The **GENERAL RADIO**
EXPERIMENTER

VOL. 3 NO. 9 FEBRUARY, 1929

The General Radio Experimenter is published each month for the purpose of supplying information of particular interest pertaining to radio apparatus design and application not commonly found in the popular style of radio magazine.

There is no subscription fee connected with the General Radio "Experimenter." To have your name included in our mailing list to receive future copies, simply address a request to the
GENERAL RADIO CO., Cambridge, Mass.

A New Relay

By C. T. BURKE, Engineering Department

With this month's EXPERIMENTER the General Radio Company announces a sensitive signal relay. This instrument, the Type 481 Relay, is illustrated in Figure 1. A permanent horseshoe magnet provides the field and forms a protecting shield about the coil and reed. The coil is mounted about midway of the sides of the magnet and the reed fixed near the toe. The distance from the center of the poles to the point where the reed is secured is 2¼ inches. The contacts with adjusting screws complete the instrument. An unusual feature of this relay is the distance between the pole pieces—0.47 inches. This wide separation provides a uniform field in the region through which the reed moves. The effect of this is to make the adjustment of the reed to the neutral position less critical.

In operation, the adjusting screws, which determine both the position of the reed in the field and its travel, are adjusted so that the reed takes up the neutral position in the field. The location of the neutral position will shift somewhat as a result of an average current in the coil, and in the case of high speed signals of considerable intensity, this shift may be comparatively large. With the reed in the neutral position, a signal (which may for convenience be supplied by an interrupter) is impressed on the relay coil. The contacts of the coil are adjusted so that the reed strikes evenly without chatter on either side. This adjustment may be made with a sounder, but it can be greatly facilitated by means of a visual type oscillograph.

The minimum operating current of the Type 481 Relay is one milliampere in the signal circuit, and it will follow impulses of frequencies as high as 125 cycles per second. The tungsten contact points will break one ampere without burning.

A relay of this type has many uses in the laboratory, as well as in the commercial communications field. The high sensitivity attained permits the use of the Type 481 Relay with little amplification for the actuation of chronographs from time signals, signal recorders, or other apparatus where remote control by means of radio, carrier or low-frequency current impulses is desired. Rectification is, of course, required where the impulse current is of high frequency.

The mechanical simplicity and ruggedness of the relay particularly recommend it for uses where little attention can be given to the apparatus.

The operation of the relay is best illustrated by a few oscillograms. The oscillograms of Figures 1 to 9 were taken on a string oscillograph, using the recently developed double string-holder which permits simultaneous viewing of the current in both the coil and the contact

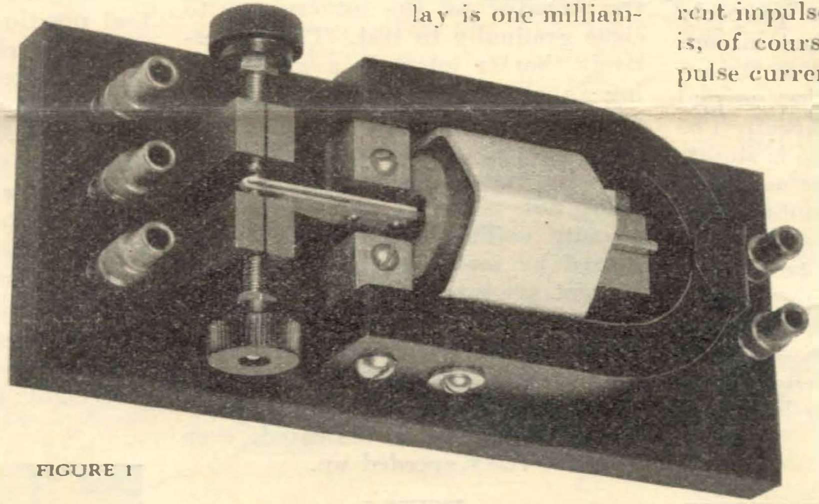
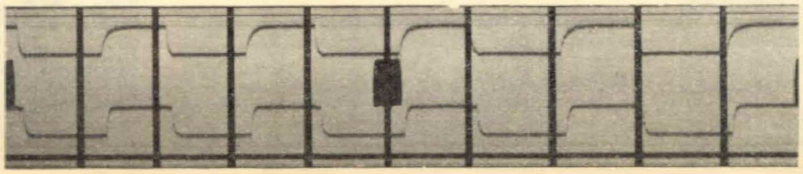


