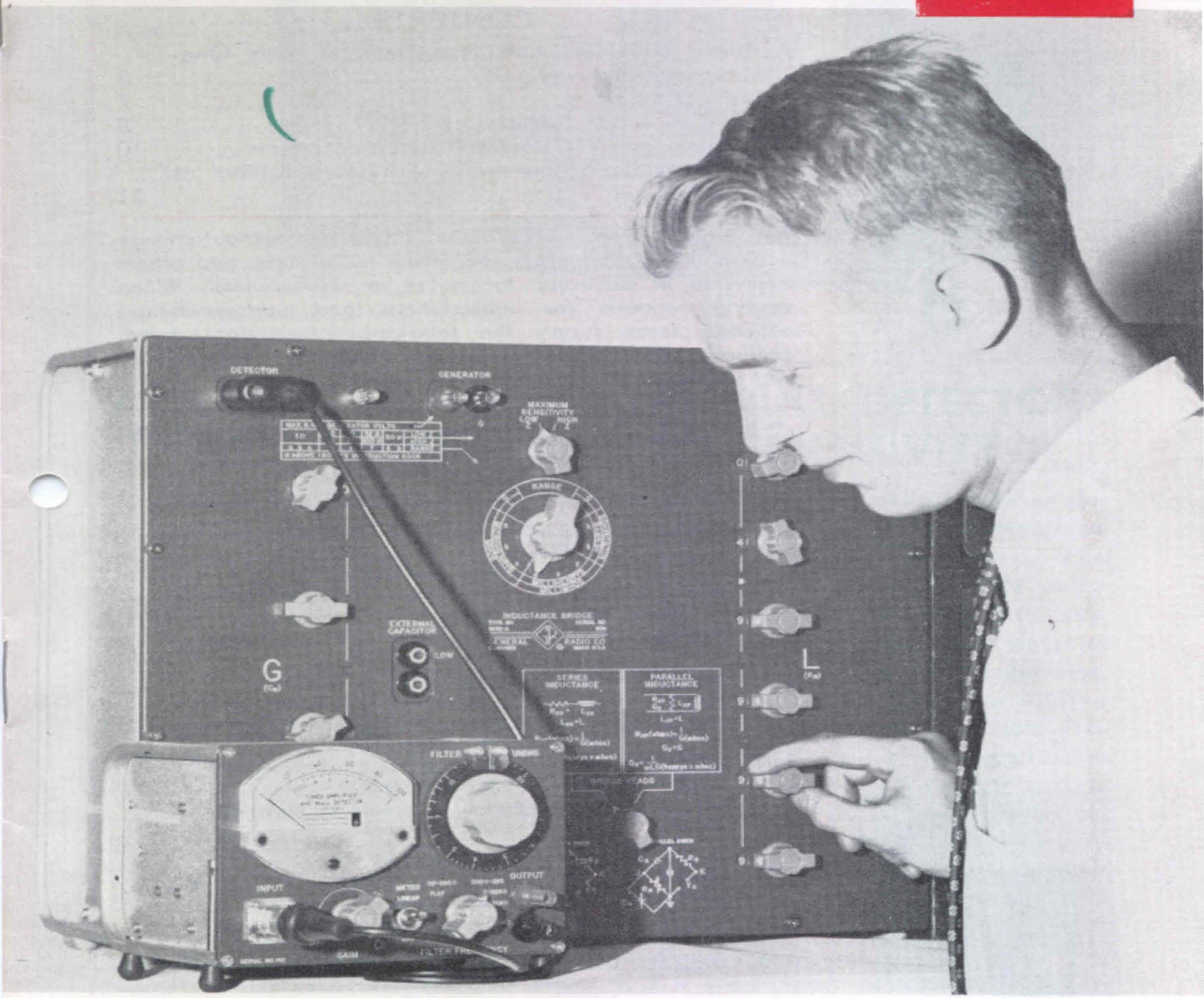
THE GENERAL RADIO

EXPERIMENTER



VOLUME 35 No. 7 JULY, 1961

IN THIS ISSUE

THE GENERAL RADIO

EXPERIMENTER

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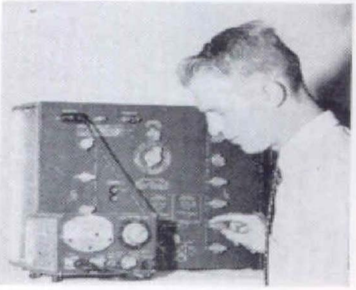


High sensitivity and low noise are features of the new Type 1232-A Tuned Amplifier and Null Detector, shown here with the Type 1632-A Inductance Bridge.

