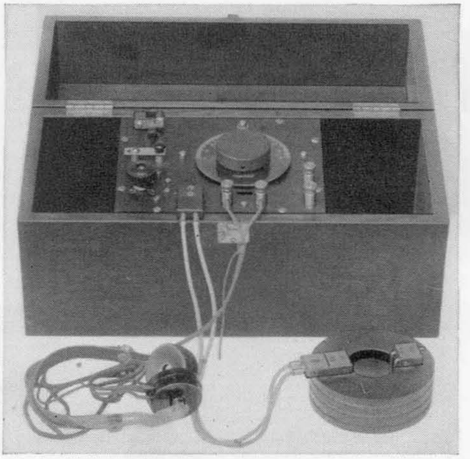
Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

paratively new idea of industrial measurements to an industry hardly born.

This young man had another idea, even further from the general industrial mind of 1915 — the concept of a manufacturing company as a community of interest among stockholders, employees, management, and customers. (Two, and eventually three, of these interests became in fact merged because there were no outside stockholders, and the Company early became employee owned and has always been employee managed.) Growth would be slow, financed from earnings, and there would be no lay-offs or shutdowns. Profit-sharing and job security would be features of employment.

Industry would be supplied with the measuring tools required to support the technology of the new fields opened by the development of the electron tube and the exploitation of frequencies above the commercial power range. An adequate engineering staff would insure timely new products, and advanced manufacturing methods would produce prices below the prevailing range for laboratory instruments. Another important departure from prevailing practice, possibly the first in the manufacture of laboratory apparatus, would be the production in quantity (relatively) of a standard line of instruments, which would be maintained in stock to provide prompt fulfillment of customers' requirements. The saving in cost and the improvement in service would be great, for the common practice at the time was to build to a customer's order.

All of these aims have been realized, and through the years the policy that what is good for the employees is good for General Radio has produced a progressing series of employee benefits. Even in the bad time of the early 30's there were no lay-offs on account of lack of work. The first productive employee hired retired a few years ago.



Wavemeter of 1915.

A steady growth has brought employment to approximately 600. Our turnover is small, and lifetime employment is frequent. All this has built a force of highly skilled production workers. No women are employed in manufacturing departments. In assembly, the artisan rather than the mass-production system is used — that is, one man usually assembles a complete instrument working from prints.

Naturally in such a company, spending about 10 per cent of its annual sales in development engineering, an unusually large porportion of the total staff are engineers, and men with engineering background are found in many other positions. The policy has been to develop men within the organization so far as possible. Co-operative courses are carried on with Massachusetts Institute of Technology and with Northeastern University, and in the later years of the course students spend about half their time in the General Radio plant. This has become an important source of engineering talent.

The growth of instruments since those early years is marked by the difference between the 9 pages of 1915's Catalog A and the 258 pages of 1954's Catalog N. However, the modern reader of Catalog A is struck by the element of continuity in an art that has developed in as many directions as has electronics since 1915. The early instruments were the fundamental tools of their day, and modern instruments to perform the same functions are still found in Catalog N.

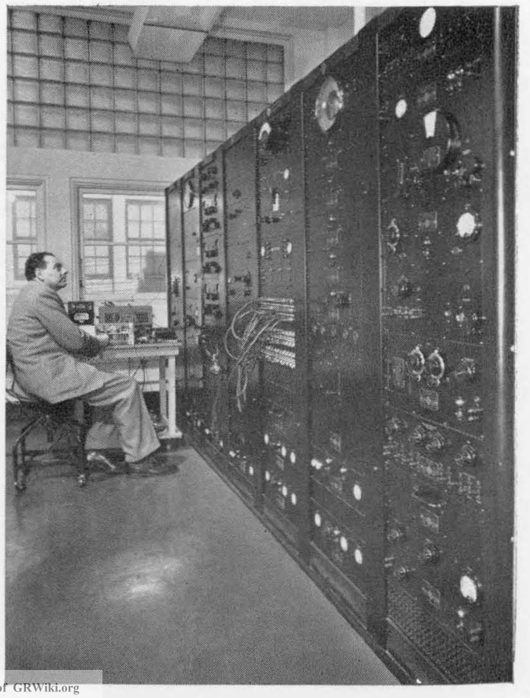
The variable air condenser was then as now a basic measurement tool. The bakelite insulation has given way to quartz and steatite, but the applications are roughly the same, and the General Radio capacitor of 1955 is, like the condenser of 1915, the best commercial device in its class. The function performed by the universal wavemeter of Catalog A (range of 150 meters to 900 meters) is met in Catalog N by a crystal frequency standard and an extensive array of auxiliary equipment. Closer relatives, wavemeters of the coil and condenser type, also appear in Catalog N. In some of them the condenser and coil have merged in a single unit, the high-frequency butterfly.

The "sensitive high-frequency meter" of the early catalogs is the remote ancestor of the vacuum-tube voltmeter. Standards of inductance and capacitance complete Catalog A's listings, all represented in Catalog N and one even carrying the same type number (107).

A single instrument in Catalog A represents a vanished function — the "Type 110-A Spark Indicator" with which "the regularity of the intensity and spacing of the separate sparks can be seen, thus allowing the user to form a correct idea of the tone value and spark of a set." This development could no doubt have been used as a stroboscope, so even it may be said to have a descendant of sorts in Catalog N.

Subsequent catalogs show a developing sophistication in these original models, and from time to time new basic instruments are added. By 1919 the 9 pages have become 32, and resistance boxes and bridges begin to appear.

In the mid-20's a new element appears — the great build-your-own broadcast-receiver boom was on, and General Radio entered into a major deviation. Radio parts (transformers, condensers, rheostats) became so numerous that by 1925 a separate parts catalog appeared. The line-operated receiver, too complicated for home construction, brought this period to a close, and by 1928 General Radio was again putting all its effort into instrument development and manufacturing. Indeed, this field had not been neglected, for during this period oscillographs, vacuum-tube oscillators, and crystal frequency standards appeared in the



1955's Frequency Standardizing Equipment in the General Radio Engineering Laboratories.

Since 1915, the radio-electronics industry has looked to General Radio for its laboratory standards. At the left is shown an early Type 107 Variable Inductor; at the right, today's direct-reading model.

Catalog, which had grown to 120 pages by 1930. The first cathode-ray oscillograph commercially available for general sale in the United States was introduced in 1931; the first standard-signal generator appeared even earlier, in 1928.

The decade of the 1930's saw a great development in the application of electronic techniques to industrial measurement problems. No longer was the radio industry the principal customer. The General Radio Company in fact became steadily more general and less radio. Firsts in all of these fields were numerous. These included the feedback-type R-C oscillator, the heterodyne wave analyzer, the electronic stroboscope, and noise-meters. The Variac® autotransformer, the first commercialization of an old idea, appeared in 1933.

The war years show a forced-draft expansion and some turning away from instrument development to the immediate requirements of national defense. A portion of our Engineering Department was in fact on leave and engaged in Government projects.

Plant facilities were expanded, and sub-contracting arrangements were entered into with neighboring plants. The booming requirements for electronic weapons produced a corresponding pressure for instruments to measure the performance not only in development but in use. General Radio was, in the early years of the war, the only source in the world outside of Germany for many of these essential tools, and even before the entry of the United States into the war, the expanded requirements of our future allies were being met. The war demands were so well met that the Company received five Army-Navy "E" Awards.

Following the war, an expanded Engineering Department redesigned many older instruments and produced new items at an accelerated tempo. Coaxial connectors and devices extended the frequency range of the Company's operations into the 5000 Mc. area. Motor speed controls appeared for the first time, expanding our interest in the industrial field, as did a voltage regulator. Both of these items were built around the Variac® autotransformer.

Television brought a station monitor, a companion to broadcast and F-M monitors long in the line, and, too new to be catalogued, at the 1955 Radio Engineering Show were displayed instruments for automatic curve tracing, a response to the current trend. Yet, among the elaborate newer instruments the old basic items are not forgotten, and among the most recent developments are found new standards of capacitance and inductance, and new types of impedance bridges.

Expansion in the field of customer service is shown also. The first catalogue listed only the factory address. During the 20's and early 30's, listings of foreign representatives appear covering, before the outbreak of hostilities, every portion of the world. District offices started by Company personnel appear first in New York in 1934, followed by Los Angeles, Chicago, Washington, and this month, Philadelphia.

No industrial reminiscences are complete without recalling the old works where everything started. General Radio, too, had its old plant, although it is doubtful if the founder ever stoked the furnace there. This building was abandoned by General Radio in 1927, and operations moved to a growing plant started nearby in 1924. This site, with additions to expand it fivefold through the years, was outgrown in 1950, and a branch plant was built in West Concord, Massachusetts, which now accommodates about one-half of the manufacturing operations.

This, then, is what we know now, the accumulated experience of 40 years. It is the foundation on which younger men are building — young men with more in their philosophies than an aging scribbler of memoirs has dreamed of.

— C. T. Burke

NEW R-F BRIDGE FEATURES SMALL SIZE AND ADDED OPERATING CONVENIENCE

Since its introduction in 1942, the General Radio Type 916-A Radio-Frequency Bridge[1] has been the radio industry's standard for measurements on antennas, lines, networks and components in the frequency range between 400 Kc and 60 Mc. The widespread acceptance accorded this bridge is due largely to two important characteristics — accuracy of measurement and simplicity of operation. A new and improved version of this bridge has recently been developed, the Type 1606-A Radio-Frequency Bridge, which retains the desirable features of the older bridge and incorporates several new ones that contribute to increased ease and convenience of operation.

As in the older bridge, the resistive and reactive components of the unknown impedance are directly indicated on separate dials when the bridge is balanced to a null. The direct-reading resistance range is from 0 to 1000 ohms, and the direct-reading reactance range is from 0 to $\pm$ $5000/f_{Mc}$ ohms, where f_{Mc} is the frequency in megacycles. Higher impedances can be measured indirectly. A modified Schering bridge circuit, shown in Figure 2, is used, in which both the resistive and reactive components of the unknown impedance are measured in terms of capacitance,

[1] Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Mc," *General Radio Experimenter*, XVII, 3, August, 1942.

and all balance adjustments are made by means of variable air capacitors.

Among the improvements in the new bridge are:

1. The volume occupied by the bridge has been halved.
2. A single bridge transformer replaces the two transformers used in the older bridge, thus eliminating the necessity of changing transformers at 3 megacycles.
3. New milled-plate variable air capacitors, which have very low losses, are used as reactance standards.
4. The resistor previously mounted in the lead used to connect the unknown to the bridge has been moved inside the bridge, which facilitates connections to the unknown.
5. The reactance dial is calibrated over a 330° arc rather than over a 165° arc, which permits more precise readings.
6. Teflon insulation is used to support the important bridge elements in order to keep losses low and to make operation possible over wide temperature ranges.
7. Dial locks are provided on the initial balance controls to prevent accidental movement.
8. A separate carrying case is made available as an accessory.

Bridge Transformer

Probably the most significant improvement in the bridge is the new broadband bridge transformer, which operates efficiently over the entire frequency range of the bridge. As shown in Figure 2, this transformer is the isolation network used to couple power from the generator into the bridge through junction points a and c.

The transformer must develop a voltage between points a and c which "floats" with respect to ground. That is, the relative potentials between point a and ground and between c and ground must be determined by the impedances in the bridge arms alone and not by stray couplings in the transformer. The transformer therefore should have only magnetic coupling between the primary and secondary, and all capacitive couplings between the windings themselves should be eliminated.

Figure 1. View of the Type 1606-A Radio-Frequency Bridge in its carrying case. Shielding is provided by the metal cabinet of the instrument, so that the bridge can be used either in or out of the carrying case.

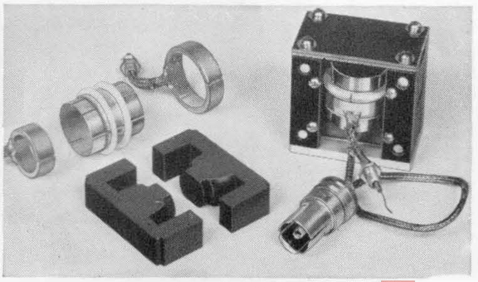
In order to keep the stray capacitance coupling negligible, the primary and secondary windings are completely shielded, and an additional shield is used between the shielded primary and secondary, as shown in Figure 3. The fixed capacitance between the middle shield and the secondary shield causes no error since it appears in parallel with the capacitive arm of the bridge and can be included as part of the capacitance C_N. The details of construction are shown in Figures 3 and 4. Note that the individual shields are not complete turns around the core but are slotted to avoid the formation of short-circuited turns.

The wide frequency range is obtained through the use of a high-permeability ferrite core ($\mu = 850$) which forms a complete magnetic path around the windings. The low-reluctance magnetic circuit results in a high degree of coupling between the primary and secondary, and, since only two turns are required on both windings to produce an adequate primary inductance for satisfactory performance at the lowest frequencies, it also results in a high self-resonant frequency for the transformer.

All connections to the windings are made by means of coaxial cables in order to minimize possible capacitance couplings.

The performance of this new transformer is completely satisfactory. It covers the entire frequency range of the bridge and does not require any

Figure 3. View of the bridge transformer with component parts shown at left.



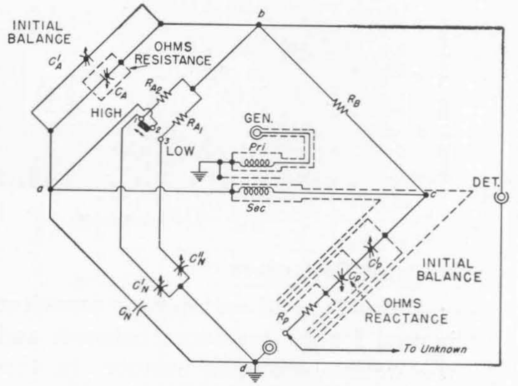
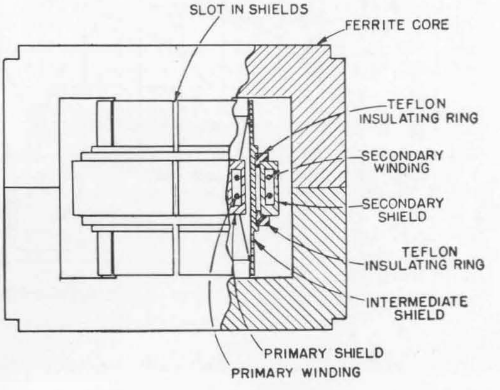


Figure 2. Schematic diagram of the bridge circuit.

adjustment in order to balance out undesired couplings. Figure 5 is a graph showing the relative voltage developed across the bridge at balance as a function of frequency. The performance of the two transformers used in the older Type 916-A R-F Bridge is also shown. As is evident, the new transformer produces a substantially larger voltage across the bridge at practically all frequencies than do the older units.

As a matter of interest, the characteristics of the transformer alone working between a 50-ohm source and a 50-ohm load were measured and are plotted in Figure 6. As can be seen, the insertion loss is reasonably low over a very wide frequency range in spite of the large physical spacing necessitated by the shielding between the primary and secondary windings.

Figure 4. Cross section drawing of the bridge transformer.



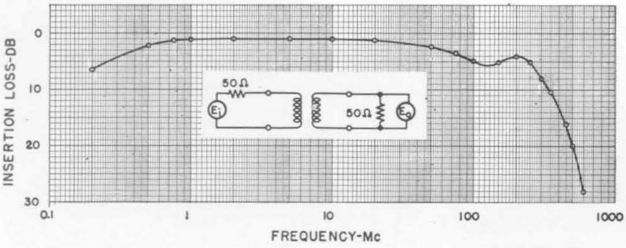


Figure 6. Insertion loss of the bridge transformer as a function of frequency, working between 50-ohm impedances.

Variable Capacitors

A new type of variable air capacitor is used for the reactance balances and the initial resistance balance. In this capacitor the complete rotor and stator sections are milled out of solid blocks of aluminum, a construction which avoids the losses at the joints between plates and spacers found in many conventional designs. Ball bearings mounted in high-temperature polystyrene-disk insulators support the glass-fiber shaft to which the rotor is clamped. Because their over-all losses are very low, capacitors of this type are excellent components for use in the bridge. Figure 7 is a view of a 220 $\mu\mu$f variable capacitor of the type used in the instrument.

Unknown Lead

In the older bridge the resistor, *Rp*, shown in Figure 2, used to make possible the initial resistance balance, is mounted external to the bridge in the lead used to connect the unknown to the circuit under test. As a result, special leads with the resistor mounted in them had to be used or an initial balance could not be obtained. In the new bridge the resistor is mounted inside the bridge, which permits much greater flexibility in the selection of connecting leads. In fact, components can often be most satisfactorily measured at high frequencies when connected directly across the unknown terminals by means of their own leads.

Carrying Case

The bridge is mounted in a sturdy aluminum cabinet, the inside of which is actually part of the bridge circuit. In field applications where some additional protection is desired, or in cases in which the instrument is transported frequently, a separate luggage-type case, shown in Figure 1, can be obtained as an accessory. The instrument can be operated while inside the case if desired.

Figure 5. Relative voltage developed across the bridge at balance as a function of frequency. Data for the older Type 916-A model are shown for comparison.

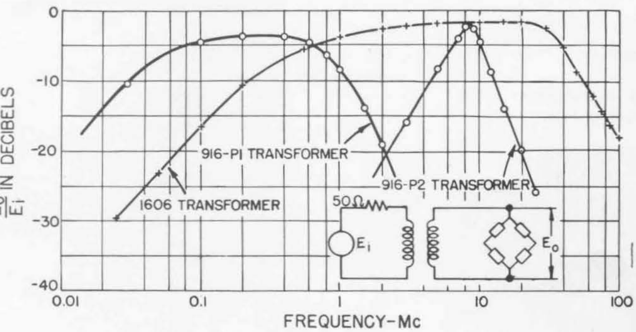
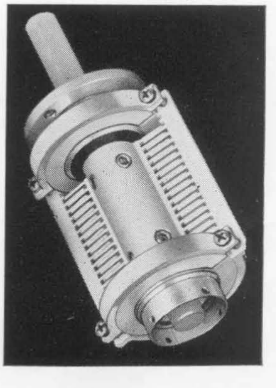


Figure 7. A variable air capacitor of the type used in the new r-f bridge.



Performance

The bridge is well suited to the accurate measurement of components, antennas, and other circuits having relatively low impedances over a frequency range from below 400 kc to 60 Mc. Figure 9 shows the results of a series of measurements made over a frequency range from 100 kc to 60 Mc on a length of transmission line terminated in a resistor and a capacitor connected in series.

At very low frequencies, that is below about 400 Kc, the resistance balance becomes progressively less sensitive than the reactance balance and as a result it becomes more difficult to measure very small resistances accurately. Since the reactance range is inversely proportional to frequency, it also becomes increasingly more difficult to measure very small reactances as the difference in dial settings for a given reactance is also inversely proportional to frequency, and in extreme cases the resolving power of the dial is approached or exceeded.

The improvements outlined in the previous paragraphs will make this bridge even more useful than was the previous model. The broadcast engineer measuring antennas and the research worker in the field will both find new features which will simplify their work.

— R. A. Soderman

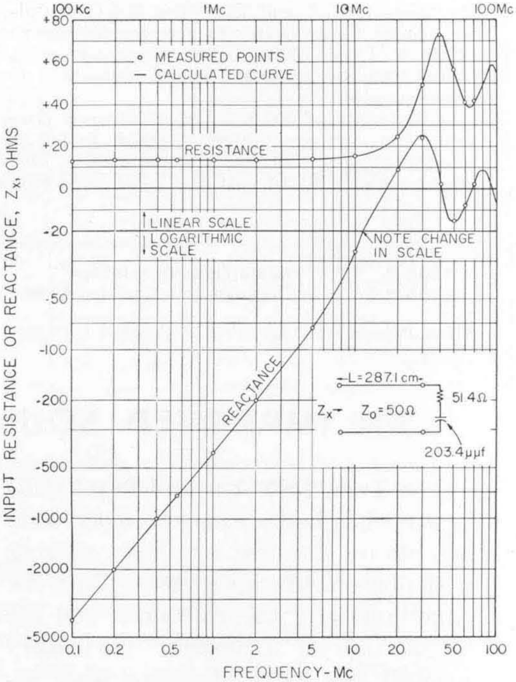


Figure 8. Resistance and reactance of a loaded transmission line as measured on the bridge (circles) and as calculated (curve).

SPECIFICATIONS

Frequency Range: 400 Kc to 60 Mc.

Reactance Range: ±5000Ω at 1 Mc. This range varies inversely as the frequency; and at other frequencies the dial reading must be divided by the frequency in megacycles.

Resistance Range: 0 to 1000Ω.

Accuracy: For reactance at frequencies up to 50 Mc, ± (2% + 1Ω + 0.0008 x R x f), where R is the measured resistance in ohms and f is the frequency in Mc.

For resistance, at frequencies up to 50 Mc,

$$\pm \left[1\% + 0.0024 f^2 \left(1 + \frac{R}{1000}\right) \% \pm \frac{10^{-4} X}{f} \Omega + 0.1\Omega \right]$$

subject to correction for residual parameters. R is the measured resistance in ohms, X is the measured reactance in ohms, and f is the frequency in Mc. At high frequencies, the correction depends upon the frequency and magnitude of the unknown resistance component. A chart from which the correction can be determined is given in the instruction book supplied with the bridge.

Satisfactory operation can be obtained at frequencies as low as 100 Kc and somewhat above 60 Mc with not quite as good accuracy as indicated above. The f^2 term is important only at frequencies above 10 Mc. The $1/f$ term is important only at very low frequencies when the resistance of a high-reactance, low-loss capacitor is measured.

Accessories Supplied: Two leads of different lengths for connecting the unknown impedance to the bridge terminals, two Type 874-R22 Coaxial Cables for connecting the generator and detector, and one Type 874-PB58 Panel Connector.

Other Accessories Required: Radio-frequency generator and detector. The Type 1330-A Bridge Oscillator and the Type 1211-A Unit Oscillator are satisfactory generators, as are the TYPE 1001-A and the TYPE 805-C Standard-Signal Generators. At frequencies above 50Mc a TYPE 1215-A Unit Oscillator or a TYPE 1021-AV Standard-Signal Generator is recommended.

A well-shielded communication receiver covering the desired frequency range makes a satisfactory detector. It is recommended that the receiver be fitted with the TYPE 874-PB58 Panel Connector or other coaxial connector to avoid leakage at the input connection.

Mounting: Welded aluminum cabinet supplied. A luggage-type carrying case is available separately and is recommended if the bridge is to be used as a portable field instrument.

Dimensions: 12½ x 9½ x 10¼ inches, over-all.

Net Weight: 23 pounds without carrying case; 29 pounds with carrying case.

Type		*Code Word*	*Price*
1606-A	**Radio Frequency Bridge***	CIGAR	**$535.00**
1606-P 1	**Luggage-type Carrying Case**	BILLY	**$15.00**

*U. S. Patents Nos. 2,125,816; 2,548,457; and 2,376,394

AN IMPROVED SOUND-LEVEL CALIBRATOR

The TYPE 1552-A Sound-Level Calibrator [1] has had an unexpectedly wide acceptance and use by those working with noise-measuring systems. With the combination of this calibrator and the TYPE 1307-A Transistor Oscillator,[2] over-all acoustic calibrations of noise-measuring systems are as simply and easily performed as electrical tests on the amplifiers and meters.

[1] E. E. Gross, "An Acoustic Calibrator for the Sound Level Meter," *General Radio Experimenter*, December, 1949.

[2] Arnold Peterson, "A Pocket-size Transistor Oscillator for Audio Frequency Testing," *General Radio Experimenter*, August, 1954.

The use of this calibrator in noisy environments is limited by its 85 db maximum output level imposed by distortion in the transducer. For successful operation, therefore, the maximum background noise level is 75 db. While this is satisfactory for a majority of uses, it may be difficult or inconvenient in industrial noise surveys to find background levels as low as 75 db. A further complication results from the acoustic resonances within the calibrator, which may amplify frequencies present in the background, so that an actual background level of only 75 db may be effectively increased as much as 10 db.

To effect an improvement it was necessary to find a small transducer unit as rugged and stable as the one being used and yet capable of producing much higher sound levels without distortion. Long-period tests were conducted on a number of different types, and the unit finally chosen is a modification of the Shure Brothers Model R-5 Controlled-Reluctance Microphone Cartridge.[3] This transducer, which can produce levels in excess of 100 db with no greater input than that required by

[3] B. B. Bauer, U. S. Patent 2,454,425, Nov., 1948.

Figure 1. View of the Type 1552-B Sound-Level Calibrator, installed on the Type 1551-A Sound-Level Meter and driven by the Type 1307-A Transistor Oscillator.

its predecessor, has been incorporated in the new Type 1552-B Sound-Level Calibrator. The view of Figure 1 shows the new calibrator, which is quite similar in external appearance to the previous model. The interior mechanical and acoustical system, however, has been completely redesigned to obtain a better frequency characteristic. This, together with the higher output from the new calibrator, is shown in Figure 2.

A minor annoyance that has been eliminated in the design of the new calibrator is the frequency shift in the Type 1307-A Transistor Oscillator caused by the reactive input impedance of the old Type 1552-A.

The new calibrator can be used on all the usual sound-level meter microphones and on a number of supplementary microphones, without the need for special adaptors. Table 1 is a list of these microphones.

