the GENERAL RADIO Experimenter

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Photo courtesy Hart Manufacturing Company

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180-600 Mc Oscillator

the GENERAL RADIO Experimenter

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COVER

The Hart Manufacturing Company of Hartford, Conn., producer of "Diamond H" precision relays and switches, maintains a continuous check on relay coils with the General Radio Resistance Limit Bridge. Two bridges are used in their production operations, one in the coil winding department for initial d-c resistance measurements and one in the inspection department for final specification checks on the assembled relay.

A NEW UNIT OSCILLATOR, 180 to 600 Mc

Butterfly circuits with their wide tuning ranges and trouble-free operation at frequencies from about 100 to 1000 Mc are used in many General Radio Unit Oscillators. Their wide ranges and stable characteristics have helped to establish these inexpensive and versatile units as almost indispensable equipment in many laboratories and on many test benches.

Butterfly-type unit oscillators for 50 to 250 Mc and for 250 to 920 Mc have been available, but, in order to cover the military aeronautical bands between 225 and 420 Mc, both of these units are needed. The new Type 1209-BL Unit Oscillator covers this range in a single unit.

As the type number indicates, the new unit oscillator is a modification of the familiar 250-to-920 Mc Type 1209-B Unit Oscillator. By elimination of one of the two parallel inductance branches of the butterfly circuit, all frequencies are reduced by a factor of $\sqrt{2}$. At the same time the minimum output obtainable at any frequency is increased from 200 to 300 milliwatts. All other characteristics and the external appearance are unchanged.

SPECIFICATIONS

Frequency Range: 180 to 600 Mc.

Tuned Circuit: Modified butterfly, with no sliding contacts.

Frequency Control: 4-in. dial with calibration over 270°. Precision drive with 4½:1 reduction.

Frequency Calibration Accuracy: ± 1%.

Warm-up Frequency Drift: 0.2%.

Output System: Short coaxial line with adjustable coupling loop on one end and coaxial connector on other. Maximum power can be delivered to load impedances normally met in coaxial systems.

Output Power: Into 50 ohms, 300 mw at any frequency.

Modulation: Plate modulation of 30% at audio frequencies can be produced by external source of 40 volts. Input impedance is about 8000 ohms. When amplitude modulation without incidental f-m is required, the Type 1000-P6 Crystal Diode Modulator or Type 1000-P7 Balanced Modulator is recommended.

Power Supply Requirements: 330 v at 36 ma; 6.3 v at 0.4 amp.

Power Supplies Recommended:

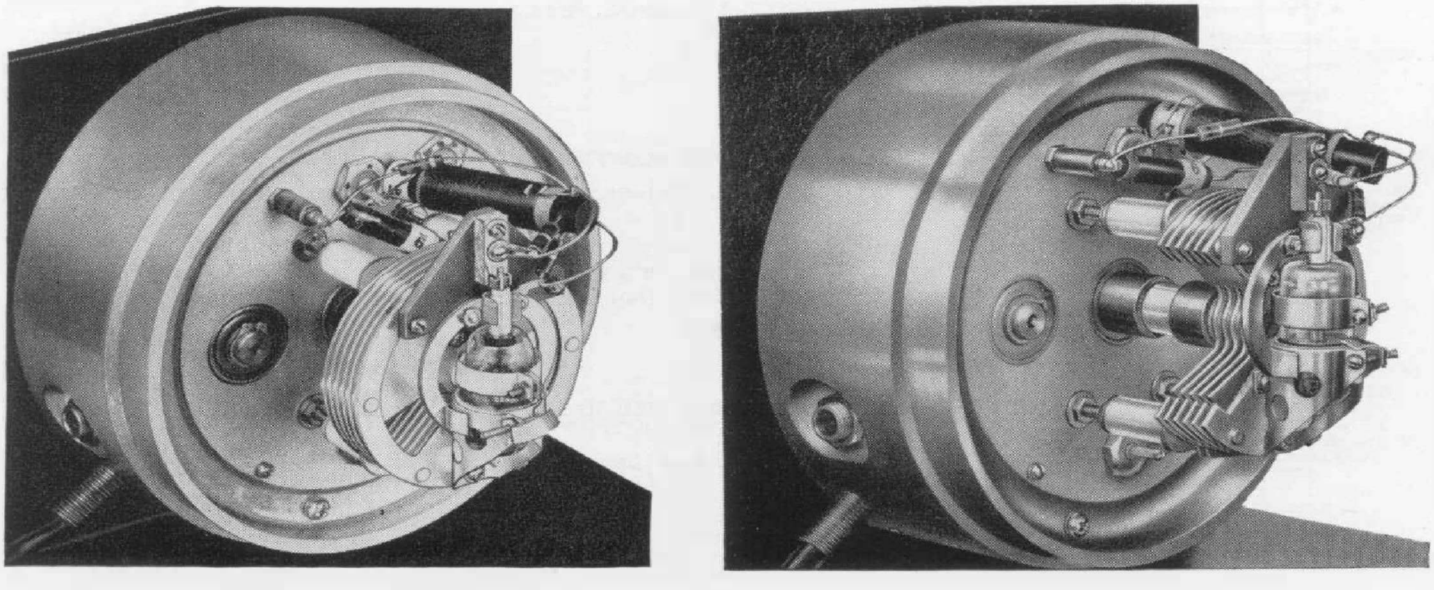
Standard: Type 1203-B Unit Power Supply, 115 volts, 50 to 60 cycles.

