THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

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THE INTERPOLATING FREQUENCY STANDARD

Also

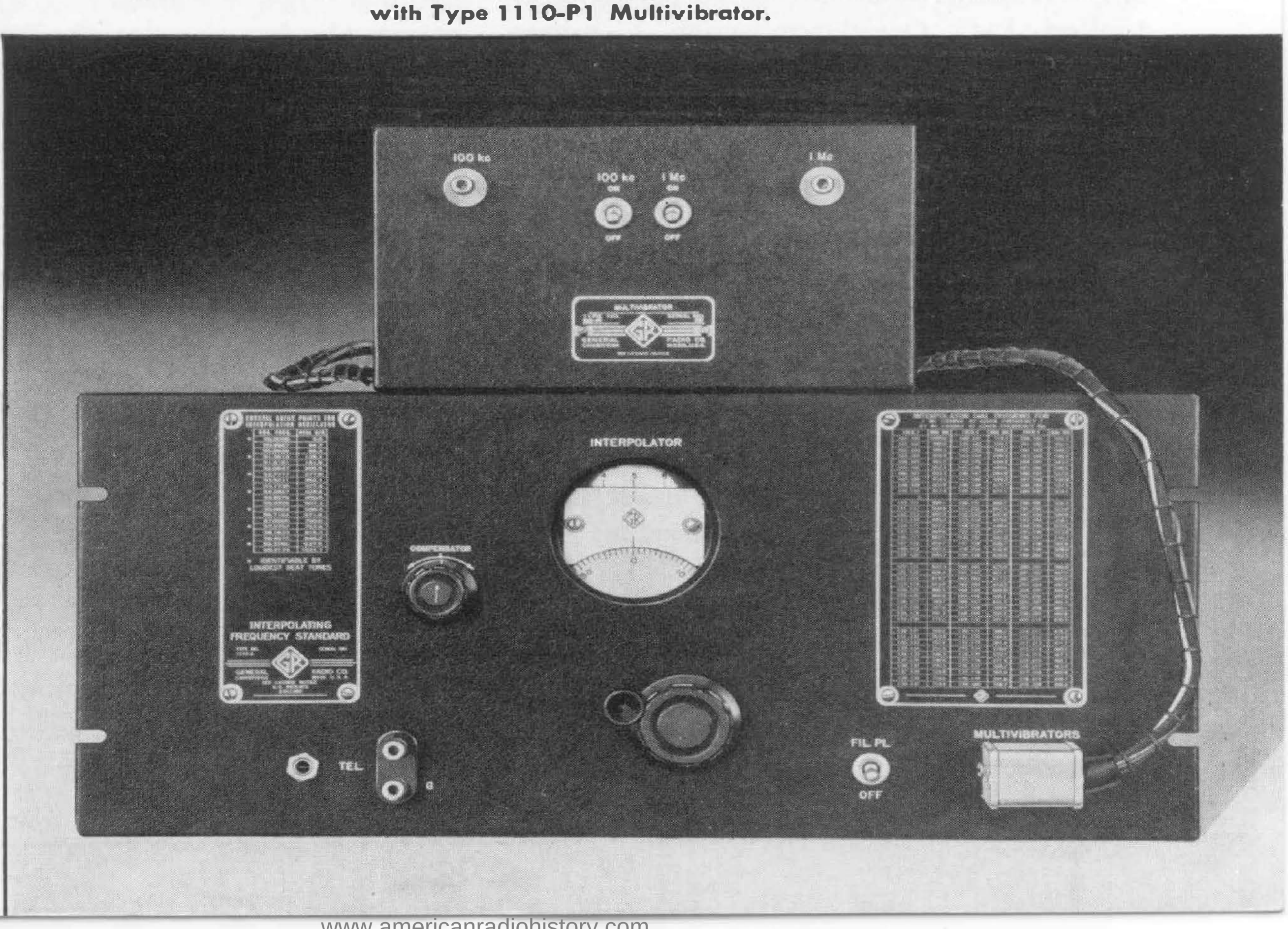
IN THIS ISSUE

Page

● **THE INCREASING IMPORTANCE** of the higher frequencies in radio communication has emphasized the need for more accurate means of frequency measurement between 100 megacycles (the nominal upper limit obtainable with commercial frequency measuring equipment based on a primary standard) and a few thousand megacycles. This range is at present covered by heterodyne frequency meters with an accuracy in the range between 0.01 and 0.1 per cent.