On all microphones in Table 1 except the BA-120 as installed in the Type 1555-A Sound Survey Meter and the now obsolete BR2S, the calibrator makes a good acoustic seal so that the background level is actually attenuated when a calibration is made. This feature coupled with the high level produced by the calibrator insures that a good

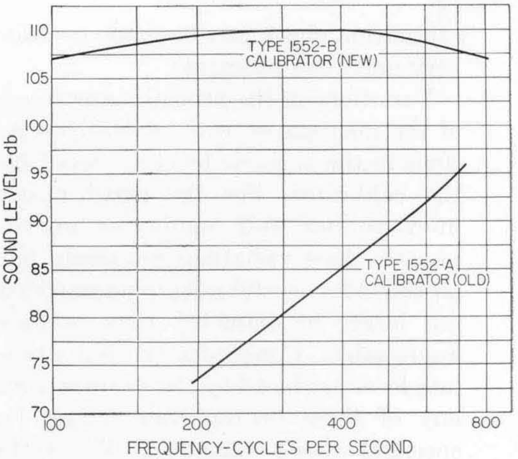


Figure 2. Output characteristics of the new and old models of the calibrator.

TABLE 1

Microphone	*Where Used*
Shure Brothers Type 9898	(G R Type 759-310 supplied on Type 1551-A Sound Level Meter & 759-B Sound Level Meter)
Brush Type BA-120	(As used in G R Type 1555-A Sound Survey Meter)
Brush Type BR2S	(Used on early G R Type 759-A Sound Level Meter)
Altec Type 633-A	(Supplied with G R Type 759-P25 Dynamic Microphone Assembly)
Shure Brothers Type 98B99	(New-type crystal microphone. Not yet available in production quantities [4])
Altec 21-BR Types	(Type 21-BR-150 and Type 21-BR-180 supplied with G R Type 1551-P1L and Type 1551-P1-H Condenser Microphone Systems [5])
Western Electric Type 640-AA	(Laboratory Standard Condenser Microphone [6])
Kellogg Microphone	(Laboratory Standard Condenser Microphone [7])
Massa Type M-141-B	(High Level Crystal Microphone [5])

[4] John Meddill, "A Miniature Piezo Electric Microphone." *Transactions of the I.R.E. Professional Group on Audio*, Vol. AU 1, No. 6, November-December, 1953, pp. 7–10.

[5] Arnold Peterson, "Sound Measurements at Very High Levels," *General Radio Experimenter*, September, 1954.

[6] M. S. Hawley, "The Condenser Microphone as an Acoustic Standard," *Bell Laboratories Record*, Vol. XXXIII, No. 1, January, 1955, pp. 6–10.

[7] J. F. Houdek, Jr., "A Stable Laboratory Standard Condenser Microphone," *Journal of the Audio Engineering Society*, Vol. 2, No. 4, October, 1954, pp. 234–237.

calibration check can be made even in very noisy environments.

Variations in the acoustic impedance of the microphone will result in variations in the acoustic level produced by the calibrator. For the small newer microphones and condenser microphones, these variations are small, but on the older crystal microphones which are larger in diameter, they become appreciable. Consequently, the absolute level produced by the calibrator on any of these microphones cannot be specified closer than ±1 db. Tests indicate that the stability of the calibrator is excellent, and so whatever level is produced at a given microphone should be reproduced within a few tenths of a db over long periods of time.

The calibrator has been designed to fit laboratory standard condenser microphones,[6, 7] and hence its accuracy can be checked against these standards. In addition, it can be used as a transfer device between the laboratory standard and a group of less stable working microphones.

Whether used as a working standard or as a stable transfer device in connection with a standard microphone, the new TYPE 1552-B Sound-Level Calibrator, because of its higher level, its flatter frequency response, and its adaptability to a number of different microphones, is a valuable aid to standardization in acoustic measurements.

— E. E. GROSS

SPECIFICATIONS

Input: 2.0 volts, 400 cycles; total harmonics must not exceed 5%.

Output: When in position on the 9898-type microphone used on TYPES 1551-A and 759-B Sound-Level Meters, the calibrator produces a sound pressure of 110±1 db (above a reference level of 0.0002 microbar) at the microphone diaphragm for rated input as specified above.

Terminals: TYPE 938-W Binding Posts.

Accessories Required: 400-cycle source, with output control and voltmeter. The TYPE 1307-A Transistor Oscillator is recommended.

Dimensions: (Length) 4½ x (diameter) 2½ inches, over-all.

Net Weight: 14 ounces.

Type		*Code Word*	*Price*
1552-B	**Sound-Level Calibrator**	NATTY	**$45.00**

SUMMER CLOSING

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

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

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

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

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PRINTED IN U.S.A.

the GENERAL RADIO Experimenter

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VOLUME 30 No. 2 JULY, 1955

THE TYPE 1603-A Z-Y BRIDGE

A New Approach to Audio-Frequency Impedance Measurement

Also IN THIS ISSUE

Anyone who has balanced an impedance bridge has probably experienced the frustration of trying to measure an impedance outside the range of the available bridge. The losses in the unknown may be too great, its impedance too high or too low; whatever the reason, the null balance cannot be obtained. Combining the unknown with another impedance element may be the solution; sometimes another instrument is available; but as often as not the measurement is abandoned without any useful information being obtained.

The new Type 1603-A Z-Y Bridge possesses the almost unbelievable characteristic that it can be balanced for *any* impedance connected to its terminals. From short circuit to open circuit, real or imaginary, positive or negative, a bridge balance can be obtained with ease. Clearly, high accuracy cannot be maintained over an infinite range. Nevertheless, good accuracy is obtained over a very wide range and, even in the ranges approaching zero impedance or zero admittance, the ability to get an answer of any kind is often very valuable.

The customary types of impedance bridges, Maxwell, Hay, Schering, etc., evaluate, more or less directly, the inductance or capacitance of an unknown

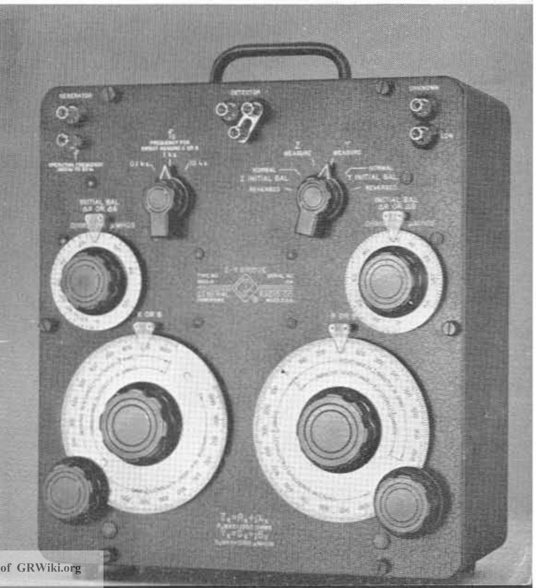


Figure 1. Panel view of the Type 1603-A Z-Y Bridge.

circuit element together with its resistance, Q, or dissipation factor. Determination of the corresponding reactance or susceptance values of the unknown then requires a computation in terms of the angular frequency ω.

The new bridge is designed for the audio-frequency range, nominally from 20 cycles to 20 kilocycles. It measures directly the quadrature components of a complex impedance $Z = R + jX$, or a complex admittance $Y = G + jB$. The unknown Z or Y may lie in any of the four quadrants of the complex plane since this bridge can measure both *positive* and *negative* values of R and G as well as X and B.

The basic circuit is the familiar resistance-capacitance bridge but is used here in a manner which is believed to represent an entirely new approach to the impedance measurement problem at audio frequencies. It bears, however, a family resemblance to the radio-frequency bridge described by Sinclair.[1,2]

Theory of the Bridge Network

The Z-Y bridge employs a substitution technique whereby an initial balance, without the unknown element, is followed by a final balance with the unknown in circuit. The difference in setting of the controls between these two balances measures the complex components of the unknown. Bridge balance is attained by the adjustment of a pair of resistive elements, one in each of two opposite bridge arms.

Figure 2 shows the basic bridge network in which the balancing controls are the rheostats R_p, calibrated in ohms of resistance, and G_a, calibrated in mhos of conductance. If R_{p1} and G_{a1} are their initial balance values, the equations for this preliminary balance are:

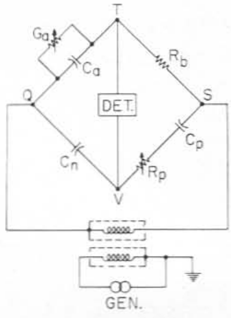


Figure 2. Basic bridge network.

$$R_{p1}C_n = R_bC_a \qquad (1)$$

$$G_{a1}R_bC_p = C_n \qquad (2)$$

It will be seen that this initial balance is independent of frequency and, furthermore, will have no sliding zero, since neither of the balancing controls occurs in both equations.

For measuring its impedance, the unknown ($Z = R_x + jX_x$) is inserted in series into the P arm of the bridge between R_p and the bridge vertex V. The final bridge balance then yields the new values R_{p2} and G_{a2}. It follows that the unknown resistance is given by:

$$R_x = R_{p1} - R_{p2} = \delta R_p \qquad (3)$$

at all frequencies. Note that R_x can be negative if R_{p2} exceeds R_{p1}. The unknown reactance

$$X_x = K(G_{a1} - G_{a2}) = K(\delta G_a) \qquad (4)$$

where the bridge constant

$$K = \frac{R_b}{\omega C_n} \qquad (5)$$

The unknown reactance is inductive if G_a is decreased in the final balance, or capacitive if G_a is increased.

For measuring its admittance, the unknown ($Y = G_x + jB_x$) is connected across the A arm of the bridge in parallel

[1] Sinclair, D. B., "A Radio-Frequency Bridge for Impedance Measurements from 400 Kilocycles to 60 Megacycles," *Proc. IRE*, Vol. 28, p. 497, November, 1940.
[2] Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Megacycles," *General Radio Experimenter*, Vol. XVII, No. 3, August, 1942.

with G_a and C_a. The final balance yields the new values G_{a3} and R_{p3} so that the unknown conductance:

$$G_x = G_{a1} - G_{a3} = \delta G_a \qquad (6)$$

at all frequencies and can be negative if G_{a3} exceeds G_{a1}. The unknown susceptance

$$B_x = \frac{R_{p3} - R_{p1}}{\mathrm{K}} = \frac{\delta R_p}{\mathrm{K}} \qquad (7)$$

is inductive if R_p decreases or capacitive if R_p increases in the final balance.

Note that in the two types of measurement the functions of the two balance controls are transposed. In the measurement of Z, the change in R_p gives directly the real component R_x, and the change in G_a determines the imaginary component X_x, while in the measurement of Y, the change in R_p determines the imaginary component B_x and the change in G_a gives directly the real component G_x.

A given scale on the R_p control can obviously be made direct reading in both R_x and B_x by the proper choice of the bridge constant, K, Equation (5). Similarly the G_a control can be made direct reading in both G_x and X_x. Inspection of the equations shows that, if these common dial scales are to be calibrated in ohms and micromhos, the required value of K is 10^6. If *complete* coverage is desired, it follows that the resistance range must be the reciprocal of the conductance range. In the Type 1603-A Z-Y Bridge, K equals 10^6, and identical ranges of 1000 ohms and 1000 μmhos have been chosen for the complex parameters of the unknown. To permit measurement of positive and negative values of R_x G_x, X_x and B_x, initial balance must occur at mid-range of both control scales.

From equation (5) it is seen that the bridge constant, K, is a function of frequency. By means of a three-position switch, the fixed parameters of the bridge network are selected to keep each of the products R_bC_a and R_bC_p constant and, simultaneously, to give K a value of 10^6 for any one of three convenient reference frequencies: $f_o = 100$ c, 1 kc or 10 kc. When the bridge is operated at the corresponding reference frequency, the dial scale for the imaginary component will be direct reading in ohms or μmhos. The R and G scales are direct-reading at *any* frequency.

When the operating frequency, f, differs from the selected reference frequency, f_o, the imaginary components are given by:

$$X_x \text{ (in ohms)} = \frac{f_o}{f} \; (\delta G_a \text{ in } \mu\text{mhos}) \qquad (8)$$

$$B_x \text{ (in } \mu\text{mhos)} = \frac{f}{f_o} \; (\delta R_p \text{ in ohms}) \qquad (9)$$

A balance of this bridge can be obtained in terms of *impedance* at any given frequency, f, if R_x and $X_x\left(\frac{f}{f_o}\right)$ are *both* below 1000 ohms. If either of these quantities exceeds 1000 ohms, an *impedance* balance is impossible. However, by connecting the unknown in parallel in the A arm, an *admittance* balance can be obtained, as the following simple consideration will show. If either component of the complex impedance

$$R_x \pm jX_x\left(\frac{f}{f_o}\right)$$

exceeds 1000 ohms, the scalar value of this impedance must exceed 1000 ohms, and the scalar value of the corresponding complex admittance, as well as each of its components, must be less than 1000 μmhos.

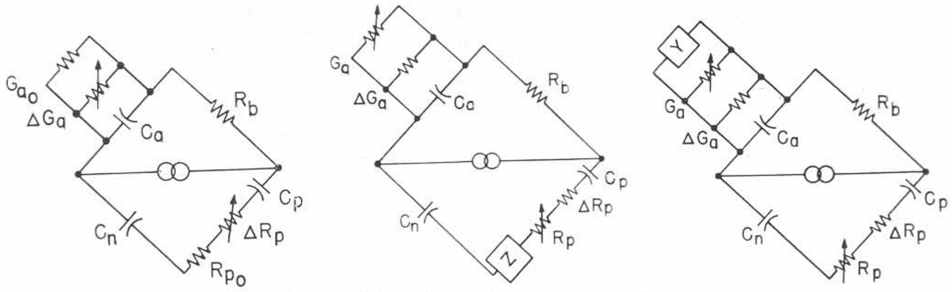


Figure 3. Normal operation of the Z-Y Bridge

Figure 3a. Initial balance obtained with controls ΔG_a and ΔR_p.

Figure 3b. Measurement of impedance. Final balance obtained with controls G_a and R_p.

Figure 3c. Measurement of admittance. Final balance obtained with controls G_a and R_p.

Conversely if *either* of the quadrature components G_x or $B_x\left(\frac{f_o}{f}\right)$ exceeds 1000 μmhos, an *admittance* balance is impossible, but an *impedance* balance can be made.

Thus either a Z or a Y balance is always possible and we have a truly universal bridge with an infinite range. The familiar equations for translating impedance to admittance components, or vice versa, can, of course, be used if desired.

In a given impedance balance it will be seen from Equation (8) that, if δG_a turns out to be less than 100 μmhos when f_o is 1 or 10 kc, a shift to the next smaller value of f_o will increase the required δG_a ten fold and thereby enhance the precision with which the reactance, X_x, is evaluated. Similarly, in a given admittance balance, Equation (9), if δR_p is less than 100 ohms when f_o is 100 c or 1 kc, a shift to the next larger value of f_o will increase the precision with which the susceptance, B_x, can be measured.

Conversely, an increase in f_o, if possible, may serve to bring within limits an "off-scale" value of X_x, while a decrease of f_o, if possible, may bring within limits an "off-scale" value of B_x.

Under these conditions, the f_o selector switch functions, in effect, as a multiplier for the X or B scale ranges, but *not* for the R or G scale ranges which are fixed at 1000 units each for all values of both f and f_o.

Operating Features

The user will appreciate the convenience of zero-centered scales on the two balancing controls which, in the final balance, read directly the values of δR_p and δG_a, and eliminate the subtraction indicated in the equations.

Each balance control consists of two separate rheostats. There are two *main* controls designated as G_a and R_p in Figure 3. These have identical linear scales, each zero-centered and calibrated to ± 1050 units in each direction to provide some desirable overlap. They are preset to their respective mid-scale values G_{ao} and R_{po} prior to making the initial balance with the two auxiliary controls ΔG_a and ΔR_p. Final balance is then made with the two main dials, which indicate directly the values of R_x (or G_x) and δG_a for Equation (8) (or δR_p for Equation (9)). The frequency ratios in these equations are indicated on the main dials.

In operation designated as *normal*, during the initial balance the two main control rheostats are removed from the circuit by switching and are replaced by two fixed resistors duplicating their mid-scale values G_{ao} and R_{po}, thus avoiding a preliminary centering of the main dials. This feature is a great convenience in making measurements over a range of frequency, since a quick readjustment of the initial balance can be made on the auxiliary dials for each new frequency.

If the Z or Y components of the unknown produce only small main dial displacements (readable with limited precision) in the final balance, a *reversed* operation technique can be used. In this case *all four* balance controls are in the circuit during the initial balance, which is made with the two main controls after the two auxiliary controls have been set to give the desired range of measurement. The final balance is then made solely on the two auxiliary controls whose incremental displacements, on expanded scales, permit more precise measurements.

For this purpose, the auxiliary dials are calibrated in the same units as the main dials and have full scale ranges of 120 units for ΔG_a and 140 units for ΔR_p. They are purposely made non-linear to permit maximum precision in the measurement of a few ohms or a few micromhos.

By selecting the appropriate arrangement of the detector terminals of the bridge, the operator may measure: (1) the *grounded* Z or Y value of the unknown with one terminal grounded and the ground capacitance of its high terminal in parallel with the unknown element, (2) the *direct* Z or Y value with the ground capacitances of both terminals removed, or (3) the *balanced* value of Z or Y with both ground capacitances of the floating unknown element existing in delta across it. This valuable feature is not possessed by many types of impedance bridges.

The generator is isolated from the bridge network by an internal shielded transformer. (Fig. 2.) A similar external transformer (not provided) is required for the detector input if the balanced value of the unknown is desired. The Type 578 Transformer is recommended.

Figure 1 shows the panel arrangement of this bridge. The two G_a controls are on the left and the two R_p controls are on the right. Switching is arranged for maximum convenience, which permits the unknown to remain

Figure 4. Impedance components of "black box" as a function of frequency.

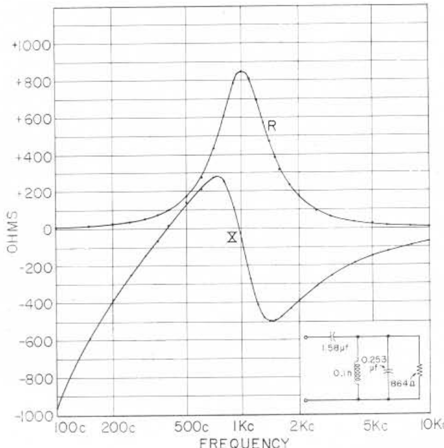
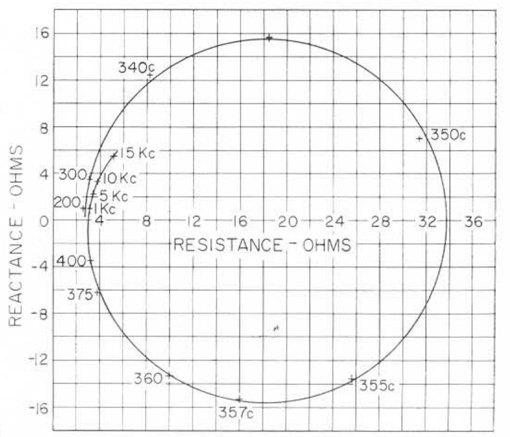


Figure 5. Reactance vs. resistance for a typical loud speaker.



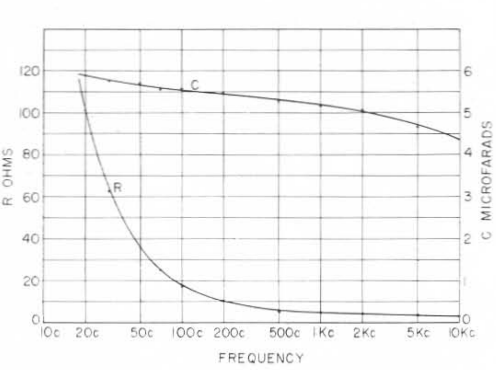


Figure 6. Impedance parameters of an electrolytic capacitor.

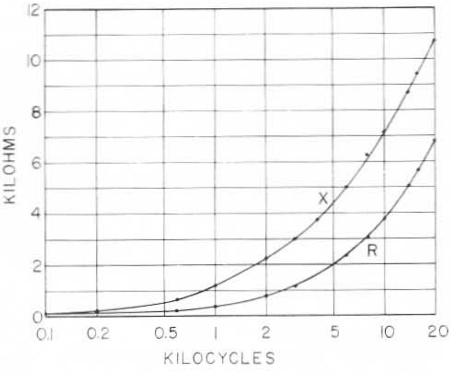


Figure 7. Impedance components of tape recorder head as a function of frequency.

attached to a single pair of terminals at all times. The function of the f_o selector switch (upper left on panel) has already been described. A six-position switch (upper right panel) provides for (1) normal initial, (2) reversed initial and (3) final balance for either Z or Y measurements. It disconnects the non-grounded terminal of the unknown for all initial balances. In addition, it shifts the bridge position of the unknown to permit Z or Y measurements, keeping the same unknown terminal grounded in all positions.

Residual Errors

Any impedance bridge is subject to certain residual errors because its resistive components cannot be made completely non-reactive, and its reactive components cannot be made to have zero losses. Furthermore, stray ground capacitance exists at each vertex of the bridge which is not directly grounded. This capacitance is not significant, of course, if the opposite vertex is grounded.

In this Z-Y bridge, see Figure 2, the bridge vertex V is grounded for impedance measurements, while the bridge vertex T is grounded for admittance measurements. Hence the residual ground capacitance at the vertex S appears across the P arm for Z measurements and across the B arm for Y measurements. To neutralize this capacitance, a small voltage of appropriate phase and magnitude is introduced at this junction S. The transformer capacitance and the ground capacitance of the vertex Q are in parallel with either C_a or C_n, where they are insignificant.

Other significant residual impedances are the small inductances of the windings of the two main rheostats. These have been neutralized at mid-scale and at the extreme scale limits by placing appropriate capacitors across each half of these rheostat windings. The remaining (reduced) errors reach a maximum at the ± 500 scale points. Correction data, significant only at high frequencies, are supplied.

The over-all accuracy of measurement depends not only on the influence of bridge residuals but also upon the resolution of the control dials and on the sensitivity of the null detector. Since the bridge constant K is a function of frequency, it should be noted that the absolute values of a measured X_x or B_x, but not R_x or G_x, depend directly upon the accuracy with which the frequency, f, of the generator is known. Nominal accuracy of the bridge is $\pm 1\,\%$.

APPLICATIONS

This new and versatile bridge is simple, convenient and rapid in operation and should find many useful applications in addition to the obvious measurement of R, L and C components. Among these are:

A. The Typical "Black Box" Problem

The two-terminal circuit network, containing a resistor, an inductor and two capacitors, was measured as an impedance from 100 c to 10 kc. Figure 4 shows the variation of R and X with frequency.

B. Analysis of Electro-Acoustic Transducers

Figure 5 shows the unclamped impedance circle for a small 2-ohm, 2-inch loud speaker measured directly, without a transformer, and demonstrates a major acoustic resonance, without a baffle, at about 350 cycles.

C. LF Characteristics of Electrolytic Capacitors

Measured values for a small electrolytic capacitor, when translated into series resistance and capacitance, Figure 6, show the progressive drop of C with increasing f and the rapid rise in R below 400 cycles.

D. Tests for Linearity of Components

A frequency run of a tape recorder head, Figure 7, showed it to be nonresonant at least up to 20 kc.

E. Resonant Frequencies of Inductors and Transformers

Figure 8 shows the susceptance variation of a 5 henry inductor with increasing frequency. This inductor first became capacitive at f_1, reverted to inductive at f_2, and became capacitive again at f_3, which is not an exact harmonic of f_1.

F. Transformer Parameters

The open and short-circuited impedance of transformers can be measured thereby yielding leakage reactance, self and mutual inductance, and coefficient of coupling; for example, this bridge has been used to measure the leakage reactance of Variac® autotransformers.

G. Audio Transmission Networks

The input and output impedance of filters and other audio frequency trans-

Figure 8. Susceptance variation of a 5-henry inductor at frequencies where distributed cpacitance produces resonance effects.

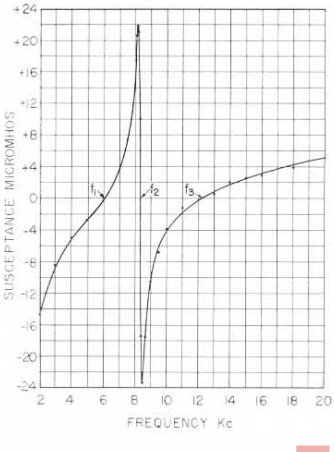
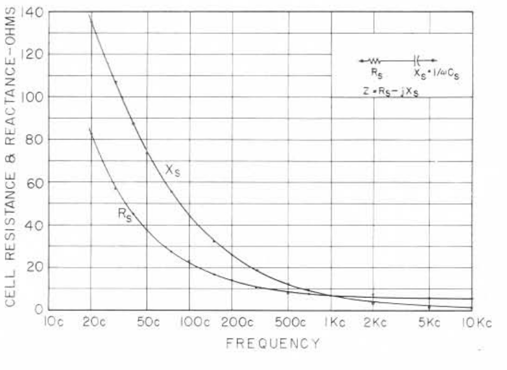


Figure 9. Impedance components of a Balsbaugh cell (110$\mu\mu$f empty) filled with tap water. Since the electrodes of this particular cell were not designed for use with water, the data are not indicative of the actual constants of the water, but are presented here only as an example of this type of measurement.



mission networks, together with their complex characteristic impedance, can be obtained.

H. Impedance of Batteries

The internal impedance of batteries can be measured provided that their resistance is less than one kilohm.

