SHORT-WAVE BLUEPRINT NUMBER

MAY 5th, 1934

RADIO WORLD

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The First National Radio Weekly

632nd Consecutive Issue Thirteenth Year

A MODULATED SIGNAL GENERATOR

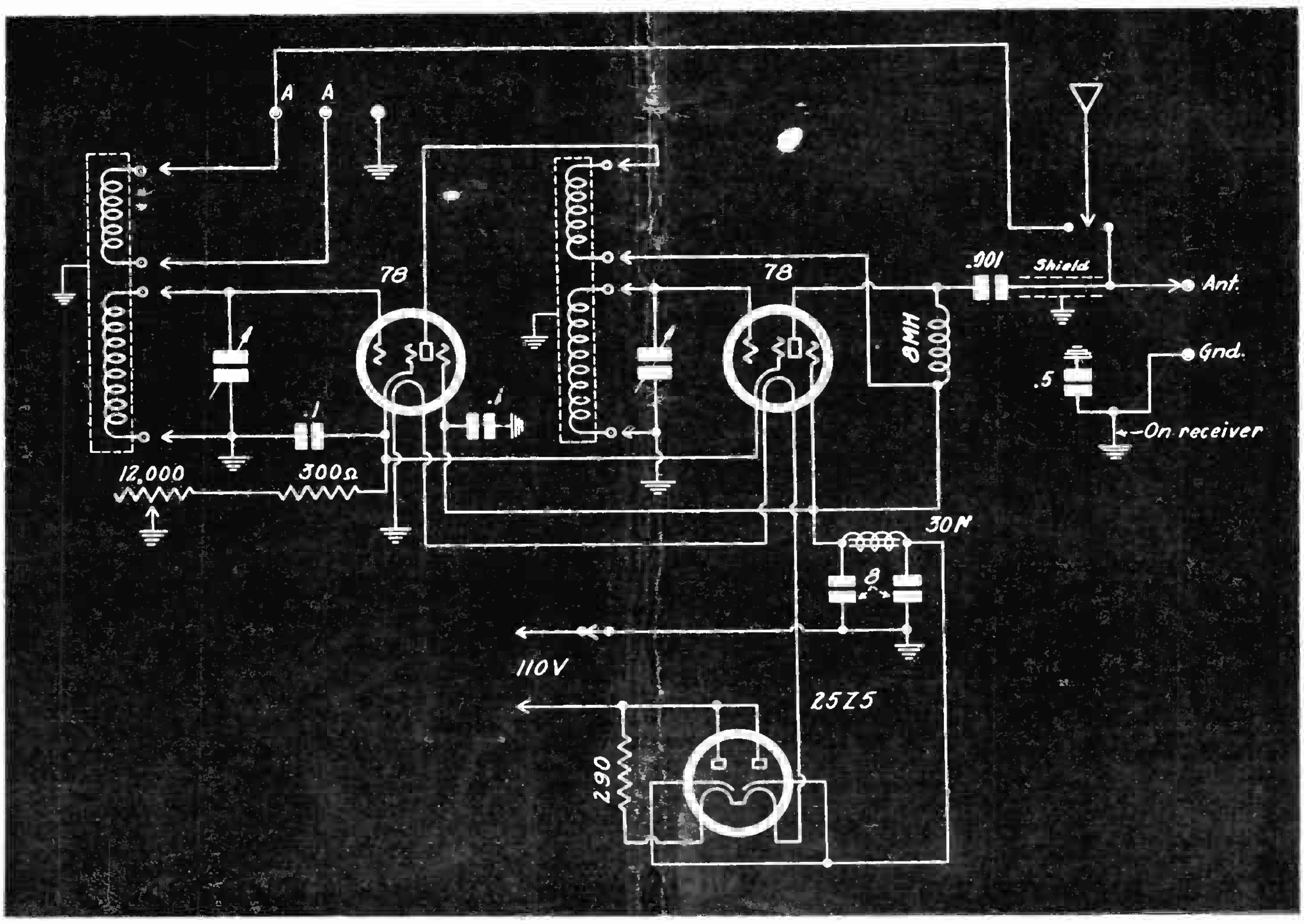
RADIO-FREQUENCY COUPLING CIRCUITS

A Two-Tube Set for Short Waves, Using Batteries

NRA

A SHORT-WAVE SIGNAL BOOSTER

15c per copy



The circuit of the Postal short-wave booster, a device to be connected ahead of any short-wave receiver to increase its range and selectivity. See article on pages 10 and 11.