Since the heterodyne frequency meter provides a means of detecting

Figure 1. Panel view of the Type 1110-A Interpolating Frequency Standard with Type 1110-P1 Multivibrator.



the signal and identifying its frequency fairly closely, an additional instrument that provides a reference standard and a means of precise interpolation, and which is designed to work with the frequency meter, is a logical, as well as the least expensive, means of achieving an increased accuracy of measurement.

The TYPE 1110-A Interpolating Frequency Standard meets the requirements for this type of instrument. It is designed to be used primarily with the TYPE 720-A Heterodyne Frequency Meter and the TYPE 620-A Heterodyne Frequency Meter and Calibrator. It can also be used for frequency measurement with high-frequency receivers if their frequency calibrations are sufficiently good to identify frequencies separated by as little as one per cent.

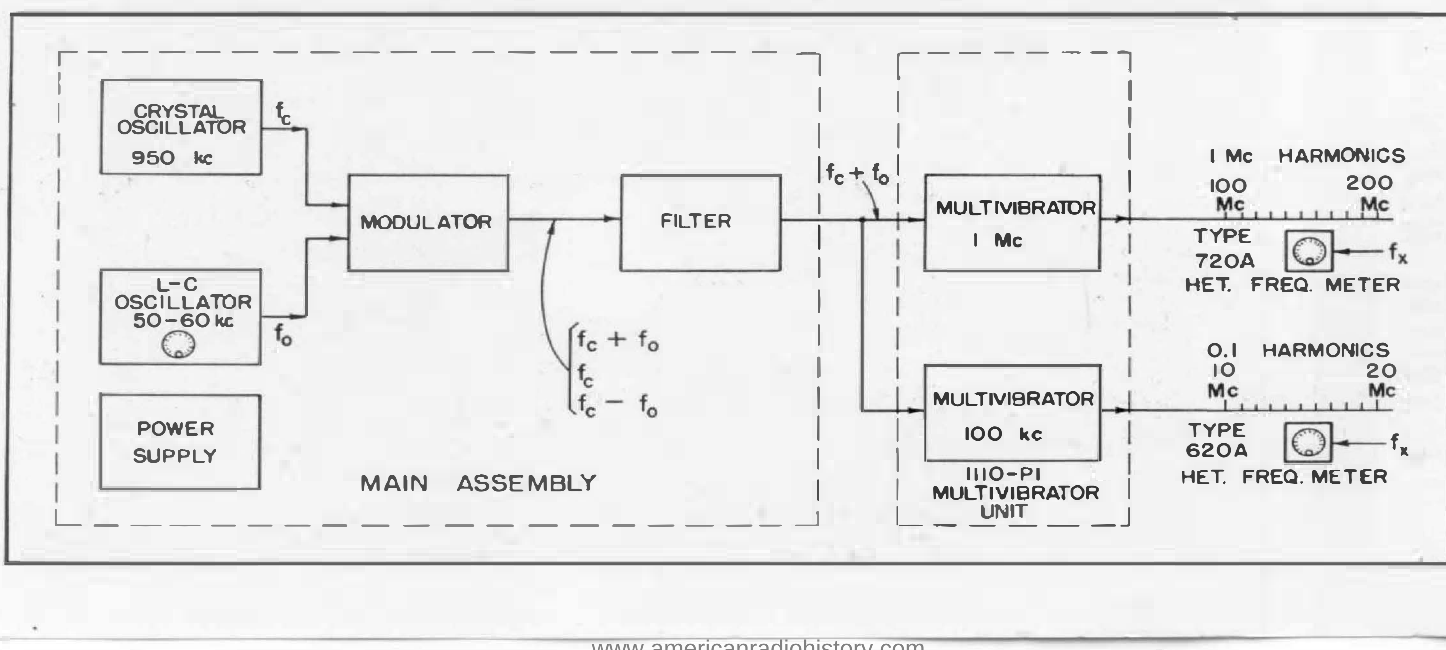
DESCRIPTION

As shown in the functional diagram of Figure 2, the Interpolating Frequency Standard contains a 950 kc quartz crystal oscillator, a 50 to 60 kc bridge-controlled L-C Oscillator, with a mixer, filters, and output amplifiers for obtaining the sum of the two oscillator frequencies as the output frequency. The control of the 50 to 60 kc oscillator is a worm-drive with a scale of 1000 divisions. The output frequency is variable from 1.000 to 1.010 Mc by varying the 50 to 60 kc oscillator over its full range. Means are provided for checking the 50 to 60 kc oscillator frequency against the crystal oscillator frequency at a number of points over the dial. Any error in the 50 to 60 kc oscillator calibration can be corrected by a control provided for the purpose.

The TYPE 1110-P1 Multivibrator Unit contains two multivibrators with output amplifiers. One multivibrator operates at 1 Mc, for use with the TYPE 720-A Heterodyne Frequency Meter, while the other operates at 0.1 Mc for use with the TYPE 620-A Heterodyne Frequency Meter. With either multivibrator, the output frequency of the Interpolating Frequency Standard is used as the control frequency. The multivibrators remain in control over the full range of variation of the control frequency.