Stabilized Plate Voltage: Type 1201-A Unit Regulated Power Supply, 105 to 125 volts, 50 to 60 cycles.

Battery Operation: Type 1202-A Unit Vibrator Power Supply, 6- or 12-volt battery or 115 volts, 50 to 60 cycles.

Adjustable Plate Voltage: Type 1204-B Unit Variable Power Supply, 115 volts, 60 cycles.

Figure 1. (*Left*) View of butterfly circuit in the Type 1209-B Unit Oscillator. (*Right*) Rear view of Type 1209-BL, showing how one of the parallel inductance branches of the butterfly is removed to lower the frequency range.



Constant Output Level vs. Frequency: Type 1263-A Amplitude Regulating Power Supply with Type 874-VR Voltmeter Rectifier, Type 874-Q6 Adaptor, and Type 274-NF Patch Cord, 115 or 230 volts, 50 to 60 cycles.

Oscillator Tube: Sylvania Type RT 434.

Mounting: Aluminum casting surrounded by spun-aluminum shield. Assembly is mounted on L-shaped panel-and-chassis piece.

Accessories Supplied: Type 874-R22 Cable, Type 974-C58 Cable Connector, Jones socket, and telephone plug.

Accessories Available: Modulator, Sweep Drives, Relay Rack Adaptor Panels are available as listed in General Radio Catalog.

Dimensions: Height 6¼ in., width 9¼ in., depth 7 in., over-all.

Weight: 6¼ lbs.

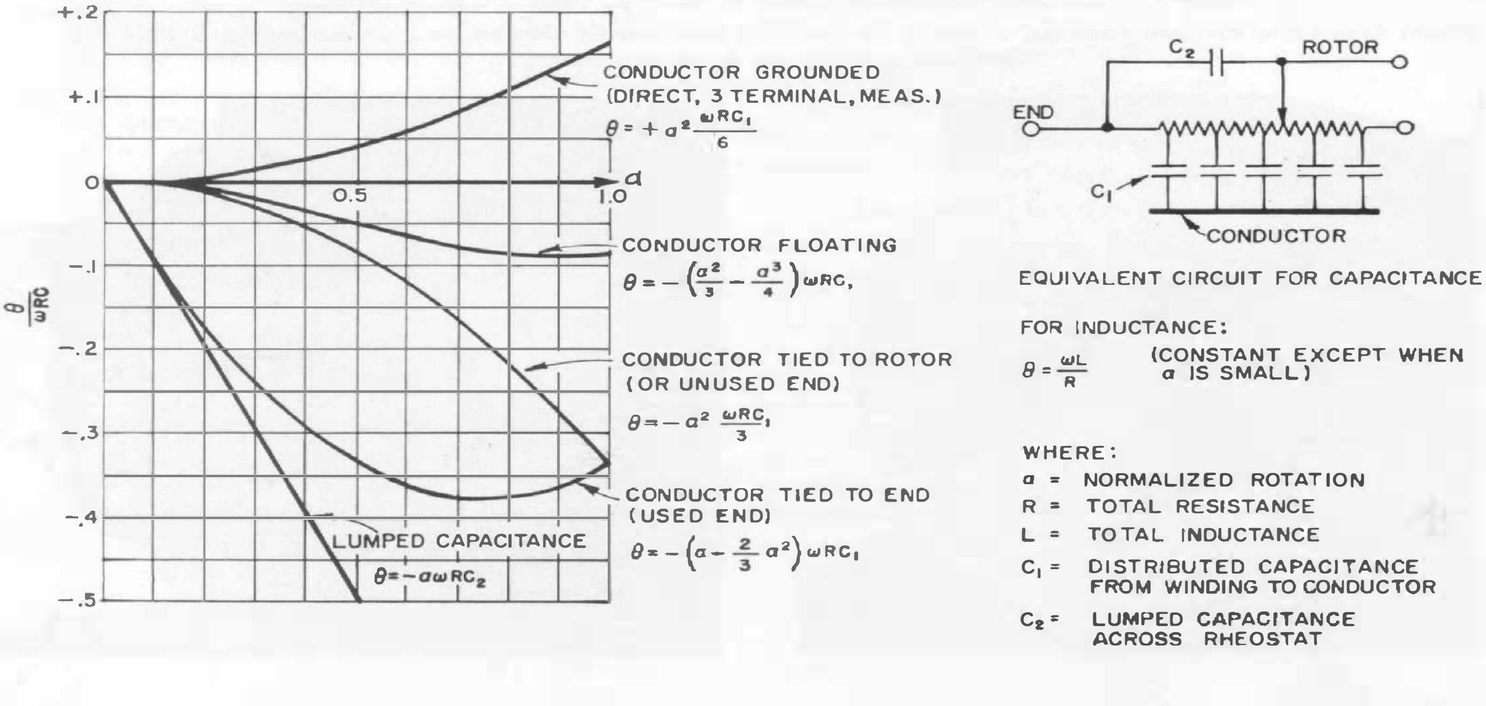
Figure 2. Panel view of the Type 1209-B Unit Oscillator. The new Type 1209-BL is identical in appearance except for the frequency calibration on the dial.