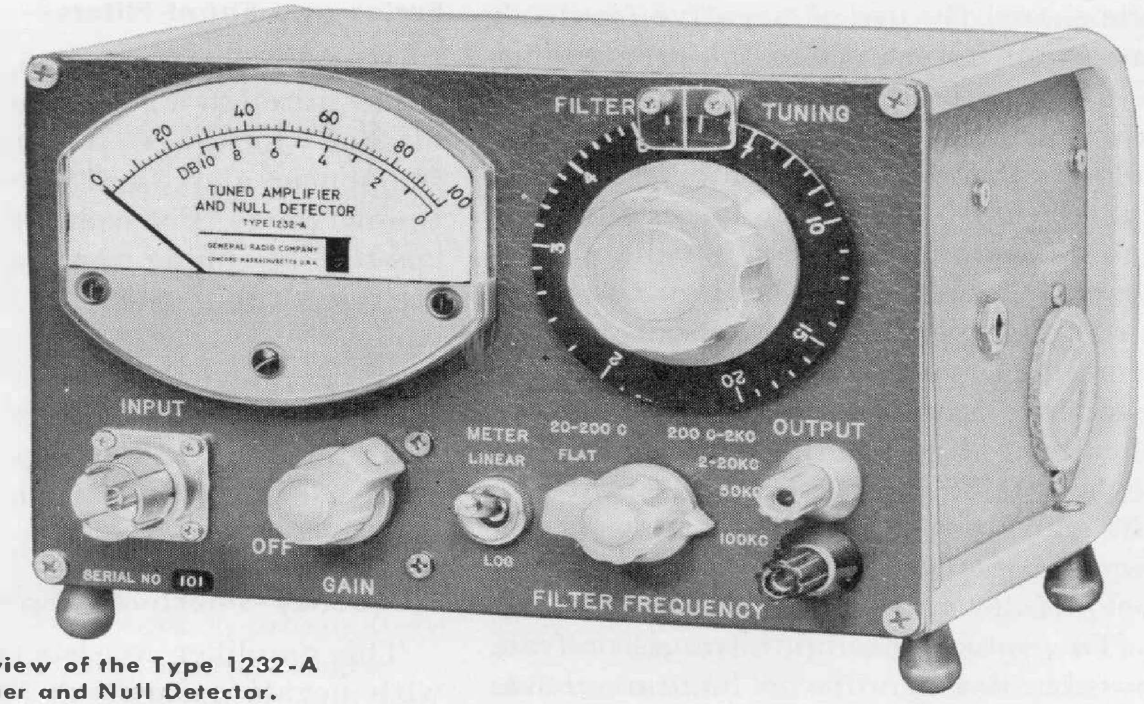


Figure 1. Panel view of the Type 1232-A Tuned Amplifier and Null Detector.

A TUNED AMPLIFIER AND NULL DETECTOR WITH ONE-MICROVOLT SENSITIVITY

The Type 1232-A Tuned Amplifier and Null Detector is a sensitive, low-noise, transistor amplifier, which tunes continuously from 20 cps to 20 kc, with additional fixed-tuned frequencies of 50-kc and 100-kc. It is intended primarily as a bridge detector but has many other important uses, among them the detection of high-frequency modulated signals (with a crystal demodulator), approximate wave analysis at audio frequencies, and as a preamplifier for transducers.

The outstanding characteristics of this instrument — one-microvolt sensitivity, low noise level, and continuous tuning — result from unusual features of circuit design.

CIRCUIT

Preamplifier

Of the elements shown in the block diagram of Figure 2, the preamplifier is one of the most important, because the minimum detectable signal is determined by the preamplifier noise level. The type of transistor for the first stage was chosen to minimize noise, not only from low impedance sources such as inductance bridges at low frequencies, but also from high impedance sources such as capacity bridges at low frequencies. In the light of simplified noise theory[1], this means a transistor with a low open-circuit noise generator, i_n, as well as low short-circuit noise generator, e_n. After noise diagrams were plotted for many transistors, it was discovered that the 2N169A transistor when operated at very low collector current had a noise figure of 3 to 5 db at an optimum source impedance of 50 kilo-ohms, which is unusually high for a

[1] A. E. Sanderson and R. G. Fulks, "A Simplified Noise Theory, and its Application to the Design of Low-Noise Amplifiers," *IRE Transactions on Audio*, July-August, 1961.

transistor. By use of negative feedback the input impedance of the preamplifier is also made 50 kilohms, and the noise level as read on the output meter is relatively constant and independent of the source impedance. This eliminates the inconvenience of having the output meter bang off scale whenever the input circuit is open circuited, as often happens with vacuum-tube amplifiers. In addition, any large difference between the short-circuit and open-circuit noise levels would require increased range on the gain control, since it is always necessary to operate with the noise level well below full-scale output on the meter.

To protect the input transistor from possible damage due to large overloads at the input, it is preceded by a limiter consisting of a series capacitor and two shunt silicon rectifier diodes. This circuit effectively prevents signals greater than 1 volt, peak-to-peak, from reaching the input transistor and does not contribute noise or distortion to low-level signals. With the gain control set for 1 μv full scale, it is possible to connect the input to a 115-volt ac line without damage to the input transistor.

Maximum gain of the preamplifier is about 40 db, which is adequate to swamp the noise of succeeding stages. The total range of the volume control is 120 db, which reduces the full-scale sensitivity to 1 volt full scale, and attenuation in db is roughly proportional to the rotation angle of the gain control.

Series and Shunt Filters

After preamplification, the signal passes through a set of series and shunt filters, which are designed to reject frequencies above and below the selected tuning range. For example, on the 200-cps-to-2-kc tuning range, a series capacitor rejects all frequencies below 200 cps, while a shunt capacitor rejects all frequencies above 2 kc. On all switch positions except FLAT and 20-200 cps, another rejection filter reduces the response at 60 cps to greater than 60 db below peak response.