Since the range of control frequency is just one per cent, it follows that, as the control frequency is varied over its range, the frequencies of all the harmonics of the multivibrators will likewise be varied over a range of one per cent. For the 100th harmonic this means that the total range of adjustment is from 100 to

Figure 2. Block diagram showing the functional arrangement of the interpolating frequency standard.



101 Mc for the 1 Mc Multivibrator and from 10.0 to 10.1 Mc for the 0.1 Mc Multivibrator. For harmonics higher than the 100th, the one per cent range is greater than 1 Mc or 0.1 Mc, so that *continuous coverage* is obtained.

METHOD OF MEASUREMENT

In making frequency measurements it is usually desired to obtain the result on a cycles basis rather than a percentage basis. To do this, it is convenient to think of the frequency of any multivibrator harmonic as its unaltered value *plus* an increment in frequency. The unaltered value is the true standard frequency value obtained when the dial of the Interpolating Frequency Standard is set at zero or, more precisely, when the 50 to 60 kc oscillator is set at 50 kc in terms of the crystal oscillator frequency. The increment in frequency is the fraction of a megacycle (or of 0.1 Mc) required to obtain the actual frequency. This increment can be calculated from the number of dial divisions required to advance any harmonic by just 1 Mc (or 0.1 Mc). These values are prepared in the form of a table mounted on the panel of the instrument. The fraction of 1 Mc (or 0.1 Mc) in any given case is then the number of dial divisions divided by the number of dial divisions for 1 Mc (or 0.1 Mc). This fraction is then *added* to the unaltered frequency of the used harmonic to obtain the final result.

NUMERICAL EXAMPLE

An illustrative example may be easier to follow. Suppose the reading of the Type 720-B Heterodyne Frequency Meter at zero beat with the frequency being measured is 162.3 Mc. The dial of the Interpolating Frequency Standard is advanced, say, 249.0 divisions to obtain zero beat with the frequency meter. The used harmonic is 162 (the next integral value below 162.3); entering the table for the range 162-163 Mc, it is found that the dial of the Interpolating Frequency Standard must be advanced by 617.3 divisions to cover the 1 Mc range from 162 to 163 Mc. Since the dial was actually advanced 249.0 divisions, the fraction 249.0/617.3 of a megacycle was actually covered, amounting to 0.404 Mc. The final result is then 162 + 0.404 = 162. 404 Mc.

