THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

HAVE YOU A TYPE 650 IMPEDANCE BRIDGE?

Also IN THIS ISSUE

● ONE OF THE MOST POPULAR General Radio laboratory instruments, since it was first introduced in 1933, has been the Type 650 Impedance Bridge — witness a sale of over 3700 of these instruments to date. By means of this bridge resistors, inductors and capacitors can be measured rapidly and conveniently over a wide range of values.

On many occasions, the need arises for using an auxiliary audio amplifier to increase the sensitivity of bridge balance when employing either headphones or an a-c galvanometer as the null detector. For this purpose General Radio has successively offered the Type 514 and Type 814 Amplifiers, and at the present time the Type 1231 Amplifier and Null Detector.

The Type 650 Impedance Bridge is self-energized by four No. 6 dry cells housed in the bridge cabinet. These dry cells supply d-c power for the Wheatstone bridge measurement of resistance and drive a one kilo-

Figure 1. View of the Type 650-A Impedance Bridge with battery compartment at the rear.

FIGURE 2. Panel view of the TYPE 650-P1 Oscillator-Amplifier, showing top of bridge panel. Connections are easily made from either the d-c or 1000-cycle terminals to the EXTERNAL GENERATOR terminals of the bridge.

cycle microphone hummer for bridge measurements of either inductors or capacitors. While such an arrangement is essential for field use where power lines are not available, most of these bridges are used exclusively in laboratories where a-c mains are always available, in which case it would be desirable to dispense with the dry cells and operate the bridge directly from the power line.

To meet these two desirable requirements, the General Radio Company now offers the TYPE 650-P1 Oscillator-Amplifier, a useful combination unit which is designed to fit into the cabinet compartment formerly housing the dry cells. This 650-P1 comprises:

(1) A source of d-c voltage for resistor measurements.

(2) A one-kilocycle vacuum-tube oscillator to replace the microphone hummer.

(3) An amplifier of sufficient gain for all uses of the bridge.

This auxiliary unit is energized from a single-phase a-c power line at a frequency of 50 to 60 cps, and having a nominal voltage of either 115 or 230. The power consumed is about 10 watts. The unit is assembled in a metallic cabinet with a top control panel which replaces the wooden cover of the battery compartment.

When installed, a short plug-terminated jumper connects the bridge input terminals to adjacent d-c or one-kilocycle terminals on the panel of the auxiliary unit. By means of an internal shielded cable a connection is made between the bridge detector terminals and the input of the amplifier. The phones or a-c galvanometer (neither of which are supplied) that are to be used as the null detector are then attached to terminals on the auxiliary unit. The TYPE 483-F Output Meter is a useful a-c galvanometer for this purpose. A complete set of instructions for installing and operating the TYPE 650-P1 is supplied.

The power-supply rectifier is a 6H6 duplex diode functioning as a voltage doubler. The maximum permissible value of the filtered d-c output is applied to the bridge. This is considerably in excess of the 6 volts originally available from batteries, so that the sensitivity of balance when measuring the larger values of resistance (one megohm maximum) is definitely enhanced using the galvanometer already incorporated in the TYPE 650 Bridge.

The one kilocycle oscillator employs a 6SL7GT duplex triode, one triode functioning as an oscillator and the other as a buffer amplifier. The oscillator is of the R-C feedback type and can be more accurately tuned to one kilocycle than is practical with the microphone hummer, thus minimizing inherent frequency errors in the reading of the Q or D dial of the bridge, since the calibration of these dials is a function of the operating frequency. The oscillator frequency is subject to a 20-cycle warm-up rise over a one-hour interval and is adjusted at thermal equilibrium to within ± 5 cycles of one kilocycle. Between the oscillator and the buffer amplifier is inserted an oscillator gain control permitting a full range adjustment of the a-c voltage applied to the bridge. This feature, which is not available in the original Type 650 Bridge unless a separate oscillator is used, is desirable in measuring iron-cored inductors at low flux densities approach initial permeability.

Between the output of the buffer amplifier and the bridge input terminals is interposed a 5/1 step-down transformer which is doubly shielded and designed to give maximum over-all efficiency with the Type 650 Bridge and to minimize certain residual capacitance errors. This transformer contains separate electrostatic shields around the primary and secondary windings with a substantial separation between them. The primary shield is grounded, while the secondary shield is connected to that secondary terminal which leads to the junction of the *A* and *N* arms of the bridge. This arrangement places a negligible capacitance of 9$\mu\mu$f across the standard capacitor (10,000 $\mu\mu$f) bridge arm, and introduces a capacitance of less than 36 $\mu\mu$f (4.4 megohms reactance) across the CRL rheostat arm (10 kilohms maximum), so that the error introduced is also negligible.