Frequency-Selective Amplifier

This amplifier consists of three stages with negative feedback through a null network, which has its null at the desired operating frequency. Since there is negative feedback at all frequencies but the desired one, the over-all response peaks at this frequency and is roughly equivalent to that of a tuned circuit with a Q of about 20 (5% bandwidth). The unique feature of this null network is its one-pot tuning[2]. Many null networks require three variable elements, either ganged capacitors or ganged potentiometers. This leads to many problems in alignment and tracking the three elements to maintain a good null. The Hall null network[2] has a perfect null in theory for any position of the tuning potentiometer, and it is possible to cover a 10:1

[2]Henry P. Hall, *IRE Transactions on Circuit Theory*, September 1955, Vol. CT-2, No. 3, p 283. See also the article on page 8 of this issue.

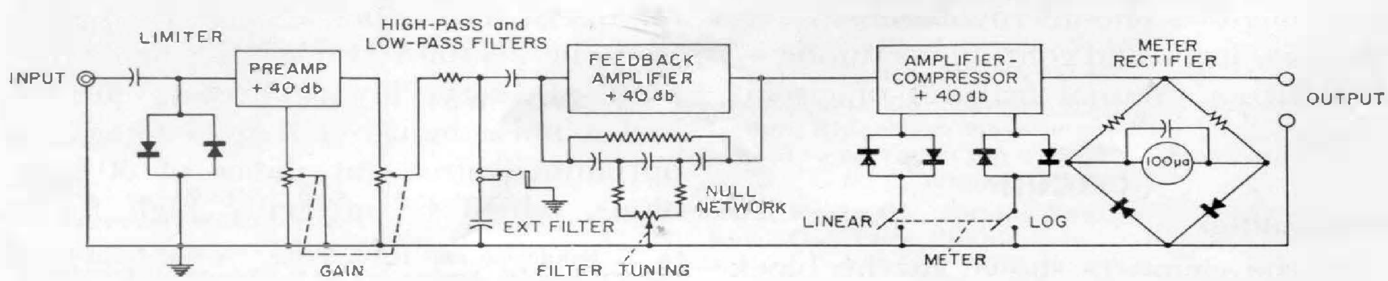


Figure 2. Block schematic of the null detector.

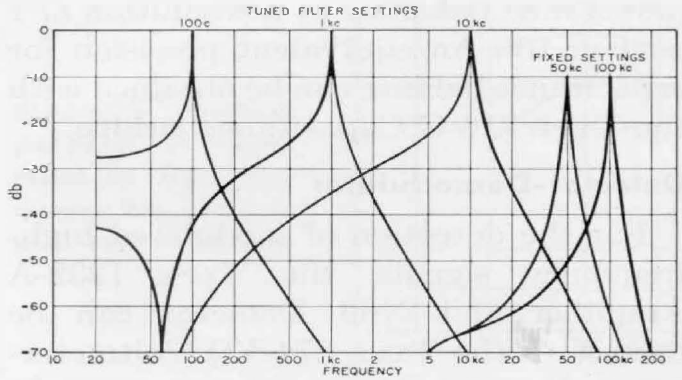


Figure 3. Typical filter characteristics.

tuning range with a 40-db exponential potentiometer. Tuning capacitors are switched to change ranges, which has the advantage of maintaining the impedance level of the null network approximately constant for the three tuning ranges.

Since the 50-kc and 100-kc null networks are not required to be tunable, conventional twin-T null networks are used.

On the FLAT position of the range switch, all filters are switched out and the frequency response is flat to within ±3 db from 20 cps to 100 kc. The overall gain of the amplifier is reduced by 26 db to keep the noise level on the output meter equal to about 10% of full scale at maximum gain.

Amplifier-Compressor

The gain of the frequency selective amplifier is about 40 db, and another 40 db of gain is supplied by the amplifier-compressor, making the total gain of the amplifier about 120 db. With the METER switch set to the LINEAR position, the amplifier-compressor functions as a linear amplifier, driving the meter rectifier circuit as well as supplying the output terminals with about 1.4 volts for full-scale deflection of the meter. The dc supplied to the last transistor is sufficient to drive the output meter to full scale, but very little more, so that it is impossible to damage the meter by overdriving the amplifier. For null detector use, the meter switch is thrown to LOG and the upper part of the meter scale is compressed. Two pairs of silicon diodes are switched in shunt with the collector resistors of two transistors to provide a nonlinear collector impedance. Due to the voltage offset of the silicon diodes, the bottom 20% of the meter scale is virtually unaffected. A signal level corresponding to 100% deflection for linear response will drop to 50% for logarithmic response. An increase of 20 db increases the reading to 80%, and another 20 db raises the reading to 100%. Thus the dynamic range of the instrument for logarithmic operation is about 40 db greater than it is for linear, although the minimum detectable signal is the same.

Meter Circuit

The meter circuit uses a full-wave rectifier in order to double the ripple frequency that passes through the meter and thus to prevent the needle from vibrating visibly at 20 cps. Resistors are used in place of two of the rectifiers in the conventional full-wave bridge in order to linearize the relation between meter indication and signal level, and to minimize distortion. No dc amplification was incorporated into the meter circuit, so that there is no need for a dc zero adjustment on the front panel and no possibility of dc zero instability. High-impedance, crystal-type earphones can be connected to the output terminals.