It is evident from the above that if the dial of the Interpolating Frequency Standard is set at zero (or, more precisely, when the 50 to 60 kc oscillator is set to 50 kc in terms of the crystal oscillator), the output harmonics are all multiples of 1 Mc (or 0.1 Mc) and can be used as standard frequencies for checking calibrations of receivers, oscillators, heterodyne frequency meters, etc.

It also should be evident that, in making frequency measurements, the dial reading of the Interpolating Frequency Standard would normally never exceed the value given in the table. For, if the frequency increment exceeds 1 Mc (or 0.1 Mc), it would be natural to use the next higher harmonic and obtain a small frequency increment.

HARMONICS OF THE FREQUENCY METER

When the equipment is used to measure frequencies lying in the fundamental frequency range of the heterodyne frequency meter, all of the steps required have been covered above. Harmonics of the frequency meter can be used, however, for extending the range of measurement to higher frequencies. In such cases, the number of the *heterodyne frequency meter* harmonic must be determined and the result obtained in measuring the frequency meter fundamental (as detailed above) must be multiplied by this harmonic number to obtain the value of the unknown frequency. In the above numerical example, if the fifth harmonic of the heterodyne frequency meter was used to beat with the unknown frequency, the final result would be 5 × 162.404 = 812.020 Mc. Identification of the harmonic order can easily be made by receiver calibration, wavemeter, or other approximate means.

ACCURACY

The interpolator dial has 1000 divisions, corresponding to 0.001 per cent, or 10 parts per million, per division. Setting the dial to one-fifth division, therefore, gives a precision of two parts per million. If the frequency error of the dial is carefully corrected by means of the trimmer dial on the panel, the overall accuracy of measurement is limited mainly by the accuracy of the crystal oscillator. Since the frequency of the crystal oscillator can be checked and adjusted in terms of standard-frequency radio transmissions to well within one part in a million, measurements to two or three parts per million are possible after these checks and adjustments are made. If the oscillator is used without trimming, the over-all accuracy is about ± 25 parts per million (0.0025 per cent).

MOUNTING

The interpolating standard is mounted on a standard 19-inch relay rack panel, and the multivibrator unit, Type 1110-P1, is mounted in a smaller cabinet attached to the interpolator by a plug-in cable. This arrangement facilitates coupling the multivibrator output to the heterodyne frequency meter or receiver, so that maximum response to weak higher harmonics can be obtained. This flexibility of mounting and the general simplicity of operation make the Interpolating Frequency Standard a convenient and easy instrument to use.

— J. K. Clapp

SPECIFICATIONS

Frequency Range: The output frequency range of the 1110-A Interpolating Frequency Standard is from 1000 to 1010 kc. The output frequencies of the 1110-P1 Multivibrator Unit are 1.0- and 0.1-Mc fundamentals with harmonics up to 200 or more.

Calibration: The variable frequency oscillator dial has 1000 divisions corresponding to 0.001 per cent or 10 parts per million per division.

A list of check settings is provided on the panel. This check can be made at any time by simply plugging a set of headphones into the jack or binding posts provided on the panel. A trimmer control on the panel provides for adjusting the oscillator to agreement with the crystal.

To facilitate conversion of the dial readings from their basic percentage or parts per million values of frequency increment to fractions of a megacycle or of 0.1 Mc (100 kc), a table listing the number of dial divisions for frequency increments of 1.0 Mc and 0.1 Mc at each harmonic from 100 to 220 is given on the panel. A simple slide-rule ratio then gives the desired frequency increment.

Crystal Oscillator: The crystal oscillator is adjusted to within one part in a million of correct frequency at room temperature. It should be reliable to within ±10 parts per million at ordinary room temperatures. The crystal frequency can be checked and adjusted in terms of standard frequency transmissions from WWV using an external receiver, maintaining the variable oscillator at exactly 50 kc in terms of the crystal.