FIGURE 1



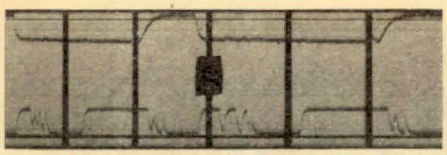


FIGURE 2

circuits. The oscillograms are all arranged with the coil current at the top and time proceeding from left to right. The zero current lines are at the bottom. The timing lines on the films mark 0.04-second intervals. Figure 2 shows the effect of a very badly adjusted relay. The effects of chattering and bouncing are very marked. The relay fails entirely on many impulses. For contrast, Figure 3 shows a well adjusted relay. A firm contact without any trace of bounce is made on each throw of the reed. The trace of the coil current shows plainly the gradual building up due to the inductance of the coil. The contact current shows no change until the coil current reaches a critical value, then rises almost at once to its final value. The effect is to give a sharper signal on the contact side than on the coil side. This would not normally hold true in signal circuits, where the inductance of instruments would slow down the growth and decay of current. Such effects may be minimized by means of condensers properly placed. The important fact in connection with the relay is that its action is quicker than the normal growth of current in the circuit. The impulse on the contact side is slightly longer than that on the coil side, due to the fact that the contact current remains at full value until the coil current has decayed to critical value for the relay at this adjustment. The tendency of the contact to stick closed is plainly shown by the fact that the current required to hold the contact closed is less than that required to close it.

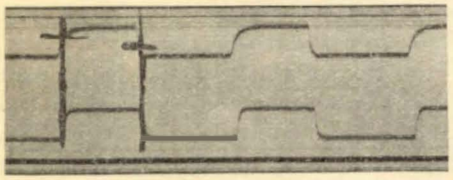
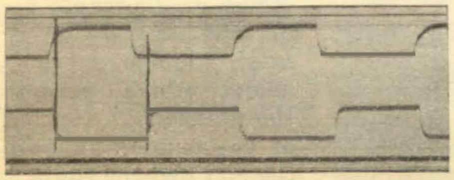


FIGURE 3
(Left)

FIGURE 4



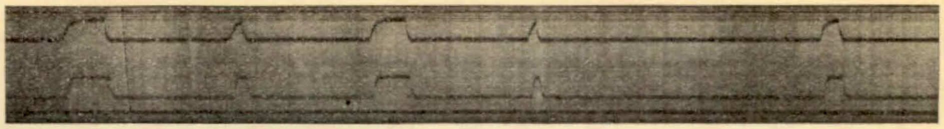


FIGURE 5

Figure 4 was made using the other contact so that an increase in coil current breaks the contact. A good relay adjustment with both contacts working similarly is indicated. The same gradual growth of current as occurred in Figure 3 will be observed. The contact stays open some time after the coil current drops. This lag is due to the sum of two effects. First, the reed does not start to move until the current drops to the critical value; and second, the contact is not made until the reed has traveled from contact to contact, i. e., the open-circuit period includes the travel time. The closed-circuit period, however, (Figure 3) includes no travel time. On this particular record the lag is somewhat excessive, and suggests that the back contact is not perfectly adjusted, a possibility that other oscillograms show to be a fact.

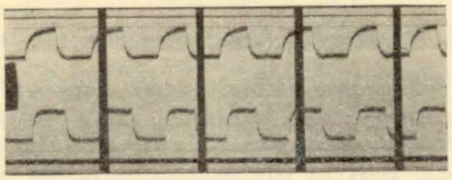


FIGURE 6 (Above)

Figure 5 was made by allowing the vibrator on the interrupter to come gradually to rest. The successively shorter intervals are interesting in showing how the relay will respond to short impulses and ragged waveforms. Nowhere does the coil current record an impulse not recorded in the contact circuit. The slight chattering caused by irregularities in the coil current are interesting.

Figures 6 and 7 are for a higher frequency of signal impulses. Both oscillograms are for the front or closed-circuit contact. No chattering or bouncing is indicated, even with the relay speeded up.

FIGURE 7

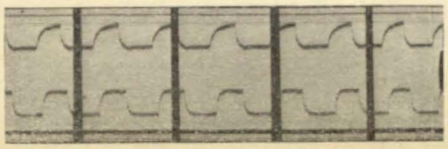


Figure 8 shows the back or open-circuit contact at high speed. The bouncing evident here reveals the faulty adjustment of this contact which Figure 4 led us to expect.

