The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

FREQUENCY CHARACTERISTICS

A DECADE-RESISTANCE box is composed of individual decades connected in series to the box terminals. Their arrangement and interconnections are shown in Figure 2. The result is not the pure resistance for which each separate resistor is adjusted by means of a direct-current bridge and which is indicated by the dial setting. In addition the resistors and their wiring have inductance and capacitance which may be conveniently represented by the network of Figure 3. These cause the box to have, at any frequency, a reactance and a phase angle. The resistance will vary with frequency, both because of the frequency characteristic of the network and because of skin effect or crowding of current to the surface of a solid conductor. The existence of reactance and the increase in effective resistance with frequency can be minimized by careful

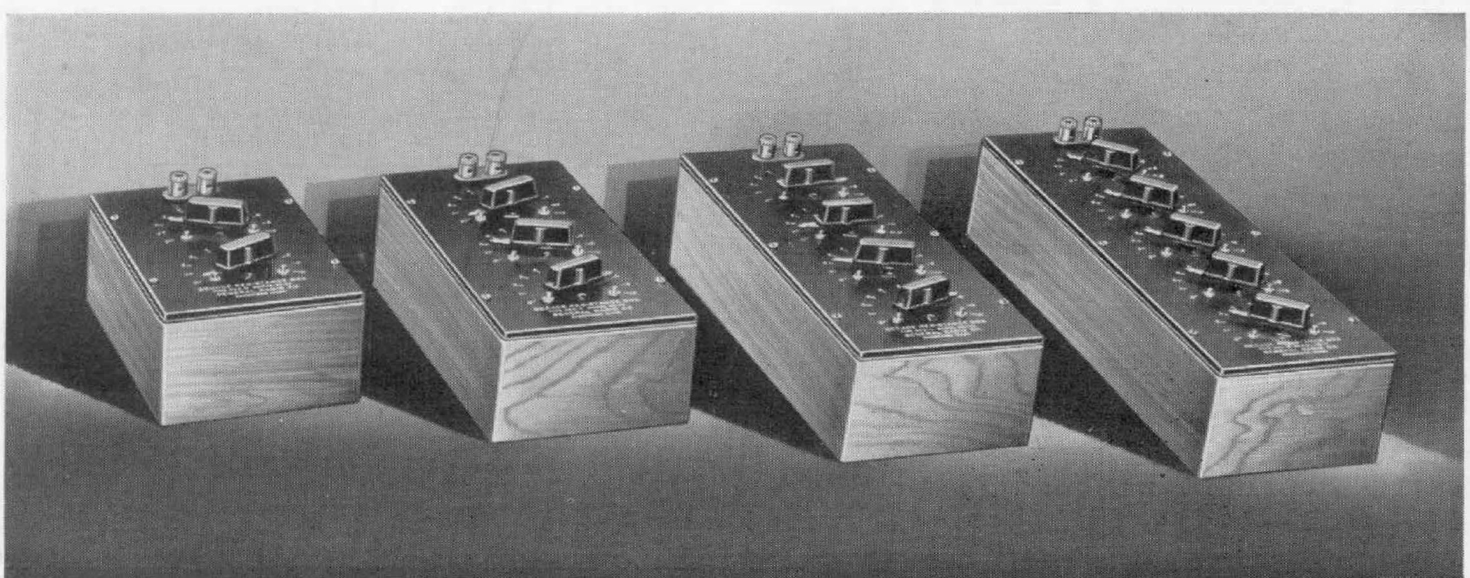


FIGURE 1. Four of the nine stock sizes of TYPE 602 Decade-Resistance Boxes. Their frequency characteristics are discussed in the accompanying article

