the GENERAL RADIO **Experimenter**

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VOLUME 30 No. 10 **MARCH, 1956**

A NEW, HIGH-SENSITIVITY ELECTROMETER

Also IN THIS ISSUE

The new Type 1230-A D-C Amplifier and Electrometer is basically a high-resistance millivoltmeter. Voltage, current, and resistance is indicated on a panel meter and can also be indicated on a recorder.

Because of its high sensitivity and excellent stability, this instrument has a wide range of applications in science, engineering, and industry. Typical examples include the measurement of:

Ionization currents, photo currents, grid currents in electron tubes, and time-current curves of capacitors during charge and discharge.

Piezo-electric potentials, bioelectric potentials, contact potentials, electrostatic field potentials, and pH indications.

Silicon-diode back resistance, interconductor resistance of cables, insulation resistance of electrical equipment and voltage coefficient of resistance.

The amplifier in this instrument is strictly direct coupled. It uses neither the relatively low input-resistance chopper system nor the high-cost vibrating capacitor system. Its stability is due to excellent supply regulation, shock mounting, liberal use of wire-wound resistors at the important places, and adequate aging of both tubes and com-

Figure 1. Panel view of the Type 1230-A D-C Amplifier and Electrometer.

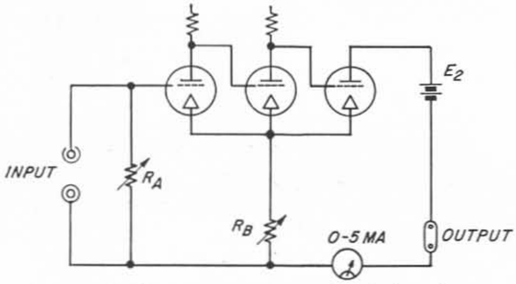


Figure 2. Elementary schematic of the Electrometer. The circuit is, fundamentally, a cathode follower in which the "tube" is a 3-stage, direct-coupled amplifier. The magnitude of the cathode resistor, R_B, determines the voltage sensitivity.

ponents. As a consequence, drift after warm-up is normally less than 2 millivolts per hour.

Grid current at the input of the 3-tube direct-coupled amplifier is negligible, because the tube in the first stage is an electrometer type. The input resistance is determined by the setting of a switch that provides resistance standards in decimal steps from 10 kilohms to a hundred thousand megohms (10^{11} ohms).

The ability to measure from 30 millivolts full-scale to 10 volts full-scale, coupled with the wide range of resistance standards, permits current measurements from one milliampere full scale to 0.3 micro-microampere (3×10^{-13} amp.) full scale at an effective "ammeter" resistance appreciably less than the value of the resistance standard.

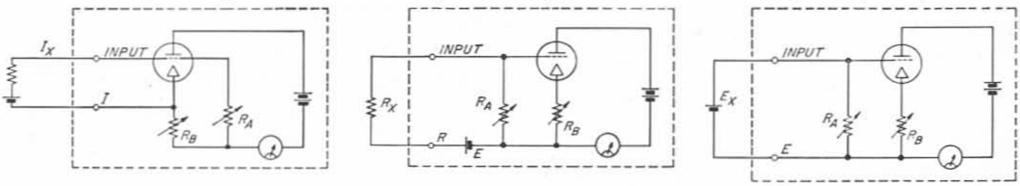
An internal stabilized-voltage source permits direct-reading resistance measurements from 300 kilohms to ten megamegohms at full scale (5×10^{14} ohms at the smallest meter division). Through use of the most sensitive voltage range and readily available external batteries, the resistance range can be extended by a factor of two hundred or more.

Circuit

Fundamentally, the circuit is a simple cathode follower where the "tube" is a three-stage amplifier as shown in the elementary schematic of Figure 2. Figure 3 shows the elementary circuit for each type of measurement. The effective transconductance is the product of the trans-conductance of the third stage and the voltage gain of the first two stages. The result is a transconductance in the millions of micromhos. Consequently, the input voltage is duplicated within a few microvolts across the cathode resistor, and excellent linearity is obtained even at the 30-millivolt scale. Voltage ranges are selected by changing the value of the cathode resistor.

The first two stages of the amplifier use sub-miniature tubes with ten-milliampere filaments. The filaments are in a resistor chain fed from a doubly stabilized voltage-regulating system. The plate and screen voltages of the first stage, as well as the screen voltage of the second stage, are obtained from this same highly stabilized supply. As a consequence of the great care used for stabilization, line voltage fluctuations have a negligible effect on performance. Balanced amplifier systems were tried but more reliable results were obtained by using the fully stabilized supply rather than the balancing method, which depends on perfect matching for adequate results.

Figure 3. Elementary schematics, showing, left to right, the circuits for measuring current, resistance, and voltage. The batteries are symbolic only; the instrument is entirely a-c operated.