I. Conductivity of Liquids

This bridge should be particularly useful for measuring the a-c conductivity of electrolytic solutions. Irrespective of dielectric constant, the reactive component of the test cell impedance can be balanced. Figure 9 shows data taken on tap water using a Balsbaugh cell.

J. Electro-Chemical Research

Circular arc plots of solids or liquids having lossy polarizations in the audio-frequency range can be obtained. Data that have hitherto been difficult to procure in this region are now easily taken.

K. Feedback Loops

The ability to measure a negative resistance with this bridge is illustrated by the data in Figure 10 which show the variation, with frequency, of the input impedance of an amplifier with cathode follower network.

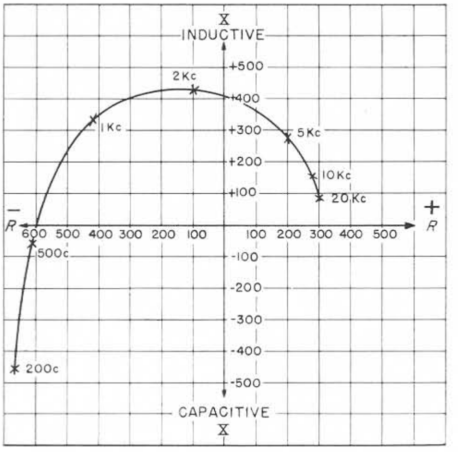


Figure 10. Input impedance of a feedback circuit showing negative resistance characteristic.

— Ivan G. Easton

— Horatio W. Lamson

Note: The circuit and method of measurement for this bridge was devised by Ivan G. Easton, Administrative Engineer. Horatio W. Lamson, Engineer, collaborated in the final design. — Editor

SPECIFICATIONS

Frequency Range: 20 cycles to 20 kc.

Impedance and Admittance Range: If the absolute resistance is less than 1000 ohms and the absolute reactance is less than $1000\,\frac{f_o}{f}$ ohms, the unknown is measured as an impedance. If the absolute conductance is less than 1000 micromhos and the absolute susceptance is less than $1000\,\frac{f}{f_o}$ micromhos, the unknown is measured as an admittance. Under certain limited conditions, a choice of Z or Y measurements is possible.

Accuracy: For real components, R or G: $\pm(1\% + [2$ ohms or 2 micromhos$])$ for the main dials; components of less than about 100 ohms (or 100 micromhos) can be measured on the auxiliary dials within $\pm(1\% + [0.2$ ohm or 0.2 micromho$])$. For imaginary component, X or B: $\pm\left(1\% + \left[\frac{2f_o}{f}\text{ohm or }\frac{2f}{f_o}\text{micromho}\right]\right)$ for the main dials; $\pm\left(1\% + \left[0.2\frac{f_o}{f}\text{ ohm or }0.2\frac{f}{f_o}\text{ micromho}\right]\right)$ for the auxiliary dials. To obtain this accuracy in the measurement of small quadrature components at the higher frequencies, correction data, supplied in the operating instructions, must be applied. The absolute measurement of X and B, but not R and G, involves the frequency error of the exciting generator.

Maximum Applied Voltage: 130 volts rms.

Accessories Required: A calibrated oscillator or other suitable a-c generator, and a null detector. The Type 1210-B Unit Oscillator and the Type 1212-A Unit Null Detector are recommended.

Accessories Supplied: 2 Type 274-NCO Shielded Cables, for connections to generator and detector.

Mounting: Aluminum cabinet and panel. Black crackle finish. Carrying handle provided.

Dimensions: Panel: (Width) 12½ × (height) 13½ × (depth) 8½ inches, over-all.

Net Weight: 21½ pounds.

Type		*Code Word*	*Price*
1603-A	**Z-Y Bridge**	CATER	**$335.00**

NEW PULSE AMPLIFIER INCREASES UTILITY OF UNIT PULSER

Designed primarily as a companion instrument for the Type 1217-A [1] Unit Pulser, the Type 1219-A Unit Pulse Amplifier offers a specific solution to the problem of producing pulses with many different characteristics of duration, duty ratio, and impedance level at higher power levels. In combination, the Unit Pulser and Unit Pulse Amplifier constitute a pulse generator approaching the wide range of durations and repetition rates characteristic of the Unit Pulser, but with the power-output characteristics usually associated with more expensive and specialized pulse generators designed to fit limited fields of application. Through the economies of standardized unit design, this versatile combination is lower in price than many narrow range pulsers designed for medium power output.

When it is driven by any available source of either positive or negative pulses, the Unit Pulse Amplifier will produce pulses of current with magnitudes up to 600 ma. This pulse of current can drive internal loads to produce either positive or negative voltage pulses, or can be used to drive a load external to the instrument. The internal load resistors are chosen to terminate a wide variety of transmission lines in their characteristic impedances.

[1] Frank, R. W., "Pulses in a Small Package", *General Radio Experimenter*, Vol. XXVIII, No. 10, March 1954, pp. 1–7.

General Design Considerations

The main objective in the design of the Type 1219-A Unit Pulse Amplifier was to obtain a maximum value of current into the load while retaining as many of the desirable wide ranges of duration and repetition rates of the Unit Pulser as possible. It was obvious at the outset that some maximum duty-ratio limitations had to be imposed if the amplifier were to produce a usefully high output power at moderate cost. A current between ½ and 1 ampere, giving an adequate voltage for direct deflection of a cathode-ray tube with the lowest normally encountered transmission-line terminating impedance, was desirable. General considerations of power supply design, economical packaging, heat dissipation, and vacuum-tube availability led to the final choice

Figure 1. Panel view of the Type 1219-A Unit Pulse Amplifier.

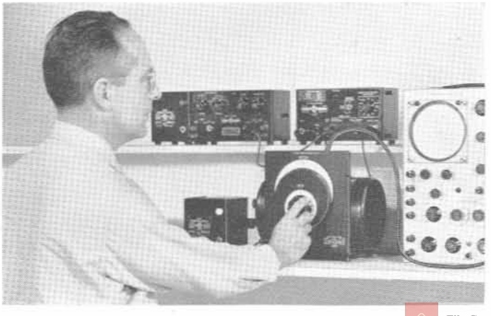
of peak current as 600 ma for very low duty ratios and 500 ma for duty ratios in the neighborhood of 0.1. The maximum duty ratio was set at 0.2 by plate dissipation in the output stage.

The auxiliary considerations of drive, bandwidth, and output circuit were chosen to make the unit as universally applicable as possible. Minimum output impedance was set at 50 ohms, and convenient values of output impedance, ranging up to 150 ohms for positive output pulses and 570 ohms for the negative pulses, were provided by internal switching. With pulses of long duration and low values of output impedance, a capacitive output coupling system would be bulky and would limit the output voltages. To overcome this problem, the output switching system was designed to permit both negative and positive output pulses to retain their d-c component relative to chassis ground.

For maximum flexibility, provision is made for both positive and negative driving pulses. A panel switch connects an amplifier-inverter stage into the circuit when positive drive is used. With this arrangement, it is possible to drive the amplifier from almost any pulse source.

To increase further the flexibility of the instrument, a switch has been provided which will reduce the output current by a factor of approximately 2.5,

Figure 2. The Unit Pulser and Unit Pulse Amplifier, as set up to pulse a Type 1218-A Unit Oscillator at 1400 megacycles.



so that it becomes possible to operate the instrument safely at duty ratios up to 0.5 with an output current of 200 ma. Two desirable features are gained by this mode of operation; it is possible to obtain a square-wave output, and the rise and decay times are improved.

As with any power amplifier where a maximum duty-ratio restriction is necessary to obtain the desired peak-power output, it is possible, by incorrect choice of the input time durations and repetition rates, to overload the output amplifier stage and therefore to damage it. The necessary protection for the output tubes and power supply is afforded by a 100-ma fuse mounted on the front panel. A neon panel lamp does double duty as pilot lamp and blown fuse indicator, since, in the event of a serious overload which will blow the fuse, the lamp is extinguished.

Circuits

The basic circuitry of the Unit Pulse Amplifier is conventional, as shown by the elementary schematic of Figure 3 and consists of a power stage using two paralleled 5763 power pentodes (V-3, V-4), a driver employing a TYPE 12AU7 (V-2), and, for positive input pulses, an amplifier-inverter stage (V-1). Two internal power supplies of 300 volts and 260 volts for the output tubes and drivers, respectively, are provided.

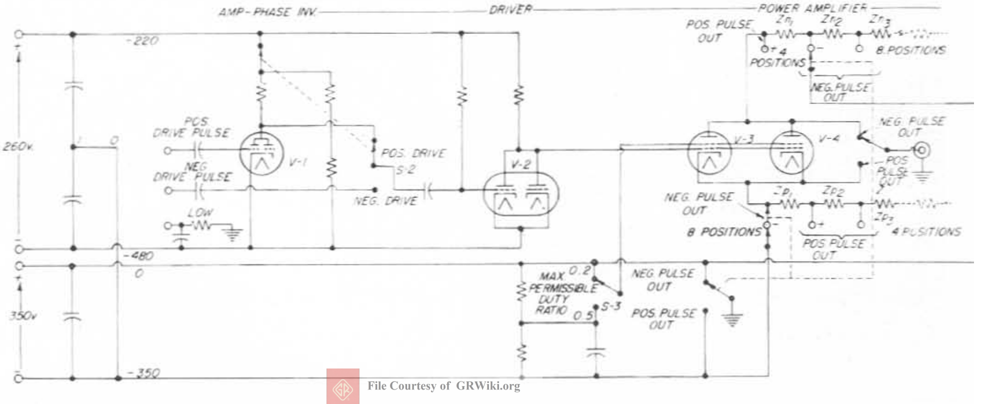
A single 12-position output switch, S-4, controls the internally available output impedances and output pulse polarity. Four positions of this switch select output pulses that are positive with respect to chassis ground at impedance levels of 50, 75, 100, and 150 ohms. In this class of operation the two output tubes are used as cathode followers, and their 300-volt power supply has its negative side on chassis ground. For pulses with negative polarity the remaining eight switch positions are used to provide internal loads with impedances ranging from 50 to approximately 570 ohms. The loads in this case are placed in the plate circuit of the 5763's, and the positive side of the 300-volt power supply is grounded to chassis. The output stage for negative pulses thus approaches a current source, and the output impedance is linear and independent of tube characteristics.

For negative pulse input, the input polarity switch connects the input terminals directly to the driver stage. In this use, the power amplifier is a two-stage unit and provides an output pulse of excellent shape (see Figure 4) in which the input pulse duration is faithfully reproduced. For a large-amplitude negative pulse, ultimate rise and decay times for the output stage are .050 and .030 μsec respectively. Pulses as brief as .050 μsec at the half-amplitude points have been faithfully reproduced. When the duty ratio switch is in the 0.5 position, the rise and decay times are improved to .030 and .020 μsec respectively (see Figure 7a).

The amplifier-inverter stage is connected to the input terminals and supplied with plate voltage when the input polarity switch is in the *Positive Input* position. This stage then provides a negative pulse to turn off the driver upon the application of a positive driving pulse. Some care must be exercised to preserve the good shape characteristics inherent in the driver-power amplifier system. An excessive positive driving amplitude will cause the output pulse to be stretched by up to 0.4 μsec and will cause a small hump of the order of 3% of the pulse amplitude to appear before the late transition (see Figure 7c).

Since the output system is direct-coupled, the input signals at the grid of the driver and amplifier must be applied through coupling capacitors. These signals must appear negative or positive with respect to the cathode potentials of either the driver or amplifier. If the input were applied relative to chassis ground rather than referenced to the negative supply, any noise or hum on this supply would add to the signal. This would unnecessarily complicate the design of the driver-power supply. Note that, in Figure 4, the input signals are referenced to the *driver supply* negative rather than to chassis ground by virtue of an insulated low input terminal. Best performance will always be obtained by floating the ground of the input system on this post. This does not preclude obtaining synchronizing

Figure 3. Elementary schematic circuit diagram of the Unit Pulse Amplifier.



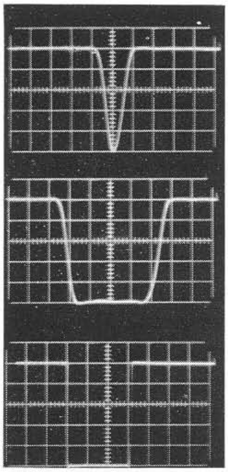
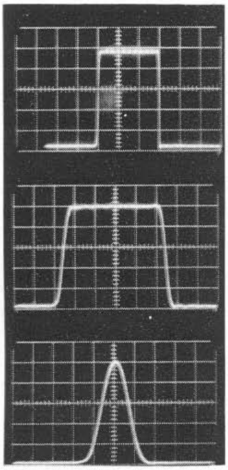


Figure 4
Negative output pulse

0.1μsec/cm P.R.F. = 10kc
50Ω 28 volts T_p = 0.1μsec

0.1μsec/cm P.R.F. = 10kc
50Ω 28 volts T_p = 0.5μsec

1μsec/cm P.R.F. = 10kc
50Ω 28 volts T_p = 3μsec

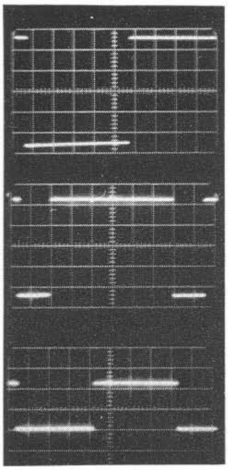


Positive output pulse

1μsec/cm P.R.F. = 10kc
50Ω 30 volts T_p = 3μsec

0.1μsec/cm P.R.F. = 10kc
50Ω 30 volts T_p = 0.5μsec

0.1μsec/cm P.R.F. = 10kc
50Ω 30 volts T_p = 0.12μsec



Negative output pulse

200μsec/cm P.R.F. = 200c
50Ω 25 volts T_p = 1000μsec
(Note slope of bottom)

133μsec/cm P.R.F. = 1kc
570Ω 270 volts T_p = 200μsec

1kc square wave
50Ω 10 volts

pulses, etc., from the driving source, since these signals are generally obtained through coupling circuits whose low-frequency impedance is negligible.

The two internal power supplies are of the full-wave-doubler variety, which make most efficient use of the power transformer copper and to which selenium rectifiers lend themselves so well. Large rectifier de-rating figures have been used to insure long life. Adequate filtering is provided by two-section R-C units for both driver and output supplies. The hum on the output pulse is less than 1%.

Some Notes on Operating Characteristics

In any specific use, careful consideration must be given to two important effects that are encountered with (1) pulses of high duty ratio and (2) pulses of long time duration. The characteristics of the TYPE 1219-A under these conditions are given in Figures 5 and 6 below.

Figure 5 shows the effect of high duty ratios on output current. This information is tabulated on the panel. The effect is due to power supply regulation, and it is an advantageous one because it permits a more economical use of the output tubes for the low duty ratios most commonly encountered. Without the protection of decreasing power supply voltage at higher duty ratios, either the range of duty ratios or the peak current at the lower ratios would have to be decreased.

Figure 6 shows the characteristics of the output pulse with regard to maximum permissible pulse durations for negative drive. Here the criterion selected was a droop of 10% in the "tube on" portion of the pulse. The ramp-off may be due to any one or a combination of three effects: (1) discharge of the internal power supply, (2) insufficient

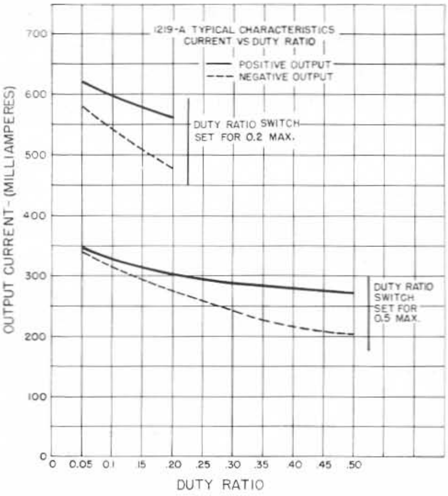


Figure 5. Effect of duty ratio on output current.

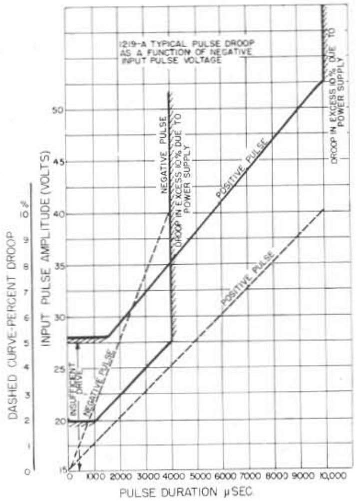


Figure 6. Output pulse characteristics as function of maximum permissible pulse duration.

driving amplitude which will cause the driver tube to come back on prematurely, or (3) a combination of low driving voltage with an external blocking capacitor in the driving pulse generator. Figure 6 shows that, with a driving voltage in excess of 27.5 volts, the first effect will predominate, and a ramp-off of 10% will be reached with an output pulse of 4000 μsec. The rate of ramp-off is very nearly linear so a 1000-μsec pulse will have a droop of 2.5% due to this effect, etc. (dotted curve). Interaction between the driver and main power supplies holds the droop for positive pulse outputs down, so that, with input amplitudes in excess of 55 volts, positive output pulses up to 10,000 μsec may be obtained. As the driving voltage is lowered below its maximum value, the effect due to discharge of the driver coupling circuit predominates, and the 10% ramp-off figure is reached sooner. For example, with only 25 volts available, the output pulse droops by 10% at 3000 μsec.

With positive input pulses, the driver stage supplies an adequate voltage to permit the maximum durations shown in Figure 6 to be reached.

Figure 7 illustrates two additional minor characteristics of the Pulse Amplifier which are of interest when the unit is used to produce brief pulses. The effects are time delay and a tendency for the input pulse to be stretched when the inverter-amplifier stage is overdriven by a positive input pulse. Figures 7, a and b, illustrate the time

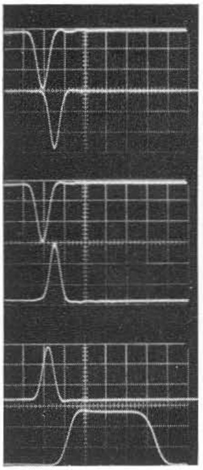


Figure 7
Time delay and overdrive effects

Input Neg. 50v 0.05μsec
Output Neg. 25v 50Ω 0.05μsec

Input Neg. 50v 0.05μsec
Output Pos. 20v 50Ω 0.05μsec

Input Pos. 50v 0.05μsec
Output Pos. 30v 50Ω 0.4μsec
(Note stretching caused by overdrive)

delay effect for both negative and positive outputs with a brief negative input pulse; the time delay through the Pulse Amplifier is of the order of 0.05 μsec. In Figure 7c, a high-amplitude positive pulse is used to overdrive the pulse input stage, and the output pulse is "stretched" by approximately 0.35 μsec. The stretching effect is reduced by reducing input amplitude.

— R. W. Frank

SPECIFICATIONS

Output Pulse: The open-circuit output pulse voltage is between 10 and 250 volts and is the product of the combination of impedance and available current listed below.

(1) Impedance:

a. Positive pulse: 50, 75, 100, 150 ohms, all ±10%

b. Negative pulse: 50, 75, 100, 150, 200, 250, 300 ohms, all ±10%; 570 ohms ±20% designed to permit *maximum* output voltage.

(2) Output Current: This quantity depends upon the position of the duty-ratio selector switch and upon the duty ratio.

DUTY RATIO	OUTPUT CURRENT (ma) POSITIVE PULSE DR Sw 0.2	POSITIVE PULSE DR Sw 0.5	NEGATIVE PULSE DR Sw 0.2	NEGATIVE PULSE DR Sw 0.5
0.05	620 ±10%	350 ±15%	575 ±10%	330 ±15%
0.1	580 ±10%	325 ±15%	550 ±10%	300 ±15%
0.2	550 ±10%	300 ±15%	475 ±10%	275 ±15%
0.5	—	250 ±15%	—	225 ±15%

(3) Transition Times: The transition times depend on the transition times, magnitude, and polarity of the input pulse, as well as on the settings of the output impedance, polarity, and duty-ratio switches. These characteristics are summarized in the table below.

(4) Maximum Pulse Duration: The maximum duration of the pulse depends only on the tolerable ramp-off during the "on" period. If 10% is chosen, then the maximum "on" period for positive pulses is 10 mμsec and for negative pulses 4 mμsec; with the Type 1217-A, the maximum for negative pulses is 1 mμsec, for positive pulses, 10 mμsec.

(5) Pulse Shape: Overshoot less than 5% of amplitude on any output switch position.

(6) Noise: Hum on the output pulse less than 1% of pulse amplitude.

(7) Input Pulse: The maximum duration of the output pulse is to some extent determined by the input pulse voltage, and tolerable droop.

Input	MAXIMUM DURATION TO 10% DROOP Positive Output	Negative Output
Negative 30 v	2000 μsec	4000 μsec
Negative 55 v	10,000	4000
Positive 10 v	10,000	6000

The droop is approximately linear, hence the

INPUT PULSE Polarity	Amplitude	Rise and Decay Time	OUTPUT CHARACTERISTIC DUTY RATIO Sw 0.2 Rise Time	DUTY RATIO Sw 0.2 Decay Time	DUTY RATIO Sw 0.5 Rise Time	DUTY RATIO Sw 0.5 Decay Time	OUTPUT Switch
Negative	30 v	2 mμsec	50 mμsec	30 mμsec	40 mμsec	20 mμsec	Negative, 50 Ω
Negative	30 v	50 mμsec	50	50	60	50	Negative, 50 Ω
			100	100	30	90	Negative, 570 Ω
			80	80	60	70	Positive, 50 Ω
			180	110	110	80	Positive, 150 Ω
Negative	50 v	1217-A Pulser	60	90	40	80	Negative, 50 Ω
			100	120	90	110	Negative, 570 Ω
			90	120	70	100	Positive, 50 Ω
			180	160	120	130	Positive, 150 Ω
Positive (Minimum necessary drive)	2.5 v	1217-A Pulser	60	240	40	160	Negative, 50 Ω
			110	240	80	160	Negative, 570 Ω
			90	180	90	120	Positive, 50 Ω
			180	240	130	160	Positive, 150 Ω
Positive (Pulse stretching 0.3 μsec)	25 v	1217-A Pulser	50	80	40	60	Negative, 50 Ω
			90	110	100	100	Negative, 570 Ω
			90	110	60	80	Positive, 50 Ω
			180	150	110	110	Positive, 150 Ω

maximum durations for 5% droop are ½ the above figures.

Input Impedance: Approximately 50 kilohms shunted by 30 $\mu\mu$f.

Power Supply: 105–125 volts, 50–60 cycles.

Input Power: 75 watts, full load, 115-volt line.

Dimensions: (Width) 10½ × (height) 5⅝ × (depth) 6¼ inches over-all. **Net Weight:** 8½ lbs.

Type		*Code Word*	*Price*
1219-A	**Unit Pulse Amplifier........................**	ACRID	**$175.00**

U. S. Patent 2,548,457

A REGULATED POWER SUPPLY FOR UNIT INSTRUMENTS

To provide the ultimate in performance from General Radio Unit Instruments, a voltage-regulated power unit, the Type 1201-A Unit Regulated Power Supply, is now available.

Although the Type 1203-A Unit Power Supply is adequate for all normal uses of Unit Instruments, there are applications where maximum stability of oscillator output amplitude and frequency is required, where amplifier hum level or pulse jitter must be minimized, or where local line voltage fluctuates so badly that regulation is a necessity. For these and other critical applications, the new regulated power unit is well suited.

The Type 1201-A Unit Regulated Power Supply is identical in size and external construction to the Type 1203-A Unit Power Supply, so that the two are completely interchangeable mechanically for the operation of Unit Instruments. The regulated unit, however, is capable of furnishing higher output current with greatly reduced ripple and noise.

The circuit, shown in Figure 2, is that of a conventional series regulator, using a 5651-type voltage reference tube and a high-gain cascode amplifier.

For critical applications, the use of the Type 1201-A Unit Regulated Power Supply will result in improved performance from GR Unit Instruments.

SPECIFICATIONS

High-Voltage Output:
Magnitude, 300 volts dc, ± 1%
Regulation, ± 0.5%
Current, 70 ma, max.
120-Cycle Ripple, 10 millivolts at full load

Heater Output: 6.3 volts, ac; 4 amp., max.; unregulated.

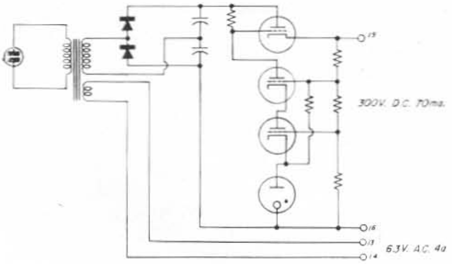
Input: 105 to 125 volts, 50 to 60 cycles, 100 watts.