Figure 9 was made with the front and back contacts tied together, so that current flowed when the reed was in contact with either side. The open-circuit spaces on this record represent the time taken by the reed to travel across the gap. It will be noted that alternate spaces are comparatively large. Comparison with the other records reveal this to be due to the faulty adjustment of the back contact already observed.

The time of transit of the relay is an important characteristic, since it has a direct bearing on the speed of signal which may be followed. Comparison with the timing lines on the film which are spaced 0.04 second apart shows that the shorter travel time was about 0.002 second and the longer about 0.008 second. The difference in time indicates that the reed was not exactly in the neutral position, and had a greater restoring force on one side.

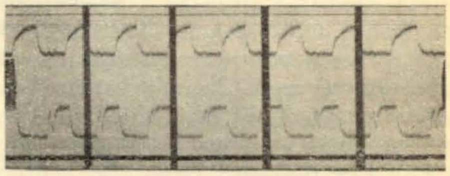


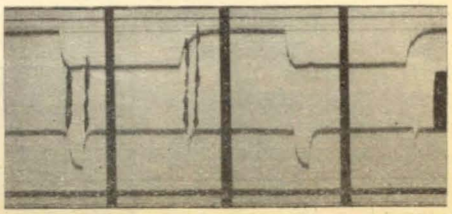
FIGURE 8
(Right)

It is interesting to note that the shorter time interval corresponds to a velocity of about 0.02 miles per hour, and an acceleration of about 20 miles per hour per second, or from standstill to sixty in three seconds without using the gears!

The price of the Type 481 Low-Current Relay is $30.00 net.

Code Word: **NOMAD.**
Dimensions: 6 x 2 x 1 inches.
Weight: 2¼ pounds.

FIGURE 9

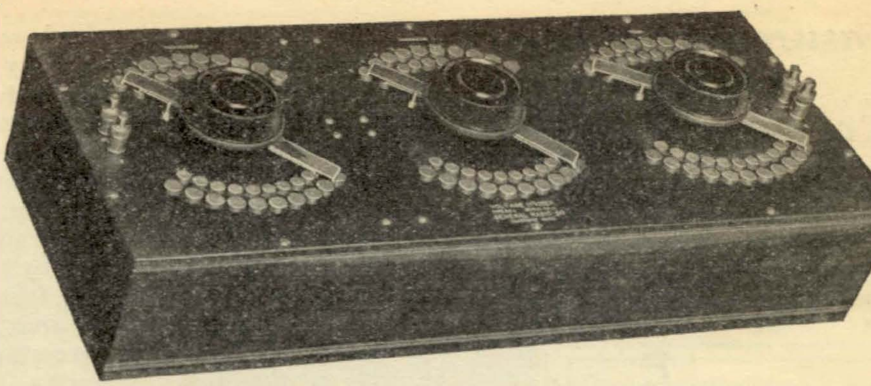


Three-Decade Voltage Divider

In laboratory procedure it is frequently desirable to subdivide a voltage with a greater precision than is possible using a single-dial type of divider. This may, of course, be accomplished by using two three-decade resistance boxes of appropriate ranges joined in series. Such an arrangement requires the second box to be set at the "complementary" reading whenever the first box is varied, if the total resistance of the divider is to remain constant, which at best is a bothersome procedure. This inconvenience may be eliminated by operating the dials of the two resistance boxes in pairs but in a reverse sense, and arranging the circuits as shown in Figure 10. Here the total resistance of the voltage divider across the input terminals remains constant, while a fraction of the drop along it is taken off at the output terminals.

If the resistance dials are progressive decades, the instrument will give a direct reading of the voltage ratio in three significant figures. For instance, in Figure 10 the dials are shown set to give a voltage ratio of 0.888. With this, as with any non-compensated voltage divider, the calibration in voltage attenuation is valid only when no current is drawn from the output terminals. The attenuation of such a multiple-dial divider must obviously be given in voltage ratios, that is, in a linear relation. Calibration in decibels, a logarithmic relation, is not possible. However, the attenuation in decibels, N, may be determined directly from the voltage ratio, R, by means of the equation:

$$N = 20 \log_{10} R$$



TYPE 554 VOLTAGE DIVIDER

It will be noted that this divider affords one common input and output terminal.