High Input Resistance

The input resistance of the amplifier is about 10^{14} ohms when the input-resistance switch is at the open position. This extremely high resistance level is due not only to the use of an electrometer tube but also to unusual construction features. Every effort was made to obtain reliable operation under high humidity conditions. The glass envelope around the grid lead is treated with silicone. The resistance-standard selector switch uses switch contacts that are mounted on individual teflon bushings set in a metal base that connects to a guard point.

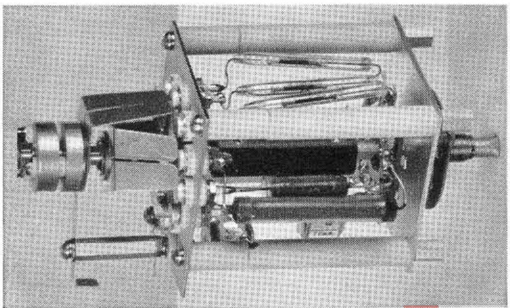
Internal Standards Calibration

To permit checking the high-resistance internal standards in terms of the low-resistance wire-wound standards, a check position is provided on the function switch. This has meant further elaboration of a switch already unusual in construction to meet the requirement of excellent performance at a 10^{14}-ohm level under adverse humidity conditions. The effort is well repaid in the ease with which the resistance of even the 10^{11}-ohm standard can be checked. A photograph of the switch is shown in Figure 4.

No Switching Transients

A switch is provided for readily disconnecting the unknown from the input without otherwise disturbing either the unknown circuit or the electrometer input circuit; to accomplish the switching without causing an electrostatic surge (due to friction of metal on dielectric) and without causing a change in capacitance with resultant voltage surge due to redistribution of charge, the contactor is raised by a teflon button with a metal rim in permanent contact with one of the blades.

Figure 4. View of the function switch.



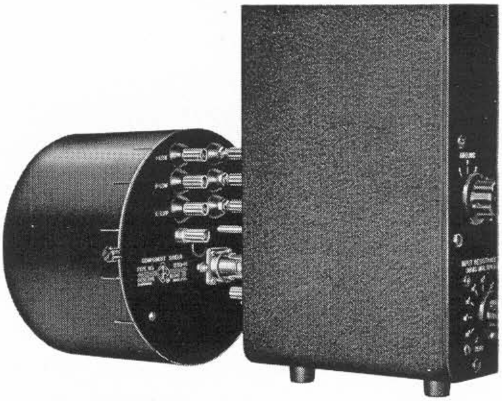


Figure 5. View of the Type 1230-P1 Component Shield plugged into the rear of the Electrometer.

Shielding

Complete shielding of the shock-mounted electrometer stage is important to eliminate grid currents due to ambient light, to prevent dust from entering and affecting the high resistance, and especially to isolate the input from random electrostatic potentials that are not usually noticed, but that become obvious at resistance levels in excess of 10^9 ohms.

The input connection is through a teflon-insulated coaxial terminal, and available accessories permit extension of the complete shielding to the unit under test. In particular, the Type 1230-P1 Component Shield provides a fully-shielded compartment within which components under measurement can be quickly and easily connected. The ground and guard terminals are duplicated on the panel of the Component Shield for greatest adaptability. Figure 5 shows the Component Shield plugged into the rear of the Electrometer.

Guard Terminals

While most measurements can be made by connecting the unknown (voltage, current or resistance) from the high input terminal to ground, there are some applications, especially in three-terminal resistance measurements, where guard points are necessary. Accordingly, the TYPE 1230-A Amplifier is provided with three guard terminals which can be grounded or not as desired. This arrangement is shown in Figure 6.

Output

The output system comprises a 0–5 milliampere panel meter and a pair of terminals in series with the meter. The panel meter has two scales calibrated in volts and two scales calibrated in ohms so that both have two ranges per decade. Any external meter or recorder at the output terminals can have as much as 1500 ohms resistance without affecting performance. Thus, either the 5 ma or the 1 ma Esterline-Angus recorder can be connected to obtain permanent recordings of results. The amplifier is an ideal companion instrument to this Graphic Recorder since it can be mounted in the same type of case. The dynamic output resistance of the amplifier is but a fraction of an ohm; therefore, it is well adapted for operation with most recorders.

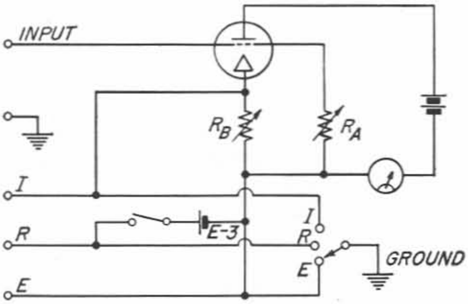


Figure 6. The I, R, and E terminals add appreciably to the versatility of the instrument. Any one of the three terminals can be used as a guard point (as in 3-terminal resistance measurements) and can be grounded by a panel switch.

Applications

This latter feature adds appreciably to the long list of uses for the amplifier (see page 1). The leakage resistance of capacitors, as well as time-current curves under charge or discharge conditions, are readily obtained. This Electrometer is well suited to the measurement of the high back resistance of silicon-junction diodes, because the potential applied to the unknown resistance is only 9.1 volts, which is within the safe operating range of the diode.