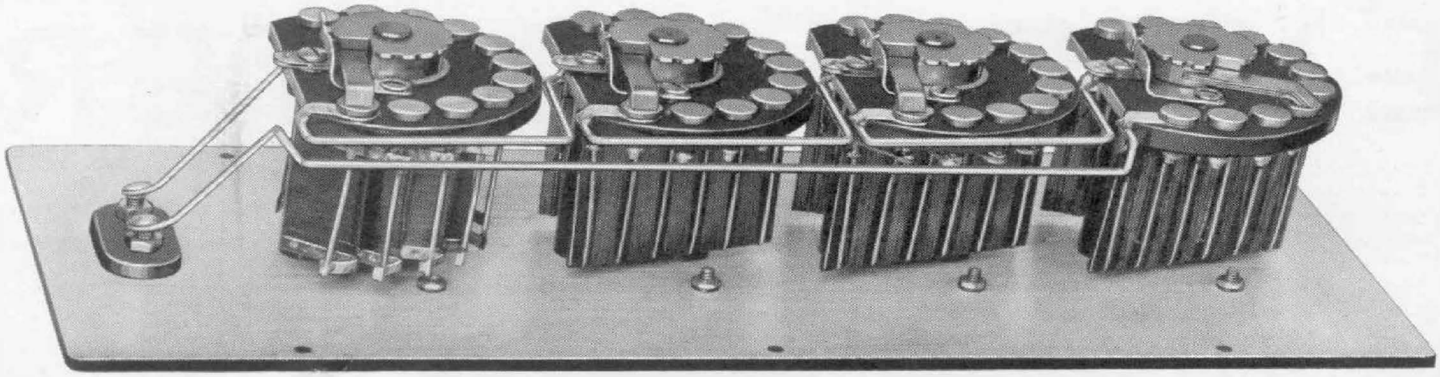


FIGURE 2. Interior of a TYPE 602-J Decade-Resistance Box. The decades are, from right to left, units, tens, hundreds, and thousands of ohms. A separate winding is used for each step

design, but they can never be eliminated. The object of all improvements in the high-frequency behavior of resistance boxes is the minimizing of these two effects.

For frequencies below 50 kilocycles the skin effect is negligible and the equivalent inductance is constant.[1]

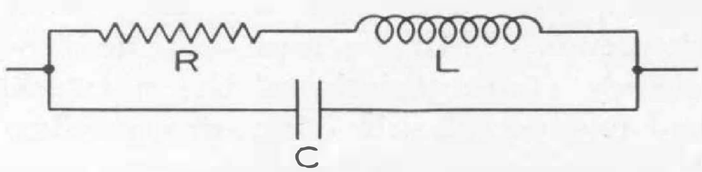


FIGURE 3. Equivalent network of a resistor

This equivalent inductance $\hat{L}$ of the network is always smaller than the series inductance L because of the shunting action of the parallel capacitance C: $\hat{L} = L - R^2C$ (1)

For small values of resistance the equivalent inductance is positive, while for larger values it is negative. The transition usually occurs in the hundreds of ohms.

Figure 4 shows the values of L and $\hat{L}$ measured at a frequency of 1 kilocycle for each of the six TYPE 510 Decade-Resistance Units. The complete boxes of Figure 1 are, essentially, assemblies of these units.

The parallel capacitance C, calculated by means of Equation (1) is about 6 $\mu\mu$f and is independent of dial setting.

The multiplicity of scales needed in Figure 4 in order to cover the wide range of values of equivalent inductance of the various decades may be reduced by using the ratio $\hat{L}/R$ of the equivalent inductance to the series resistance. This ratio has the dimensions of time and is called the time constant. When the equivalent inductance is negative, the time constant is still taken as positive, since the network is capacitive. In plotting it is

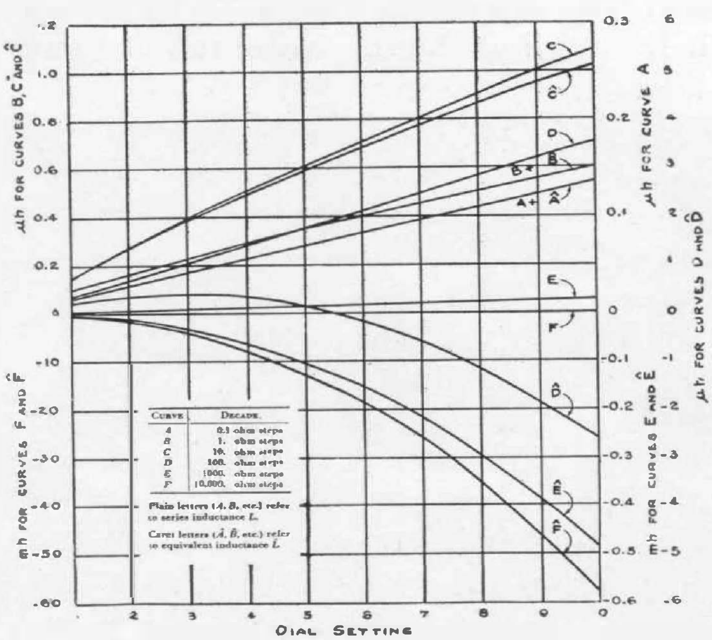


FIGURE 4. Equivalent inductance and "series inductance" as a function of dial setting for the TYPE 510 Decade-Resistance Units with their shields removed