Accuracy of Measurement: The over-all accuracy of measurement is ±25 parts per million using the oscillator dial directly. If the oscillator is carefully trimmed in terms of the crystal, the over-all accuracy is limited principally by the error of the crystal.

Vacuum Tubes: The following tubes are supplied:

2 — 6AC7	3 — 6J5GT/G
4 — 6SN7-GT	1 — 5R4GY
1 — 6SJ7	1 — 9001
1 — 6SA7	1 — 2LAP-430 (Bridge Circuit Lamp)

Power Supply: Either 105-125 or 210-250 volts, 50-60 cycles.

Power Input: 85 watts from 115-volt, 60-cycle line.

Mounting: TYPE 1110-A Relay Rack; TYPE 1110-P1 (attached to 1110-A by cable) small metal cabinet.

Accessories Supplied: Line connector cord and TYPE 1110-P1 Multivibrator Unit with connecting cable.

Accessories Required: Head telephones.

Dimensions: 1110-A Panel (length) 19 x (height) 8¾; behind panel, (length) 17¼ x (height) 8⅜ x (depth) 14 inches. 1110-P1 (length) 9¼ x (height) 5¼ x (depth) 5¼ inches.

Net Weights: TYPE 1110-A assembly, 40 pounds; TYPE 1110-P1 Multivibrator Unit 7½ pounds.

Type		*Code Word*	*Price*
1110-A	**Interpolating Frequency Standard* . . . . .**	RAVEN	**$725.00**

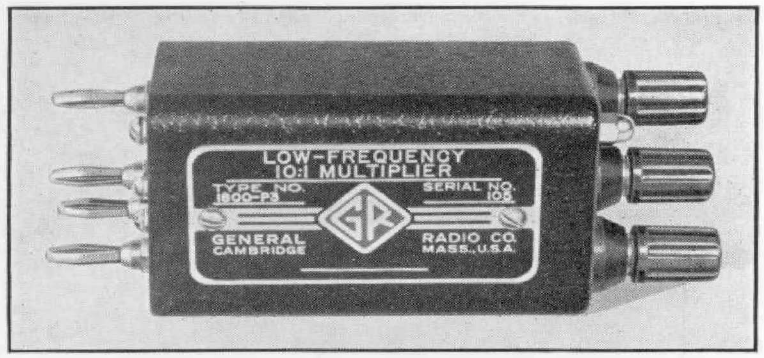
*U.S. Patent 2,012,497.

Licensed under patents at the American Telephone and Telegraph Company and under patents and patent applications of G. W. Pierce.

Note: The method of frequency measurement described in the foregoing article was also discussed in a paper by J. K. Clapp entitled "Frequency Measurement by Sliding Harmonics," which appeared in the October, 1948, issue of the *Proceedings of the Institute of Radio Engineers.* — EDITOR.

A LOW-FREQUENCY MULTIPLIER FOR THE VACUUM-TUBE VOLTMETER

The TYPE 1800-P3 Multiplier extends the range of the TYPE 1800-A Vacuum-Tube Voltmeter to 1500 volts for both d-c and low-frequency a-c measurements. This multiplier plugs into the binding posts on the panel of the voltmeter. For d-c use the multiplier consists of a fixed resistance voltage divider giving a 10:1 reduction in the voltage applied to the voltmeter, while for a-c measurements a capacitance-resistance voltage divider is used.



View of the Type 1800-P2 Low-Frequency Multiplier.

The multiplier is not intended for use at frequencies above 5 megacycles. For higher frequencies the TYPE 1800-P2 Multiplier[1] is recommended.

SPECIFICATIONS

Multiplier Ratio: DC, 10:1 ±1 per cent for all TYPE 1800-A Voltmeters.

AC, Adjustable to 10:1 ±0.5 per cent. A multiplier ordered with a TYPE 1800-A Voltmeter is adjusted at 1500 cycles and 15,000 cycles to that voltmeter at our factory. When the multiplier is ordered for use with a TYPE 1800-A Voltmeter already in the hands of the user, the necessary adjustments can be made by the user. If these adjustments are not made, an additional error of ±5 per cent is possible.