Type		*Code Word*	*Price*
1209-BL	**Unit Oscillator, 180 to 600 Mc**	ADMIT	**$245.00**

PHASE-ANGLE MEASUREMENT ON RHEOSTATS

An analysis of the effects of inductance and capacitance, both lumped and distributed, on the phase angle of a potentiometer used as a rheostat was presented in a previous article.[1] The distributed capacitance was assumed to be between the winding and a conducting surface (the housing, a metal mandrel, a mounting plate, or a shield), and the curve of the phase angle (θ) vs. fractional rotation (α) took various shapes, depending upon the potential of the conductor. These formulas and curves are summarized in Figure 1. The measured curves of the previous article were chosen to illustrate each effect separately. This article will describe the phase-angle characteristics of several potentiometers to show how their curves depend upon a combination of several effects.

Figure 1.



EQUIVALENT CIRCUIT FOR CAPACITANCE

FOR INDUCTANCE:

$\theta = \frac{\omega L}{R}$ (CONSTANT EXCEPT WHEN α IS SMALL)

WHERE:

α = NORMALIZED ROTATION
R = TOTAL RESISTANCE
L = TOTAL INDUCTANCE
C_1 = DISTRIBUTED CAPACITANCE FROM WINDING TO CONDUCTOR
C_2 = LUMPED CAPACITANCE ACROSS RHEOSTAT

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[1] H. P. Hall, "The Phase Angle of Potentiometers used as Rheostats," *General Radio Experimenter*, 32, 4, September, 1957.

Measured Curves

Measured curves of θ vs. α for various potentiometers are given in Figures 2 to 8. The θ values are all given for 1 kc in order to facilitate comparison, although many of the measurements were made at higher frequencies in order to increase the sensitivity. The curves for the different types of potentiometers show quite a variation in magnitude and shape. The capacitances are more or less constant for all potentiometers of one type; a change in resistance should change only the resulting magnitude of θ. The inductance, however, depends upon the number of turns and wire size, so that it will vary as the resistance changes. The effect of resistance magnitude is illustrated in Figures 5 and 7, where two potentiometers of the same type are measured.

On potentiometers that do not have a metal case, such as the General Radio Type 970 Series, the "no plate" curve may be approached by using spacers to mount the potentiometer to the metal mounting plate. Figure 8 shows the behavior of a Type 977 Potentiometer spaced ¼ inch from the mounting plate, which gives substantial improvement over the curves of Figure 5. The "floating conductor" curve often gives the lowest θ for potentiometers with a metal case, but the case potential is affected by nearby objects. The "grounded conductor" connections usually result in an inductive phase angle, which can be easily compensated with a capacitor