—A. G. BOUSQUET

SPECIFICATIONS

Voltage Ranges: ± 30, 100, and 300 millivolts, ± 1, 3, and 10 volts, dc, full scale. Accuracy is ± 2% of full scale on the five highest ranges; ± 4% of full scale on the 30-mv range.

Current Ranges: ± 1 milliampere d-c (10^{-3} amp.) full scale to ± 300 milli-micromicroamperes (3×10^{-13} amp.) full scale, in twenty ranges (two per decade). Accuracy is ± 3% of full scale from 10^{-3} amp to 3×10^{-9} amp; ± 10% of full scale from 10^{-10} amp to 3×10^{-13} amp.

Resistance Ranges: Direct reading in resistance from 300 kilohms to 10 mega-megohms (10^{13} ohms) at full scale (5×10^{14} ohms at smallest meter division). There are sixteen ranges (two per decade). At full scale (low-frequency end) accuracy is ± 3% from 3×10^{5} ohms to 10^{10} ohms; ± 8% from 3×10^{10} ohms to 10^{13} ohms. The voltage across the unknown resistance is 9.1 volts.

The resistance range may be extended considerably, and voltage coefficients of resistors determined, by the use of external batteries. With a 300-volt battery, the highest resistance range is 10^{15} ohms full scale (6×10^{16} ohms at the smallest meter division). The full battery voltage appears across the unknown resistance.

Resistance Standards: 10^{4}, 10^{5}, 10^{6}, 10^{7}, 10^{8}, 10^{9}, 10^{10}, and 10^{11} ohms. The switch also includes "zero" and "infinity" positions. The 10^{4}- and 10^{5}-ohms resistors are wire wound and are accurate to ± 0.25%. The 10^{6}-, 10^{7}- and 10^{8}-ohm resistors are of deposited-carbon construction and are accurate to $\pm 1\%$. The 10^9, 10^{10} and 10^{11} resistors are carbon, have been treated to prevent adverse humidity effects and are accurate to $\pm 5\%$. A switch position permits quick checking of the higher resistance standards in terms of the wire-wound units.

Input Resistance: The input resistance is determined by the setting of the resistance standards switch. In the infinity position, it is approximately 10^{14} ohms.

Drift: Less than 2 mv per hour after one-hour warmup.

Output: Voltage, current and resistance are indicated on a panel meter. Terminals are available for connecting a recorder (such as the Esterline-Angus 5-ma or 1-ma graphic recorder). The recorder can have a resistance of up to 1500 ohms.

Frequency Characteristic: With a 1500-ohm load at the OUTPUT terminals, the frequency characteristic is flat within 5% from zero to 10, 30, 100, 300, 1000 and 3000 cycles at the 30-, 100-, 300-millivolt, 1-, 3-, and 10-volt ranges respectively.

Terminals: The input is connected through an 874-type coaxial terminal assembly. In addition, there are three "low" terminals to provide versatility in guard and ground connections, as required, for example, in three-terminal network measurements.

Input Switch: A panel switch permits disconnection of the unknown without transient electrical disturbances in either the unknown or the measuring circuit.

Input Insulation: Entirely teflon or silicone-treated glass.

Temperature, Humidity, Line Voltage Effects: Negligible.

Tube Complement: One 5886 electrometer, one CK6418, one 6AN5, one 6AL5, one 6627, and three 0B2.

Accessories Supplied: One TYPE 874-411 Adaptor, one TYPE 1230-P1-300 Panel Adaptor Assembly, two TYPE 274-MB Plugs, one TYPE 274-SB Plug, spare fuses and TYPE CAP-35 Power Cord.

Accessories Available: TYPE 1230-P1 Component Shield.

Mounting: Aluminum front and rear panels finished in black-crackle lacquer and encased in an aluminum black-wrinkle-finished sleeve-like cabinet. The instrument is also available mounted inside a recorder case.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. Power input is approximately 35 watts at 115 volts.

Dimensions: (height) 13¼ × (width) 7⅝ × (depth) 9 inches, over-all.

Net Weight: 15¼ lbs.

Type		*Code Word*	*Price*
1230-A	D-C Amplifier and Electrometer	MASON	$440.00
1230-AE	D-C Amplifier and Electrometer in Esterline-Angus Case	MISTY	502.00
1230-P1	Component Shield	MANOR	40.00

A LOW-COST MICROWAVE SIGNAL SOURCE

One of the most frequently needed instruments in the electronics laboratory is a simple, convenient, and inexpensive signal source. General Radio Unit Oscillators were developed in answer to this need, and their constantly increasing popularity is conclusive evidence of how well they perform their tasks.

Unit Oscillators have been available

Figure 1. Panel view of the Type 1220-A Unit Klystron Oscillator with a Type 1201-A Unit Regulated Power Supply.