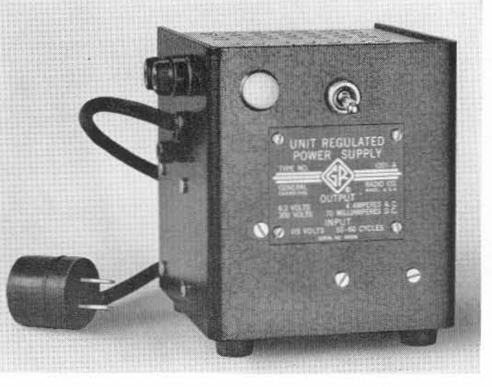
Tubes: 1 — 12AX7 1 — 6AV5GT 1 — 5651

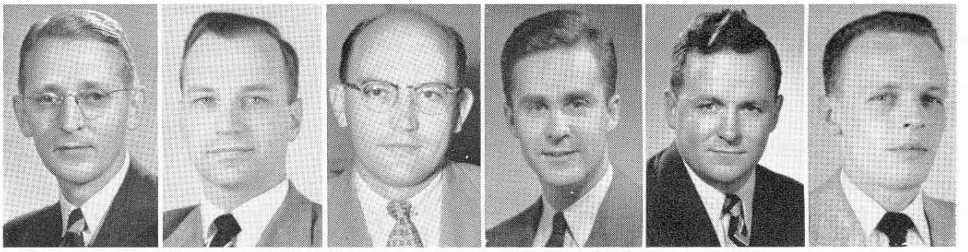
Dimensions: (Width) 5 × (height) 5¾ × (depth) 6¼ inches, over-all, not including power cord. **Net Weight:** 5 pounds.

Type		*Code Word*	*Price*
1201-A	**Unit Regulated Power Supply**	ASSET	**$80.00**

Figure 1 (right). Panel view of the Unit Regulated Power Supply. Figure 2 (below). Elementary schematic.







K. Adams W. M. Ihde R. E. Bard W. R. Thurston G. G. Ross C. W. Harrison

NEW PHILADELPHIA OFFICE

In order to give better service to our customers in the Philadelphia and Camden areas, General Radio has opened a new branch office at 1150 York Road, Abington, Pennsylvania. Mr. Kipling Adams, for nine years manager of the Chicago office, is now manager of the new Philadelphia office.

Mr. William M. Ihde, who has been associated with our Chicago office for five years, becomes manager of the Chicago office and will be assisted by Mr. Robert E. Bard, who has for the past three years been on our Cambridge Sales Engineering staff.

OTHER BRANCH OFFICE CHANGES

Mr. William R. Thurston, well known in the New York area as manager of our district office and as Chairman of the Northern New Jersey Section of the IRE, is returning to the home office at Cambridge to assume new responsibilities with the Sales Engineering group.

Mr. George G. Ross becomes the new manager of the New York office. He will be ably assisted by Mr. C. William Harrison, who for the past two years has been a sales engineer at Cambridge.

NEW DISTRIBUTOR FOR ISRAEL

We take pleasure in announcing the appointment of the Landseas Products Corporation, 39 Broadway, New York 6, New York, as our exclusive representative for Israel.

It is expected that we shall be able to render the best possible service to our friends in Israel through the good offices of the parent concern and its resident branch, the Landseas-Eastern Company, P. O. Box 2554, Tel Aviv, Israel.

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

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TELEPHONE: TRowbridge 6-4400

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PRINTED IN U.S.A.

the GENERAL RADIO Experimenter

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 30 No. 3 AUGUST, 1955

AN ACCURATE VOLTAGE DIVIDER FOR DC AND AUDIO FREQUENCIES

Also IN THIS ISSUE

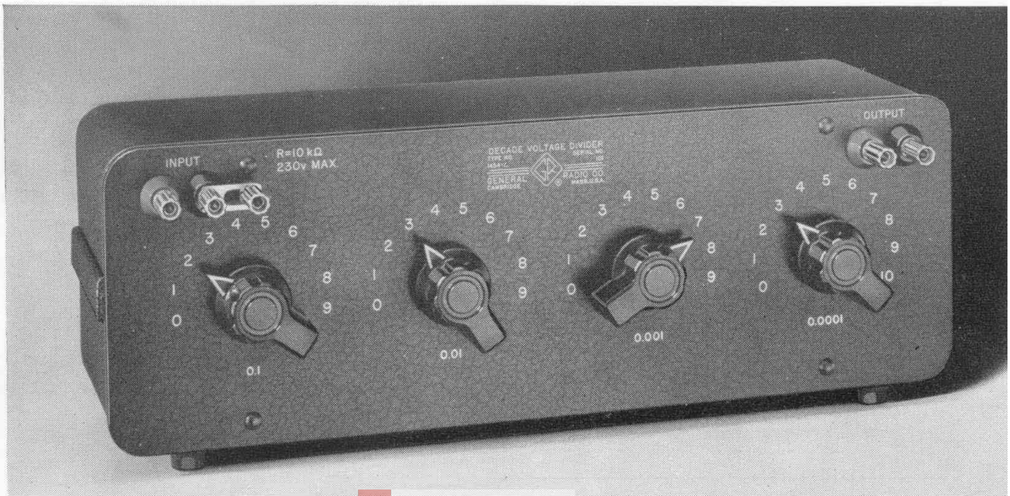
Page

An accurate decade voltage divider is one of the basic tools of the electrical laboratory. Among its many uses are the calibration of voltmeters, linearity measurements on continuously adjustable transformers and resistors, the measurement of gain and attenuation, and the precise measurement of the frequency response characteristics of audio-frequency networks.

The General Radio Company has been manufacturing this type of voltage divider for over 25 years. The latest model is the Type 1454-A Decade Voltage Divider, which has a higher accuracy than its predecessors and since it uses four decades of voltage division, rather than three, it also has a higher resolution. At dc, its accuracy is adequate for many measurements for which the slide-wire potentiometer is commonly used, while its equally good a-c performance extends its field of application to the entire audio-frequency range.

The new Voltage Divider, shown in Figure 1, has a constant input resistance of 10,000 ohms. The method of voltage division, which is attributed to Kelvin and Varley, is shown in the schematic diagram of Figure 2. There are eleven equal resistors comprising the first

Figure 1. Panel view of the Type 1454-A Decade Voltage Divider.



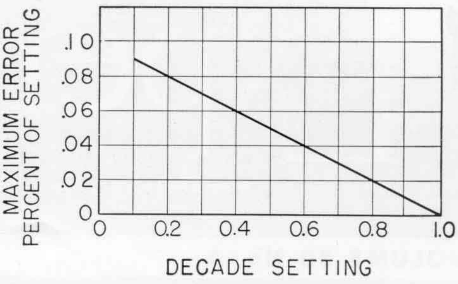


Figure 3. Maximum error as a function of scale setting.

decade. The next decade has resistors one-fifth the resistance of the first and bridges any pair of resistors of the first decade. Across the second decade is placed, therefore, one-tenth the potential of the input, and this increment may be chosen as any one of ten equal increments between zero and full voltage on the first decade. In a similar manner, the third decade has units one-fifth the value of the second and is bridged across two resistors of the eleven in the second decade. The fourth decade is a conventional ten-step voltage divider.

The construction of the Type 1454-A is very similar to that of the Type 1432[1] Decade Resistors except that the switching operation requires two switch arms insulated from each other. Both input and output terminals are insulated from ground, and a separate ground binding post is provided. The divider may thus be used in either a grounded or an ungrounded circuit, with the metal case usable as a grounded shield for either method of connection.

Accuracy Considerations

With fixed precision resistors in this voltage-divider circuit, extremely high accuracy of voltage division is obtained. Consider a single decade. At maximum output setting the error in voltage *division* is, by definition, *zero*. The possible error in division for a given setting, expressed as a percentage of that setting, increases as the setting is decreased. Figure 3 shows the linear nature of the variation of maximum error as a function of setting. Since the resistors are accurate to 0.05%, the maximum error is .09% at 0.1 setting. In terms of full-scale setting, which is a common method of expressing instrument errors and voltage-divider errors, the maximum error that can occur is ±.025%. This error can occur at mid-point, and the variation with setting is shown in Figure 4.

The values of Figure 3 and Figure 4, although indeed gratifyingly low, are very conservative. Whether the errors in adjustment of the values of the individual resistors are random or systematic, the error in voltage division will rarely approach the maximum figures cited. The fact that the division ratio depends on a large number of resistors reduces the error, on a statistical basis, when *random* errors of adjustment are considered. If *systematic* errors occur, their effects are greatly reduced in taking the ratio of two sets of resistance values. Consequently, actual errors will rarely exceed one-half the values indicated by Figures 3 and 4.

[1] Easton, I. G., "The New Type 1432 Decade Resistors," General Radio Experimenter, Vol. XXVI, No. 1, June, 1951.

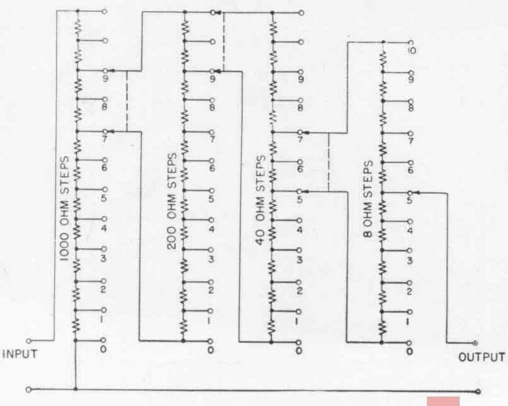


Figure 2. Schematic diagram showing the method of voltage division.

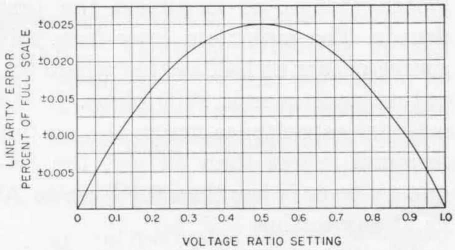


Figure 4. Maximum error in per cent of full-scale maximum setting.

Effect of Zero Resistance

With all decades set to zero, the output voltage of the divider should ideally be zero. Actually there will be some output caused by current flowing through the resistance of the wiring and the contact resistances at the switches, which are in series in the output circuit. Analysis of the circuit shows that the total voltage developed in the output circuit, for a four-dial divider, set at zero, is $E\left(\frac{7}{8}\right)\frac{R_c}{R_o}$ where E is the impressed input voltage, R_o the input resistance of the divider and R_c the contact and wiring resistance that may exist between the zero points of the successive switches. With the input resistance at 10,000 ohms and the zero resistance of the order of a few milliohms, it is clear that the residual output voltage, although less than a microvolt per volt of input, impairs the absolute accuracy of the smallest output step.

When the divider is used for d-c voltage division, potentials caused by thermo-electric[2] forces, contact potentials, electrolytic action, and the like can cause additional small errors. Conservative allowance for all these effects is made by including in the accuracy statement a fixed error of ±.000001 in ratio which is equivalent to ±1 microvolt per volt of input.

[2] All resistors are wound with resistance alloys having low thermal emf to copper.

Output Resistance

The decimal voltage division is the ratio of the open-circuit output voltage to the voltage impressed on input terminals, and the voltage divider is primarily intended for use with high impedance loads, as, for example, in null circuits where no current is drawn. For loads of finite impedance, it is necessary to know accurately the effective output impedance of the divider in order to calculate the actual voltage on the load, or to know the impedance approximately in order to estimate the reduction in voltage. To determine the ouput resistance of the resistive divider, it is helpful to consider first the output resistance of a simple divider system, as shown in Figure 5.

Analysis of the multiple-decade circuit of Figure 2 shows that the output resistance is the sum of the equivalent output resistances of the individual decades. For the purpose of the equivalent circuit of Figure 6, the potential of each decade must be taken as the sum of its setting plus that of the succeeding decades. This is best illustrated by a specific numerical example. Suppose the TYPE 1454-A (a 10,000-ohm divider) is set at .2373. The first resistor in the equivalent circuit is the output resistor of a simple 10,000-ohm divider set at .2373, the second resistance is that of a 1000-ohm divider set at .373, the third that of a 200-ohm divider set at .73 and finally a 40-ohm divider set at .3.

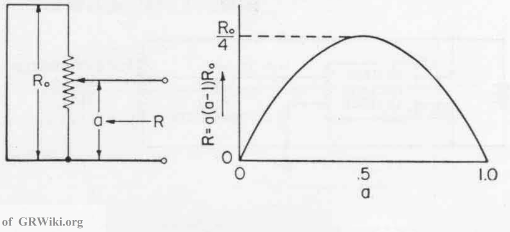


Figure 5. Output resistance characteristic of a simple voltage divider.

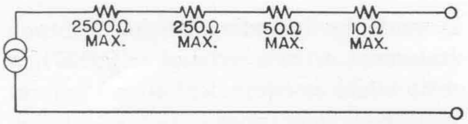


Figure 6. Equivalent circuit of a four-decade divider.

The corresponding resistances are 1809.9, 233.9, 39.4, and 8.4 or a total of 2091.6 ohms. The output voltage, of course, is .2373 times the input voltage. This calculation is cumbersome and, for estimating the approximate impedance, linear interpolation between points in Table I is usually adequate.

TABLE I

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	0	189	356	501	624	725	804	861	896	909
.1	900	1069	1216	1341	1444	1525	1584	1621	1636	1629
.2	1600	1749	1876	1981	2064	2125	2164	2181	2176	2149
.3	2100	2229	2336	2421	2484	2525	2544	2541	2516	2469
.4	2400	2509	2596	2661	2704	2725	2724	2701	2656	2589
.5	2500	2589	2656	2701	2724	2725	2704	2661	2596	2509
.6	2400	2469	2516	2541	2544	2525	2784	2421	2336	2229
.7	2100	2149	2176	2181	2164	2125	2064	1981	1876	1749
.8	1600	1629	1636	1621	1584	1525	1444	1341	2116	1069
.9	900	909	896	861	804	725	624	501	356	189

Frequency Response

No independent absolute method of checking the a-c response of a highly accurate divider such as the Type 1454-A is available. The performance can be deduced, however, from calculations based on the known parameters of the system and checked by measurements at frequencies sufficiently high to magnify the errors that occur.

The resistors have in themselves extremely low residual inductance and capacitance, and it can be shown that the significant factor in a-c performance is the shunt capacitance of wiring and switch frames as it affects the first decade. The maximum error from this source occurs at half setting where the output resistance is 2500 ohms. If the external capacitance across the output terminal is less than 50 $\mu\mu$f, the frequency error is less than 0.1% up to 20 kc at any setting.

At settings approaching zero, the inductance of the wiring introduces an error of the same nature as previously described for zero resistance. The total output loop inductance is approximately 0.7 μh. At 10 kilocycles, this produces an output voltage at zero setting equal to one microvolt per volt of input. This error increases directly with frequency.

USES

The high accuracy as detailed above makes the Type 1454-A Decade Voltage Divider useful for a wide variety of laboratory measurements. A number of suggested applications are outlined herewith.

Calibration of Vacuum-Tube Voltmeters

The simple circuit shown in Figure 8 has been adopted in the Engineering Labs at General Radio for the periodic checking of all a-c and d-c vacuum-tube voltmeters. The standard meter is relied upon for only a calibration value near its full-scale reading, where best accuracy is obtained.

D-C Null Method for Linearity Checking

A voltage comparison method is widely used for checking the linearity of wire-wound potentiometers. A simple

Figure 7. Voltage divider in null circuit for linearity tests.

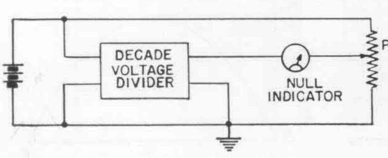
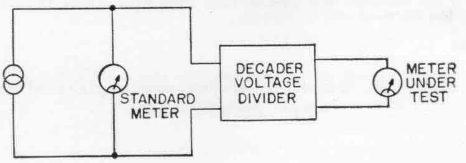


Figure 8. Circuit for calibration and test of vacuum-tube voltmeters.



schematic diagram of the method is shown in Figure 7. With the voltage divider adjusted for null indication, no current is drawn from the divider, and the open-circuit calibration is correct.

A-C Null Method

The null method of Figure 7 is equally applicable at power and audio frequencies although capacitive loading must be watched as a possible source of error. Even when the system is balanced to a null, current is still drawn by the ground capacitance of the null detector. By the use of shielding (for example, by using a TYPE 578 transformer), the location of the ground capacitance can be controlled and placed where it will be least harmful. In general, if the device under test has an impedance greater than 2500 ohms (the maximum output impedance of the voltage divider), the shielding should be arranged to place the ground capacitance across the divider output. On the other hand, if the device under test is low compared to 2500 ohms, less error will be introduced by shunting the capacitance across the output of the device.

Ungrounded Measurements

Greatest immunity from the effects of stray capacitance, both external to and within the divider, is obtained by operating ungrounded. This requires the use of shielded transformers both at input and at the null detector.

Generally speaking, at the very important frequencies of 400 and 1000 cycles, no difficulty should be encountered from stray capacitance if reasonable precautions are taken, and the accuracy of measurement be taken as the d-c accuracy.

Gain-Loss Measurements

Other important uses include the measurement of gain or loss in amplifiers, attenuators, filters, and other networks; and the determination of turns ratio in transformers.

— IVAN G. EASTON

SPECIFICATIONS

Voltage Ratio: .0001 to 1.0000 in steps of .000100.

Accuracy: ± (0.1% + .000001). All resistors are adjusted to within ± 0.05% of nominal values. The voltage ratio error will rarely exceed this figure, although at low settings of each decade, the error can theoretically approach ± 0.1%.

Frequency Characteristics: If the external capacitance placed across the output terminals is less than 50 μμf, the frequency error is less than 0.1% to 20 kc for any setting.

Input Impedance: 10,000 ohms. This value is engraved on the panel.

Output Impedance: Varies with output setting, depending primarily on the setting of the highest decade in use.

Maximum Input Voltage: 230 volts rms (or dc) for 40° Centigrade rise of resistors in the input decade. This value is engraved on the panel.

Resistance Units: Similar to TYPE 510. Unifilar on mica for two decades. Third and fourth decades are Ayrton-Perry on phenolic cards.

Temperature Coefficient: Of the individual resistors, less than + 0.002% per degree Centigrade. Since the voltage ratio is determined by the ratio of resistors of similar construction, the temperature coefficient of the voltage ratio is, for practical purposes, very nearly zero at normal room ambient temperatures and within the power rating of the box.

Terminals: Jack top binding posts with standard ¾-inch spacing at input and output. A separate ground post is provided, so that the divider circuit can be used grounded or ungrounded, with the shield grounded.

Mounting: Aluminum panel and cabinet.

Dimensions: (Length) 15¾ x (width) 5¼ x (height) 5 inches, over-all.

Net Weight: 7¼ pounds.

Type		*Code Word*	*Price*
1454-A	**Decade Voltage Divider**	ABACK	**$135.00**

NEW COAXIAL ELEMENTS

The widespread use of u-h-f instruments and components based on the GR Type 874 Coaxial Connector is constantly bringing to light the need for additional components to extend the scope of measurements. A continuous development program already has produced many new items, and several more are under development. Latest additions to the line are described here.

COAXIAL STANDARDS

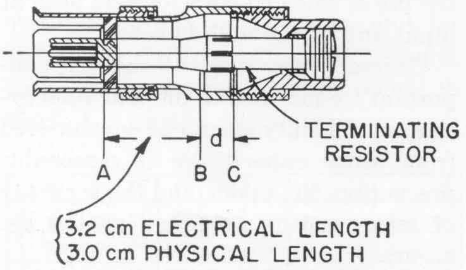
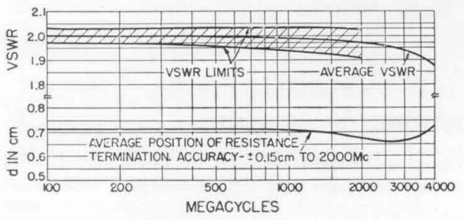


Figure 1. Cross sectional view of Types 874-W100 and W200 Coaxial Standards. The effective position of the pure resistance termination is at C. Type 874-WN and WO Short and Open-Circuit Termination Units effectively terminate a line at A and Type 874-WN3 and WO3 3cm Short and Open-Circuit Termination Units effectively terminate a line 3 cm from the front face of the insulator at B. The distance between B and C, labeled d, is plotted in Figures 2a and 2b as a function of frequency.

The new Type 874-W100 and Type 874-W200 Terminations produce known resistive terminations at specific locations on coaxial lines. They are very useful in testing the operation of measuring circuits, as, for instance, in checking the linearity of the detector in a slotted line and the accuracy of measurements made with directional couplers, bridges, and admittance meters. Figures 2a and 2b show the VSWR of each unit as a function of frequency, as well as the location of the resistive termination with respect to a known point in the connector. The known location of the pure resistive termination makes possible the production of many known complex impedances through the addition of sections of Type 874-L Air Line.



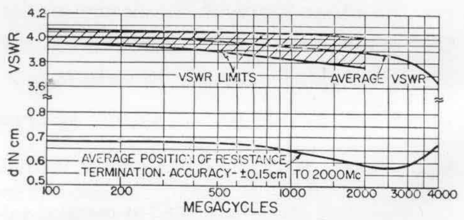


Figure 2a. Plot of the VSWR and position of the pure resistance termination, for a Type 874-W100 100-Ohm Coaxial Standard. The distance, d, is the distance from the position of the short or open circuit produced by a Type WN3 or WO3 Termination Unit to the position of the pure resistance termination as indicated in Figure 1. The cross-lined area indicates the tolerances on the characteristics.

Figure 2b. Plot of the characteristics of a Type 874-W200 200-Ohm Coaxial Standard.

Type 874-W100 100-Ohm Coaxial Standard
D-C Resistance: 100 ohms ± 1%
Maximum Power: 1/3 watt
Net Weight: 3 ounces

Type 874-W200 200-Ohm Coaxial Standard
D-C Resistance: 200 ohms ± 1%
Maximum Power: 1/4 watt
Net Weight: 3 ounces

Type		*Code Word*	*Price*
874-W100	**100-Ohm Coaxial Standard**	COAXCENTER	**$12.50**
874-W200	**200-Ohm Coaxial Standard**	COAXTILTER	**12.50**

BALUN ACCESSORIES

200-Ohm Terminal Unit

The Type 874-UB Balun is used to connect balanced circuits to unbalanced coaxial circuits and vice versa. It operates as a 4:1 impedance transformer; a 50-ohm coaxial system appears as 200-ohms at the balanced terminals. The balanced termination supplied with the balun was designed for the commonly used 300-ohm balanced transmission line. However, in cases in which the balun is used with a coaxial measuring device for measurements of the actual complex impedance of a balanced network rather than the VSWR on a 300-ohm line, the use of a 200-ohm balanced line and a balun terminal unit can greatly simplify the procedure. The 4:1 impedance transformation produces a 50-ohm grounded impedance, and therefore the 200-ohm balanced line can be treated as an extension of the 50-ohm line in the measuring device. A suitable line for this purpose is the TYPE RG-86/U, and the new TYPE 874-UB-P2 Balun Terminal Unit (200 ohms) has been designed to connect to it.

Characteristic Impedance: 200 ohms.
Frequency Range: 0 to 1000 Mc.
Recommended Transmission line: RG-86/U.
Net Weight: One ounce.

300-Ohm Terminal Pad

It is often necessary to obtain a 300-ohm balanced source when available generators have 50-ohm coaxial outputs. The TYPE 874-UB-P3 300-ohm Balun Terminal Pad converts to 300 ohms the 200-ohm balanced output impedance produced from a 50-ohm unbalanced source by the TYPE 874-UB Balun. This unit contains a built-in 50-ohm resistor in series with each balanced lead. The same arrangement can be used to terminate a 300-ohm balanced line in 300-ohms if the coaxial connector on the balun is connected to a matched TYPE 874-WM 50-Ohm Termination Unit or to a matched detector. Figure 4 shows the VSWR of such a load over a wide frequency range.

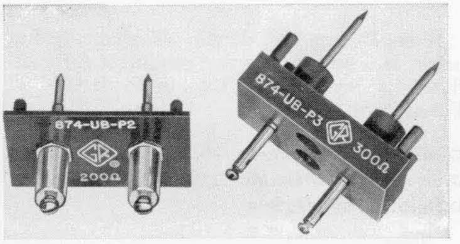


Figure 3. Type 874-UB-P2 Balun Terminal Unit (200 ohms) and the Type 874-UB-P3 300-Ohm Balun Terminal Pad.

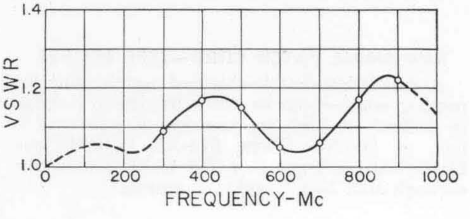


Figure 4. Plot of the VSWR at the 300-ohm terminals of a typical Type 874-UB-P3 Terminal Pad as a function of frequency when the pad is inserted in a properly adjusted balun whose coaxial circuit is terminated in 50 ohms.

Frequency Range: 0 to 1000 Mc.
Input or Output VSWR: When coaxial line is terminated in 50 ohms, VSWR at 300-ohm balanced terminals is less than 1.2 up to 300 Mc. and less than 1.3 up to 1000 Mc.
Net Weight: 2 ounces.

Type		*Code Word*	*Price*
874-UB-P2	Balun Terminal Unit (200 ohms)..........	COAXTERMER	$5.00
874-UB-P3	300-Ohm Balun Terminal Pad	COAXTUGGER	9.00

300-OHM BALANCED TERMINATION

One very useful element for balanced-line measurements is a simple 300-ohm termination. The TYPE 874-BM 300-ohm Balanced Termination shown in Figure 5 is such a device which has a VSWR of less than 1.2 at frequencies up to 900 Mc. The VSWR of a typical unit is shown in Figure 6.

Frequency Range: 0 to 1000 Mc.
D-C Resistance: 300 ohms ± 5%.
Net Weight: 1½ ounces.
VSWR: Less than 1.2 from d-c to 900 Mc.