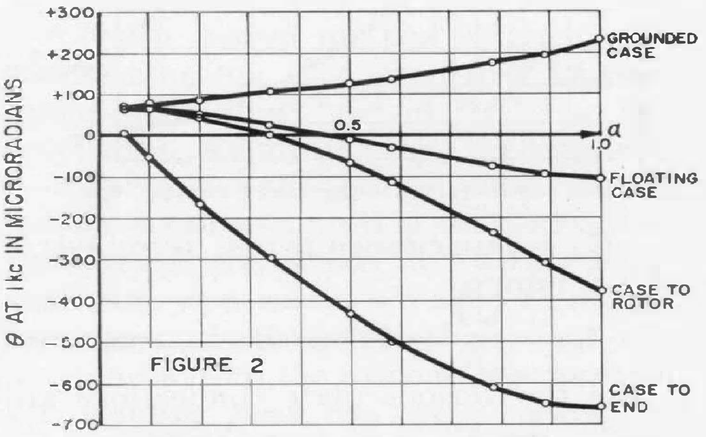


FIGURE 2

PHASE ANGLE CHARACTERISTICS
FOR
CLAROSTAT TYPE WX, 10KΩ, WIREWOUND POTENTIOMETER

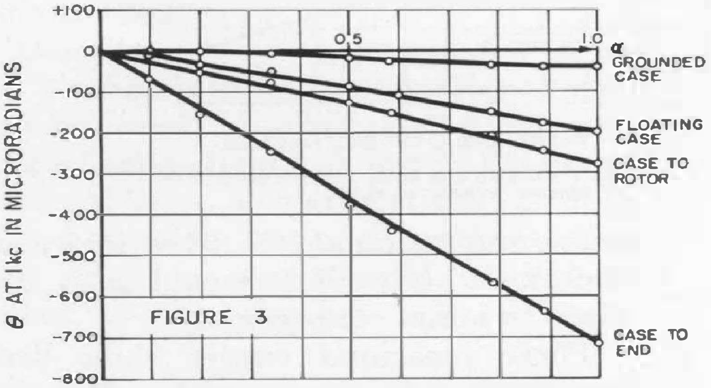


FIGURE 3

PHASE ANGLE CHARACTERISTICS
FOR
ALLEN BRADLEY TYPE JS, 10KΩ CARBON POTENTIOMETER

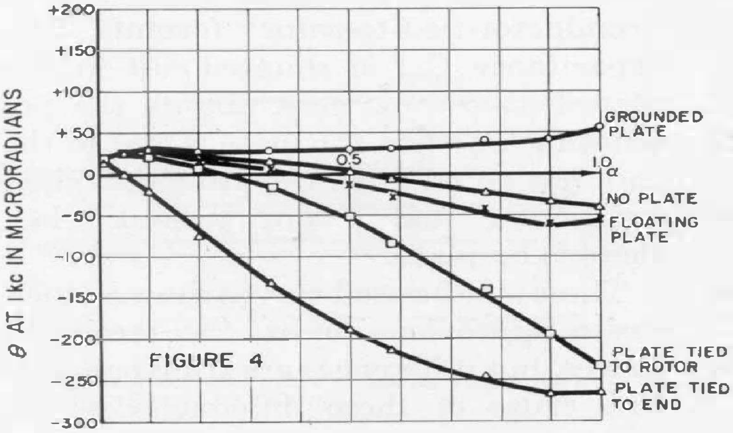


FIGURE 4

PHASE ANGLE CHARACTERISTICS
FOR
TYPE 971-N, 10KΩ WIRE WOUND POTENTIOMETER

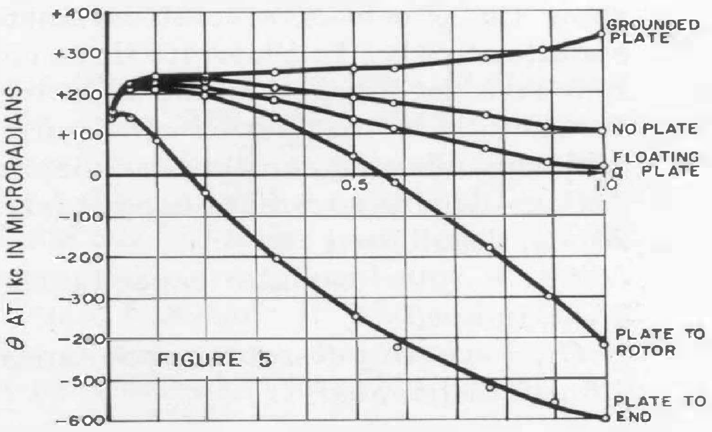


FIGURE 5

PHASE ANGLE CHARACTERISTICS
FOR
TYPE 977-N, 10KΩ, WIRE WOUND POTENTIOMETER

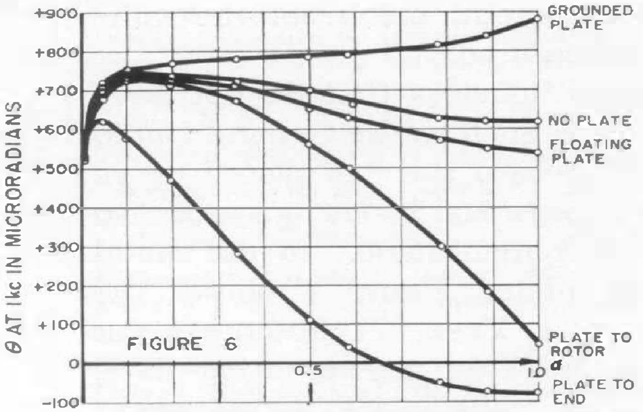


FIGURE 6

PHASE ANGLE CHARACTERISTICS
FOR
TYPE 978-N, 10KΩ WIREWOUND POTENTIOMETER

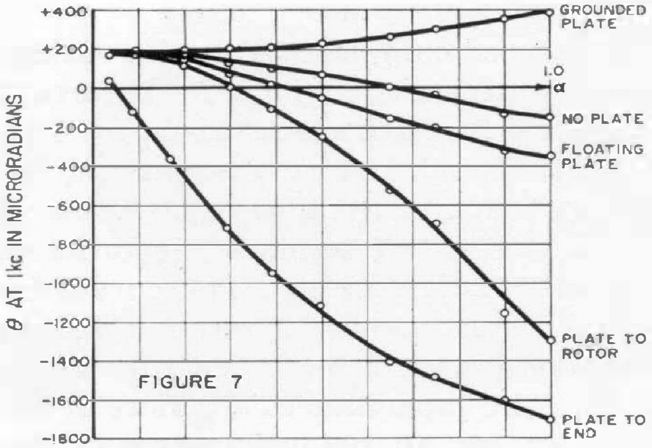


FIGURE 7

PHASE ANGLE CHARACTERISTICS
FOR
TYPE 977-P, 20KΩ WIREWOUND POTENTIOMETER

