THE General Radio EXPERIMENTER

VOLUME XX Nos. 6 and 7 NOVEMBER and DECEMBER, 1945

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

AN IMPROVED MEGOHMMETER FOR A-C OPERATION

Also

IN THIS ISSUE

● **THE MEGOHMMETER**, since the introduction of the Type 487-A instrument in 1936,[1] has become a familiar piece of laboratory equipment. The measurement of high-valued resistors and of leakage resistance up to several thousand megohms becomes, with the megohmmeter, as simple as low-resistance circuit testing, and many special applications have developed.

The Type 1861-A Megohmmeter is a redesign of the Type 487-A instrument. The principal changes are the addition of a range at the low-resistance end with a center scale value of 0.1 megohm, stabilization of the voltage applied to the unknown, and provision of a switch and an additional scale on the meter so that the high resistance tube voltmeter used in the megohmmeter circuit can be made available for d-c voltage measurements from 0–100 volts. Other changes from the original Type 487-A design in-

[1] F. Ireland "An Ohmmeter for the Megohm Ranges," *G. R. Experimenter*, Vol. 9, Nos. 4 & 5, September-October 1936.

Figure 1. Panel view of the Type 1861-A Megohmmeter. Superseding the Type 487-A, this new instrument measures resistances from 2000 ohms to 50,000 megohms and can also be used as a d-c voltmeter.

clude elimination of the zero-setting knob and rearrangement of the panel so that the long dimension is from top to bottom. The size of the instrument is unchanged.

The new low range, also incorporated in the Type 729-A Battery-Operated Megohmmeter,[2] makes possible a deflection of at least a full division for resistances from 2,000 ohms to 50,000 megohms, a range of 25 million to one. The wide range and the addition of the voltmeter scale greatly increase the utility of the instrument in trouble shooting.

The stabilized circuit not only makes unnecessary a preliminary zero adjustment before use, but also eliminates fluctuations in the meter reading resulting from line voltage variations. As a result, accurate measurements in the very high ranges of resistance can be made very rapidly and conveniently.

The instrument is applicable to general high resistance and leakage testing except where specified test voltages must be applied, or where the high-value standard resistances employed in the circuit would result in an excessively large time constant. The latter limitation means that the equipment is suitable for the rapid testing of condensers up to only a few thousandths of a microfarad in capacitance. The Type 544-B Megohm Bridge is recommended for leakage testing of higher valued condensers. For applications not subject to special requirements of this kind and for resistances up to 10,000 megohms, the new Type 1861-A Megohmmeter will be found equally accurate and far more rapid and convenient in use.

The standard resistances of 0.1, 10, 100, and 1,000 megohms employed in the megohmmeter circuit can be connected across the voltmeter as desired, so that the voltmeter resistance can have the four corresponding values from 1,000 ohms per volt up to 10 megohms per volt. For applications where the voltage drop of 100 volts can be tolerated, the instrument can also be used as a microammeter having a maximum full-scale sensitivity of 0.1 microampere.

The instrument, like its predecessor, is suitable for many special applications such as determination of the moisture content of wood, paper, dehydrated products, and similar materials. The additional scale makes such determinations possible for a wider range of materials and for higher moisture contents.

— W. N. Tuttle

[2] W. N. Tuttle, "A Portable Megohmmeter," *G. R. Experimenter*, Vol. 15, No. 2, July 1940.

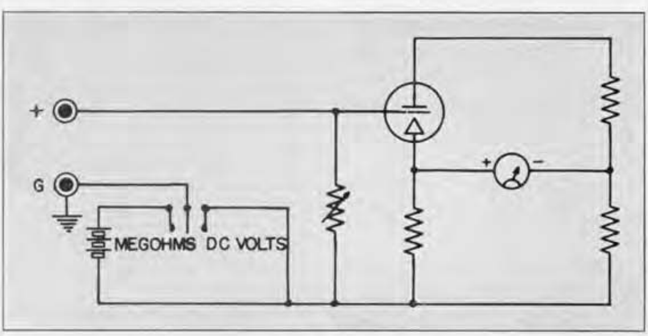

Figure 2. Elementary schematic circuit diagram of the megohmmeter. The circuit is similar to that of the conventional ohmmeter, but a vacuum-tube voltmeter is used as the indicator.