External Filter

External filters can be connected at the EXT FILTER jack. When a telephone plug is inserted in this jack, the built-in shunt filter is disconnected. The external filter may be either a series tuned circuit to trap out an undesired frequency, or an antiresonant parallel tuned circuit to enhance the selectivity at the desired frequency. For the purpose of calculating the Q of the external filter, the source impedance is about 700 ohms. Since the external filter is plugged into the circuit at a point beyond the 60-cycle rejection filter and where there is 80 db gain to the meter circuit, it is important that the external filter be shielded and preferably that it use a toroidal inductor for minimum sensitivity to hum pickup.

USES

The high sensitivity, low noise level, and continuous-tuning features of this instrument foster a wide variety of uses.

Figures 3, 4, 5, and 6 show the selectivity, response and noise characteristics as functions of frequency.

Bridge Balancing

The above combination of features makes possible extremely precise bridge settings, even with very low-power generators, at any frequency in the audio range. Provision for logarithmic response makes adjustments of generator level unnecessary. The new General Radio meter case, with open, easily read scale, further facilitates the bridge balance.

With the Type 1632-A Inductance Bridge, this null detector makes possible inductance balances to a resolution of 1 part in 10^6. An equivalent precision for capacitance balance can be obtained with the Type 716-C Capacitance Bridge.

Detector-Demodulator

For the detection of modulated high-frequency signals, the Type 1232-A Amplifier and Null Detector can be used with the Type 874-VQ Voltmeter-Dectector. Sensitivity is approximately 200 µv full scale up to about 2000 Mc.

Amplifier or Preamplifier

The high sensitivity of this instrument permits its use as a preamplifier for transducer outputs or oscilloscope input. As a general-purpose laboratory amplifier, it offers both selective and flat characteristics.

Audio Spectrum Analysis

The tuned amplifier can be used as an audio-frequency wave analyzer with a sensitivity of one microvolt and a bandwidth of about 5%. For approximate measurements, the gain can be assumed to be constant with frequency, but excellent accuracy can be obtained if the amplifier is first calibrated with a constant-amplitude, variable-frequency signal.

Since the range of the db scale on the output meter is limited to 10 db, a calibrated attenuator is necessary for greater ranges. With the Type 546-C

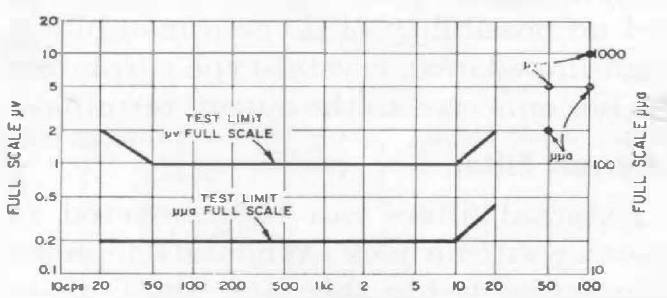


Figure 4. Test limits for both voltage and current as functions of frequency.

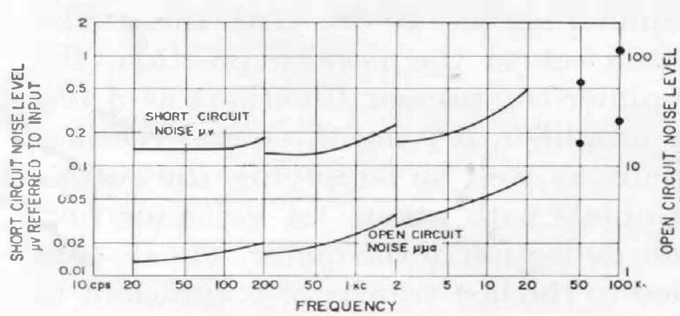


Figure 5. Typical noise levels as a function of frequency.

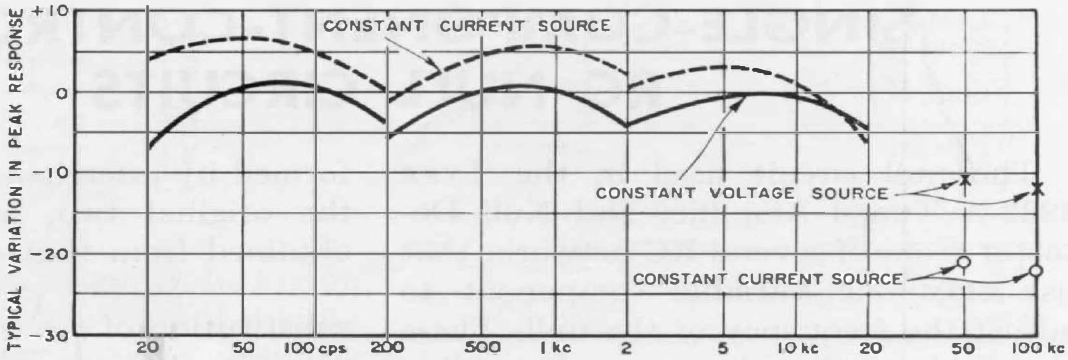


Figure 6. Typical variation in peak response with frequency for constant gain-control setting.

Microvolter, the input to the amplifier can be increased in known steps to cover a measurement range of 120 db.

The author has also found this amplifier with a microphone and a pair of earphones, a valuable aid in tuning his piano. — A. E. SANDERSON

CREDITS

The development of the TYPE 1232-A Tuned Amplifier and Null Detector was carried out by Albert E. Sanderson, author of the foregoing article. The design of the tuned null network was contributed by Henry P. Hall, author of the article starting on page 8. The project was under the direction of R. A. Soderman. — EDITOR

SPECIFICATIONS

Frequency Response:

Tunable Filters: 20 cps to 20 kc in 3 ranges; 6% bandwidth; 2nd harmonic at least 34 db down from peak, 3rd at least 40 db down; rejection filter on two highest ranges reduces 60-cycle level to at least 60 db below peak. Frequency dial accuracy is ±3%.