The full output of the oscillator somewhat exceeds that of the microphone hummer and has a distinctly purer wave form. Twenty milliwatts into a matching load of 2 kilohms may be obtained with a harmonic content of less than 2% at full output. The open circuit voltage is in excess of 12 volts, and the hum level is less than 15 millivolts.

The amplifier comprises two stages utilizing a second 6SL7GT tube. The first stage is tuned by means of a degenerative R-C network to afford peak gain and maximum selectivity at one kilocycle, thus facilitating bridge balances by minimizing harmonics, especially when measuring nonlinear circuit elements such as iron-cored inductors. An open circuit voltage-ratio gain in excess of 50 db is available with a discrimination in excess of 10 db at 0.5 and 2 kilocycles. With average phones a gain of about 45 db is realized. This amplifier is preceded by a gain control affording full range adjustment of detector sensitivity. The hum level is less than 10 millivolts. A blocking capacitor removes any d-c component from the output to the phones or a-c galvanometer and par-

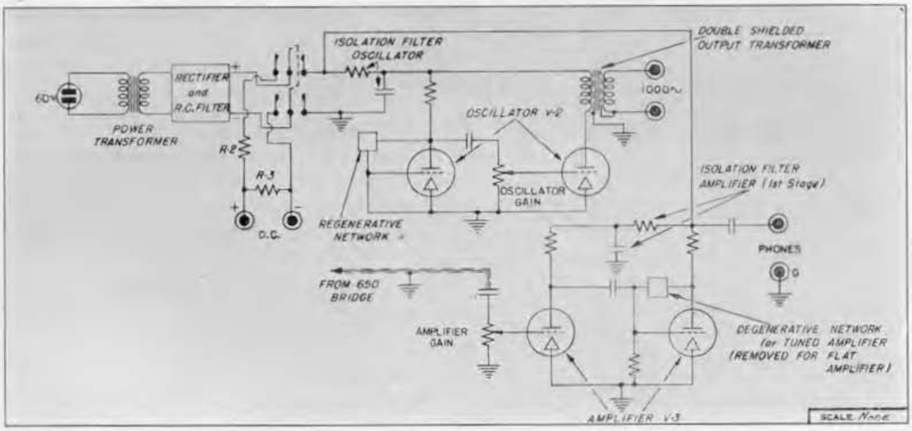

Figure 3. Elementary schematic circuit diagram of the Type 650-P1 Oscillator-Amplifier.

tially resonates the average headphones to one kilocycle. Crosstalk between the oscillator and amplifier components is reduced to an imperceptible minimum by the use of isolation filters and compartment shielding.

In order that this same amplifier may conveniently be used when making a bridge measurement at some frequency other than one kilocycle (using, of course, some other oscillator) a switch is provided whereby the tuning network may be removed, thus giving the amplifier a flat gain characteristic. This flat amplifier has a gain of about 60 db at one kilocycle, dropping by 0.6 db at 100 cycles and 3.5 db at 5 kilocycles. The hum level is less than 400 millivolts.

The hum levels for the two amplifiers quoted above are obtained when employing a resistive load such as the TYPE 483 Output Meter. Due to resonance selectivity, when using head phones these hum levels are reduced about 20 db and become audibly imperceptible.

On the control panel of the TYPE 650-P1 are the following items: an input socket for attachment to an a-c power line together with a line switch and pilot light; d-c, 1-kc and phone terminals; a switch for selecting either d-c or 1-kc excitation of the bridge; a switch for rendering the amplifier flat or tuned to 1 kc; and separate control knobs (uncalibrated) for adjusting the oscillator output level and the amplifier gain.

While the TYPE 650 Impedance Bridge will continue to be sold equipped with the microphone hummer and dry batteries, the addition of this new auxiliary unit should prove beneficial to many old and new users of this bridge.

The TYPE 650-P1 Oscillator-Amplifier is specifically designed to be used with the TYPE 650 Bridge. However, as an individual item, it should prove useful with many other bridge systems, providing, in compact form, both a one kilocycle oscillator for exciting such a bridge and an amplifier for the bridge detector. The unit can also serve as a convenient source of well-filtered d-c power (but cannot be used simultaneously as an oscillator-amplifier). The open-circuit d-c voltage is 190 volts with a hum level less than 0.1 volt, and the regulation is closely linear and represented by the equation:

$$\text{Terminal Voltage} = 190 - 23I$$

wherein I is the load current in milliamperes. No harm is done by short-circuiting the d-c terminals which affords a maximum current of 8 milliamperes.