SPECIFICATIONS

Range: 2,000 ohms to 50,000 megohms in five overlapping ranges; zero to 100 volts, dc.

Scale: The standard direct-reading ohmmeter calibration is used; center scale values are 0.1, 1, 10, 100, and 1000 megohms. Length of scale, 3¼ inches; center decade, 1⅝ inches. The scale is illuminated by a lamp in the indicating meter. The voltage scale is linear.

Accuracy: Within ±5% of the indicated value between 30,000 ohms and 3 megohms, and within 8% between 3 megohms and 3000 megohms when the central decade of the scale is used. Outside the central decade the error increases because of the compressed scale. For voltage measurements the accuracy is ±2% of full scale.

Input Impedance: For voltage measurements the input impedance in megohms is indicated by the selector switch.

Temperature and Humidity Effects: Over the normal range of room conditions (65° Fahrenheit to 95° Fahrenheit; 0 to 95% relative humidity) the accuracy of the instrument is substantially independent of temperature and humidity.

Voltage on Unknown: The applied voltage on the unknown does not exceed 106 volts and varies with the indication.

Tubes: The necessary tubes, one type 1-v, one type 85, and one OC3/VR-150 are supplied.

Power Supply: 105 to 125 (or 210 to 250) volts, 40 to 60 cycles ac. The power required is 10 watts.

Accessories Supplied: A seven-foot connecting cord.

Mounting: The instrument is supplied in a walnut case and is mounted on an engraved black crackle-finish aluminum panel.

Dimensions: (Width) 10 x (height) 8 x (depth) 5½ inches, over-all.

Net Weight: 8¼ pounds.

Type		*Code Word*	*Price*
1861-A	Megohmmeter	ONION	$95.00

AN ANALYZER FOR VIBRATION MEASUREMENTS

● **MEASUREMENT** of the effective amplitude of vibration acceleration, velocity, or displacement with a vibration meter and vibration pickup is in some instances adequate for complete solution of a vibration problem. This is true when the vibration is known to be essentially sinusoidal in waveform.

A complex vibration, on the other hand, involving a number of components of differing frequency and amplitude, while measurable in its overall effect by the vibration meter, can be handled completely only if broken down into its various components by some form of analyzer.

The Type 762-A Vibration Analyzer[1] was designed to work with the Type 761-A Vibration Meter over an extended frequency range of 2.5 to 750 cps (150 to 45,000 rpm). The frequency band from 2.5 to 25 cps, covered by two ranges in the instrument, provides a most important extension to the spectrum which can be analyzed. The major components in a complex vibration will often be found here, and it is seldom that an analysis does not reveal at least one component in this region of the spectrum.

Modified to permit faster analyses and a wider range of application over the same frequency range, the instrument now in production is known as the Type 762-B Vibration Analyzer. Its important characteristics and its use in analyzing complex vibration and voltage waves are described in succeeding para-

[1]This analyzer was described in "An Analyzer for Sub-Audible Frequencies" by H. H. Scott, *Journal of the Acoustical Society of America*, Vol. XIII, No. 4, pp. 360–362, April, 1942.

graphs. The panel arrangement is shown in Figure 1.

As in the sound analyzer, the circuit of the vibration analyzer includes a linear amplifier with a resistance-capacitance-tuned feedback network, resulting in high selectivity over the entire frequency range. The selectivity provided is similar to that of a constant Q, constant impedance-level, resonant circuit in the vicinity of the tuning peak.

Two band widths, one corresponding to an effective Q of about 50 and the other to an effective Q of 10, are available with panel switching. Figure 2 shows typical selectivity curves in three regions of the spectrum and includes for comparison similar curves obtainable with a heterodyne analyzer such as the TYPE 736-A Wave Analyzer, which is designed primarily for electrical wave analysis and has a constant band width in cycles. The advantages of the constant percentage band width of the degenerative analyzer are illustrated clearly in this figure. The broad selectivity feature is extremely helpful in locating components quickly in a fast sweep over the spectrum, the final determination of frequency and amplitude being made with the sharper network.