Type		*Code Word*	*Price*
874-BM	300-Ohm Balanced Termination............	COAXLOADER	$5.00

Figure 5. Type 874-BM 300-Ohm Balanced Termination Unit.

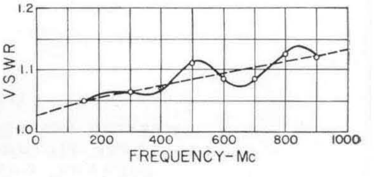


Figure 6. A plot of the VSWR as a function of frequency of a typical Type 874-BM 300-Ohm Balanced Termination Unit.

874-A3 COAXIAL CABLE

A small-diameter, double shielded, 50-ohm cable. Has stranded center conductor for good flexibility and long life. Used in Type 874-R22 Patch Cord.

Characteristic Impedance: 50.0 ohms ± 5%.
Diameter Over Dielectric: .116″.
Dielectric: Polyethylene.

Center Conductor: 19 strands of 0.0066 inch, tinned soft copper wire.
Outer Conductor: Double braid.
Jacket: Polyvinyl chloride, diameter .206″.
Nominal Attenuation: 5.3 db/100 feet at 100 Mc.
22.0 db/100 feet at 1000 Mc.
45.0 db/100 feet at 3000 Mc.

Type		*Code Word*	*Price*
874-A3	**Coaxial Cable**	COAXGABBER	**$0.35/foot 0.20/ foot for 25 feet or more**

NEW SMALL PATCH CORD—TYPE 874-R22

A small-size double-shielded patch cord for making connections in which minimum leakage is desired at high frequencies. Consists of 3 feet of 50-ohm Type 874-A3 Polyethylene Cable with a Type 874-C58 Cable Connector on each end. Net Weight: 4 ounces.

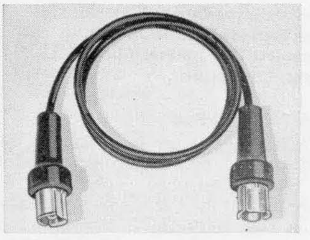


Figure 7. Type 874-R22 Patch Cord.

Type		*Code Word*	*Price*
874-R22	**Patch Cord**	COAXFANNER	**$6.00**

Two new rigid-line adaptors, panel connectors, and cable connectors will be described in the September *Experimenter*.

CORRECTION—July, 1955 issue, page 14. The maximum pulse durations listed in section (4) of the output pulse specifications should all be in milliseconds and not milli-microseconds.

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PRINTED IN U.S.A.

the GENERAL RADIO **Experimenter**

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VOLUME 30 No. 4 SEPTEMBER, 1955

A CALIBRATOR FOR AIRCRAFT FUEL GAGES

Also IN THIS ISSUE

Anyone who has been forcibly made aware of the vagaries and inaccuracies of gasoline gage indicators by running out of gas in some remote spot in his car will have no difficulty in understanding why aircraft fuel gages have been made more accurate, even at the cost of considerable complication. For the motorist, running out of gas is at most an inconvenience, rarely a matter of life and death as it could be to the flier.

Until 1943, most airplanes made use of float-type fuel gages.[1] A float in each tank actuated a rheostat, and a meter, indicating the current traversing the rheostat, had a dial calibrated in amount of fuel. While it was possible to totalize the fuel in several tanks and do other desirable operations with a float-type system, the method suffered for lack of flexibility and never remotely approached the accuracy and durability of a capacitance null-type device.

Despite all these disadvantages, the float-type fuel gages went unchallenged for a couple of decades. Finally, during World War II, capacitance-type indicating equipment first appeared. The early versions showed improved flexibility over float-type systems but still made use of a quantity-indicating meter. The final devising of a null-balanced capacitance-type fuel gage using a

[1] Some vertical-tube sight gages were also used but were not satisfactory under flight conditions.

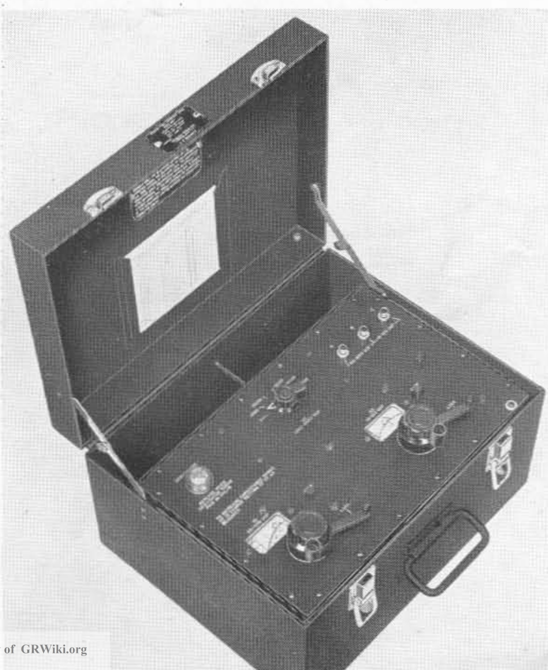


Figure 1. View of the Type P-579 Field Variable Capacitance Tester, mounted in its transit case.

servo-balanced 400-cycle bridge introduced a system having both the accuracy and flexibility of those at present in use, manufactured by four firms, namely, Avien, Liquidometer, Minneapolis-Honeywell, and Simmonds Aerocessories.

As an example, Figure 2 illustrates schematically the self-balancing bridge circuit basic to the Minneapolis-Honeywell product. This system was developed in 1944 by Minneapolis-Honeywell Regulator Company. One can see in this figure portions of the circuit essential to this article, namely, the TANK UNIT, the EMPTY ADJUST and FULL ADJUST potentiometers, and the DIAL. Necessarily, the DIAL must be made to read properly at both ends of its scale. To bring this about, the EMPTY ADJUST potentiometer is set to DIAL zero when the TANK UNIT is replaced by a capacitance of proper value for empty tank. With full tank simulating capacitance in place of TANK UNIT, FULL ADJUST potentiometer is set to make DIAL read proper maximum.

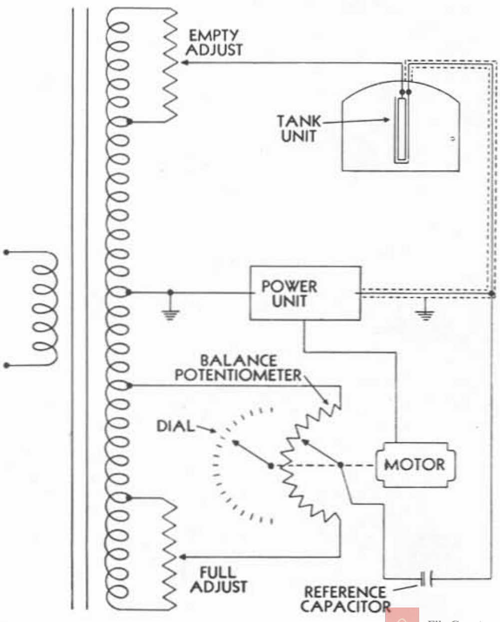


Figure 2. Schematic diagram of the capacitance null-type fuel gage, employing a self-balancing bridge. (Minneapolis-Honeywell)

An inaccurate system does not demand very much of its testing equipment. With an accurate system, of course, the converse is true. If the system's inherent accuracy is to be realized, it must be very carefully installed and adjusted in each airplane. Minneapolis-Honeywell early recognized the need, both military and commercial, for precise equipment to use in lining up their fuel gage equipment, both at time of installation and for routine maintenance purposes. It is obvious to even the most casual observer that it is impractical to set the FULL and EMPTY positions of the indicator by repetitively filling and emptying the various tanks involved.

The logical alternative was to provide standard capacitors which would simulate the EMPTY and FULL capacitances of the sensing units in the tanks. Since these capacitance values might be different for each tank, the number of different capacitance standards required could be enormous, and continually growing. This could be avoided by the use of an adjustable capacitor, if one could be obtained having accuracy sufficient for the job.

It was at this point that the collaboration between Minneapolis-Honeywell and General Radio began on the development of what ultimately became the Type 0-3 Field Variable Capacitance Tester, which is described in specification MIL-T-5911A. A Type 722 Capacitor with appropriate modifications would meet requirements nicely. Figure 3 illustrates the parts which were manufactured by General Radio for inclusion by Minneapolis-Honeywell in their HT-109 Tester, a device meeting the requirements for the 0-3. Included are three-terminal capacitors, variable and fixed, and a three-terminal connector accepting the plug-in range-extending fixed mica capacitors.

Eventually other manufacturers of 0-3 Testers of their own designs were supplied variable and fixed capacitors and three-terminal connectors by General Radio. These included The Jackson Electrical Instrument Company and Monument Engineering Company.

As experience with the TYPE 0-3 Testers slowly piled up, it became apparent that some changes could be made which would improve the convenience of use. One of these changes consisted of eliminating the loose external plug-in range-extending capacitors and substituting for them switched capacitors within the instrument. Some of the 0-3 types had this feature. The other desirable change was to substitute coaxial connectors for the three-binding-post arrangement. By maintaining the coaxial shielding unbroken, measurement errors and inconsistencies could be avoided. This change never appeared on the 0-3, but became a feature of its successor, the MD-1.

A more cogent reason appeared for obsoleting the 0-3, namely, the ubiquity of the jet plane. Practically every military base would have to service such planes with their more complicated fuel-indicating systems.

Why must they be more complex? Because jet fuel indications in the older, simple systems are dependent on both fuel composition and temperature. Aviation gasoline, for reciprocating engine craft, gives quantity indications (in pounds rather than gallons) essentially independent of source and temperature. Its composition, and consequently its dielectric constant, are essentially uniform from refinery to refinery. It happens that the expansion in volume on heating is just balanced by the reduction in dielectric constant. Thus a given weight of fuel gives the same capacitance in the tank sensing element and hence the same dial reading, almost regardless of the temperature.

Jet fuel on the other hand, is not a homogeneous, approximately single chemical compound, but almost any sort of a mixture within a wide range of hydrocarbon combustibles, depending on where and when it was refined. It exhibits relatively broad variations in dielectric constant and density. Jet fuel indications with simple systems, therefore, had appreciable composition and temperature variations. Hence jet fuel systems had to include an added fixed sensing element in the bottom of each tank to introduce an appropriate correction into the bridge circuit of the indicator. This meant that another precision variable capacitor would be needed in the tester, since the system during calibration could indicate and be adjusted properly only if it had attached to it simulating capacitors for both sensing and compensating units.

This, then, brings us to the TYPE MD-1 Field Variable Capacitance Tester, described in specification MIL-T-

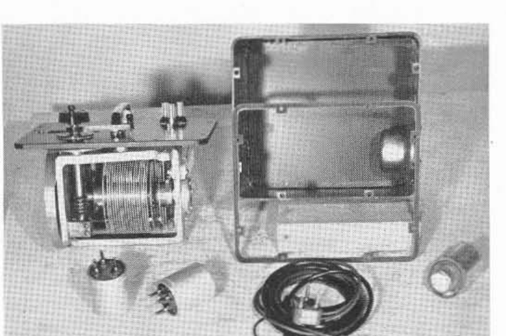


Figure 3. Elements supplied by the General Radio Company for the 0-3 Tester built by Minneapolis-Honeywell Regulator Company.

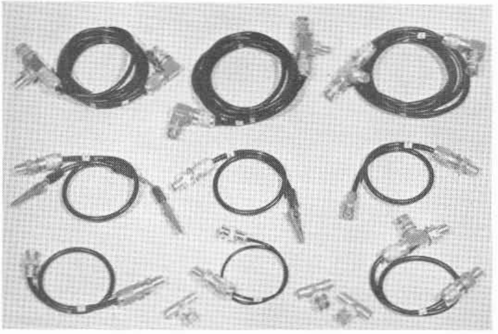


Figure 4. Connectors supplied with the Type P-579 Tester for connecting it to the many types of fuel gages now in use.

8579, which was prepared at the Wright Air Development Center of the Air Research and Development Command. Its essential differences from one or more of the predecessor 0-3 Testers were: first, the added variable capacitor; second, the internally switched range-extending capacitors; and third, the three mutually different Minneapolis-Honeywell coaxial connectors. Over the past several years, General Radio developed the new precision capacitor, which had to be direct reading (that is, linear) down to 10$\mu\mu$f, and, following the completion of that development, built and submitted samples of an MD-1 to MIL-T-8579 for qualification testing. Following completion of qualification tests late in September of 1954, production was immediately expedited so that early shipments could be made to meet the urgent needs of a number of the air-frame manufacturers.

This instrument, known as General Radio TYPE P-579 Field Variable Capacitance Tester and illustrated in Figure 1, contains, in addition to what has been mentioned before, a number of cables and tee adapters, illustrated in Figure 4, to enable it to be connected for measurement purposes to any of the existing fuel gage systems in military planes now flying. The capacitors are mounted in a moisture-resistant aluminum case having a removable desiccant cartridge, and this case is shockmounted inside a transit case. The transit case, also of aluminum, contains a compartment for stowing the cables and on the lid a holder into which is slipped the correction chart for the capacitors, laminated into 40-mil-thick clear plastic.

It is expected that TYPE P-579 Testers will be in stock for prompt shipment by about the middle of September 1955. They will be available for commercial or military use, and can be supplied with or without Government inspection at our plant. Detailed specifications of the equipment, which are quite lengthy, may be obtained upon request. They indicate the performance of the various capacitors included and describe the environmental and other tests which the product will meet.

— P. K. McELROY

MORE NEW COAXIAL PARTS

In addition to the new Type 874 Coaxial Elements described in the August issue of the Experimenter, the following items are now available.

RIGID-LINE ADAPTORS

A low-reflection adaptor from TYPE 874 Connectors to 7/8″ 50.0-ohm UHF Rigid Air Line and an adaptor to 1 5/8″ 50.0-ohm UHF Rigid Air Line are now available. The VSWR's of pairs of these units are shown in Figure 7. These adaptors provide low-reflection means of making connections to the newer 50.0-ohm u-h-f lines. The u-h-f adaptors are fitted with a flange and an anchor terminal assembly containing a Teflon bead as shown in Figure 8. With these adaptors and GR coaxial measuring equipment, many types of measurements including the determination of very low standing-wave ratios, can be made on rigid-line circuits.

Figure 8. Type 874-QU1 and QU2 Adaptors.

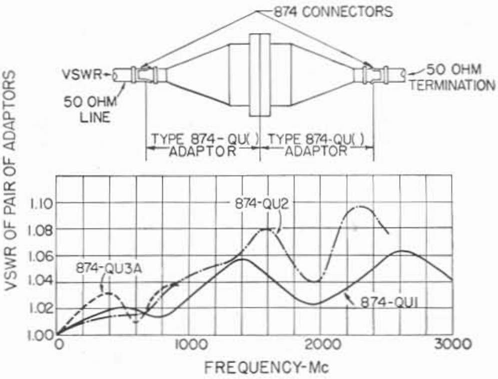


Figure 7. A plot of the VSWR as a function of frequency of pairs of adaptors from Type 874 Connectors to various sizes of 50.0-Ohm UHF Rigid Transmission Line.

SPECIFICATIONS

874-QU1
For use with: 7/8″ 50.0-ohm UHF rigid transmission line.
VSWR: less than 1.03 to 1000 Mc., less than 1.06 to 3000 Mc.
Net Weight: 8 ounces.

874-QU2
For use with: 1 5/8″ 50.0-ohm UHF rigid transmission line.
VSWR: less than 1.03 to 1000 Mc., less than 1.06 to 2500 Mc.
Net Weight: 1 pound, 5 ounces.

Type		*Code Word*	*Price*
874-QU1	**Adaptor to 7/8″, 50-ohm, UHF Line..........**	COAXYUMBER	**$21.00**
874-QU2	**Adaptor to 1 5/8″, 50-ohm, UHF Line.........**	COAXYUSHER	**46.00**

NEW PANEL CONNECTORS

A new type of panel connector is now available which mounts on the panel by means of four screws. These connectors can be installed closer together and are more easily removed than the older type.

Panel connector which mounts with four 4-40 screws, 13/16 apart. Size of flange is 15/16 square. 7/8″ diameter hole in panel required. Can be mounted either in front of or behind panel. Available to fit cables as shown in Table I. Net Weight: 2 ounces.

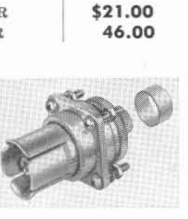


Figure 9. 874-PB Panel Connector.

CABLE CONNECTOR FOR RG-9/U CABLE

In response to customer requests, a cable connector for use with Type RG-9/U Cable is now available. This connector can be supplied for mounting on the free ends of cables or on either the old or new types of panel mountings. Table I shows most of the cables which can be used with the Type 874 Cable Connectors now available. Armored cables can also be used with these connectors, but no provision is made for anchoring the armor. Net Weight: 2 ounces.

TABLE I

Panel Connector Type	*Cable Connector Type*	*Cable Type* Matched	Unmatched
874-PB	**874-C**	**874-A2**	**RG-7/U**
874-PB8	**874-C8**	**RG-8/U**	**RG-11/U,-63/U, -114/U,-133/U,-144/U**
874-PB9	**874-C9**	**RG-9/U,-87A/U,-116/U**	
874-PB58	**874-C58**	**RG-29/U,-55/U,-58/U, -141/U,-142/U**	
874-PB62	**874-C62**		**RG-59/U,-62/U,-71/U, -140/U**

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

Type		*Code Word*	*Price*
874-PB	**Panel Connector**	COAXAPPLER	**$2.50**
874-PB8	**Panel Connector**	COAXBATHER	**2.50**
874-PB9	**Panel Connector**	COAXCANKER	**2.50**
874-PB58	**Panel Connector**	COAXABATER	**2.50**
874-PB62	**Panel Connector**	COAXBARKER	**2.50**

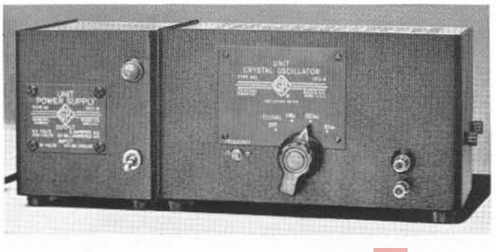
Type		*Code Word*	*Price*
874-C	**Cable Connector**	COAXCABLER	**$1.70**
874-C8	**Cable Connector**	COAXCORDER	**1.70**
874-C9	**Cable Connector**	COAXCAMMER	**1.70**
874-C58	**Cable Connector**	COAXCALLER	**1.70**
874-C62	**Cable Connector**	COAXCANDER	**1.70**

IMPROVED UNIT CRYSTAL OSCILLATOR NOW AVAILABLE

The TYPE 1213-A Unit Crystal Oscillator [1] is a compact and inexpensive instrument providing frequency markers at 1 Mc, 100 kc and 10 kc intervals up to relatively high frequencies. The original design has now been slightly modified to improve performance with respect to line voltage fluctuation, and to increase the amplitude of the 1-Mc harmonics above 500 Mc. The improved instrument is designated as the TYPE 1213-AB Unit Crystal Oscillator.

In the original design, the panel frequency-setting adjustment was a capacitor in series with the crystal with the rotor off ground. This connection caused a small change in frequency when a metal screwdriver was touched to this adjustment for setting the crystal frequency, thus making a difficult task of setting to WWV with high precision. In the modified design, the capacitor in series with the crystal is retained as a coarse adjustment, while the panel control tunes the plate circuit of the crystal oscillator stage, thus giving a fine frequency adjustment with a grounded rotor.

Voltage regulation has been added to the oscillator stage in the form of a pair of gas regulator tubes. The locking range of the 100-kc multivibrator has been increased by a change in the value of the grid resistors and by increased coupling to the oscillator. The addition of voltage regulation to the oscillator minimizes frequency change when the multivibrators are switched on. The amplitude of the 1-Mc harmonics above 500 Mc has been made more uniform by a different value of the coupling capacitor and the addition of a damping resistor. The price paid for this improvement in the u-h-f range is a decrease in



[1] Robert B. Richmond, "The Unit Crystal Oscillator, A Simplified Frequency Standard for the Small Laboratory", *General Radio Experimenter*, XXVI, 9, February, 1952, pp. 1–4.

Figure 1. View of the Type 1213-AB Unit Crystal Oscillator with the Type 1203-A Unit Power Supply.

output voltage at lower frequencies.

All new orders for the Type 1213-A will receive delivery of the improved Type 1213-AB at no increase in price. For those customers, who already own a Type 1213-A, the improved performance can be obtained by the purchase and installation of a modification kit available for a nominal charge from the Service Department.

Like other General Radio Unit Instruments, the Unit Crystal Oscillator combines small size and low-price with unusually good performance and wide utility. In addition to its many uses as a calibrator and marker generator in the laboratory it can, in conjunction with the Type 1202-A Unit Vibrator Power Supply,[2] be operated from a storage battery for field measurements.

[2] Bousquet, A. G., "The Unit Vibrator Power Supply" *General Radio Experimenter*, XXIX, 9, February, 1955, pp. 6–7.

PHASE MONITORING SYSTEM

By S. A. Olson*

An interesting problem of continuously checking the phase of a customer's generating station against the phase of the stand-by power-mains from the Commonwealth Edison Company of Chicago was solved through the use of the phase shifting capabilities of the Variac autotransformer when connected to a three-phase circuit.

The application is a phase monitoring scheme which automatically opens a customer's generating station bus tie breaker to the Commonwealth Edison Company system when the two systems drop out of phase for any reason.

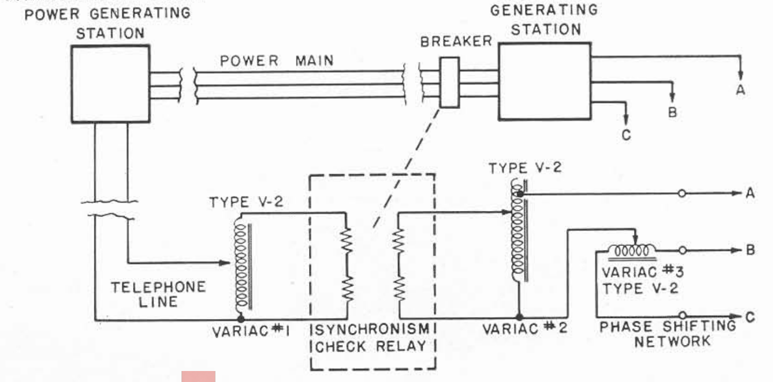
At the customer's generating station a synchronism-check relay continuously compares the phase angle between the customer's voltage and the Commonwealth Edison voltage. The two voltage sources are approximately ten miles from each other, and their comparison is possible via leased Illinois Bell Telephone Company circuits. If the phase angle between the two systems exceeds approximately five degrees for a short time, the synchronism-check relay will operate to separate the two systems.

All control equipment is owned by the customer.

The circuit, shown below, contains three Type V-2 Variacs and a synchronism-check relay. The distant reference voltage from the Commonwealth

* Planning Engineering, Commonwealth Edison Company

Functional diagram of the circuit used for phase monitoring.



Edison Company is fed into Variac #1. The purpose of this Variac is to compensate for any normal voltage drop in the leased Illinois Bell Telephone Company circuit. Variac #2 is used to boost the voltage from the phase shifting circuit, and Variac #3 is used in the phase shifting portion of the circuit.

Phase angle between the two systems is compared in the synchronism-check relay which opens its contacts to "break parallel" when the two systems differ by a predetermined angle.

The scheme is placed in operation by adjusting the voltage of the leased circuit with Variac #1 and adjusting the phase and voltage of the customer's system with Variacs #2 and #3. Any change in phase occurring after the scheme is in operation causes the relay to operate and opens the customer's paralleling tie breaker between the customer and the utility company. It is then the customer's responsibility to recheck the phase to determine whether the two systems are in phase, prior to reclosing of the tie breaker and paralleling the systems.

CORRECTION—TYPE 1219-A UNIT PULSE AMPLIFIER

In the July issue, the power supply input requirements for this amplifier were given as 102-125 volts, 50 to 60 cycles. The correct statement is 105 to 125 (or 210 to 250) volts, 50 to 60 cycles.

GENERAL RADIO COMPANY

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VOLUME 30 No. 5 OCTOBER, 1955

NEW VARIAC® SPEED CONTROLS IN 1 and 1½ hp RATINGS

Also IN THIS ISSUE

During the two years since the announcement of the Type 1704-A and 1705-A Variac® Speed Controls,[1] rated 1 and 1½ hp respectively, the need has become apparent for simpler controls without the expensive magnetic contactors for starting, stopping and reversing. The unmounted controls, Type 1704-AW and 1705-AW, announced about a year later,[2] were primarily for machine manufacturers who would mount the controls in the cabinets of their machines and provide their own switching for reversing and dynamic braking as desired. But a lower-priced, complete control suitable for the general user was still much needed.

Such a control requires a rugged inexpensive switch, and the so-called "drum" controller, which had been used increasingly with Variac Speed

[1] W. N. Tuttle, "Five New Variac Speed Controls Round Out the Line," *General Radio Experimenter*, XXVIII, 7, December, 1953.
[2] "Unmounted Motor Speed Controls for Assembly into Other Equipment," *General Radio Experimenter*, XXIX, 5, October, 1954.

Figure 1. The new Type 1704-B Variac Speed Control installed on a bench lathe. The controller is installed just below the headstock where it is conveniently accessible, and the Variac, which is the speed adjustment control, is below the controller, on the bench cabinet. The chassis, which carries the transformers and rectifiers, is inside the cabinet.