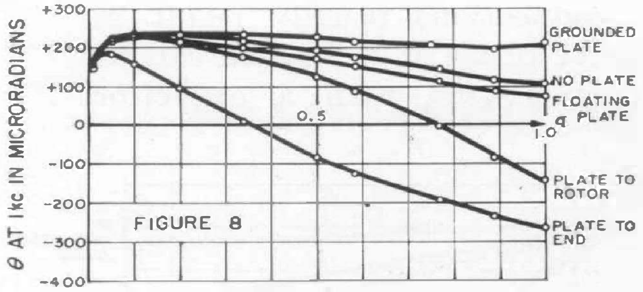


FIGURE 8

PHASE ANGLE CHARACTERISTICS
FOR
TYPE 977-N, 10KΩ WIRE WOUND POTENTIOMETER WITH 1/4" SPACERS TO MOUNTING PLATE.

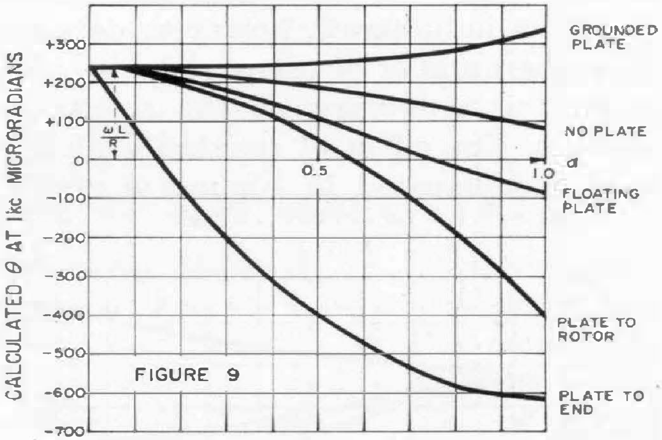


FIGURE 9

SYNTHESIZED PHASE ANGLE CURVES

across the terminals. Not too many applications, however, would use this three-terminal connection.

These measured curves show some similarity to the curves of Figure 1, but large differences are apparent. The curves of Figure 1 show the effect of each parameter separately, whereas measurements on the potentiometer show the effects of several parameters simultaneously. To illustrate these combined effects, Figure 9 shows an attempt to synthesize the curves of Figure 5, with the following constants assumed:

C_{wp} = winding-to-plate capacitance = 24 $\mu\mu f$, distributed

C_{rp} = rotor-to-plate capacitance = 3 $\mu\mu f$, lumped

C_{wr} = winding-to-rotor capacitance = 4.5 $\mu\mu f$, distributed

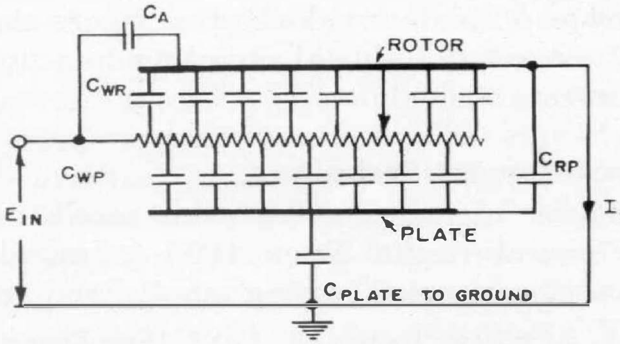
C_A = capacitance across terminals = 1 $\mu\mu f$, lumped

$$\theta_L = \frac{\omega L}{R} = 240 \ \mu\text{radians, constant}$$

As the various plate connections are made, the effect of C_{wp} changes as do the curves of Figure 1. However, C_A is always across the terminals, and the effect of C_{wr} is always as given by the "conductor-tied-to-rotor" formula. The capacitance C_{rp} is shunted out in the plate-tied-to-rotor case, shunts the potentiometer when the plate is tied to the end, has no effect in the grounded-plate connection, and is not present when there is no plate.

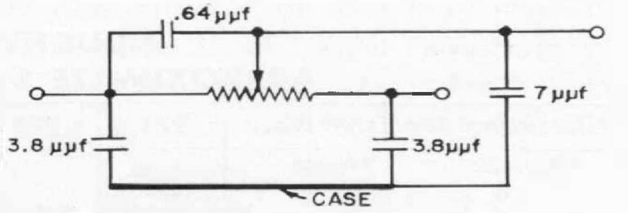
These synthesized curves show a much closer approximation to the measured curves, but differences are still apparent. One cause of these differences is the effect of capacitance from the winding and from the mounting plate to ground or to free space, which may be several micromicrofarads. This capacitance increases if grounded surfaces are brought near the plate. The effect of the winding-to-ground capacitance is the same as that of the capacitance from winding to plate in the "grounded-conductor" case when a direct measurement is made. This capacitance affects mainly the "no-plate" curve and makes it more positive. The plate-to-ground capacitance affects only the "floating-plate" curve, and, although the effect is more complicated, it makes this curve more positive also. Figure 10 shows an equivalent circuit for the "floating" case with the ground capacitance added, where the θ measured is that of the direct impedance, $\frac{E_i}{I_o}$.

Figure 10.



EQUIVALENT CIRCUIT FOR FLOATING PLATE WITH CAPACITANCE TO GROUND.

Another reason for the differences is the assumption that the stray capacitances are evenly distributed. For example, the assumption that the winding-to-rotor capacitance is evenly distributed is only a fair assumption for Series 970 Potentiometers, which have a ring rotor structure, and would not hold at all for most potentiometers. If there were capacitances from the rotor to that part of the winding near the rotor contact, θ would vary as $-\frac{1}{\alpha}$ rather than as $-\alpha^2$ as it does in the evenly distributed case. Not all the capacitances are included in the synthesized plots. In addition to the ground capacitance, there is probably some terminal-to-plate capacitance, which was not taken into account. Capacitances between various parts of the winding may also have a slight effect.



EQUIVALENT CIRCUIT FOR POTENTIOMETER OF FIGURE 3

Figure 11.

Still another effect is the presence of lumped capacitances which vary with α. For example, the capacitance from the terminal structure to the rotor will vary as the rotor is moved.

The curves for the carbon pot (Figure 3), which are almost straight lines, may be closely approximated if only the lumped capacitances shown in Figure 11 are considered. The area of the resistive element in this type of potentiometer is very small, so that distributed capacitances to the element are relatively small.

Summing up, we see that, although a combination of simple effects gives an approximation to the measured curves, differences are apparent, which are caused by additional factors that are much harder to analyze.

Phase-Angle Characteristics of General Radio Type 970-Series Potentiometers

Because several customers have inquired about the phase-angle characteristics of our 970-series pots, approximate specifications are given below. Usually it is not necessary to know the exact shape of the curve; the extreme values will be sufficient. The curve shapes are