As frequently occurs in vibration work, a component may be drifting back and forth or warbling by several percent about a mean frequency. Under such conditions the high Q network would provide unstable or unreliable indications of amplitude because of its sharply peaked characteristic. Here the broad selectivity network finds another important use in making final determination of mean frequency and amplitude of components. The flat topped character of the broad selectivity curve as compared with the peaked characteristic of the sharp selectivity curve in the immediate vicinity of a tuning peak is shown in Figure 3.

The voltmeter of the instrument has an approximately logarithmic scale calibrated in linear units, so as to provide usable indications of relative amplitude of components down to about 1% of the largest component without switching. Two scales are furnished to match those on the indicating meter of the TYPE 761-A Vibration Meter.

FIGURE 1. Panel view of the TYPE 762-B Vibration Analyzer.

In an analysis to determine the relative amplitudes of the components of a complex wave (vibration acceleration, velocity, or displacement as determined by vibration meter switching), a preliminary sweep over the spectrum is made to determine the component of greatest amplitude. With the analyzer tuned to this component, the SENSITIVITY control is adjusted to an indication of 100 on the upper (black) scale. This control is left fixed at the above setting for the remainder of the analysis and a final sweep over the spectrum is made. As each component is tuned in, its amplitude and frequency are recorded. Amplitudes are then direct reading in percent of the amplitude of the largest component. The upper (black) scale is the only analyzer scale used for this type of analysis.

A complete analysis of a complex vibration, which yields the amplitudes of the various components in terms of their normal units (i.e., inches per second per second for acceleration, microinches per second for velocity, and microinches for displacement), may be made with only one modification of the procedure just outlined — the method of setting the SENSITIVITY control of the analyzer. For this adjustment a sinusoidal signal must be applied to the vibration meter and the analyzer adjusted to give the same indication as that of the meter. This may be most simply done by using the 110-volt, 60-cycle, signal applied through the power cord to the vibration meter as in the normal calibration of this instrument. With the CALIBRATION-1 button depressed, the METER READS switch set for acceleration, and the METER SCALE switch of the vibration meter adjusted to give an indication greater than one-third of full scale, the SENSITIVITY control of the vibration analyzer is adjusted to give an analyzer indication identical with that of the vibration meter. This makes the analyzer direct reading for all components, in the units determined by the subsequent switch settings on the vibration meter. The SENSITIVITY control must, of course, not be shifted throughout succeeding analyses, and corresponding scales are read on both the analyzer and meter indicating instruments.

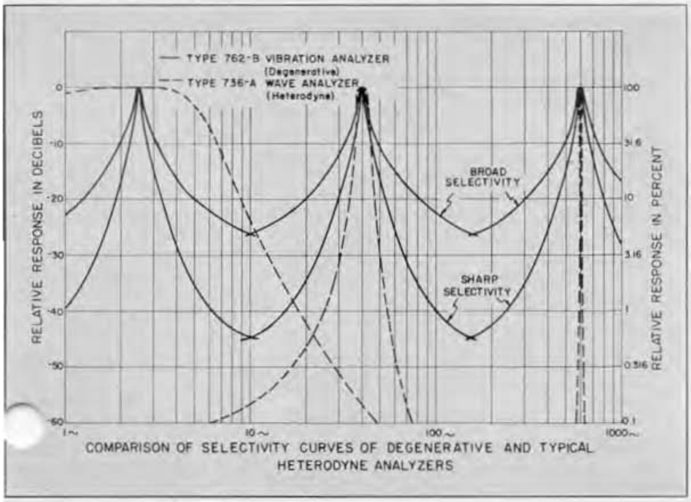

FIGURE 2. Comparison of selectivity curves of the degenerative and heterodyne analyzers. For vibration analysis, the degenerative type is preferable because it has a constant percentage band width.