Controls installed in our own plant, proved to be just what was needed. Ample switching capacity can be provided in a small unit, and contacts are available for dynamic braking. The new controls consist of the drum switch, the rectifier chassis, and the Variac adjustable transformer controlling the speed. Overload protection of the Klixon type with appropriate time-delay characteristics is incorporated in the Variac. The new chassis differ from the older stripped-down versions, TYPE 1704-AW and 1705-AW, in that a dynamic braking resistor and dust cover are included.

The complete 1-hp control as supplied is shown in Figure 2. A line switch or cutout box is the only additional component required. The control operates on 230 volts a-c input, but terminals are provided so that a pilot light, if desired, can be operated on 115 volts. The control cabinet can be mounted out of the way in any location where there is adequate ventilation, as access to it is required only for maintenance. When an overload trips the breaker, resetting is done at the Variac, which is handy to the operator. The drum switch is sufficiently small to permit mounting in the frame of the driven machine. In production work it may be desirable to have the control lever at the hand of the operator and the speed adjustment knob farther away. Separate units for these functions give flexibility to meet such requirements.

An inside view of the drum controller is shown in Figure 3. The contacts are cam-operated and there is only enough wiping action to keep them clean. Wear is minimized and long life results. The cam design gives a fast break, with very little sparking. Two a-c contacts and four d-c contacts operate in series to make or break the armature current, as indicated in the wiring diagram, Figure 4.

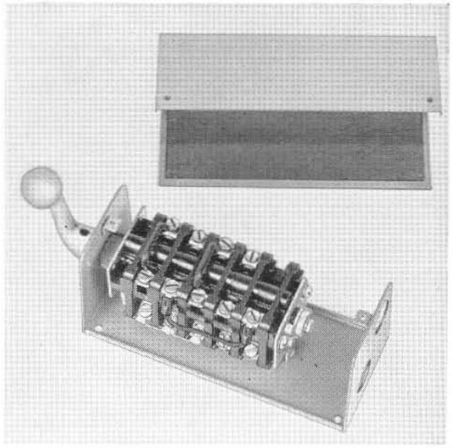


Figure 3. Interior view of the controller.

The new controls, like the others of the Variac Speed Control line, are suitable for a wide variety of applications. The 1 and 1½ hp ratings, however, are particularly suitable for small lathes. A back-geared lathe requires only a simple single-ratio belt drive to handle work of all sizes within its capacity. A lathe without back gears can be used for small-diameter cuts with only a single drive ratio but should have a second

Figure 2. View of the Type 1704-B Variac Speed Control (1 horsepower), showing the three elements: chassis, Variac, and controller. The basic model, Type 1704-BW, consists of chassis and Variac only, with the switching to be supplied by the customer. The 1½ hp models, Type 1705-B and Type 1705-BW, are identical in dimensions and external appearance with those shown here.

SPECIFICATIONS

			Type 1704-B	Type 1704-BW	Type 1705-B	Type 1705-BW
Motor Horsepower Range:			1	1	1½	1½
Power Supply Single-Phase		Volts	230	230	230	230
		Full-Load Amperes	6.5	6.5	8.5	8.5
Line-Voltage Limits		At 60 Cycles	210–250	210–250	210–250	210–250
		At 50 Cycles	210–250 [3]	210–250 [3]	210–250 [3]	210–250 [3]
Input Power In Watts		Full Load	1500	1500	1950	1950
		Standby	90	90	90	90
Motor Control Output DC	Armature	Amperes	4.5	4.5	6.0	6.0
		Volts	0–230	0–230	0–230	0–230
	Field	Amperes	0.5	0.5	0.5	0.5
		Volts	230 / 160 / 128	230 / 160 / 128	230 / 160 / 128	230 / 160 / 128
	Speed Range		0 to rated / 0 to 1.12 × rated / 0 to 1.25 × rated	0 to rated / 0 to 1.12 × rated / 0 to 1.25 × rated	0 to rated / 0 to 1.12 × rated / 0 to 1.25 × rated	0 to rated / 0 to 1.12 × rated / 0 to 1.25 × rated
Dynamic Braking			Automatic in stop position	Braking resistor furnished	Automatic in stop position	Braking resistor furnished
Armature	Overload Protection		Circuit Breaker in Variac	Circuit Breaker in Variac	Circuit Breaker in Variac	Circuit Breaker in Variac
Control Station			Variac and drum switch furnished	Variac furnished. Switching to be provided by user	Variac and drum switch furnished	Variac furnished. Switching to be provided by user
Over-all Dimensions in Inches [1]	Chassis		20½ × 13⅜ × 5⅝			
	Variac		7⅞ × 5 11/16 × 9 11/16			
	Controller (supplied with cabinet model only)		3 × 3⅞ × 9 (including handle)			
Net Weight in Pounds	Chassis		38½	38½	44½	44½
	Variac		21¼	21¼	21¼	21¼
	Controller		3		3	
	Code Word [2]		WEEDY	FAVOR	WAXER	SAXON
Prices Net F.O.B. Factory	1 to 4 units		**$330.00**	**$308.00**	**$380.00**	**$358.00**
	5 to 19 units		**316.00**	**294.00**	**365.00**	**343.00**
	20 Units and up		**302.00**	**280.00**	**350.00**	**328.00**

MOTORS FOR USE WITH ABOVE VARIAC SPEED CONTROLS [4]

Motor ratings: open drip proof, reversible, 40C. rise continuous, horizontal, rigid base. General Radio Designation Horsepower	Compound with Interpoles MOD-9 1	Compound with Interpoles MOD-10 1½
Frame Size [1]	N-203	N-204
Speed RPM	1750	1750
Leads (brought out separately)	6	6
Bearings	Ball	Ball
Net Weight — Pounds	75 lbs.	87 lbs.
Code Word [2]	MOTOR	MOTOR
Price	**$185.00**	**$210.00**

[1] Dimension drawings available on request.
[2] To order motor with Variac Speed Control, use compound code word, WINDYMOTOR, AMAZEMOTOR, etc. Motors are not sold separately.
[3] Special Variac required; hp rating reduced 11%.
[4] Motor specifications not critical. Any motor within control ratings can be used.

drive ratio available for heavy cuts on large-diameter pieces. For most of the work the control would be used over a wide range of working speeds without shifting the belt. The range of speeds covered is continuous, and the speed giving the fastest production can be set quickly. In our own plant we have obtained substantially increased production from lathes equipped with Variac Speed Controls.

Figure 1 shows the drum controller supplied with the new controls installed on a Rivett Model 908 Bench Lathe. Very little space is required and the location is particularly convenient for production work.

Although the cost of the complete controls is about 25 per cent lower than that of earlier models, the performance is unchanged. Rated torque of the motor is available for continuous operation

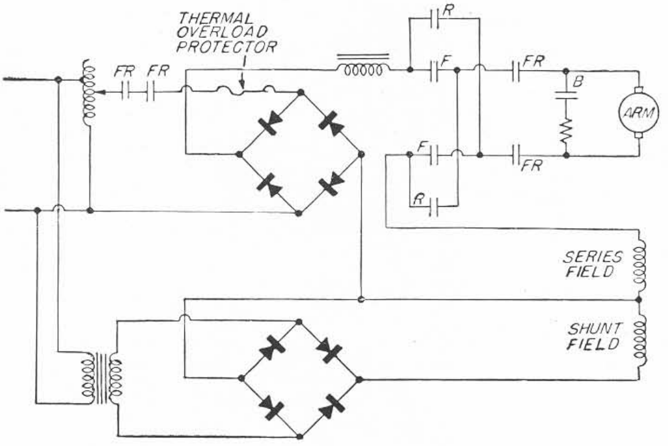


Figure 4. Basic circuit of the Variac Speed Control, showing the switching arrangement for forward, reverse, and stop (braking) operations.

over the entire range from rated speed to zero speed. Torque pulsations are negligible even in the most exacting work. Starting torque can be smoothly controlled in starting delicate operations, or fast high-torque starting can be used for rapid production work. Over a period of years maintenance requirements of the Variac Speed Controls have proved almost negligible.

— W. N. TUTTLE

A CONVENIENT TEST FIXTURE FOR SMALL CAPACITORS

In the measurement of small capacitors of the disc-ceramic type, the wire leads attached to the capacitor can affect the measured value of capacitance unless a standard technique of connection, to eliminate lead capacitance, is used. A fixture for this purpose, described by Stout and Wonso[1] of Radio Materials Corporation, is designed to plug into a General Radio Precision Capacitor for measurements by a substitution method.

A new fixture, similar in concept, but modified to accept many different types of capacitors, is shown in Figure 1. This fixture, the TYPE 1691-A Capacitor Test Fixture, can be used with the various capacitors shown in Figure 3: disc-type ceramic, with either wire or tapered-tab leads; disc-type with molded jacket; encapsulated mica; and tubular paper. Length of usual leads is immaterial, since the leads are eliminated from the measurement.

[1] Earl Stout and John Wonso, "Measurement of Small Capacities," *RMC Discap Review*, Vol. 1, No. 3, May, 1954.

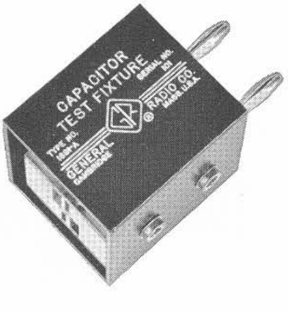


Figure 1. (left) View of the Type 1691-A Capacitor Test Fixture. (right) View showing disc-type ceramic inserted in fixture.

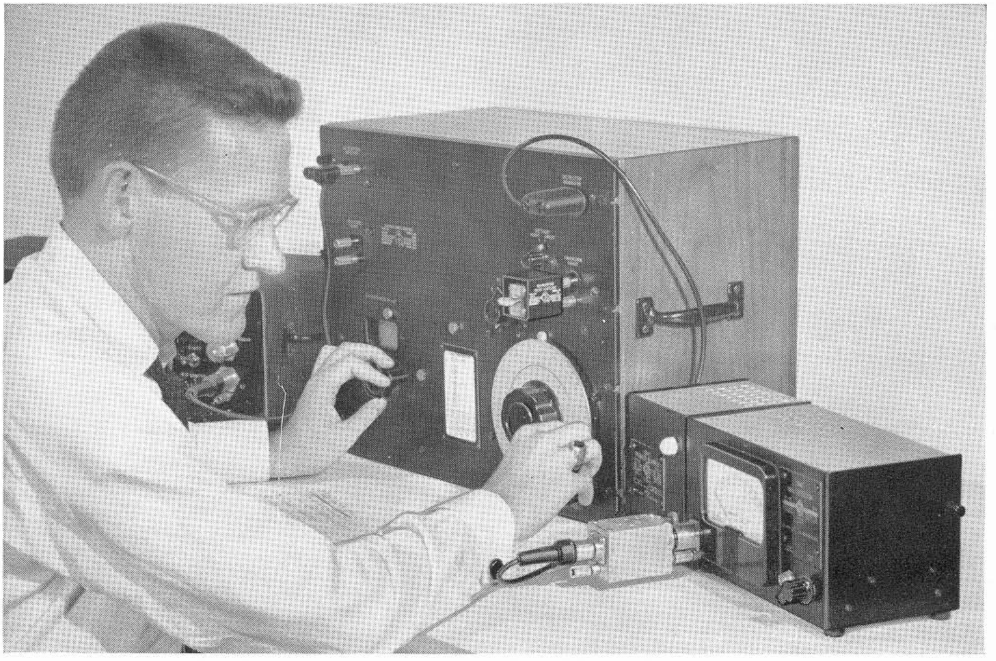


Figure 2. View of equipment for measuring disc-type capacitors at one megacycle. The Capacitor Test Fixture is installed on a Type 716-CS1 Capacitance Bridge. The generator is a Type 1330-A Oscillator, and the detector, a Type 1212-A Unit Null Detector. A one-megacycle filter is used at the input of the detector to reduce harmonics and noise.

Each lead slides into a hollow shield and is held by a spring clip, while an outer shield surrounds the entire assembly. The capacitor leads are pushed into the clips until the capacitor itself touches the fixture (see Figure 1), so that connection is made at the same point on every capacitor, regardless of lead length. The leads, from their ends to the point of connection, are completely covered by the shield and do not enter into the measurement.

The fixture terminals are Type 274 Plugs on ¾-inch spacing, which plug directly into a Type 722 Precision Capacitor or into any of the several General Radio Capacitance Bridges.

For the measurement of disc-type ceramic capacitors at one megacycle, the Type 716-CS1 Capacitance Bridge, shown in Figure 2, is recommended. With this bridge, dissipation factor as well as capacitance can be accurately measured at or near one megacycle. At lower frequencies, these and other low-capacitance units can be measured on the Type 716-C Capacitance Bridge.

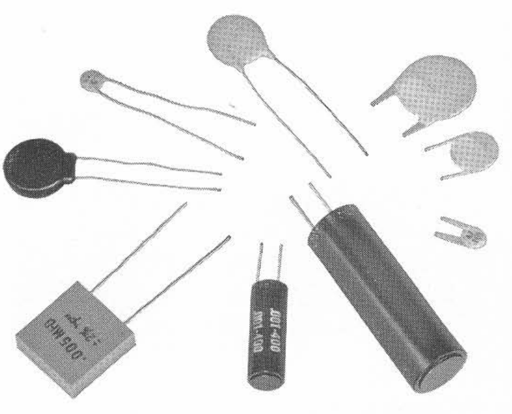


Figure 3. The Capacitor Test Fixture will accept all of the types of capacitors shown here.

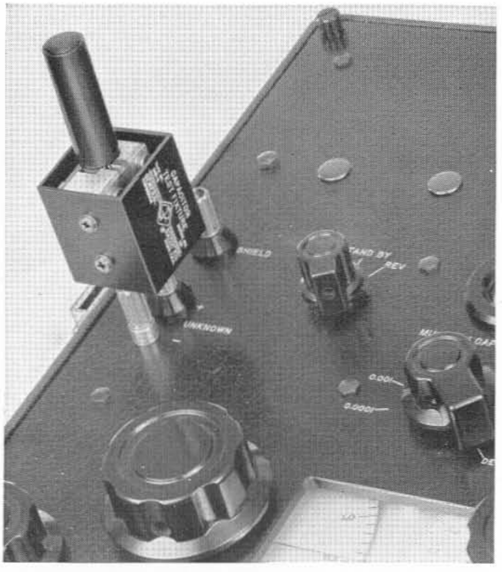


Figure 4. The fixture plugs easily fit into the terminals of General Radio bridges or into other equipment having jack-top binding posts, spaced ¾ inch. The bridge shown here is a Type 1611-A Capacitance Test Bridge, and the capacitor is a tubular paper type.

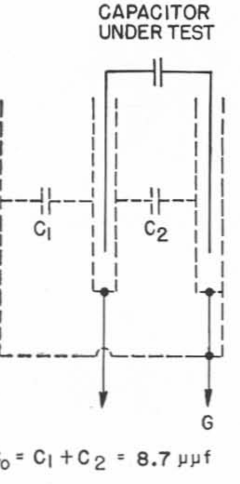


Figure 5. Sketch showing the nature and magnitude of the zero capacitance. This capacitance does not enter the measurement when a substitution method is used.

While lead capacitance is usually insignificant in the measurement of tubular paper capacitors, this fixture offers a convenient and standardized means of connection. Figure 4 shows the Type 1611-A Capacitance Test Bridge, with fixture installed, for 60-cycle measurements. The fixture is equally useful with the Type 1604-B A-C Comparison Bridge.

SPECIFICATIONS

Zero Capacitance: 8.7 micromicrofarads.
Terminals: Type 274 Plugs on ¾-inch spacing.
Dimensions: 1½ × 1½ × 2½ inches, over-all, including plugs.
Net Weight: 4 ounces.

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

VARIACS® IN THREE-PHASE DELTA CIRCUITS

When Variac® Autotransformers are connected to supply a three-phase delta load, one of the circuits of Figure 1 is ordinarily used. In a typical application recently encountered, each leg of the delta was rated at 20 amperes, 230 volts. In the circuit of Figure 1a, two 230-volt Variacs, each capable of supplying 34.5 amperes, would be required, while that of Figure 1b uses three 115-

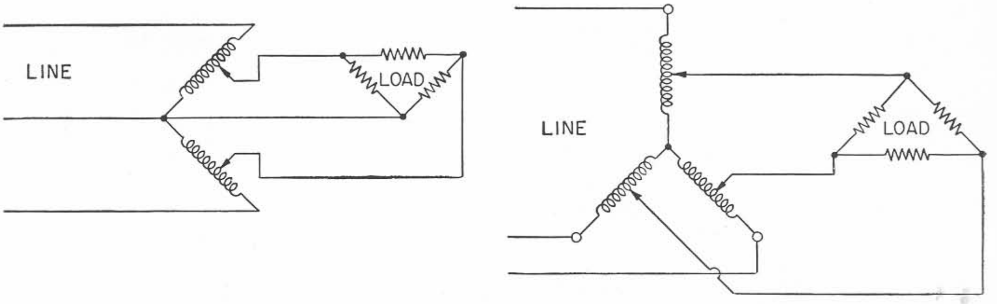


Figure 1. (a) Delta connection and (b) wye connection of Variacs to supply a 3-phase load.

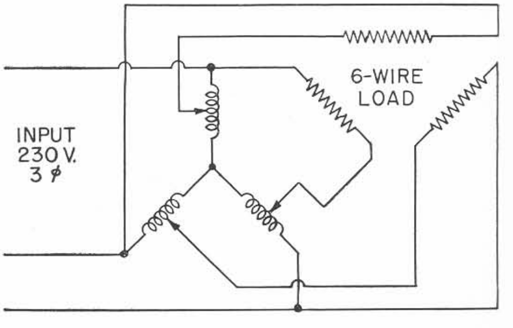
volt units, supplying 34.5 amperes. This meant that TYPE 50 Variacs connected in wye, as in Figure 1b, become the only choice, since the 230-volt TYPE 50-B Variac is rated at 31 amperes.

In this particular application, however, it was found that the load did not have to be connected in delta, but could be handled as three individual loads.

In addition, a maximum power variation of 3:1 was found to be adequate. With these modifications of the original requirements, the arrangement of Figure 2 was recommended. Here, the 20-ampere Variac, TYPE V20, could be used, which gave a considerable saving in cost over the TYPE 50 units of Figure 1b.

In general, a 3-gang assembly of a given size Variac is less expensive than either the 2-gang or the 3-gang assembly of the next larger size. This saving is possible whenever the load can be connected as three single-phase elements and where a 1.6:1 range of voltage adjustment is adequate.

Figure 2. Connection for separate loads and limited range of adjustment.



GR EXHIBITS IN NOVEMBER

East Coast Conference on Airborne and Navigational Electronics, Lord Baltimore Hotel, Baltimore, Maryland, October 31 and November 1. In Booths 36 and 37, General Radio will have on display sweep drives, pulsers, oscillators, bridges and other new products recently announced in the *Experimenter*.

Chicago Exposition of Power and Mechanical Engineering, Chicago Coliseum November 14–18. Come to Booth 151 to see GR motor speed controls, stroboscopes, noise-measuring instruments and other items for the power and mechanical industries.

This photograph, taken with a General Radio Type 651 Recorder, shows the flight of a 30-caliber bullet, fired from a T44 rifle. The illumination was supplied by a high-speed stroboscope, manufactured by Edgerton, Germeshausen, and Grier, Incorporated, operating at 10,000 flashes per second.

Camera aperture was f/1:5 with Background X Panchromatic Negative film. The stroboscopic lamp was mounted directly above the recorder lens and the bullet was photographed against a "Scotchlite" background. The bullet speed was 10,000 feet per second.

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the GENERAL RADIO Experimenter

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VOLUME 30 No. 6 NOVEMBER, 1955

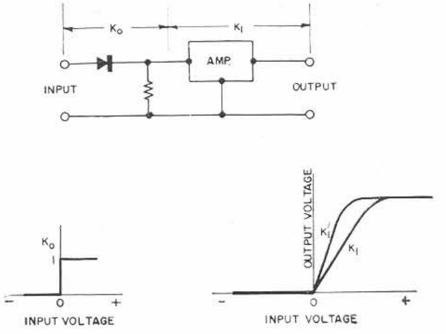
A NEW CIRCUIT FOR AMPLITUDE COMPARISON

Also IN THIS ISSUE

One of the fundamental operations to be performed with electronic circuits is that of amplitude comparison. *Amplitude comparison* is the determination of equality between two voltages, rather than the selection of a waveform that is above or below a given amplitude, as in *amplitude selection*. The amplitude comparator does not result in the faithful reproduction of a portion of a waveform, but rather, produces an output pulse at the moment of equality of two voltages.

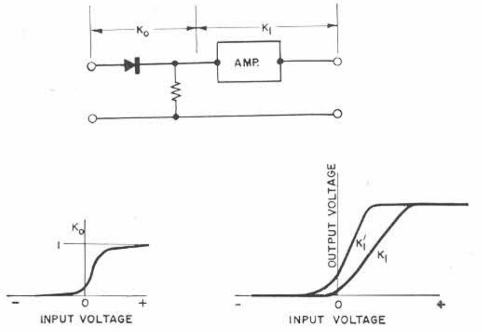
The operation of any amplitude comparator depends upon the characteristics of some non-linear device. First, let us consider an amplitude comparator using an ideal diode, as shown in Figure 1. The diode is simply a switch. When the input voltage is negative, the output is zero; when the input voltage is positive, the output is K times the input until the amplifier reaches saturation. A change in the amplifier gain can change only the slope of the input-output relation. The discontinuity of slope is determined completely by the ideal diode. If the output is differentiated, a voltage step will be obtained at the moment the input crosses zero volts. Only the magnitude of the step will depend on the amplifier gain and the rate

Figure 1.



IDEAL DIODE

Figure 2.



PRACTICAL DIODE

of change of the input voltage.

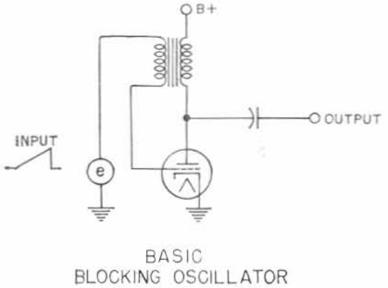
Figure 2 shows what happens when a more practical diode is used. There is no discontinuity of slope. The amplifier gain changes not only the slope of the input-output characteristic, but also the point at which the curve appears to depart from zero. If this output is differentiated, a pulse will be obtained. Both the magnitude and position of the output pulse, however, depend upon amplifier gain. Thus, the accuracy of an amplitude comparator based on a practical diode depends not only upon the stability of the diode characteristic, but also upon the ability of the circuitry to determine some point on the non-linear characteristic.

There are two basic classes of amplitude comparators. First, are those that use linear amplification and pulse shaping. This group is subject to the difficulties shown in Figure 2. They are all "slope sensitive," that is, the time at which the output waveform reaches a given voltage level depends upon the frequency or slope of the input voltage. The amount of gain in the amplitude comparator determines the minimum frequency at which operation is possible. Obviously, these circuits are useless as d-c comparators.

The second group consists of those that use a regenerative amplifier around a non-linear device. In this group, the output pulse is initiated when the input voltage reaches some predetermined d-c level. The pulse rise time is determined by the bandwidth of the regenerative amplifier. In many of these circuits, the regenerative amplifier and non-linear device are combined into one triode. The familiar blocking oscillator shown in Figure 3 is a typical example. The transformer in the plate circuit provides the positive feedback path. If the input is sufficiently negative, the tube is cut off. As the input voltage rises, a point is reached where the tube starts to conduct, and at this point a regenerative action starts, providing a sharp negative pulse at the plate with a slope independent of the input waveform. The amplitude comparison depends not only on the stability of the triode characteristics but also on the applied plate and heater voltages, since these seriously affect the cut-off voltage.

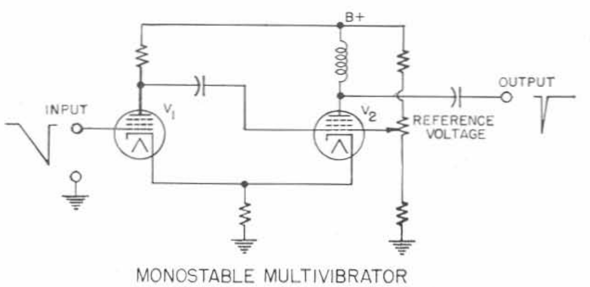
Another example shown in Figure 4 is a monostable multivibrator, often called the "long-tailed pair." V_2 is normally off, and V_1 is on, acting as a cathode follower since the cathode resistor is large. As the input voltage and, therefore, the cathode of V_2 go negative, a point is reached, determined by the reference voltage on the grid of V_2, where V_2 starts to conduct. This completes a positive feedback path from the plate of V_1 back to the cathode of V_1, and a regenerative action starts, producing a sharp negative pulse across the

Figure 3.

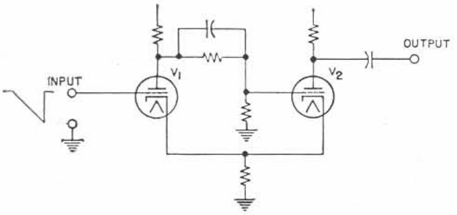


BASIC BLOCKING OSCILLATOR

Figure 4.