[1]The equivalent reactance below 50 kilocycles is then $\hat{X} = \omega\hat{L}$

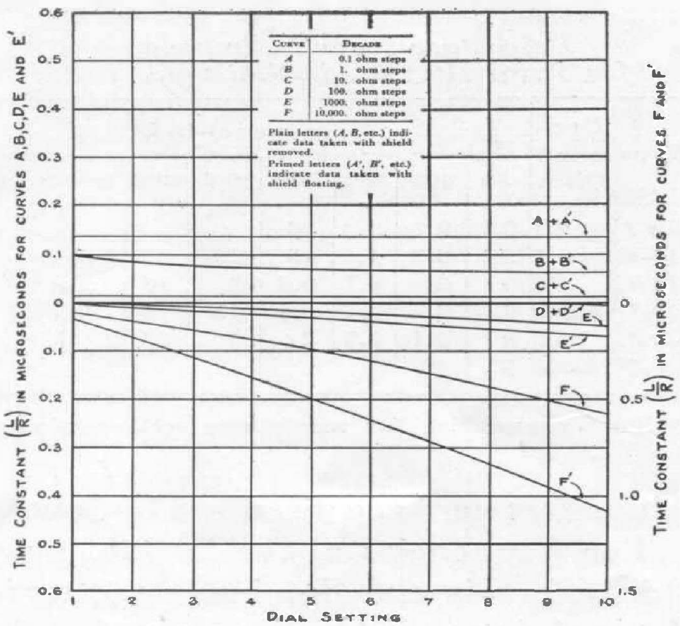


FIGURE 5. Time constant is plotted as a function of dial setting for TYPE 510 Decade-Resistance Units

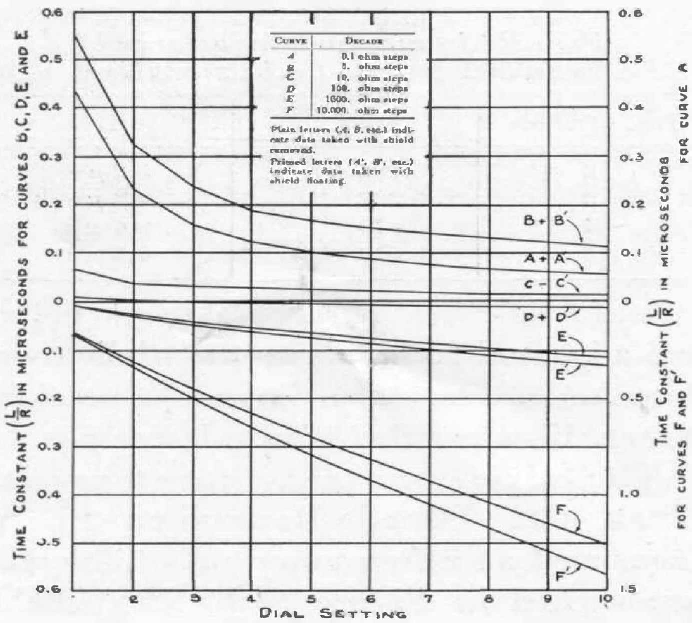


FIGURE 6. Time constant for the different decades of four-dial TYPE 602 Decade-Resistance Boxes

convenient to extend the time constant scale below the zero axis in order that the curves may be continuous.

The time constants for the TYPE 510 Decade-Resistance Units are plotted in Figure 5, both with the shield removed and with it in place but not connected, i.e., floating. The addition of a shield increases the parallel capacitance and thus affects the equivalent inductance and time constant of the larger decades by increasing the term R^2C. When the shield is connected to a terminal of the decade this capacitance is still further increased and is no longer constant for the various dial settings.

Values of these capacitances for the larger decades under the various conditions of shielding are given in Table I. The time constant for these conditions may be found by adding algebraically to the time constants given in Figure 5 that of the added capacitance.