Chart Relating Short-Wave Frequencies, Capacities and Inductances

THIS chart gives the relationship connecting frequency, capacity, and inductance for frequencies from 1.6 megacycles up to 100 megacycles, for inductances from 0.1 microhenry to 100 microhenries, and for capacities from one micromicrofarad up to 1,000 mmfd. That is, the chart covers the entire short-wave range for values of inductance and capacity likely to occur in practice.

The chart may be extended in either direction, but there is little object for doing so, for in the direction of lower frequencies other and more suitable charts are available and in the direction of higher frequencies the equation on which the curves are based ceases to have any real significance because inductance and capacity become distributed. It may be added, though, that the lower left-hand corner of the graph represents a frequency of 503 megacycles.

Gives Value of Unknown Directly

The object of the curves is to give the frequency when the inductance and capacity are known, to give the inductance when the capacity and the frequency are known, and to give the capacity when the inductance and the frequency are known.

Suppose we want to find at what frequency an inductance of 90 microhenries and a capacity of 50 mmfd. resonate. We follow the horizontal line headed 90 to the vertical line headed 50. The two lines intersect half way between two diagonal lines, one marked 2.5 megacycles and the other marked 2.25 megacycles. Hence, we say that the frequency of resonance is the mean of these two, or 2.375 megacycles.

Suppose, again, that we have a condenser with a maximum capacity of 150 mmfd. and it is required to find the inductance of the coil that will tune to 4.5 megacycles with this condenser. We go up the vertical line representing 150 mmfd. until we come to the diagonal lines marked 4.5 megacycles and read the inductance at the left on the line where the two intersect. We find that the two intersect at 8.3 microhenries.

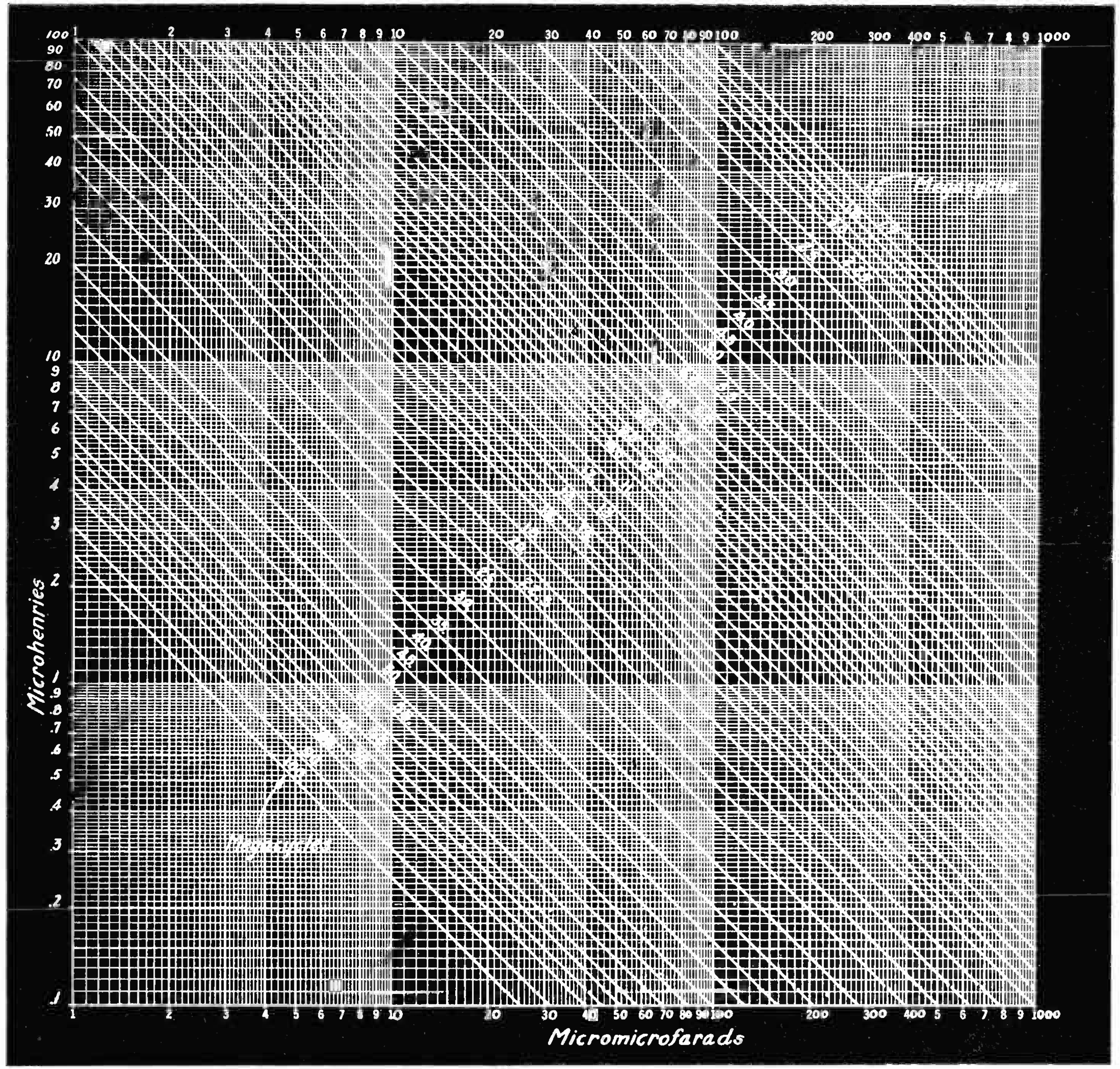
Again, let it be required to find the capacity that will tune a coil of 16 microhenries to 5 megacycles. We follow the horizontal line representing 16 megacycles until we come to the diagonal line representing 5 megacycles and note the capacity on the vertical line passing through the intersection. We obtain 63 mmfd.