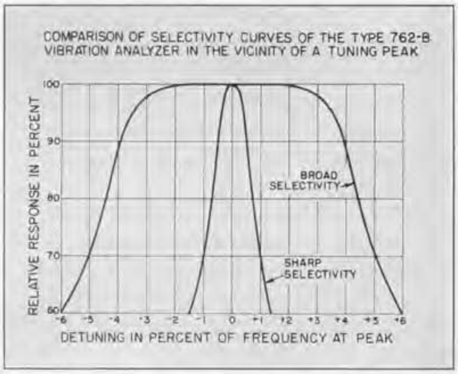

FIGURE 3. Plot of the relative band widths for BROAD and SHARP selectivity positions.

Many applications in the field of wave analysis in the low audio- and subaudio-frequency regions are possible with the instrument used directly as a voltage analyzer. As a tuned detector in low-frequency bridge applications it is probably best used again in conjunction with the TYPE 761-A Vibration Meter. Here the vibration meter is used as a high-input-impedance, high-gain, linear amplifier (the acceleration characteristic of the meter is that of a linear amplifier over approximately the frequency range of the analyzer), and is inserted between the bridge and the analyzer. The input impedance of the vibration analyzer varies from 20,000 to 30,000 ohms depending upon the setting of the SENSITIVITY control. With the SENSITIVITY control set at a maximum, full scale indication is obtained with an input voltage of about 0.1 volt. Under circuit conditions where these input characteristics are satisfactory, the instrument may be used directly as a voltage analyzer or tuned voltmeter. The procedure to be followed in making the instrument direct reading in volts or in percent of the major component is identical with that outlined for vibration analysis.

— W. R. SAYLOR

SPECIFICATIONS

Frequency Range: 2.5 to 750 cycles, covered in five ranges as follows: 2.5 to 7.5, 7.5 to 25, 25 to 75, 75 to 250, 250 to 750.

Band Width: For the sharp selectivity position, the relative attenuation is approximately 30% (3 db) at a frequency differing by 1% from that to which the analyzer is tuned. For the broad selectivity position, the attenuation is 30% for a frequency difference of 5%. At one octave from the peak, the relative attenuations are 98% (35 db) and 90% (20 db), respectively.

Frequency Calibration: The accuracy of frequency calibration of the sharp selectivity network is ±1½% or ±1½ cycles, whichever is the larger, over the three highest ranges (25 to 750 cycles); on the two lower ranges (2.5 to 25 cycles), the accuracy is ±5% or ±0.2 cycle, whichever is the larger. The frequency as determined with the broad selectivity network deviates on the average by less than ±2% from that determined with the sharp selectivity network.

Frequency Response: The response of the sharp selectivity network is flat within ±2 db over the entire range. At points where two ranges overlap, the sensitivity is the same on either range within ±1 db. The sensitivity of the broad selectivity network is the same as that of the sharp selectivity network to within ±2 db.

Voltage Range: The analyzer will give usable indications on input voltages ranging from 1 millivolt to 10 volts. The meter scale is calibrated for reading directly component tones down to 1% of the fundamental or strongest component. Accordingly, to make full use of this feature, the input voltage at the strongest component or fundamental should be 0.1 volt or higher.

Input Impedance: The input impedance is between 20,000 and 30,000 ohms, depending upon the setting of the sensitivity control. A 3-μf blocking condenser is in series with the input.

Temperature and Humidity Effects: Under very severe conditions of temperature and humidity only slight, and generally negligible, shifts in calibration, sensitivity, and band width will occur.

CIRCUIT: The circuit consists of a three-stage amplifier made selective by the use of degeneration, and an approximately logarithmic vacuum-tube voltmeter circuit, which allows a range slightly in excess of 40 decibels, or 100 to 1, to be read on the meter scale.

Meter: The indicating meter is calibrated down to 1% of the fundamental or strongest component.

Telephones: A jack is provided on the panel for plugging in a pair of head telephones, in order to listen to the actual component of the sound to which the instrument is tuned. This is also useful when using the analyzer as a bridge-balance indicator.