The General Radio Company has developed such a three-decade voltage divider known as the Type 554 Voltage Divider, which is shown in the illustration. This has a total resistance of 10,000 ohms subdivided into

9 steps of 1,000 ohms each
9 steps of 100 ohms each
10 steps of 10 ohms each

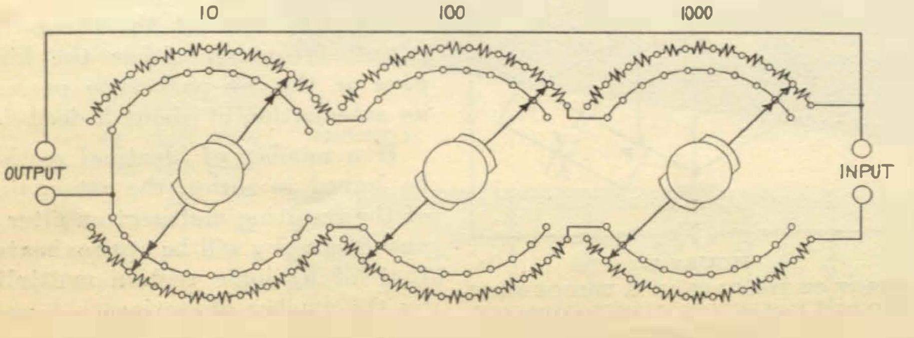
which enables a convenient direct setting of the voltage ratio from 0.001 to 1.000 in steps of 0.001. By using an external resistance of 90,000 ohms in series with the input terminals of the instrument, the voltage ratio may be adjusted from 0.0001 to 0.1 in steps of 0.0001, etc.

The Type 554 Voltage Divider is mounted in a walnut cabinet 22 x 9½ x 4 inches and is provided with a dust cover. The resistance units are wound to be non-reactive and are adjusted to a precision of 0.1%.

The net price of this instrument, assembled with a total resistance of 10,000 ohms, is $175.00.

Other resistance values may be made to special order.

FIGURE 10. WIRING DIAGRAM FOR TYPE 554 VOLTAGE DIVIDER



Coils for Types 389 and 489 Magnetostriction Oscillators

The General Radio Company has standardized a series of coils to be used with either of the Types 389 or 489 Pierce Magnetostriction Oscillators. These coils are designed to be used with ⅜-inch nichrome rods covering the frequency range from 5,000 to 50,000 cycles. Their applicability is indicated in the schedule below.

Coil	Frequency —Kilocycles per Second							
	5	7.5	10	15	20	30	40	50
389-A					x	x	xxx	xxx
389-B			x	x	xxx	xxx	x	x
389-C		x	xxx	xxx	x			
389-D	xxx	xxx	x					

x indicates coil may be used with rod of this frequency.

xxx indicates best coil for use at corresponding frequency.

It will be noted that Coils 389-B and 389-D together cover the entire range, although not always with optimum efficiency.

These coil assemblies carry a net price of $30.00 each.

The Experimenter to Have a New Editor

Starting with the next issue the EXPERIMENTER will have for its Editor, John D. Crawford who joined our Engineering Department on February 1. He is a graduate of the Massachusetts Institute of Technology and for the past two years has been Assistant Managing Editor of The Technology Review.

Measurement of Direct Capacity

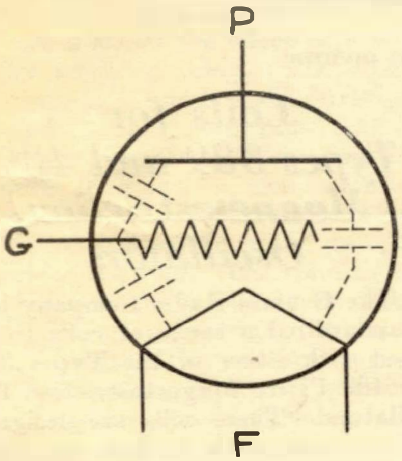


FIGURE 11

In the design of vacuum-tube circuits it is sometimes necessary to distinguish between the capacity as measured between two tube terminals and the direct capacity between the elements. The capacity as measured between terminals includes the direct capacity plus the capacity to the third element. Referring to Figure 11, the measured grid-filament capacity consists of the capacity C_{GF} and in addition C_{GP} and C_{PF} in series, or

$$\underset{\text{(Apparent)}}{C_{GF}} = C_{GF} + \frac{C_{GP}\,C_{PF}}{C_{GP}+C_{PF}}$$

the symbols indicating direct capacity except where apparent capacities are specified. Similar equations may be written for the capacity between any pair of terminals, and the direct capacities may be computed from the three measured capacities.