TABLE I
INDUCTIVE PHASE ANGLE
APPROXIMATE θ_L in MICRORADIANS at 1 kc

Potentiometer Type No.		971	972	973	974	975	976	977	978
Type Letter	*Ohms*								
B	2	6500							
C	5	6300	9300	10600					
D	10	1800	3900	4900	9500				
E	20	740	1800	2200	4900				
F	50	620	910	1200	2800				
G	100	460	610	850	980				
H	200	340	430	730	760				
J	500	350	410	640	750	890			
K	1 K	130	440	330	640	730	900	1200	
L	2 K	72	102	147	275	360	610	820	980
M	5 K	63	73	120	170	215	420	610	990
N	10 K	30	68	80	120	165	210	240	730
P	20 K	16	15	35	62	130	130	200	250
Q	50 K	For these resistances, inductive effects are negligible compared to capacitive effects.							
R	100 K								
T	200 K								
U	500 K								

TABLE II
CAPACITIVE PHASE ANGLE at $\alpha = 1$
$\theta_{C\ max}$ in MICRORADIANS at 1 $k\Omega$ and 1 kc

Potentiometer Type		971	972	973	974	975	976	977	978
	No Plate	− 6.8	−11	− 8.6	− 9.4	− 7	−12	−13	−10
Plate Connected	to Ground	+ 3.4	+ .4	+ 5.7	+ 3.3	+11	+ 5.2	+12	+17
	to Winding End	−29	−33	−35	−36	−55	−57	−81	−81
	to Rotor	−26	−31	−30	−35	−46	−50	−66	−68
	Floating	− 8.3	−13	− 6.5	−12	−14	−18	−20	−17

These values depend upon the dielectric constant of phenolic, which varies with batch and with frequency.

quite similar for the various size pots, so that the complete curves can easily be approximated by drawing curves similar to those of Figures 4, 5, and 6.

Table I gives the approximate value for θ_L, the component of θ due to winding inductance for each size of each type of pot, except for the very large resistance values where the inductive effect is negligible compared to the capacitive effects. Table II gives $\theta_{C\ max.}$ the θ value at $\alpha = 1$ caused by the capacitive effects. The value of $\theta_{C\ max}$ depends upon the connection used and is negative except for the grounded-plate connection. The mounting plates used for these measurements were square, and the edge dimension was one inch greater than the diameter of the pot.

To get the values at $\alpha = 1$, the appropriate value of θ_L and $\theta_{C\ max}$ should be chosen. The value of θ at $\alpha = 1$ is then:

$$\theta = f\,(\theta_L + R\theta_{C\ max})$$

where f is in kilocycles and R in kilohms. As α approaches zero, θ, for the synthesized curves, approaches θ_L as shown in Figure 9. Actually, as shown in Figure 5, the inductive component of θ drops off at low values of α, where the full extent of mutual coupling has not been established.

Measurement Technique

These measurements were made on a General Radio Type 1605-A Impedance Comparator[2], using small fixed re-

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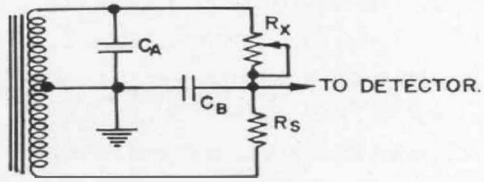
[2] Hall, H. P., and Holtje, M. C., "A High Precision Impedance Comparator," *General Radio Experimenter*, 30, 11, April, 1956.

sistors as phase-angle standards. This instrument presents on two meters the difference in magnitude and the difference in phase angle between the standard and the unknown impedances. The high sensitivity (one division = .0001 radian on the most sensitive range) and the wide frequency range (100 c, 1 kc, 10 kc, and 100 kc) make possible measurements over a very wide range of time constant (θ/ω).

In the measurement, the rheostat is adjusted for an approximate magnitude null, and then the $\triangle\theta$ value is read from the meter. For the most precise measurements, the standard resistors should have low capacitance and short leads. Because we are interested in the θ *difference*, the capacitance of leads to the rheostat can be balanced out by using similar leads to the standard.

It is interesting to see how direct measurements can be made if the rheostat is adjusted for a magnitude balance. The shunting capacitances C_A and C_B (Figure 12) have no effect in a direct measurement. C_A shunts half of the tightly coupled bridge transformer and causes negligible error if it is of reasonable size (less than .0001 radian error for $C_A = 0.1\mu f$ at 1 kc). The other stray capacitance, C_B, shunts the input and causes an error of $\frac{1}{2}\triangle R\,\omega C_B$, where $\triangle R$ is the resistance difference between the rheostat and the standard resistor. It is of course impossible to set $\triangle R = 0$, particularly for wire-wound potentiometers of limited resolution. However, if C_B is of the same order of magnitude as the capacitance causing the phase angle, the error is usually negligible.



BRIDGE CIRCUIT WITH STRAY CAPACITANCE

Figure 12.

The author wishes to thank R. G. Fulks and J. M. Flower for making many of the measurements used in this article.