When a number of TYPE 510 Decade-Resistance Units are assembled on a panel to form a TYPE 602 Decade-Resistance Box, the resistance and inductance of the wiring connecting the various decades and the additional capacitances of the decades increase the equivalent resistance and reactance over that of the separate units. The resistance and inductance at zero setting of two-, three-, four-, and five-dial boxes are given in Table II. These zero resistances are not included in the resistances of the various units, which

TABLE I

Parallel Capacitance in μμf of Decade Resistors

Type of Unit	Decade Ohm	Shield Connection*			
		Removed	Floating	On Zero	On Switch
510-D	100	6-6			
510-E	1000	6-6	7-7	31-17	9-16
510-F	10,000	6-6	10-10	33-21	12-18
602-J	1				
	10				
	100	18-17	21-19	41-35	53-53
	1000	17-12	19-14	27-20	63-63

*First figure is for zero setting, second figure is for maximum setting of the decade in question.

TABLE II

Zero Resistance and Inductance of TYPE 602 *Decade-Resistance Boxes*

No. of Dials	R	L
2	0.005 ohm	0.2 μh
3	0.007 "	0.3 μh
4	0.010 "	0.4 μh
5	0.012 "	0.5 μh

are adjusted to be correct at their own terminals. They also have a large skin effect, because the wiring is copper.

The time constants for four-dial TYPE 602 Decade-Resistance Boxes measured at a frequency of 1 kilocycle are shown in Figure 6 for the shield both removed and floating. The parallel capacitances are considerably larger for such a box than for a single decade and are given in Table I. They depend both on the number of decades in the box and on the position of the decade in question with reference to the other decades.

The effect on the parallel capacitance of the largest decade of connecting the shield to a terminal of the box is least when that terminal leads directly to the smallest decade. This connection however increases the resistance of the smallest decade because the resistances of the higher decades are placed in series with their capacitances to shield.

TABLE III

Percentage Error in Resistance for TYPE 510 *Decade-Resistance Units*

Type	Decade* Ohm	Frequency in kc 50	100	200	500	1000	2000	5000	10,000
510-A	0.1	0	0.1	0.2	1.5	5	15		
510-B	1.0	0	0	0.1	0.3	1	4	25	
510-C	10	0	0	0	0.1	0.5	2	11	
510-D	100	0	0	0	0.1	0.3	0.8	4	15
510-E	1000	0	0	0	−0.3	−1	−4	−30	
510-F	10,000	0	−0.2	−2	−6	−16			

*Percentages are for maximum setting of each decade.

TABLE IV

Percentage Error in Impedance for TYPE 510 *Decade-Resistance Units*

Type	Decade* Ohm	Frequency in kc 50	100	200	500	1000	2000	5000	10,000
510-A	0.1	0.2	0.7	2	15				
510-B	1	0.1	0.2	1	5	20			
510-C	10	0	0	0.1	0.2	2	10		
510-D	100	0	0	0	0.1	0.3	1	5	15
510-E	1000	0	0.1	0.5	2	6	20		
510-F	10,000	5	20						

*Percentages are for maximum setting of each decade.

This effect has been discussed by Jones.[2]

For frequencies above 50 kilocycles skin effect is the dominant factor in determining resistance except for the largest decades. Approximate values of the ratio (expressed as percentage error) of high-frequency resistance to d-c resistance of each of the TYPE 510 Decade-Resistors are given in Table III.

When a single decade or a number of decades are used as a voltage divider, the impedance of the different units is the factor determining the accuracy of the voltage division. Values of the ratio (expressed as percentage error) of high-frequency impedance to d-c resistance of each of the TYPE 510 Decade-Resistance Units are given in Table IV.

For the TYPE 602 Decade-Resistance Boxes the values of resistance and impedance at high frequencies are greater than for the corresponding TYPE 510 Decade-Resistance Units by amounts determined by the connecting wires as shown in Table II. When used in substitution methods where the change in resistance rather than its absolute value is significant, Table III still applies, except for moderate changes in the highest decades.

— ROBERT F. FIELD

[2]Jones and Josephs, *Journal of the American Chemical Society*, Vol. 50, 1928, p. 1049.