Input Impedance: DC, 10 megohms.

AC, 10 megohms parallel resistance; 10 $\mu\mu$f parallel capacitance.

Frequency Error: 20 — 20,000 c ±2 per cent.
20 kc — 5 Mc ±4 per cent.

Waveform Error: As with the TYPE 1800-A Voltmeter, the deviation from r-m-s reading can be as large as the percentage of harmonics present in the signal, but the error will not necessarily be the same as that of the voltmeter used without the multiplier because of the different impedance presented to the voltmeter by the multiplier.

Dimensions: 5 x 2 x 2 inches.

Net Weight: 8 ounces.

Type		*Code Word*	*Price*
1800-P3	**Low-Frequency Multiplier . . . .**	ABEAM	**$25.00**

[1] "A Voltage Multiplier for the Vacuum-Tube Voltmeter," *General Radio Experimenter*, May, 1948.

MORE VARIAC WATTS FOR YOUR DOLLAR

With the new V-5, V-10, and V-20 series now in stock, it seems advisable to point out to our friends and customers that the judicious selections of the proper Variac or Variac combination may often result in substantial savings for a given power requirement.

Reference to Table I will quickly reveal that certain load requirements may be met by several Variac assemblies, of which one is an outstanding bargain when considered on the basis of KVA rating per dollar of list price. In this respect, parallel combinations of the V-20 series have considerable advantage over the older 50 series Variacs.

Note particularly the following comparisons: For 115-volt service in the 10 KVA load range, a V-20G3 parallel gang delivers 10.35 KVA for $204 versus a 50-AG2 parallel gang delivering 10 KVA for $320. Here the V-20 series delivers 62 per cent more KVA per dollar. In 230-volt service a V-20G2 series gang delivers 6.9 KVA for $126 versus a 50-B, which delivers 7.0 KVA for $140, a 9.6 per cent gain for the V-20 over the 50-B. Other examples will be apparent on ex-

TABLE I

SINGLE-PHASE VARIAC UNITS AND COMBINATIONS

Listed by Common Line Volts and Increasing KVA

Model	Connection	KVA	Cost of Variacs	Cost of Chokes	Total $	KVA/$
115-Volt Service						
200-B	———	.170	12.50	———	12.50	.0136
V-5	———	.862	18.50	———	18.50	.0466
V-10	———	1.725	33.00	———	33.00	.0523
V-20M	———	3.45	55.00	———	55.00	.0627
50-A	———	5.00	140.00	———	140.00	.0357
V-20G2	Parallel	6.90	126.00	10.00	136.00	.0507
50-AG2	Parallel	10.00	310.00	10.00	320.00	.0313
V-20G3	Parallel	10.35	182.00	22.00	204.00	.0507
50-AG3	Parallel	15.00	460.00	22.00	482.00	.0311
230-Volt Service						
V-5H	———	0.575	21.00	———	21.00	.0274
V-10H	———	1.15	34.00	———	34.00	.0338
V-5G2	Series*	1.725	49.00	———	49.00	.0352
V-20HM	———	2.30	55.00	———	55.00	.0418
V-10G2	Series*	3.45	79.00	———	79.00	.0437
V-20HG2	Parallel	4.60	126.00	10.00	136.00	.0338
V-20G2	Series*	6.90	126.00	———	126.00	.0548
50-B	———	7.00	140.00	———	140.00	.0500
50-BG2	Parallel	14.00	310.00	10.00	320.00	.0438
50-GB3	Parallel	21.00	460.00	22.00	482.00	.0436
460-Volt Service						
V-5HG2	Series*	1.15		———	54.00	.0213
V-10HG2	Series*	2.30		———	81.00	.0284
V-20HG2	Series*	4.60		———	126.00	.0365
50-BG2	Series*	14.00		———	310.00	.0452

*Cannot be used where a common connection between input and output is required.