50 kc and 100-kc Filters: 2nd harmonic at least 60 db down.

Flat Response: ±3 db 20 cps to 100 kc.

Sensitivity: One microvolt, full scale, or better, over most of the frequency range. See Figure 4 for test limits.

Noise Level: Independent of source impedance; see Figure 5.

Input Impedance: Approximately 50 kilohms to one megohm, depending on gain-control setting.

Max Input Voltage: 200 volts ac or 400 volts dc, without damage.

Gain: 120 db on the tunable ranges; 100 db, flat range; 106 db at 50 kc; 100 db at 100 kc position.

Output: 1 volt into 10,000 ohms. Internal impedance is 3000 ohms.

Meter Linearity: Db differences on scale are accurate to ±5% for inputs of less than 0.3 volt.

External Filter: Source impedance, 700 ohms.

Compression: Reduces full-scale sensitivity by 40 db. Does not affect bottom 20% of scale.

Distortion: (In flat position) less than 5%, practically all attributable to the meter rectifiers.

Power Supply: 12 volts dc, from 9 mercury (M72) cells in series. Estimated battery life is 1500 hours. Cost is about 0.4 cent per hour.

Transistor Complement: Six 2N169A, two 2N1395.

Accessories Supplied: TYPE 874-R34 Patch Cord.

Dimensions: Width 8, height 6, depth 7½ inches (205 by 150 by 190 mm) over-all.

Net Weight: 5¾ pounds (2.6 kg).

Type		*Code Word*	*Price*
1232-A	**Tuned Amplifier and Null Detector**	VOCAL	**$360.00**
480-P308	**Relay-Rack Panel Extensions (Pair)**	EXPANELDOG	**7.00 Pair**

U.S Patents 2,548,457 and D187,740.

VACATION CLOSING

During the weeks of July 24 and 31, 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 commercial information, will receive our usual prompt attention. Our Service Department requests that, because of absences in the manufacturing and repair groups, shipments of equipment to be repaired at our plant be scheduled to reach us after the vacation period.

SINGLE-COMPONENT-CONTROLLED RC NULL CIRCUITS

The null circuit used in the TYPE 1232-A Tuned Amplifier and Null Detector is one of several RC networks that use only one variable component to adjust the frequency of the null. These circuits have the advantage of avoiding the use of ganged, variable components which must track closely to maintain stability when used in highly selective feedback amplifiers.

The only single-control-element RC null circuits known for many years were those discovered by Sacerdote[1] shown in Figures 1 and 2. These four-terminal bridge networks give a true null at a frequency ω_0 and have tuning laws of:

$$\omega_0 = \frac{1}{RC}\sqrt{\frac{\alpha-1}{\alpha}} \text{ and } \omega_0 = \frac{1}{RC\sqrt{1-\alpha}},$$

respectively, where α is the normalized value of the variable component. These functions do not give as wide a frequency change for a given change in α as do the Wien bridge and the twin-T with ganged components, for which $\omega_0 \sim \frac{1}{\alpha}$. The first bridge is particularly interesting, however, because it gives a zero-frequency null using components of finite value.

Clothier[2] and Doyle[3] showed that the "duals" of these circuits, Figures 3 and 4, also null and have the same frequency characteristics. These are not duals in the usual sense, but are topological duals with R's and C's interchanged. Each pair of dual circuits has the same tuning law, and the two other circuits, formed by interchanging R's and C's in the original two, have a tuning law obtained from that of the first two by substitution of $\frac{1}{1-\alpha}$ for α. Similar sets of four circuits can be formed from the circuits of Figures 5 and 6. These circuits have the same tuning laws.

These frequency bridges all have three complex bridge arms. A simpler arrangement for use in feedback circuits is to have two arms of the bridge consist of a fixed voltage divider. The other two arms of the bridge are formed by a three-terminal network whose output voltage is equal to that of the divider at some frequency, as in the familiar

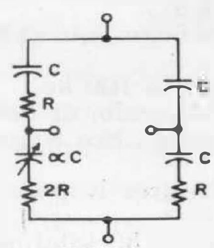


FIGURE 1

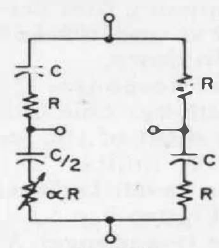


FIGURE 2

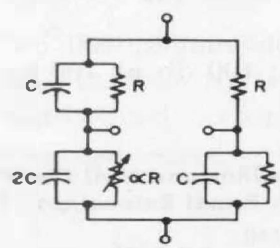


FIGURE 3

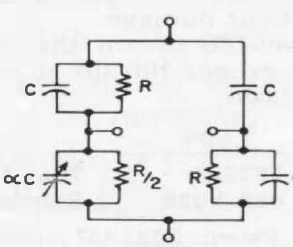


FIGURE 4

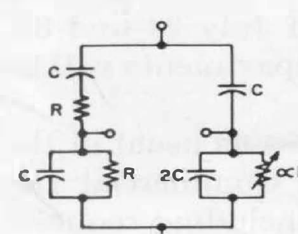


FIGURE 5

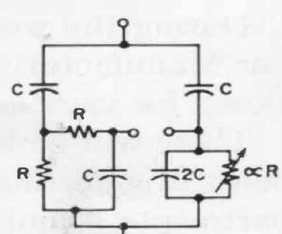
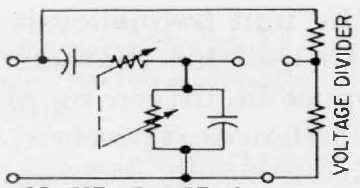


FIGURE 6

[1]Sacerdote, *Alta Frequenza*, August 1934, p. 437.