A DUPLEX SIPHON RECORDER

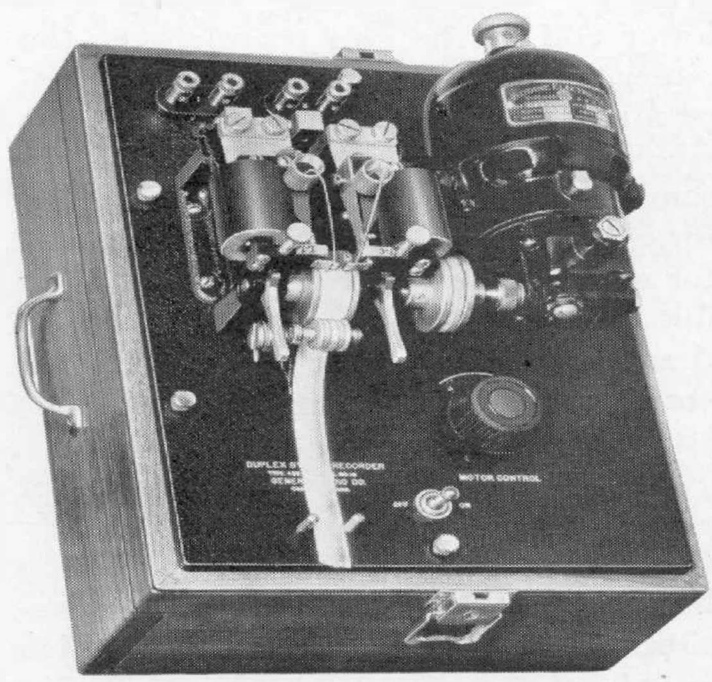
In the September, 1931, issue of the *Experimenter*, we announced a high-speed chronograph. Time-interval measurements to be made with a precision of something better than 0.001 second.

The present article describes another form of chronograph for use in problems requiring a less-accurate measurement of time intervals, the maximum precision being of the order of 0.01 second. This is the Type 456-A Duplex Siphon Recorder, shown below.

The siphon recorder is a well-known device which, among other things, has found extensive use in the automatic recording of telegraphic code signals. Some form of writing stylus, pen or pencil, is made to move a short distance to and fro by the starting and stopping of current through an appropriate electromagnet system. This stylus traces a line upon a strip of paper moving with a suitable speed perpendicular to the motion of the stylus.

If the design of the energizing electromagnet is such that the deflecting force increases, in general, with the displacement, and if the moving member carrying the stylus operates between fixed "back" and "front" stops, then the familiar block form of trace will be produced which gives practically no indication of the waveform of the energizing current, but which affords deflection intervals proportional to the duration of the current. At slow paper speeds, these traces are rectilinear in appearance. At the higher speeds, the to-and-fro motion traces a curved line, the extent of which (along the time axis) depends upon the inertia and restoring force of the moving member. The instant at which the motion of the stylus is stopped; that is, on striking the front contact on being energized, or the rear contact on being released, can, however, be determined with a sufficient precision to permit measurements to 0.01 second at the higher paper speeds. These are the fundamental operating conditions for the Type 456 Duplex Siphon Recorders.

As the name implies, this instrument carries two separate and individual pens which make adjacent traces upon the ½-inch strip of "ticker" paper. This paper, obtained in 5-inch diameter rolls, is mounted on a reel housed in a drawer in the cabinet base of the instrument. The paper is threaded up through the panel and, subsequently, over a rubber-faced drum which is driven by a 110-volt universal-type motor. Driving friction is produced by a grooved tension roller pressing the paper against the drum.



Type 456-A Duplex Siphon Recorder with the protecting cover removed. Tape is fed from a reel in the base

While passing over the top of the drum, the paper is marked with the two traces by the pens, which, of course, move parallel to the drum axis.

The pen arms are energized by two separate closed electromagnet assemblies, the windings of which terminate in two pairs of terminal posts. The two magnet and pen assemblies may each be raised and lowered by thumb screws to adjust the contact of the pens upon the paper. Two cam arms are likewise provided for raising the pens and holding them away from the paper without disturbing the adjustment of these thumb screws. The travel of each pen arm may be controlled by an adjustable "back" screw. The restoring force of each arm may be adjusted to best meet operating conditions. Increasing this restoring force increases the speed of the moving member at a sacrifice, of course, of the sensitivity.

The pens consist merely of two fine silver tubes which are mounted on the arms by suitable spring clamps. The lower end of the pen travels over the paper, while the upper end is suspended free from contact in an ink cup which is mounted on the magnet assembly. Inks of different colors, as, for example, red and blue, may be used for each of the two traces. The flow of ink is produced by siphonic action. A small suction nozzle is provided for starting the siphons. Also, two medicine stoppers for filling the ink cups.

For maximum sensitivity, the lower ends of the pens need not actually touch the paper, the flow of the siphon being maintained by capillary attraction. Suitable inks are provided which enable the device to be kept idle in readiness for operation for at least twenty-four hours. The ink cups are readily emptied and the pens cleaned by siphoning water through them.