The trade name VARIAC is registered at the U. S. Patent Office. Variacs are patented under U. S. Patent No. 2,009,013 and British Patent No. 439,567 amination of Table I. For series operation of 230-volt units on 460-volt circuits, however, the TYPE 50-BG2 gives the greatest KVA per dollar.

There are practical limitations on the use of such assemblies. It should be noted that ganged units do not mount in the same space as a single unit, and that series connections cannot be used when a common ground is required between line and load. Further, chokes are necessary with parallel-connected Variacs, and choke equipment has to be mounted and connected, so that the ease and simplicity of use that characterizes the single-unit Variac is partially lost. A 2-gang or 3-gang unit with chokes cannot, for instance, be used conveniently on a laboratory bench, unless a special mounting is devised with proper plug-in terminal equipment.

On the other hand, for building into permanent equipment, where mounting and grounding requirements can be controlled, ganged assemblies can often be selected that will meet the power requirements at considerably lower cost than that of the next larger single unit.

While standard gang assemblies of Variacs are limited to a maximum of three units, two or more gangs can be mechanically coupled by the user to obtain the same advantage in three-phase delta or wye circuits.

— GILBERT SMILEY

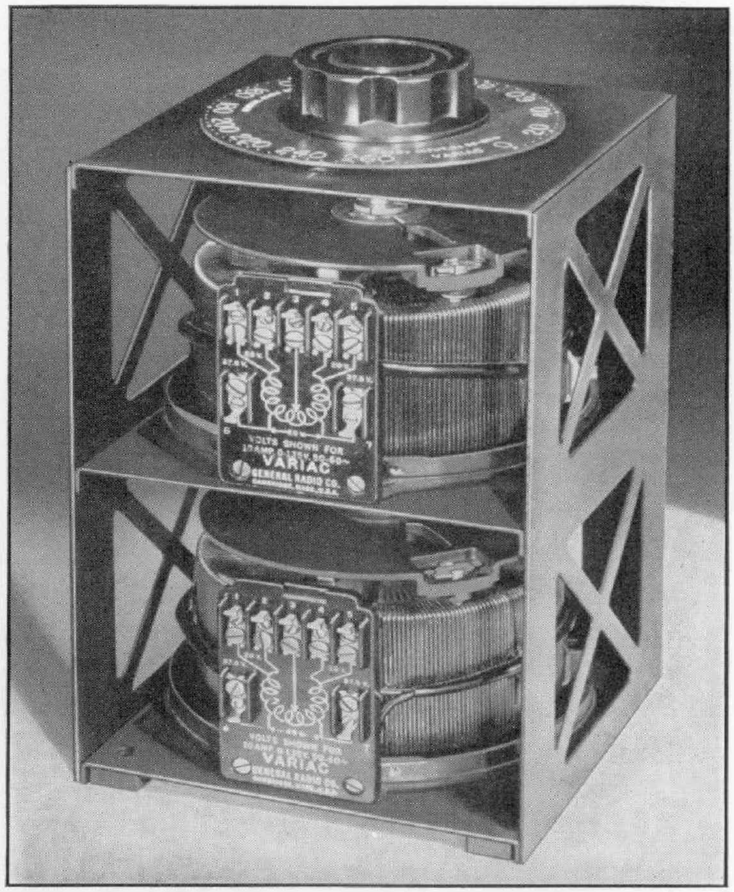
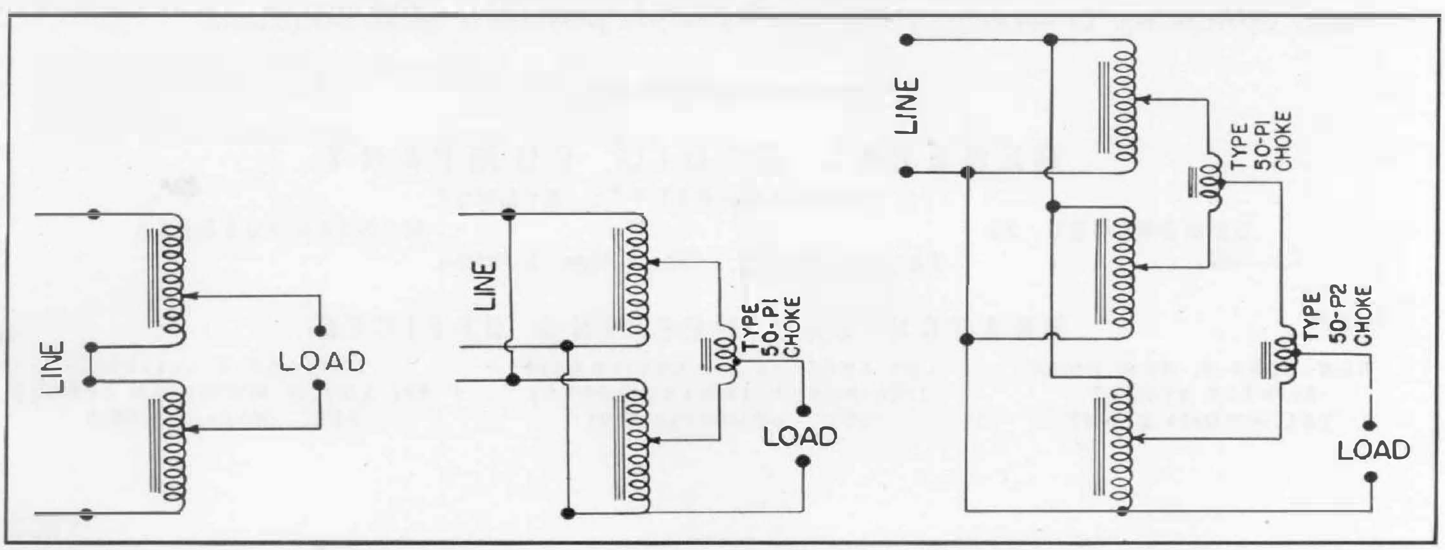