[2]Clothier, W. K., *IRE Transactions on Circuit Theory*, March 1955, p 97.

[3]Doyle, E. D., See Hague, *AC Bridge Methods*, 5th Edition, page 611.



SELECTIVE NETWORK
FIGURE 7

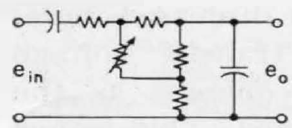


FIGURE 8

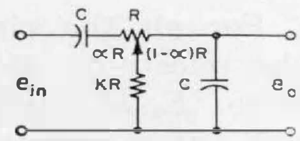


FIGURE 9

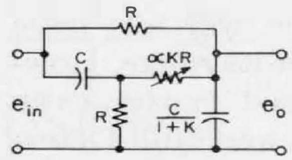


FIGURE 10

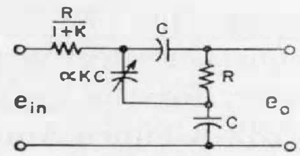


FIGURE 11

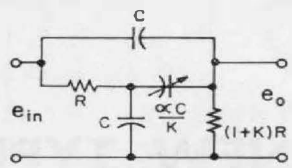


FIGURE 12

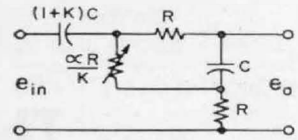


FIGURE 13

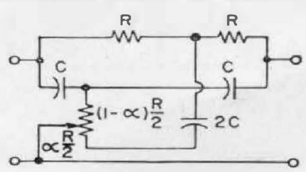


FIGURE 14

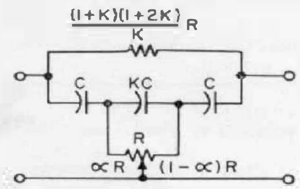


FIGURE 15

Wien bridge[4,5] which is shown in Figure 7. Wigan[6] presents single-control circuits of this type, and his simplest circuit is shown in Figure 8. This one has a very narrow tuning range, but, by making it slightly more complicated, he derives a circuit that has a frequency range from a fixed value to infinity. The circuit of Figure 9 is related to Wigan's circuit by a Y-Δ transformation of the resistors but requires a potentiometer for obtaining a variable-frequency null. It has a tuning law of $\omega_0 = \dfrac{1}{RC\sqrt{K + \alpha - \alpha^2}}$, and there is a dual of this circuit using a differential capacitor.

A new network, shown in Figure 10 (with its derivative networks in Figures 11, 12, and 13), has the interesting tuning law, $\omega_0 = \dfrac{1}{RC}\sqrt{\dfrac{1-\alpha}{\alpha}}$, which theoretically balances for any frequency from 0 to ∞ as α is varied from 1 to 0. This suggests its use in a wide-range oscillator or tuned amplifier. Also, for a 10-to-1 frequency range, it gives a frequency scale very close to the usually desired logarithmic scale.

Another class of network, which often is still easier to use in selective circuits consists of three-terminal RC circuits that give a complete null without being balanced against a voltage divider. The twin-T[7] is the most familiar of this group but is only one of innumerable possible networks. Andreyev[8] discovered a variation on the twin-T (Figure 14) that gives frequency adjustment with a single potentiometer. The tuning law for this circuit is $\omega_0 = \dfrac{1}{RC\sqrt{1-\alpha^2}}$. The only other known circuits of this type are the one used in the TYPE 1232-A Tuned Amplifier and Null Detector and its dual[9]. This circuit, shown in Figure 15, has a tuning law of $\omega_0 = \dfrac{1}{RC\sqrt{\alpha(1-\alpha)}}$. In order to span a 10-to-1 logarithmic frequency range, the potentiometer must have an exponential characteristic of over 100-to-1.

[4] Wien, M., *Wied. Ann.*, 1891, 44, 689.

[5] Field, R. F., "A Bridge-Type Frequency Meter", *General Radio Experimenter*, 6, 6, November 1931.

[6] Wigan, E. R., *Electronic Technology*, June, 1960, p. 223.

[7] W. N. Tuttle, "Bridged-T and Parallel-T Null Circuits for Measurements at Radio Frequencies", *Proc IRE*, January, 1940.

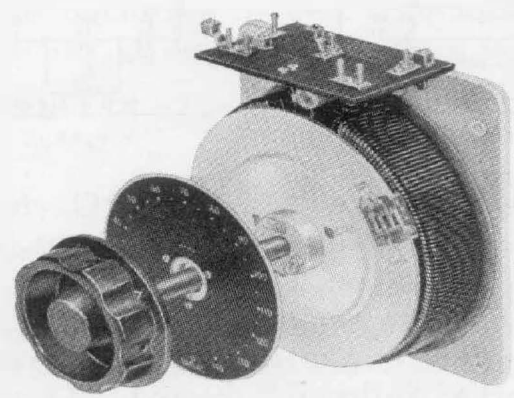
[8] Andreyev, *Telecommunications* No. 2, 1960, p. 195 (Pergamon Press Translation).