The shaft of the driving motor is connected to the drum shaft through a built-in reduction gear system, which is an integral part of the motor. By the use of different motors, paper speeds from 0.1 inch to 7 inches per second can be obtained. A rheostat is provided which enables the paper speed with any one motor to be varied over a ratio of about 4:1.

The standard form of pen magnets is each wound to a resistance of approximately 2400 ohms which enables the pens to be operated by a minimum current of 2 milliamperes (5 volts across the winding). A special higher resistance winding would permit operation by minimum currents between 0.5 and 1 milliampere.

The standard motor used has a gear reduction 144:1 and by means of the rheostat gives paper speeds from 0.8 inch to 3.5 inches per second. Other motors having gear reductions 72:1, 595:1, and 1120:1 are available for substituting to obtain proportional changes in paper speed.

In making time interval measurements with this chronograph it is customary to energize one pen at known time intervals such as 0.1 second, 1.0 second or any other desired value, while the other pen responds to electrical currents associated with the phenomenon to be timed. An example of such a technique was described in conjunction with the cardiotachometer in the July, 1930, issue of the *Experimenter*. Here the time intervals were one second apart and the second pen recorded each heart beat. In this manner a continuous and permanent record of the heart rate was obtained.

This same procedure may be adapted to a wide variety of problems involving timing operations as, for example, the timing of chemical phenomena, of athletic events, of vehicle speeds, of traffic distribution, of the flow of liquids and of the fall of balls in viscous media, etc.

The method used for securing the reference time intervals depends upon the particular problem at hand. One-second and one-minute intervals can readily be obtained from suitable clock mechanism, while one-second and 0.1-second intervals can be obtained from contacts operated by synchronous motors driven by 60-cps or any other regulated alternating-current sources. If the regulation of such current is not sufficiently precise for the problem, it is quite feasible to superimpose one-second intervals from an accurate clock upon a series of 0.1-second intervals from the synchronous commutator, the latter serving merely to decimate the accurate one-second intervals. The speed of the paper will be sufficiently uniform to enable one to interpolate to 0.01 second between the marked 0.1-second intervals.

The price of the Type 456-A Duplex Siphon Recorder, described above and shown in the illustration, is $190.00.

In some lines of work, it becomes desirable to provide a remote and intermittent control for this siphon recorder so that sample records may be obtained at stated intervals instead of a continuous record over a long run. For this purpose, the recorder may be fitted with two solenoids which, when not energized, release the pens from contact with the paper, and thus interrupt the flow of the ink. The driving motor may, of course, be stopped at such times, thus minimizing the amount of paper used. The Type 456-B Duplex Siphon Recorder, which is fitted with these solenoids, is priced at $225.00.