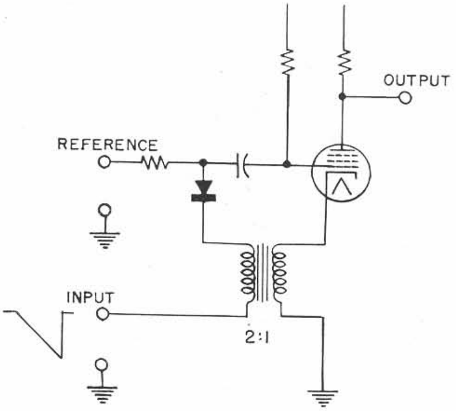
MONOSTABLE MULTIVIBRATOR



SCHMITT TRIGGER CIRCUIT

Figure 5.

inductor in the plate of V_2. The accuracy of this circuit also depends upon the stability of the tube characteristics and upon the applied voltages, although



MULTIAR

Figure 6.

drift from heater voltage changes tends to cancel to some degree.

Figure 5 shows the familiar Schmitt trigger circuit. V_1 is normally on and its low plate potential holds V_2 off. A decreasing input voltage waveform will eventually permit V_2 to conduct. Positive feedback through the common cathode resistor starts a regenerative action, which cuts off V_1 and gives a negative output at the plate of V_2. As in the previous circuits, the point of amplitude comparison depends upon both the triode characteristics and the applied voltage.

One other circuit which is useful, because it is reasonably independent of the amplifier tube characteristics and the applied plate voltage, is the Multiar shown in Figure 6. Accuracy of amplitude comparison depends primarily upon the diode characteristics. Normally, the pentode is conducting. The positive feedback path through the transformer is broken by the diode, which is nonconducting. When the input voltage decreases to the point where the diode conducts, a regenerative action starts, rapidly cutting off the pentode.

Optimum sensitivity for this type of circuit can be derived and demonstrates the fundamental limitation. In the functional circuit of Figure 7, the open loop gain is

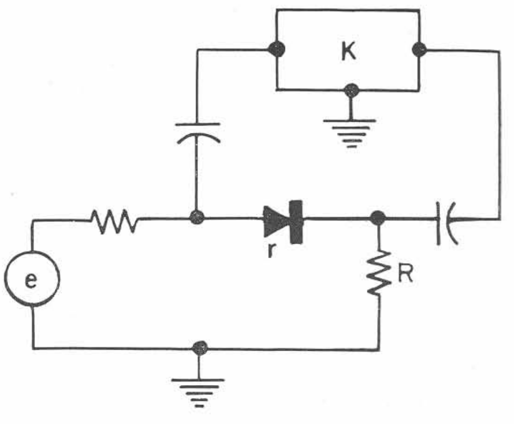
$$G = \mathrm{K}\frac{R}{R + r}.$$

The change in loop gain caused by a change in the diode resistance is

$$\frac{dG}{dr} = -\frac{R\mathrm{K}}{(R + r)^2}$$

The value of R for maximum sensitivity, can be found by differentiating this expression with respect to R and setting the result equal to zero.

Figure 7. Functional schematic of the regenerative feedback type of circuit.



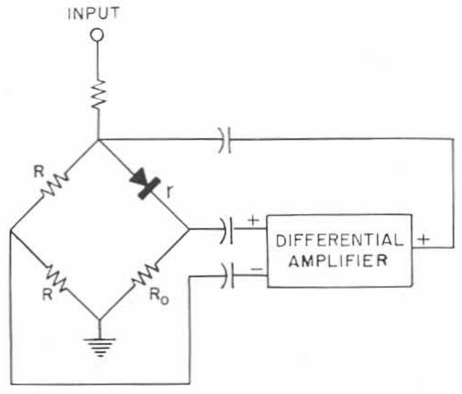


Figure 8. Functional diagram of new circuit, in which sensitivity increases directly with amplifier gain.

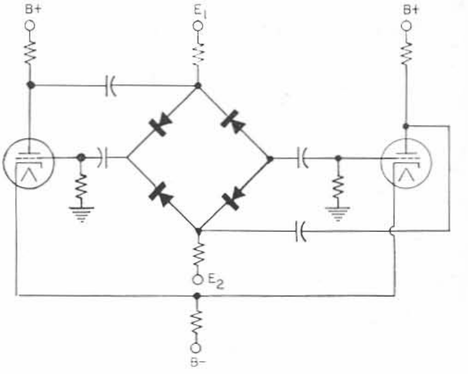


Figure 9. An amplitude comparator, based on the circuit of Figure 8.

$$\frac{d\left(\frac{dG}{dr}\right)}{dR} = -\mathrm{K}\,\frac{(R+r)^2 - 2R\,(R+r)}{(R+r)^4}$$

$$= 0$$

Solving this equation, we get

$$R = r$$

For maximum sensitivity, therefore, the diode should be operated at its most non-linear point, and the series resistor should be chosen to equal the resistance of the diode at this point. The amplifier gain required for optimum sensitivity is K = 2.

In this type of circuit, the diode is used to change the amount of positive feedback. When the loop gain reaches plus one, the circuit will oscillate. Increased sensitivity can not be obtained by increasing the amplifier gain beyond K = 2.

Figure 8 shows a new circuit in which the sensitivity increases directly with ampiifier gain.

The significant difference between this circuit and previous circuits is the use of two feedback paths: a positive feedback path including the diode and the resistor R_o; and a negative feedback path including the two resistors R. The polarity of the net feedback depends upon the diode resistance. When the diode resistance is greater than R_o, the net feedback is negative. When the diode resistance is less than R_o, the net feedback is positive. As the input voltage varies from negative to positive, the diode impedance changes, thus changing the sign of the feedback from negative to positive. As in other regenerative circuits, oscillation occurs when the loop gain reaches plus one. However, in this circuit, a loop gain of plus one can be reached by progressively smaller changes of diode resistance as more and more gain is used in the amplifier.

This circuit makes it possible to determine a point on the characteristics of the non-linear device with as much precision as desired. However, no circuit can improve the inherent stability of the non-linear device.

An amplitude comparator[1] based on this idea is shown in Figure 9. The use of four diodes in the bridge gives another factor of four in the sensitivity and provides some cancellation of drift in diode characteristics with tempera-

[1] U. S. Patent No. 2,715,718.

ture. To insure that the amplitude comparator will operate at a particular voltage level, independent of the slope of the input voltage, requires that the four capacitors that couple the diode bridge to the differential amplifier be sufficiently small so that a negligible amount of the input signal be coupled to the amplifier stage. For proper operation, the input voltage serves only to change the effective resistance of the diodes and, therefore, the polarity of the feedback. Noise in the amplifier stage should then trigger the regenerative action.

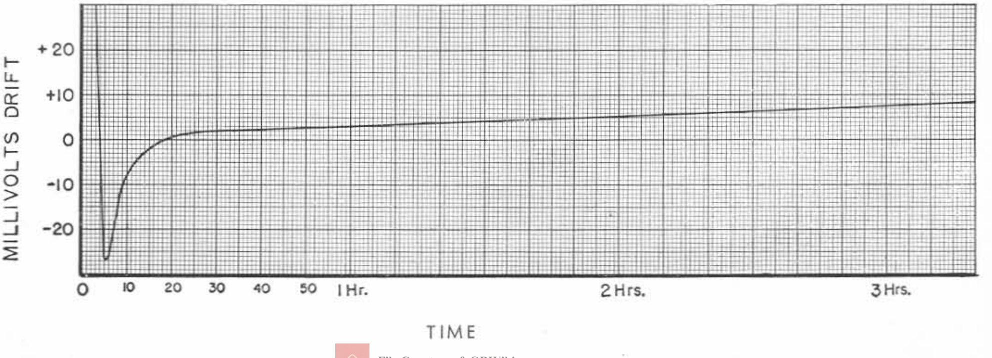
If a d-c voltage greater than that required to start the regenerative action is applied to the diode bridge, an output pulse will be generated. After this pulse, it is necessary for the plate and grid coupling capacitors to recharge. As soon as recharge occurs, another pulse will be generated. Thus, the output consists of a train of pulses spaced by the recovery time. If the input voltage consists of a sawtooth sweep, the recovery time can be made sufficiently long so that the circuit will be reset by the trailing edge of the sweep, and a single output pulse can be obtained.

Another effect of the diodes and the coupling capacitors is a hysteresis effect. If the time constants are not chosen carefully, it will be found that once the circuit starts to oscillate, it requires a relatively large change of applied voltage to stop the oscillation. One of the simplest methods to avoid this effect is to use small inductors to couple the signal voltage to the diode bridge.

By using sufficient amplifier gain, the effects of plate and heater voltage changes can be made as small as desired. With a single double triode such as the 12AT7, the gain is sufficient to reduce these effects to a few millivolts. The sensitivity of this circuit is about one-tenth of a millivolt. This sensitivity is so much greater than the stability of the diodes being used that any further increase in sensitivity, which could easily be obtained by adding another stage, would be useless.

In order to measure the sensitivity and also to determine how much stability could be obtained, a comparator was built with four germanium diodes. To reduce the effect of temperature on the diode characteristics, they were placed in a small octal-socket-size crystal oven. This oven held the diode temperature constant within one degree. Figure 10 shows the drift from a cold start for a three-hour period. The shape of the curve for the first few minutes as the oven warms up is irrelevant. Drift with the cycling of the oven is less than one millivolt. The slow drift is about 2.5 millivolts per hour and ends as the diodes stabilize their characteristics, as shown in Figure 11. Figure 12 shows the effects of line voltage. Both plate

Figure 10. Three-hour record of drift of the new circuit from a cold start.



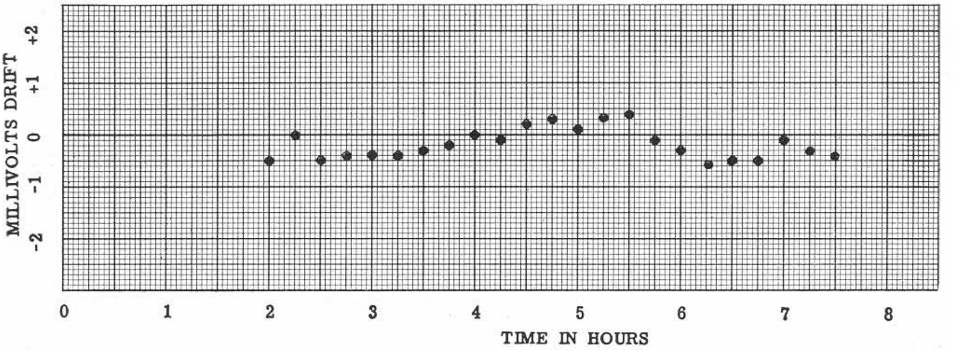


Figure 11. Drift record after diodes and other circuit elements reach temperature equilibrium.

and heater supplies were varied simultaneously.

Since the sensitivity of this comparator is so much greater than the stability of the diodes used in the bridge, it seems desirable to find some other non-linear device which is more stable with temperature than the germanium diodes. As long as the non-linear device is stable, more sensitivity can be obtained by adding additional amplifier gain. Much work remains to be done in this direction.

In addition to its many applications in electronic equipment, this circuit has interesting possibilities in industrial measurement and control systems. Wherever it is possible to generate a variable impedance with temperature, pressure, position, or other quantity, it is possible to use this comparator circuit directly, without first generating a voltage proportional to the quantity to be measured. The circuit does not require voltage information but can generate an output pulse directly from an impedance change. For such applications, the diode bridge would be replaced by a combination of linear resistors and elements with a resistance change proportional to the quantity to be detected. Thus any of these quantities could be controlled by a relatively simple circuit with high sensitivity.

— M. C. Holtje

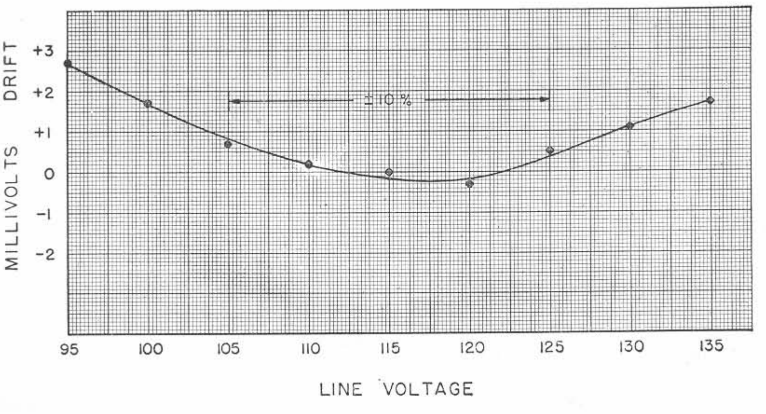


Figure 12. Effect of line voltage variations.

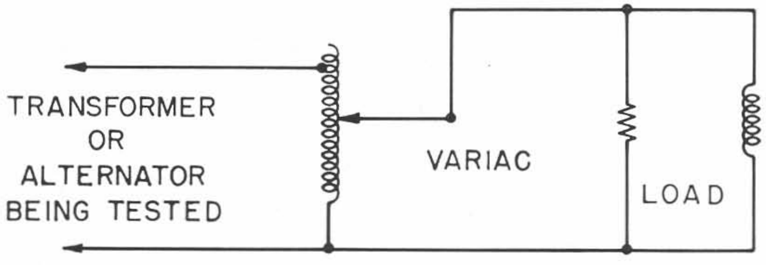
THE VARIAC® AS A MEANS OF PROVIDING CONSTANT-POWER-FACTOR, VARIABLE-CURRENT LOAD

In educational-laboratory testing of alternators and transformers it is frequently desirable to provide a constant-power-factor, variable-current load. Adjustment of both resistive and reactive elements to achieve ten or twelve points for a curve is both tedious and time consuming. With the circuit of Figure 1, the desired load magnitude can be obtained quickly and easily.

At a 1:1 ratio adjustment of the Variac Autotransformer the reactive and resistive components are made to take approximately full load current at the desired power-factor. For other currents the Variac is adjusted to other ratios. The load then appears to the source as $(N_1/N_2)^2\ (R + jX)$, where N_1 and N_2 are the turns in the primary and secondary circuits, respectively, and $R + jX$ are the equivalent series components of the load. While the parallel inductance and resistance of the Variac must be taken into account at high transformation ratios, the simple expression is adequate for most uses.

The single-phase illustration is easily extended to three-phase circuits by use of a three-phase Variac® assembly.

Note: We are indebted to Professor J. Bruce Wiley, of the University of Oklahoma, for this interesting application of the Variac. — EDITOR



Load magnitude is varied by adjusting Variac, while power factor remains fixed.

MISCELLANY

Among the friends from overseas whom we have welcomed to our plant and laboratories at Cambridge during the past several months are:

Professor Abrahao Izecksohn, of Escola Nacional de Engenharia, Rio de Janeiro; and Dr. Guilherme Ribeiro, Civil Engineer, Sao Paulo, Brazil.

C. S. Rangan, Scientific Officer, National Physical Laboratory, New Delhi; and V. K. B. Unni, Senior Technical Assistant, India Meteorological Department, New Delhi, India.

Enzo Finardi, Sales Manager, Ing. Giovanni Canegallo, Technical Director, and Dorando Massimello, Director, Societa Elettrotecnica Chimica Italiana, Milan, Italy.

Dr. Masashi Naito, Electro Technical Laboratory, Tokyo; Keiichi Takama, Director and Assistant Chief, Meisei Denki K. K., Tokyo; and Yoshiji Toyoshima, Furukawa Electric Company, Ltd., Yokohama, Japan.

André Levy Soussan, Realisations Electroniques Du Maroc, Casablanca, Morocco.

Dr. M. Gevers, Research Project Engineer, Philips Research Laboratories, Eindhoven, Netherlands.

Dr. John R. Whittaker, Principal, Technical College, Dundee, Scotland.

Karl-Ake Jarbelius, General Swedish Electric Company, Ludvika, Sweden.

SOME BULLET!

Before the munitions makers start bidding for the right to our new atomic rifle, we hasten to explain that, in the photograph on page 8 of our October issue, the bullet was travelling about 2,700 feet per second, not 10,000. The 10,000 figure is the flashing speed of the stroboscope, as stated in the first paragraph of the caption. Our ballistics expert denies all responsibility for the second paragraph, claiming that the error is obviously an editorial one.

After an exhaustive investigation the editor has decided to apologize and to claim he was out of town when it happened.

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Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

VOLUME 30 No. 7 DECEMBER, 1955

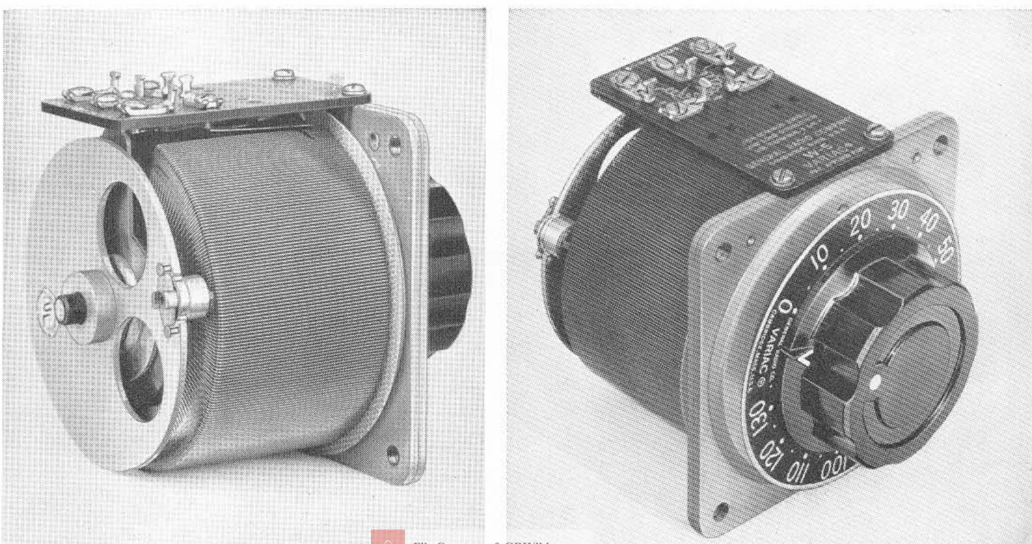
THE TYPE W5 VARIAC® — A NEW AND BETTER VARIABLE AUTOTRANSFORMER

To maintain leadership, today's product must keep abreast of the times. Small changes in design and construction, to upgrade quality, are made continually, but major improvements dictate a new design.

The new TYPE W5 Variac ® represents the second basic model change since the adjustable autotransformer was introduced by the General Radio Company over twenty years ago. The new design incorporates the latest features which customer experience has shown to be useful, and it reflects progress in the fields of metallurgy, dielectrics and metal working as well as General Radio's more than twenty years of experience in the design and manufacture of continuously-adjustable autotransformers.

The important improvements include Underwriters Laboratories listing, military ruggedization, and counterbalanced rotating parts. The basic open unit, TYPE W5, has an increased rating and an extended rectangular flange mounting. An additional feature of the cased models is total enclosure, with ready accessibility to the interior. Cased models also include new wall mounting

Figure 1. Two views of the new Type W5 Variac.



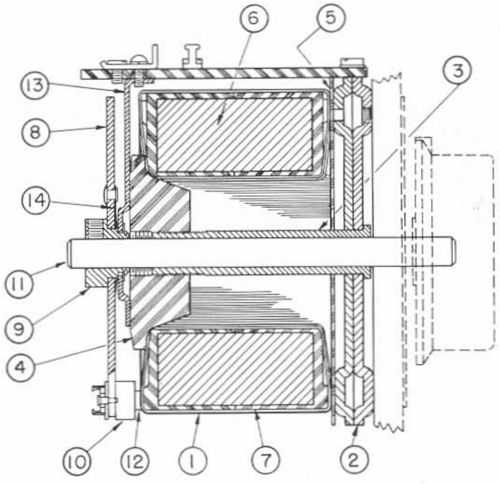


Figure 2. Sectional view of the Type W5 Variac, showing details of design and construction.

types with conduit knockouts, for ganged assemblies as well as for individual units. A new portable model, which can be used in either a horizontal or a vertical position, has a built-in overload protector and is equipped with a carrying handle. This type is available with the new three-wire grounded cord set and receptacle, as well as in the usual two-wire arrangement.

By a careful choice of fabricating methods and materials, plus extensive tooling, the whole series, including the foregoing improvements, has been made available at prices comparable to or less than the types that it supersedes, in spite of increased material and labor costs.

Design Features

Specific features can best be shown by a detailed discussion of the construction. Fig. 1 shows the basic Type W5 Variac. The first new distinguishing characteristic to catch the eye is its square base. This flange-type base permits surface mounting and post-type ganging, which makes the unit more easily adaptable to motor drives and to an ever-increasing list of similar special structures.

The base assembly is built up of two identical stamped pieces of wrought aluminum alloy and is substantially stronger and more resistant to impact than the die-cast base of its predecessor. In addition to the four corner mounting holes, three interior mounting holes, matching those of the older Type V5, are provided. Thus, in the majority of installations, the new Type W5 is interchangeable with the Type V5.[1]

Fig. 2 is a sectional view and shows how the coil (1) is clamped to the base (2) with a hollow sleeve bolt (3) and a molded phenolic nut (4) of thick section. This simple, direct attachment to the heavy gauge base provides a structure that withstands most military shock and vibration tests. The coil and base are in contact over a large annular surface, with a glass-cloth insulator (5) between them so that good thermal conductivity is maintained.

The improved thermal coupling between coil and base allows an increase in rating of the Type W5 of twenty per cent versus that of the Type V5. Underwriters Laboratories, Inc., list the basic (uncased) unit for 6-amperes rated current. W5H models retain the 2-ampere rating of the earlier V5H, but operate with a somewhat lower temperature rise.

The advantages of higher rating were weighed against those of total enclosure, and total enclosure was the decision on the merits of excluding dust, dirt and other harmful outside influences. For this reason, the cased models, Types W5M and W5MT, are rated at 5 amperes for continuous duty.

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[1] For those few applications where it may not be, manufacture of the V5 will be continued as required.

The low-loss, high-silicon core material now used in Variacs can be operated at flux densities believed impossible only ten years ago, and still shows lower losses than earlier cores at far lower flux densities. Wire insulation and coil insulation are steadily being improved in the interest of longer life under adverse operating conditions. The coil is wound with triple-Formvar-coated copper to provide adequate breakdown strength between banked turns at elevated temperatures.

The core (6) is completely encased by two identical winding forms (7) of molded phenolic in the shape of annular cups. Precision molded grooves in these forms insure positive positioning of turns and a smooth, uniform banked winding at the inner radius. The butt joint between cups is sealed when the coil is dipped in baking varnish, so that the core is completely enclosed with high-dielectric-strength material.

After baking, the brush track is ground in several successive steps to an extra fine finish for smooth operation and long brush life. The *Duratrak* finish is then applied to give maximum thermal and electrical performance plus high corrosion resistance.

The terminal leads to the winding are tapped in a few turns from the winding end to permit the brush to reach zero or maximum voltage without traversing the end turn.

Figure 4. The shaft can easily be adjusted or replaced without disturbance to the rest of the assembly.

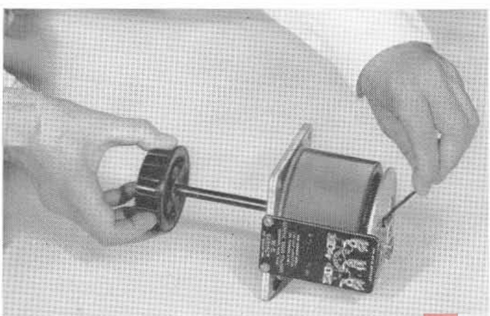


Figure 3. View of the Type W5M Variac in typical installation.

The terminal board (15) is imprinted with terminal numbers, wiring diagram and other pertinent information. The 115-volt model has five terminals to permit wiring for 115-volt or 135-volt maximum output in either direction of rotation. The 230-volt model has two extra terminals, thereby providing taps at 115 volts or 230 volts from either end of the 270-volt winding. The terminals are equipped with both screws and solder lugs, and all leads to the coil run behind the terminal board from the bottom of the coil, so that there are no vulnerable and unsightly external joints or wires.

The radiator assembly is an aluminum disc (8) with screw-machine bosses (9) and (10) to receive the shaft (11) and the unit brush (12). This full disc construction protects the brush track against damage and provides counter-balance and radiating surface.

The whole assembly is made loosely captive to a brass take-off connector (13), which is rigidly attached to the phenolic coil-clamping nut and to the terminal board. A polished phosphor-bronze leaf spring (14), riveted to the radiator disc, carries current to a polished section of the brass connector.

Although all rotating parts are firmly guided by the shaft, the captive radiator construction permits shaft adjustment or replacement for ganging, etc., without disturbing the Variac assembly.

The unit brush is the same as that used in the TYPE V5, thus retaining interchangeability in service replacement.

Each unit comes equipped with an easy-to-grip phenolic knob with a white-filled index pointer and a readily visible large white dot for quick reference, and a reversible dial-plate calibrated on one side for 115-volt maximum output and on the other for 135 volts. Screws for mounting both Variac and dial-plate are furnished.