[9] Hall, H. P., *IRE Transactions on Circuit Theory*, September 1955, p 283.

For all the circuits discussed here, the selectivity of the transfer voltage ratio, E_0/E_{in}, is not constant as the null frequency is adjusted. This means that a conventional selective amplifier using this characteristic will not have constant selectivity over its range. However, for the circuit used in the TYPE 1232-A Tuned Amplifier and Null Detector, the selectivity of the transfer admittance, I_0/E_{in} (or y_{21}), is quite constant as the null frequency is changed. In order to use this characteristic, the network must be driven by and loaded by low impedances. Therefore, it is used in a feedback circuit with an amplifier having low input and output impedances and a transfer resistance, E_0/I_{in}, (or a real Z_{12}) that is chosen to give the desired selectivity. This combination provides a second harmonic rejection of 34 db over each 10-to-1 frequency range.

— H. P. HALL

THE NEW TYPE W30 VARIAC® AUTOTRANSFORMERS

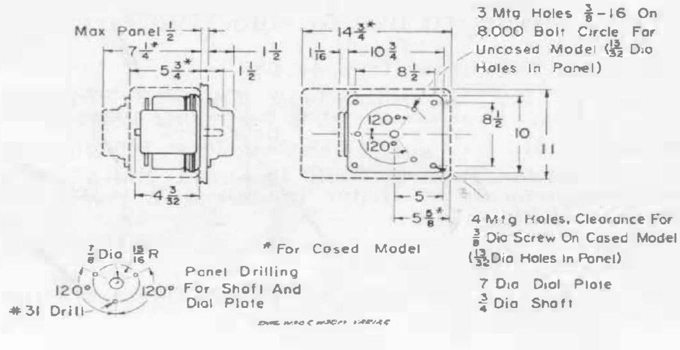


For some time we have felt that the gap between the 20-ampere, TYPE W20, and the 50-ampere, TYPE W50, Variac® Autotransformers was too great. The user contemplating the control of loads in the 30-ampere region was given no alternative but to use either a 50-ampere unit or two 20-ampere units in parallel. Both of these methods being costly and inefficient, we have developed the new 30-ampere models, TYPES W30 and W30H. Their high-power ratings conveniently bridge the gap between those of the TYPES W20 and W50 models.

Sharing the family resemblance common to all Series-W units, the TYPE W30 models incorporate the quality components and proven design features now included in all General Radio Variac autotransformers. These features include an overvoltage connection, to provide an output voltage range from zero to 17% above line voltage, and the patented DURATRAK coating process, for longer brush-track life.

TYPE W30 models are available in open, cased, ganged, and motor-driven assemblies, with or without ball bearings.

The ratings for the TYPES W30 and W30H single-unit models are given in the table below. Complete descriptions and ratings for the TYPE W30 ganged assemblies may be found in the current General Radio catalog.



SPECIFICATIONS

Core loss at 60 cycles: 35 watts, all models.

Driving Torque: 50-100 ounce-inches, all models.

Turns on Winding:
Types W30 and W30M 184
Types W30H and W30HM 367

Angle of Rotation: 320°.

DC Resistance of Winding:
Types W30 and W30M 0.14 ohm.
Types W30H and W30HM 1.17 ohms.

Dial: Reversible dial, line-voltage scale on one side, overvoltage scale on reverse side; calibrated for rated input voltage applied.

Type	Input Voltage (50-60 cycles)	OUTPUT						Replacement Brush	Net Weight, Pounds	Code Word	Price
		Line-Voltage Connection				*Overvoltage Connection*					
		KVA Load Rating (See Note A)	Voltage Range	Rated Current, Amperes	Maximum Current, Amperes (See Note A)	Voltage Range	Rated Current, Amperes (See Note B)				
W30 (Uncased)	120	4.32	0–120	30	36	0–140	30	VBT–13 $4.00	36	KALAL	$75.00
W30M (Cased)	120	3.84	0–120	28	32	0–140	28	VBT–13 $4.00	46	KALER	97.00
W30H (Uncased)	240 120	3.74 —	0–240 —	12 —	15.6 —	0–280 0–280	12 6	VBT–14 $4.00	29	ZABAL	75.00
W30HM (Cased)	240 120	3.74 —	0–240 —	12 —	15.6 —	0–280 0–280	12 6	VBT–14 $4.00	36	ZABER	97.00

Notes

A. Maximum current can be drawn at maximum voltage for the line-voltage connection only. Kva as listed = normal input line voltage times maximum current.

B. Rated current should not be exceeded for the overvoltage connection. Output kva for overvoltage connection = output voltage times rated current.