— HORATIO W. LAMSON

SPECIFICATIONS

Oscillator: Frequency — 1000 cps ±1%; Harmonics — less than 2% at full output; Open-circuit Voltage — continuously adjustable up to maximum of 12 to 15 volts; Internal Impedance — 2000 ohms; Hum Level — 15 millivolts.

Amplifier: Voltage Gain (with average phones) — continuously adjustable up to about 45 db; Attenuation to Second Harmonic (when tuned to 1000 cycles) — approximately 15 db. Hum Level — inaudible.

D-C Output: Maximum Current — 8 milliamperes, no adjustment provided; can be short-circuited without damage; Hum Level (no load)—less than 100 mv; Open-Circuit Voltage—190 volts, approximately; Internal Resistance — 23,000 ohms.

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

Power Input: 10 watts.

Vacuum Tubes (supplied):
1 — 6H6 type 2 — 6SL7GT type

Accessories Supplied: Connector for use between bridge and oscillator-amplifier; line cord-and-plug assembly; spare pilot lamp; one Type 274-M Plug.

Dimensions: Cabinet — 10½ x 2½ x 6¾ inches; Panel — 12 x 3⅜ inches.

Net Weight: 9 pounds.

Type		*Code Word*	
650-P1	Amplifier-Oscillator	BOGUS	$140.00

MULTIPLE PHOTOS WITH THE MICROFLASH

● **AN ELECTRONIC SEQUENCE TIMER**, developed by the Air Technical Service Command at Wright Field, permits multiple exposures on a single film to be made with the Microflash. Developed by Captain C. H. Coles of the ATSC engineering division, the timer utilizes the constant rate of voltage increase across a linearly charged condenser to excite six amplifiers which are set to progressively decreased sensitivity. Each amplifier trips one Microflash lamp.

The interval between flashes is varied by simply turning dials on the sequencer panel, and the total time required for all six pictures can be adjusted between 0.6 second and 0.0003 second.

The photograph of Figure 2, which shows three exposures of a 0.50 caliber machine-gun bullet was timed by the electronic sequencer.

ASTC engineers found many uses for the Microflash during the war, in addition to bullet photography. Among these was the study of rupturing propeller blades. By using X-ray film, an f/2.5 night aerial camera lens, and a special developer, they have taken Microflash pictures successfully at distances of 40 to 50 feet from the lamp.

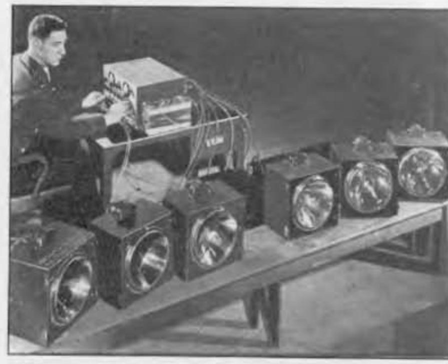

Figure 2. The electronic sequence timer and a battery of six Microflash units. Captain C. H. Coles of the Air Technical Service Command, who developed the timer, is shown at the controls.

Figure 1. Three-exposure photograph of a 0.50 caliber machine-gun bullet.

MEASURING LATERAL MOTIONS IN A ROTATING SYSTEM WITH THE STROBOLUX

● **A NOVEL APPLICATION** for the Type 648-A Strobolux has recently turned up in connection with the measurement of small lateral motions in a rotating shaft.

An investigation of these minute irregularities in the moving parts of their line of tachometers was being carried out by the Barbour Stockwell Company of Cambridge, Massachusetts. These tachometers are of the conventional fly-ball type, having three weights spaced at 120° around the spindle, each connected by one link to a sliding collar near the other end of the spindle. A helical compression spring surrounding the spindle between the fixed and sliding collars tends to separate these collars. Centrifugal force moves the weights outward from the shaft, thus causing the links to swing outward from their stationary position parallel to the shaft. This moves the sliding collar along the shaft toward the fixed collar in opposition to the restoring force furnished by the helical spring. The position of the sliding collar is translated into dial reading by means of a spring-loaded follower, bearing against the face of the sliding collar and connected to the dial mechanism.