— H. P. Hall

THE NEW MIDWEST OFFICE

July 15, 1957, marked the opening of our new office in Oak Park and the closing of the old office at 920 South Michigan Avenue in Chicago, which had been in operation since 1943. During the intervening years, the office had grown in size more than threefold. This expansion in personnel together with our plans for a Midwest repair department made it necessary to move to larger quarters. A suburban location was desirable, because more and more of our customers were moving away from the downtown area.

Our new location at 6605 West North Avenue is in Oak Park about ten miles west of Chicago's Loop. Easy access to and from locations in Chicago is possible via North Avenue, the main east-west artery, or the Congress Expressway located nearby. Also, several north-south arteries, such as Harlem Avenue and Cicero Avenue, are in the vicinity. Convenient public transportation is also available, while those who drive will find the location easily and will have no difficulty in parking. There is a parking lot at the rear of the building as well as ample space on the adjacent streets.

There is a large demonstration room equipped with representative General Radio instruments and soon a good stock will be available for over-the-counter sales.

The New Service Department

One of the major considerations in the new location was to provide a complete factory service department, and about one half the space is now devoted to servicing General Radio equipment. Alfred J. Guay, a factory-trained service engineer, is in charge of this operation and is ably assisted by expert service technicians. This department has been in operation since August 1. Facilities are available for standardization, recalibration, and repair of General Radio instruments.

Sales engineers at the Midwest office. Left, Bob Bard; right, Bill Ihde.

View of the new front door — 6605 West North Avenue, Oak Park, Illinois.

The service laboratory at General Radio's new Midwest office. ***Left to right,*** **Al Guay in charge of service activities and George Hanson.**

For those customers interested in making their own repairs, a good stock of replacement parts is available.

Many service problems can be solved by discussing them with us. Please call on Bill Ihde or Bob Bard if you have a measurement problem, or Al Guay if you have a service problem in connection with GR equipment.

We cordially invite you to call or to visit us at any time.

Telephone: VIllage 8-9400.

— WILLIAM M. IHDE

SCIENCE FOR THE BLIND

A unique publication, *Science Recorded*, entered its third year in October, 1957. *Science Recorded* is a scientific periodical, recorded on magnetic tape, and sent each month to some 200 blind subscribers in the United States, Great Britain, Australia, and Mexico. It is handled by a nonprofit organization, Science for the Blind, a subsidiary of the Philadelphia Association for the Blind. In the twelve months ending October, 1957, over 4000 tapes were sent out.

The staff is made up primarily of volunteers who serve as readers and mailers. The editor is Professor T. A. Benham of Haverford College, who is well known for his work in the development and adaptation of scientific instruments for use by the blind.

Among the sources of material for publication in *Science Recorded* is the *General Radio Experimenter*.

. . . IMPORTANT . . .

Be sure to save the new General Radio price list enclosed, and file with your Catalog O.

Effective date: **January 20, 1958**

Ira G. Mercer

GR REPRESENTATION FOR HAWAII

Radio-Television Corporation, Ltd., 777 Ala Moana, Honolulu, Hawaii, has been appointed General Radio's representative for the Territory of Hawaii. Ira G. Mercer, Manager of the Electronics Division and well known in electronic engineering circles both on the mainland and in Hawaii, is in direct charge of GR sales.

All interested in electronic test equipment and instrumentation questions are cordially invited to get in touch with our new representative. The telephone number is 50-2901.

NEW LOCKING SYSTEM FOR UNIT INSTRUMENTS

General Radio Unit Instruments have plug-in power supplies. This feature makes possible the most efficient use of power-supply units and also permits the user to select either a regulated or an unregulated supply, as the immediate requirements may dictate.

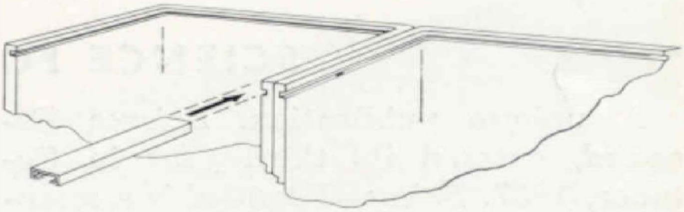


Figure 1.

With the rectangular-cabinet type of unit instrument, it is possible to combine this feature with the advantages of a single structure. This is accomplished by the use of locking strips, which hold the power-supply cabinet and the instrument cabinet firmly together, so that they can be handled as a single assembly. The locking strips are now supplied with all rectangular-cabinet unit instruments. Installation is simple, as shown in Figure 1. Two locking strips are used, one at the top and one at the bottom.

General Radio Company

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