GENERAL RADIO DEMONSTRATES TRAVELING EXHIBIT AT PARIS SEMINAR

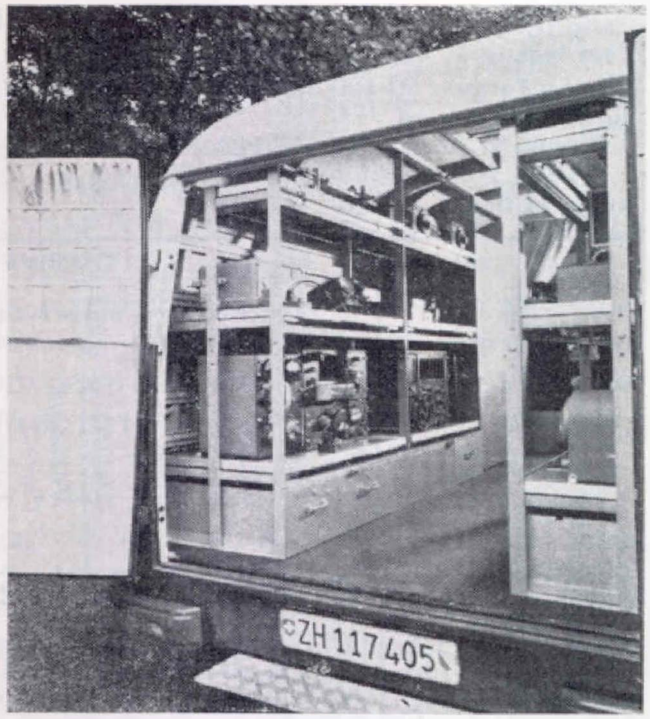
At the second biennial General Radio overseas sales and engineering seminar, a new traveling exhibit of General Radio products was demonstrated to more than 40 engineers and export sales representatives from 16 countries.

Held in Paris at the offices and laboratory of Etablissements Radiophon, General Radio representatives for France and the French colonies, the seminar included both

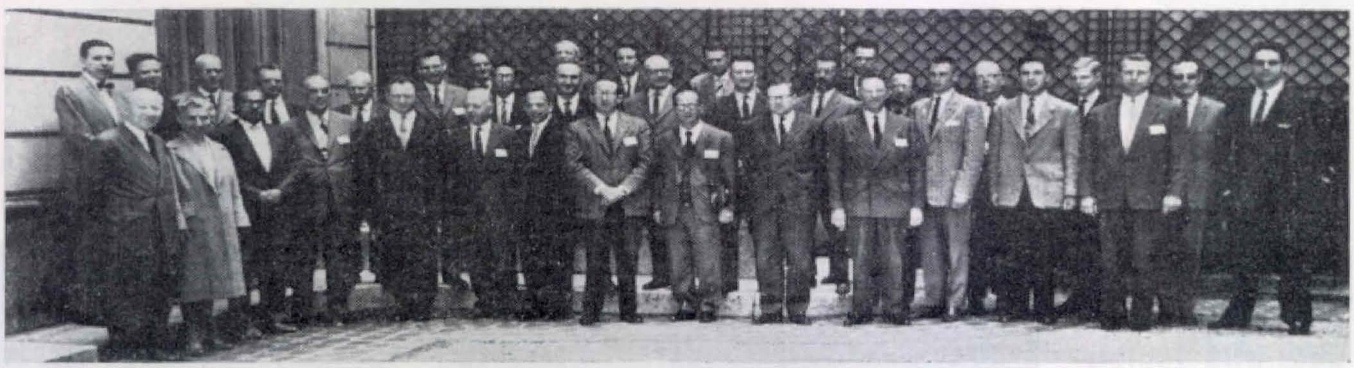
The General Radio traveling exhibit is demonstrated to export sales representatives by Peter J. Macalka, of General Radio Company.

lectures and laboratory workshops to acquaint the representatives with new GR products and their applications.

The traveling exhibit will be handled by General Radio's new technical and commercial organization, General Radio Company Overseas, with headquarters at Zurich. The exhibit is housed in a specially equipped Mercedes Benz station wagon. The instruments are mounted on ten custom-built tables, which stow snugly into the wagon for transportation, but are quickly and easily removed and set up in customers' plants or other locations. This ingeniously designed traveling show will house over 100 instruments, as much equipment as can be shown in a standard 40-foot display booth at a conventional exhibit. The over-all design follows the general pattern of the station-wagon shows that have been used successfully by General Radio for several years in the United States.



Interior of the station wagon, showing the tables securely installed for transporting.



Left to Right:

M. C. Holtje	General Radio
Paul Fabricant	France
D. B. Sinclair (rear)	General Radio
Mlle. Claude Naichouler	France
A. Bergholtz	Sweden
B. Archer	England
T. T. Joseph	India
A. E. Thiessen	General Radio
H. C. Parish	Australia
L. Kohn	France
U. Clementz	Sweden
M. Berlin	France
C. E. Worthen (rear)	General Radio
H. Nagakura	Japan
R. Danziger	Israel
I. G. Easton (rear)	General Radio
G. Belotti	Italy
A. Lara Saenz	Spain
G. Molac (rear)	France
G. Nusslein	Germany
G. Binetti	Italy
P. van Gent	Holland
P. Cornet	France
K. Teir	Finland
L. Goett	France
K. Lindenmann (rear)	Switzerland
R. Peel	Belgium
R. Christensen	Denmark
A. R. Buys	Holland
K. L. Nyman	Finland
E. Lyons	England
P. Nyman	Finland
H. A. Molinari	Switzerland
J.-L. Robert	France
P. J. Macalka	General Radio

Also present, but not in picture, were:

I. Myrseth	Norway
H. Klip	Holland
T. Kenny	Israel
K. Karayannis	Greece
J. Keller	Switzerland