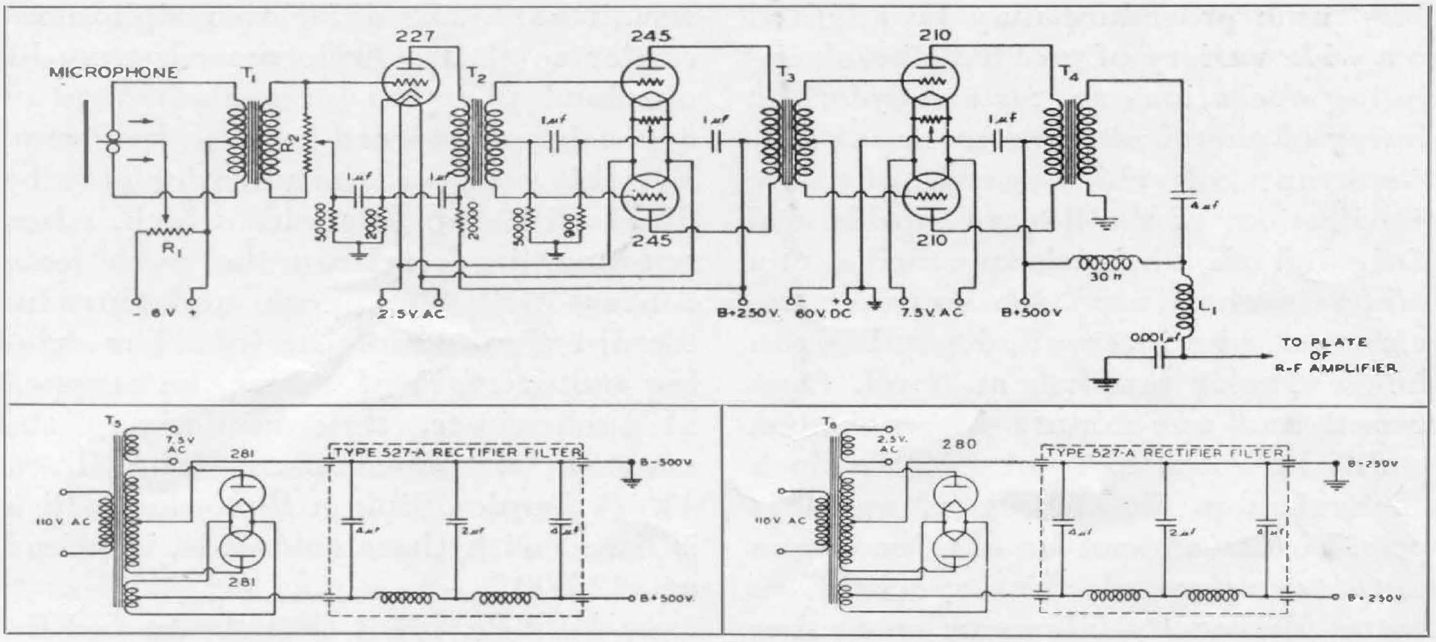
It will be evident that the to-and-fro motion of the pen arm, energized by such feeble currents, could simultaneously be used as a sensitive relay to control a considerably greater amount of electrical energy than that required to drive the arm. For such a purpose, it is quite feasible to fit one of the pen arms with suitable relay contacts. In the cardiotachometer equipment, for instance, the pen arm energized by the heart pulses is provided with such contacts through which an impulse counter is driven, thus affording a count of the total number of heart beats in any given interval, in addition to the variation in heart rate from time to time as shown by the tape records.

— Horatio W. Lamson

100% MODULATION FOR THE AMATEUR PHONE

The Class B Modulator, using transformer coupling to the radio-frequency amplifier, eliminates the high wattage tubes with the high plate voltages used in the Class A modulator system, and permits 100% modulation with relatively low power. A modulator and a speech amplifier as shown in the accompanying diagram, using only two 210-type tubes in push pull as the modulators, will easily modulate 100% some 50 watts plate input to a Class C radio-frequency amplifier.

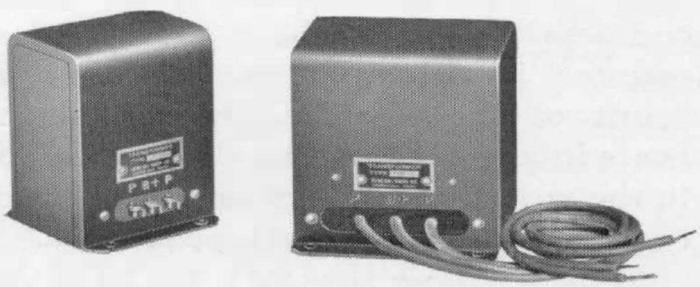
In the diagram the microphone and speech amplifier circuits are typical of those in use in amateur modulation



*Wiring diagram for a omplete speech amplifier and Class B Modulator, capable of modulating 50 watts of plate input for a Class C radio-frequency amplifier. See the Legend below.**

systems at the present time. The necessary additions are the input and output transformers of the modulator. General Radio Type 292-A and Type 292-B Transformers have been designed and built to fulfill the needs of the amateur desiring to change his modulator system to Class B.

— M. C. Hobart



Left: Type 292-A Transformer
Right: Type 292-B Transformer

*LEGEND

R_1	Type 301 Potentiometer, 200 ~	$1.00
R_2	Type 471 Potentiometer, 100,000 ~	6.00
R_3	Type 437 Center-Tap Resistor	.50
L_1	Type 379-T R-F Choke	1.25
T_1	Type 585-M Transformer (for single-button microphone)	10.00
	Type 585-M2 Transformer (for double-button microphone)	10.00
T_2	Type 541-A Transformer	7.50
T_3	Type 292-A Transformer	7.00
T_4	Type 292-B Transformer	10.00
T_5	Type 565-B Full-Wave Transformer	13.50
T_6	Type 545-B Transformer	10.00
	Type 527-A Rectifier Filter	17.50

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