Figure 1. View of a Type V-10G2 Ganged Variac Assembly. The supporting structure is of welded steel and can be mounted either vertically or horizontally.

Figure 2. Connection diagrams for ganged Variacs in single-phase circuits. Left, 2-gang series connection; center, 2-gang parallel; and, right, 3-gang parallel.



MISCELLANY

PAPERS — By Donald B. Sinclair, Assistant Chief Engineer, "A New Method of Measuring the Product of Two Voltages Using a Single Vacuum Tube," at the West Coast Convention of the I.R.E., Los Angeles, October 1, and at a meeting of the Boston Section, I.R.E., November 18. The paper was based on the work of Dr. M. A. H. El-Said, Senior Lecturer at Fuad I University, Cairo, Egypt. Dr. El-Said has been in this country on a Fellowship Technical Mission provided by the Egyptian Government. Some of the experimental work covered by the paper was performed by Dr. El-Said in collaboration with R. A. Soderman in the General Radio Laboratories.

RECENT VISITORS to our plant and laboratories — Dr. Jean Mercier, Dr. Rene Musson-Genon, and Mr. Ernest Rostas of the Hyperfrequency Research Laboratories, Cie. Francaise Thomson-Houston, Paris; and Mr. D. R. Austin, Consulting Engineer, Bartle and Co., Johannesburg, South Africa, distributors of General Radio products in South Africa.

NORWAY — It is with pleasure that we announce for the first time on these pages our representation in Norway by the firm Maskin-Aktieselskapet ZETA, Drummensveien 26, Oslo 22. ZETA has been the distributor of our products in Norway for several years and was appointed on an exclusive basis last spring. As our Norwegian friends know, the management is in the capable hands of Messrs. Braenne, Elligers, and Hammerik. Mr. G. Hammerik is in charge of the department that handles our products.

DENMARK — We also take pleasure in announcing the appointment of Mogens Bang & Co., Copenhagen/Skodsborg, as our representatives for Denmark. Mr. Mogens Bang is equipped to provide our Danish customers with all information concerning our products.

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

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