Tubes: Three 1H4-G and one 1F7-GV tubes are required. A neon regulator tube (type T-4½) is also used. A complete set of tubes is supplied with the instrument.

Batteries: The batteries required are four Burgess No. F2BP 3-volt batteries, or the equivalent, and three Burgess No. Z30N 45-volt batteries, or the equivalent. A compartment is provided in the case of the analyzer for holding all batteries, and connections are automatically made to the batteries when the cover of this compartment is closed. A set of batteries is included in the price of the instrument.

Accessories Supplied: A shielded cable-and-plug assembly for connecting the analyzer to the vibration meter.

Case: The analyzer is built into a shielded carrying case of airplane-luggage construction. In addition to the handle on the carrying case, a handle is provided on the panel of the instrument for convenience in moving the instrument about while it is in operation.

Dimensions: (Length) 18 x (width) 10 x (height) 11½ inches, over-all.

Net Weight: 34 pounds, with batteries; 27¼ pounds, without batteries.

Type		*Code Word*	*Price*
762-B	Vibration Analyzer	AWARD	$275.00

MISCELLANY

● **PAPERS** — H. B. Richmond, Chairman of the Board, spoke at the conference on "Instrumentation and the University," held at Carnegie Institute of Technology on October 17. His subject, "Educational Preparation for an Instrumentation Career in the Electronic Industry."

On November 12, E. E. Gross of the Engineering Department spoke at the Rochester Fall Meeting on "A Coaxial Modification of the Butterfly Circuit."

Dr. A. P. G. Peterson of the Engineering Department spoke at the Cincinnati Section of the I.R.E., November 20, on "High-Frequency Measurements."

Ivan G. Easton of the Sales Engineering Department delivered a paper entitled "The History and Technology of the Stroboscope" at a meeting of the Textile Division of the American Society of Mechanical Engineers in New York, November 29.

● **WE HAVE ALWAYS BEEN PROUD** of the broad distribution of GR products in industry. A good illustration has just come to our attention. In the October, 1945, issue of *Electronics*, scattered among the advertisements and articles there are fourteen pictures of GR equipment in as many different uses. We thank the users for their confidence.

● **DON'T MISS** the General Radio exhibit at the Winter Technical Meeting of the I.R.E., to be held at the Hotel Astor, New York, January 23–26, 1946. New designs will be displayed and General Radio engineers will be on hand to answer your questions.

EASTON TO NEW YORK ENGINEERING OFFICE

● EFFECTIVE about December 1, Ivan G. Easton becomes manager of the New York Engineering and Sales Office of the General Radio Company. Martin A. Gilman, manager of this office for the past two years, returns to the sales engineering staff at the Cambridge office.

Mr. Easton was born in 1916 and attended the public schools of Rockport, Massachusetts. He received his B. S. degree in electrical engineering from Northeastern University in 1938 and his M. S. degree from Harvard in 1939. Upon completion of his graduate work at Harvard, he joined the engineering staff of the General Radio Company and has worked in both the development engineering and sales engineering groups. Readers of the *Experimenter* will recall his many articles on bridge circuits and impedance measurements.

Mr. Easton is a senior member of the I. R. E. and for the past two years has been Program Chairman for the Boston Section. He is also a member of the A. I. E. E., a member of the Society for Experimental Stress Analysis, and company representative of the American Society for Testing Materials. During the war Mr. Easton has taught ESMWT courses in radio engineering at Northeastern University.

GENERAL RADIO COMPANY
275 MASSACHUSETTS AVENUE
CAMBRIDGE 39 MASSACHUSETTS
TELEPHONE: TROWBRIDGE 4400

BRANCH ENGINEERING OFFICES

NEW YORK 6, NEW YORK
90 WEST STREET
TEL.—WORTH 2-5837

CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
TEL.—WABASH 3820

LOS ANGELES 38, CALIFORNIA
1000 NORTH SEWARD STREET
TEL.—HOLLYWOOD 6321