Cased Model—Type W5M

A typical installation of the new totally enclosed TYPE W5M is shown

SPECIFICATIONS FOR W5 VARIACS | **LINE-VOLTAGE CON-**

Type	Description	Rated Input Voltage		Rated Output Current in Amperes	Output Voltage Range	Maximum Output Current in Amperes
W5	Uncased		115	6	0–115	7.8
W5M	Completely enclosed, with Conduit knockouts		115	5	0–115	6.5
W5MT *	Bench model, completely enclosed, with overload protector, switch, carrying handle, two-wire cord, plug, and outlet		115	5	0–115	6.
W5MT3 *	Bench model, similar to Type W5MT, but with 3-wire, cord, plug, and outlet		115	5	0–115	6.
W5H	Uncased		230 115	2 1	0–230	2.6
W5HM	Similar to W5M		230 115	2 1	0–230	2.6
W5HMT *	Similar to W5MT		230	2	0–230	2.4
W5G2 W5G2M	Two-gang W5 Two-gang W5 with case	Series Circuit	230 230	6 5	0–230 0–230	7.8 6.5
W5G3 W5G3M	Three-gang W5 Three-gang W5 with case	3-Phase Wye	230 230	6 5	0–230 0–230	7.8 6.5
W5HG2 W5HG2M	Two-gang W5H Two-gang W5H with case	3-Ph. Delta Series	230 460	2 2	0–230 0–460	2.6 2.6
W5HG3 W5HG3M	Three-gang W5H Three-gang W5H with case	3-Phase Wye	460	2	0–460	2.6

* MT models are shipped with overvoltage connections, but can be supplied wired for line volt-
† Dial has overvoltage scale on one side, line-voltage scale on the other.

in Fig. 3. The smooth, gray, round-cornered case is provided with four knockouts for ½ in. conduit or armored cable, two on the end and one on each side, plus ample inside wiring space for ease of installation. Complete access for wiring, maintenance, etc., is accomplished by loosening two set screws in the knob and removing two screws in the cover. The front half of the case can then be removed easily, exposing all terminals, mounting holes, brush, and brush track. Mounting screws to wall or panel attach directly to the structural flange of the unit inside through clearance holes in the attached case.

Provision is made for ready conversion of this model, by the user, to back-of-panel mounting. The shaft can be adjusted to extend from the opposite side of the case by loosening two set

NECTION	OVERVOLTAGE CONNECTION †						
Output KVA at Maximum Output Volts	Output Voltage Range	Rated Current in Amperes	60 No-load loss—watts	Driving Torque ounce—inches	Net Weight pounds	Code Word	Price
0.9	0–135	6	9	10–20	6¾	COTAL	$17.00
.75	0–135	5	9	10–20	7½	COTER	21.50
.69	0–135	5	9	10–20	8¼	COTIC	26.50
.69	0–135	5	9	10–20	8¼	COTOM	28.50
.6	0–270 0–270	2 1	9	10–20	6½	JOBAL	19.00
.6	0–270 0–270	2 1	9	10–20	7¼	JOBER	23.50
.55	0–270	2	9	10–20	8	JOBIC	28.50
1.8 1.5	0–270 0–270	6 5		20-40	14¼ 15¾	COTALGANDU COTALBONDU	41.00 49.00
3.1 2.6	Not recommended			30-60	21¼ 23¼	COTALGANTY COTALBONTY	61.00 69.00
1. 1.2	0–270 0–540	2 2		20-40	14 15½	JOBALGANDU JOBALBONDU	45.00 53.00
2.1	Not recommended			30-60	20¾ 22¾	JOBALGANTY JOBALBONTY	67.00 75.00

age connections on special order.

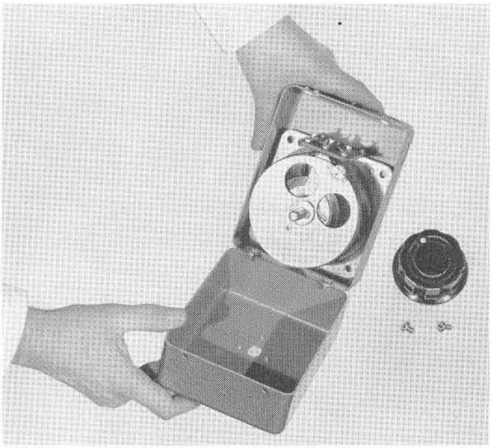


Figure 5. The front half of the case is easily removed for access to terminals, mounting holes, and brush.

screws; two more set screws and three self-tapping screws will release the knob and dial-plate for relocation on a panel; and two holes are provided for moving the nameplate over the shaft hole left in the cover.

The new cased model is offered at a price substantially lower than that of its nearest functional equivalent (Type V5MTC) in the superseded V5 series.

Portable Model—Type W5MT

The bench and portable version, Type W5MT, shown in Figure 6, offers a number of new features over previously available units. Outstanding among these is a resettable thermal overload protector in the brush lead. Operating partly on ambient temperature and partly on load current, this permits short-time overload, which the *Duratrak* Variac is capable of withstanding, but opens on sustained overloads or abnormal internal case temperature. It can be reset only if the condition which caused the interruption has been rectified, thus assuring continued protection. Current-time and current-temperature characteristics are shown in Figs. 8 and 9.

The case is made of two identical drawn aluminum boxes with embossed feet on both back and end. When the unit is used on its back, with the dial-plate horizontal, the input and output cords will run toward the back of the bench.

Figure 6a (left). View of the Type W5MT3 Variac for bench and table use. Type W5MT is identical in appearance. Figure 6b (right). The portable model is equipped with a convenient handle and so is easily carried around in the test shop or laboratory. Both the 2-wire and 3-wire models are equipped with overload protector.

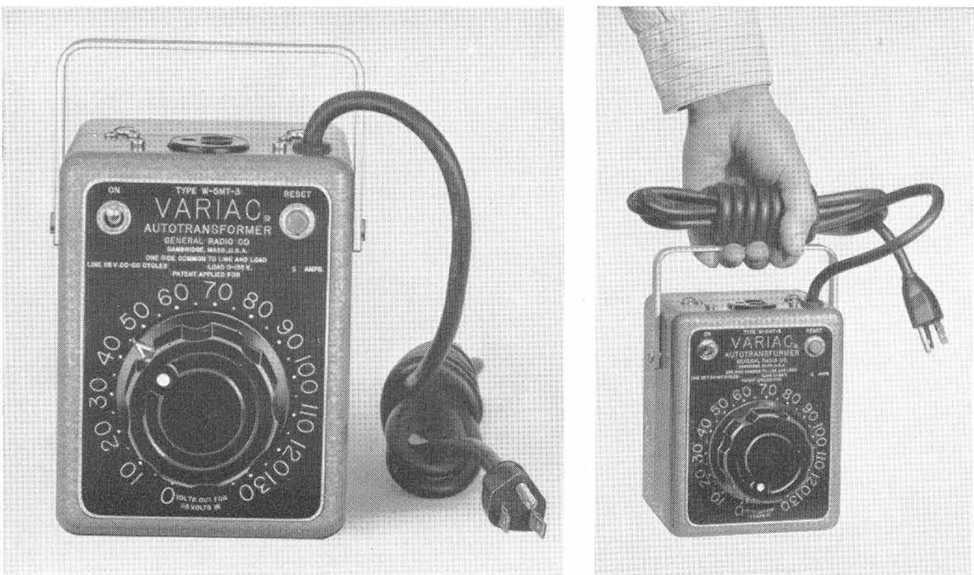


Figure 7a. The portable model can be used either vertically (Figure 6) or horizontally as shown above.

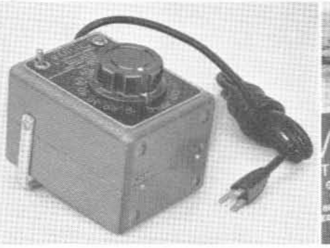


Figure 7b. In the horizontal position, the handle can be used to give the panel a slight incline.

Figure 7c. The overload protector, a new feature of the T-models, is easily reset from the front panel.

The knob, switch, and reset button are all conveniently grouped on a single surface, which is free from cords and other obstructions. The removal of only two screws, in this model, permits withdrawing half of the case, exposing the interior for inspection and maintenance.

Both two-wire (Type W5MT) and three-wire (Type W5MT3) models for 115-volt service are offered. The Type W5MT3 uses the new NEMA three-wire output receptacle and plug and will be welcomed by the many laboratories wired in the new standard three-wire system with separate grounding wire. For 230-volt service, a two-wire model, Type W5HMT, is available.

Ganged Assemblies

Ganged assemblies provide greater flexibility in mounting than did previous designs. One unit in each gang is reversed, so that there is a mounting base at each end of every assembly. Thus there is no distinction between "panel" and "base" mounted units. Fig. 10 shows a typical ganged assembly and illustrates the sturdy simplicity of construction gained by the square flanged base and four posts. The posts are attached to the end units by means of special steel bolts whose heads are tapped for screws. This yields four tapped mounting holes in each end of a gang so that it can be mounted to a panel, supported at its far end, or attached to angle brackets, which are supplied as a part of the standard hardware with each assembly. Because of the many voltages encountered in applying ganged Variacs, the dial-plate is not calibrated but carries an arbitrary 0–10 scale.

Figure 8. Current-time characteristic of the overload protector at 57.5-volt output is shown by the lower curve. Upper curve shows permissible overload as a function of time. Note that the breaker always operates before the limit is reached.

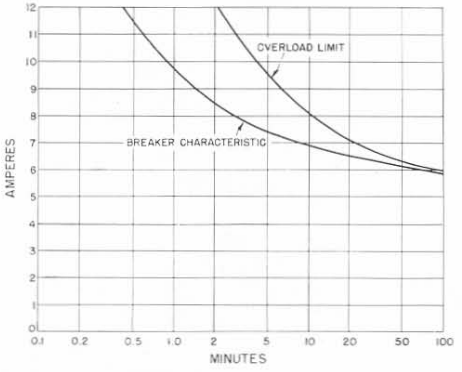
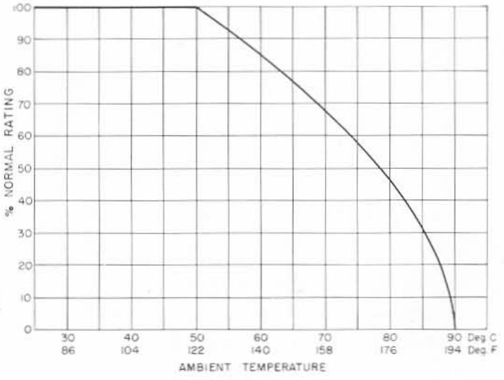


Figure 9. Standard temperature derating curve for Variacs. The overload protector operates partly on ambient temperature and will open the circuit before these values are reached.



The two end mounting plates together with the connecting posts at each corner provide protection for the coils and brush tracks against gross mechanical abuse. Nevertheless, a case (see Figure 10) for the assembly is available for applications where complete enclosure of Variacs and wiring is desired. The case is made up of two drawn boxes with conduit knockouts as used in the TYPE W5M. These boxes are affixed to the assembly, and the enclosure is completed by two U-shaped covers, in matching gray finish, which are readily removable for installation and service. Clearance holes permit access to the four tapped holes in each end of the assembly inside, so that the unit can be mounted in the same manner as the uncased model.

Special Modifications

The flexibility and versatility of the new design has already been demonstrated by the variety of modifications that have been developed for special applications. Several of the special modifications are described below.

Ball-Bearings [2]

Although the bearing provided by the phenolic shaft turning in the sleeve-bolt is entirely adequate for all manual operation and for many motor-driven applications, the desirability of being able to provide ball-bearings at a minimum of added cost was kept in mind during the development of the new design. In high-speed servo applications such as the GR TYPE 1570-A Automatic Line-Voltage Regulator more precise alignment, lower and more constant torque, and longer life can be obtained with ball bearings. Fig. 11 shows how ball bearings are accommodated in a W5-type Variac very simply by using a larger sleeve-bolt, in each end of which a ball bearing is mounted.

Motor-Drives [2]

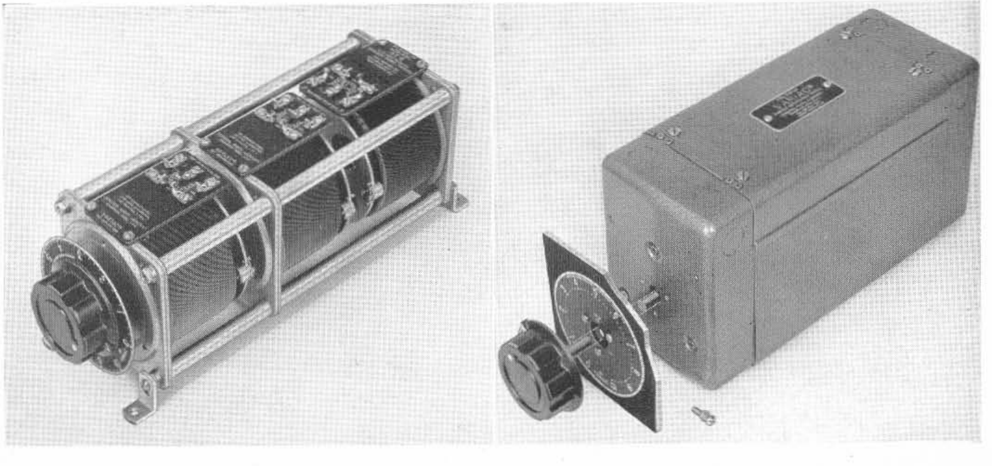
Fig. 13 shows a servo motor mounted on a W5 Variac. The structure is somewhat similar to that of a ganged Variac assembly. The motor mounting plate is attached to the base by four posts. The motor is gear-coupled to the Variac shaft.

Continuous Rotation

Certain specialized applications have called for continuous, 360° rotation.

[2] Standard listings of ball-bearing and motor-driven Variacs will be announced in forthcoming issues of the *Experimenter*. The other modifications described are available on special orders only.

Figure 10. Views of uncased and cased models of a 3-gang, Type W5 Variac. The L-shaped foot brackets shown on the uncased model are supplied as accessories but are not installed before shipment.



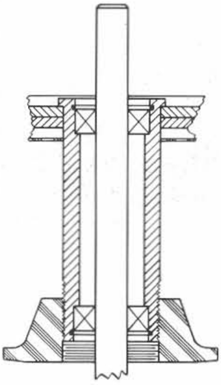


Figure 11. Section drawing showing how larger sleeve bolts are used when ball bearings are installed.

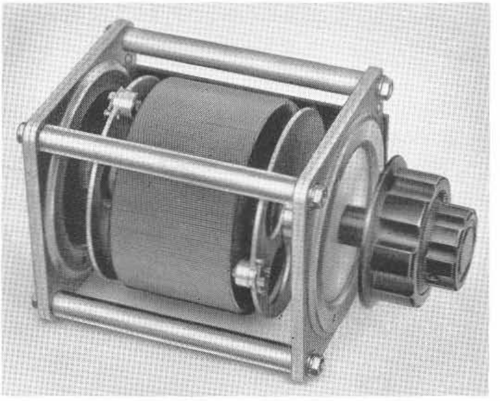


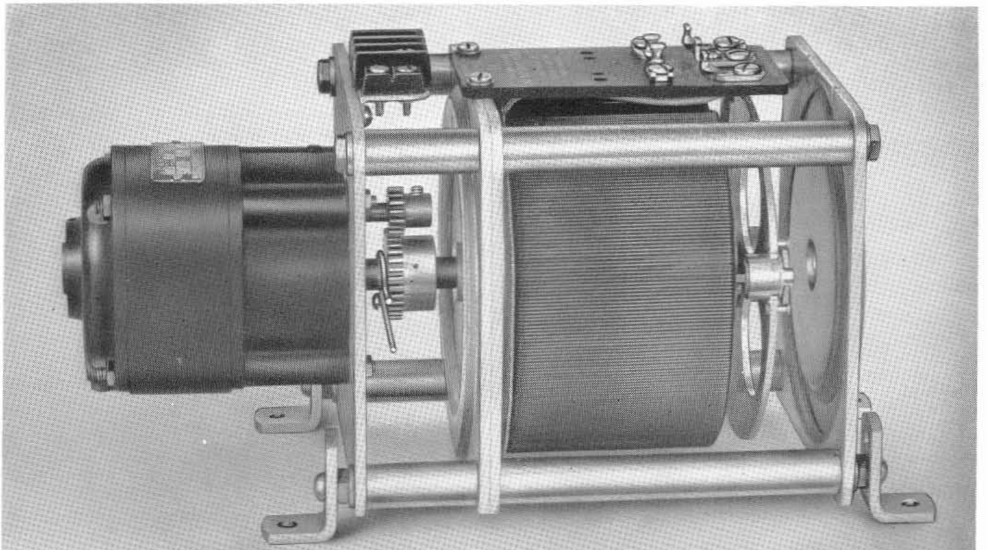
Figure 12. A W5 Variac with two brushes, one at each surface of the winding.

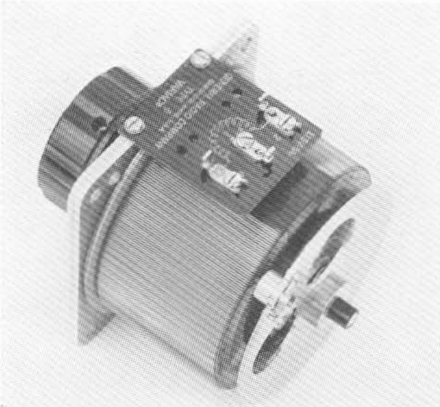
The new W5 design allows ready modification for this purpose. As shown in Figure 14, the take-off connector, which normally serves also as stop for the usual 320° operation, can be cut off to permit traverse of the brush through the "keystone" gap in the winding. The brush lead is brought down through the center of the toroid and out to the terminal plate in the same manner as the tap leads.

Double Track

One of the most interesting special models encountered to date is the double-track unit shown in Fig. 12. Since the two winding forms for the coil are identical, it is possible to form a brush track at each end of the coil. A radiator and take-off structure is mounted at each end in a manner requiring no special parts except a modified sleeve bolt. The coil structure is mounted between two standard bases which serve in this case as bearing supports for the rotating structure. The unit shown is a coaxial design, which

Figure 13. Servo motor and gear coupling can be installed without complicated structures.





permits independent adjustment of the two brushes.

By planning for all of the foregoing features and flexibility in the W5 Variacs at the inception of the redesign program, the resulting types form a well-integrated group which the General Radio Company is proud to offer to its customers.

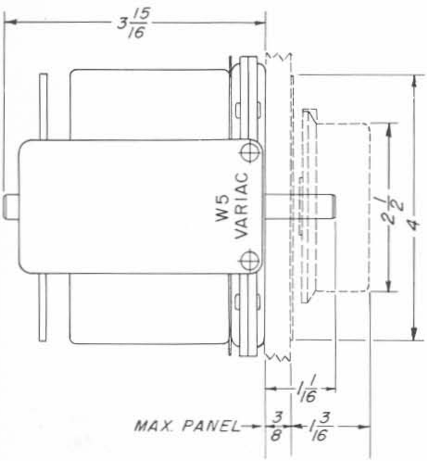
Figure 14. Complete traverse of the brush over 360° can be provided. The winding covers 320°.

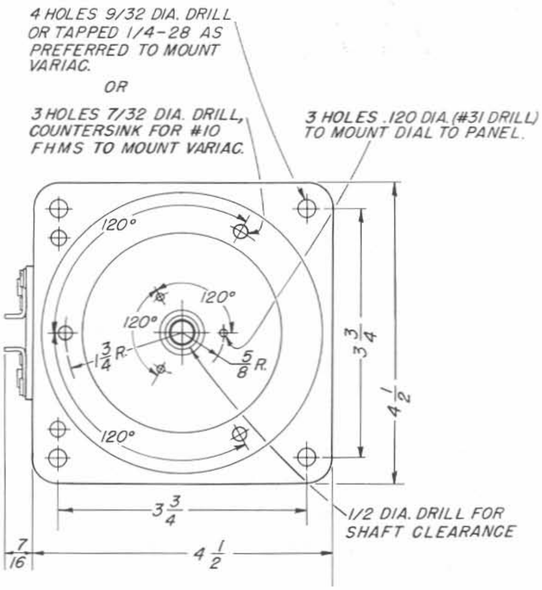
CREDITS: Engineers contributing to the development include G. Smiley, C. A. Tashjian, H. S. Wilkins, and H. M. Wilson. Credit is also due to G. C. Oliver and A. W. Chase for their suggestions in the course of drafting and model making, respectively. The project was under the direction of Ivan G. Easton.

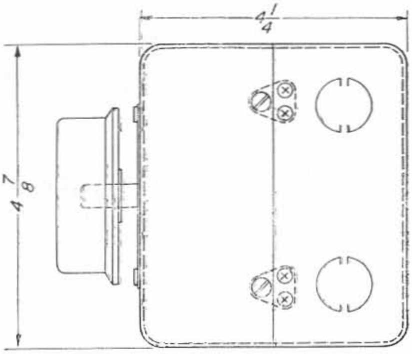
> The cased models, Types W5M, W5MT and W5MT3, are listed under the reexamination service of the Underwriters Laboratories and may be installed in any normal locations. The uncased Type W5 is listed for use in applications where the installation is approved.

FOR COMPLETE SPECIFICATIONS AND PRICES, SEE PAGES 4 AND 5.

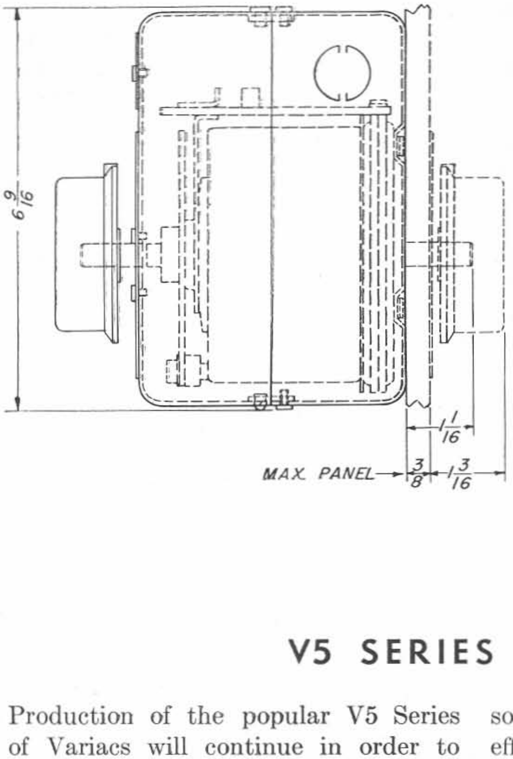
DIMENSIONS OF TYPE W5 AND TYPE W5H VARIACS

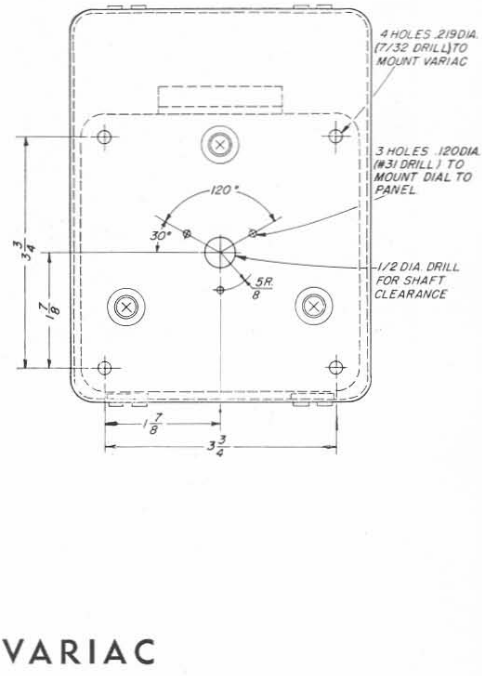






DIMENSIONS OF TYPE W5M AND TYPE W5HM VARIACS

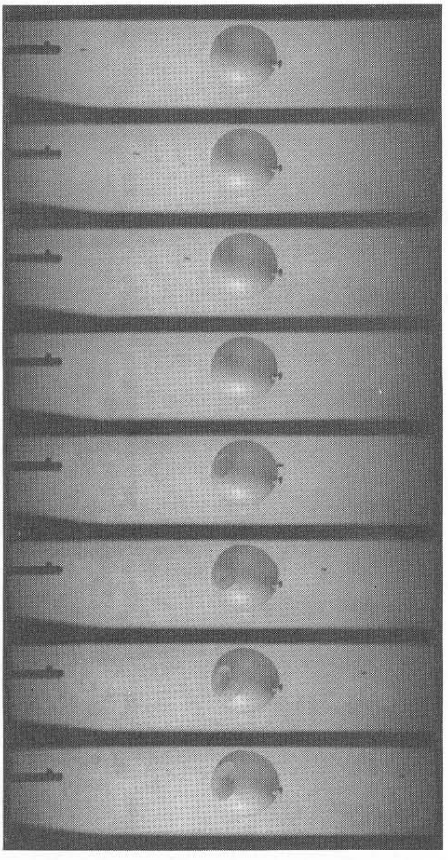




V5 SERIES VARIAC

Production of the popular V5 Series of Variacs will continue in order to accommodate those who are using the V5 types in applications that will not permit substitution of the new W5 types. Owing to recent increases in the cost of labor and materials, it has become necessary to revise the prices of some models in the V5 series. Prices effective January 1 are as follows:

Type	*Price*	*Type*	*Price*
V5	$18.50	V5HM	$21.00
V5M	21.50	V5HMT	28.50
V5MT	26.50	V5MTC	24.00
V5H	23.50	V5MTF	36.00



MISCELLANY

A sequence of photographs taken at 4,000 per second with an exposure time of 1 microsecond, showing a .22 caliber long rifle bullet striking a balloon. The fourth picture from the top shows the bullet inside the balloon. The bullet emerges from the balloon on the fifth picture. Waves caused by the impact of the bullet and by the muzzle blast from the gun can be seen on the rubber surface. This photograph was made on 35 mm film in a General Radio type 651-AH camera, using an Edgerton, Germeshausen and Grier, Inc. High-Speed Stroboscope, Type 501.

Photo courtesy H. E. Edgerton

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