The computation may be avoided, and the direct capacities measured, by means of a simple modification of a standard bridge circuit. The third element is brought to the junction point of the bridge arms. The bridge circuit with this connection in place is shown in Figure 12.

The bridge circuit in the figure is that of the General Radio Type 383 Bridge, in which the unknown is shunted across a calibrated variable capacity, and the circuit balanced against a fixed capacity before and after the addition of the unknown. In Figure 12 it will be seen that the direct capacity between terminals (e. g. grid-filament capacity) is shunted across the standard condenser. The grid-plate capacity is connected across the null indicator, and does not affect the measurement, since there is no voltage across it at balance. The third capacity (plate-filament) is shunted across one of the resistance arms of the bridge, and may be compensated for by the readjustment of the power-factor correction condenser. The capacity as measured with this circuit is, therefore, the direct capacity between the elements.

The following figures are illustrative of the values of capacity as measured by the ordinary method and the direct capacity.

Between	*Total Capacity*	*Direct Capacity*
P – G	10.6 mmf.	8.78 mmf.
G – F	6.75 mmf.	5.06 mmf.
F – P	6.4 mmf.	3.71 mmf.

Since the direct measurement is often needed, the Type 383-A Bridge will be provided with a terminal for the connection of the third element as standard construction.

The change can be made on bridges previously manufactured at a cost of $5.00.

The change consists of an additional terminal so placed that the three-plug plate supplied with the bridge will make the connection to the third element. If the filament must be kept hot i. e. is connected to a battery, or a particular terminal must be kept at ground potential for any other reason, it will be possible to make connection to the third bridge terminal by means of the three plug plate for only one of the two possible measurements. A flexible lead may then be used for connection to the third bridge terminal.

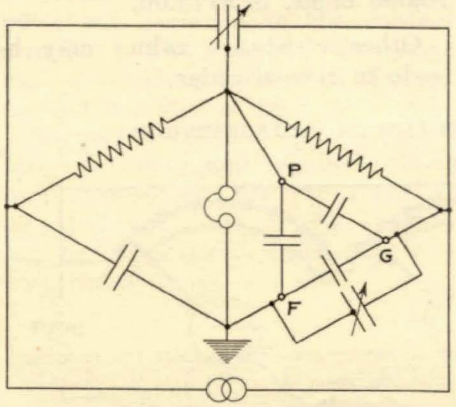


FIGURE 12
CIRCUIT OF THE TYPE 383-A BRIDGE MODIFIED FOR MEASURING DIRECT CAPACITY

Characteristic Curves of Filters

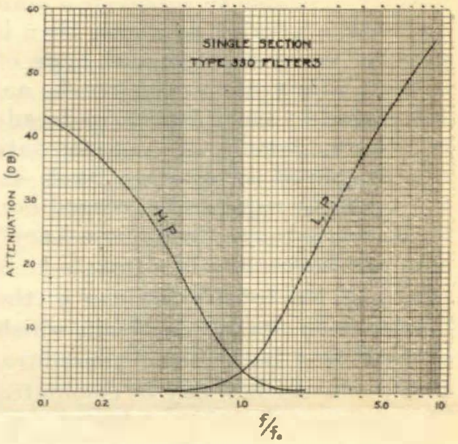


FIGURE 13

Assume that we have a series of single-section low-pass filters, having different values for cut-off frequency and iterative impedance, but constructed with a given type of inductance unit. A single curve may then be used to represent, with a good approximation, the attenuation characteristic of any one of these filters, providing we plot attenuation as ordinates and the ratio of the corresponding frequency to the theoretical cut-off frequency as abscissae.

Likewise, a single curve may represent the characteristics of a series of high-pass filters. This is illustrated in the figure which shows both the low-pass and high-pass characteristics for a single section of filter working between a generator and a load each having the impedance of the filter. The low-pass sections are of the π-type, consisting of one series (inductive) and two shunt (capacitive) elements, while the high-pass sections are of the *T*-type, comprising two series (capacitive) and one shunt (inductive) elements.

We note that at the theoretical cut-off frequency either the high-pass or the low-pass type presents an attenuation of about 3 decibels.

If a number of identical sections be joined in series, the attenuation of the resulting multisection filter at any frequency will be approximately that of a single section multiplied by the number of sections.