In the course of the investigation, a contour comparator of the familiar shadow-projection type was used. This consists of a light source with a suitable lens and mirror combination so arranged that a sharply defined and greatly enlarged shadow of the sample is projected upon a ground glass screen. For measurement purposes, the screen had vertical and horizontal reference lines. Graduated micrometer screws were provided to move the stage in a plane normal to the light beam so any point on the image could be set to the fixed reference lines.

It then occurred to Mr. Frank P. Wilkins, one of the engineers working on the project, that the dynamic conditions might be rather different from the static conditions. These could be readily observed if the light source of the comparator were replaced with a stroboscopic light. The arrangement shown in Figure 1 was set up with the lamp housing of a Type 648-A Strobolux replacing the incandescent lamp. The convex glass was removed from the Strobolux lamp housing and a piece of heavy paper substituted. This had a 2½″ hole cut in the center to admit light

Figure 1. View of the tachometer mounted in the contour comparator with Strobolux lamp above.

to the condensing lens, while shielding the ground glass screen from direct light. It was recognized that this arrangement would pass only about 10% of the available light into the system.

The tachometer sample was then rotated at a speed of 2500 rpm, and the Type 631-B Strobotac, which controlled the Strobolux, was set to flash at a speed only a few rpm less than this. The picture shown in Figure 2 illustrates the image which appeared, rotating slowly, on the ground glass screen. A cyclic motion of the spring-loaded follower bearing against the face of the sliding collar was immediately seen. This appeared to be caused by a very slight wobble on the face of the collar, although the condition had not been noticed on a static check when the spring surrounding the shaft was extended. Only a little less obvious was a small erratic lateral motion of the shaft which appeared to take place slowly under the effect of the light from the Strobolux. It was also possible to observe and to measure the very small variations in the radial displacement of the three weights.

Two separate improvements in the tachometers were made possible or greatly facilitated by the use of the Strobolux with this arrangement.

The first was the elimination of a small amount of bouncing of the spring-loaded follower against the face of the rotating sliding collar. Before the investigation this had been manifested only as a very small and erratic motion of the pointer on the dial at medium high speeds.

The second improvement was effected by experimenting with the ball bearings on the spindle and observing the results. This enabled the engineers to fix tolerance standards for these bearings that will eliminate the small lateral motion of the spindle.

The engineers on this project felt that the results were quite satisfactory but decided to reduce the loss in the stroboscopic illumination by constructing a small holder and reflector for the Strobolux lamp which could concentrate a greater part of the available light into the small condensing lens of the contour comparator. This will produce an even sharper and brighter image of the sample permitting greater accuracy in the measurements.

— Kipling Adams

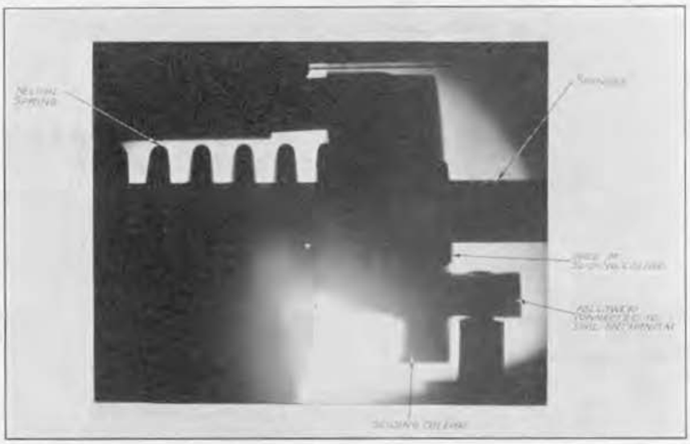

Figure 2. View of the image appearing in the ground glass screen of the comparator.

MISCELLANY

● **FOR RADIO-FREQUENCY IMPEDANCE** measurements Globe Union, Inc., of Milwaukee, manufacturers of Centralab radio products, have designed and built the convenient and attractive console shown here. The sloping desk top houses a Type 821-A Twin-T Impedance Measuring Network, while in the vertical panel are the r-f power source, a Type 605-B Standard-Signal Generator, and a radio receiver for use as a null detector. Drawers in the front provide a convenient place for storing accessories.

Manufacturers of capacitors and inductors find the Twin-T the most precise instrument available for the measurement of reactance and loss at radio frequencies.

IMPORTANT

Enclosed with this issue of the *Experimenter* is a new net price schedule for all General Radio products. This new schedule becomes effective on and after April 15, 1946.

Since a number of price changes have been made, all are urged to consult the new revised list before ordering.

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

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