Edward M. Shiepe's Method

Let us take one more illustration. The minimum capacity in a certain circuit is 10 mmfd., including the self capacity of the coil, and the inductance of this coil is 5 microhenries. What is the highest frequency to which this circuit can be tuned? We follow up the vertical line for 10 mmfd. until we come to the horizontal line headed 5 microhenries. Through their intersection the diagonal line representing 22.5 megacycles passes. Hence, that is the highest frequency to which the circuit will respond resonantly.

The method of using log-on-log paper to enable the resultant "curve" to be a straight line was first used by Edward M. Shiepe in his book, "The Inductance Authority," as a supplement to which the same type of chart is furnished, but for a much wider range of frequencies, including in fact from audio frequencies to ultra frequencies, on 18x20-inch printing surface.

While the chart as shown is for short waves and thus enables closer reading for that purpose, the manner of attaining the inductance, sometimes a problem to the constructor, is not revealed. Of course that requires a series of charts, and it is just such a series that Mr. Shiepe's book comprises. Hence the present chart may be gainfully used by all possessors of the book.



The frequency numbers are in megacycles, some not clear. From top right to lower left the frequencies are: 1.6, 1.7, 1.8, 1.9 (not designated), 2.0, 2.25, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10, 11, 13, 14, 15, 16, 18, 20, 22.5, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 90, 100.

POSTAL BOOSTER

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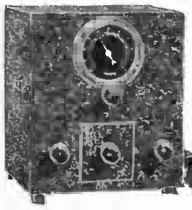

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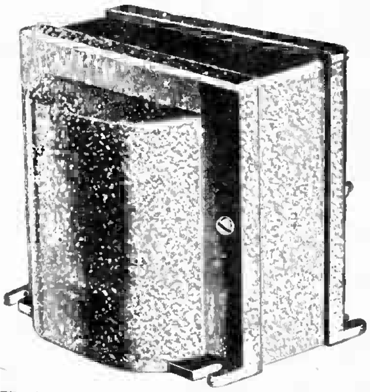

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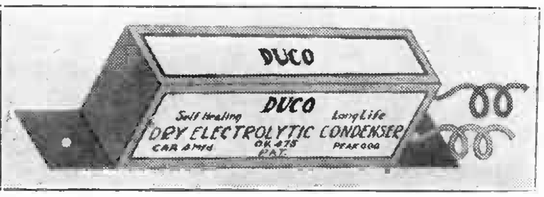

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ROLAND BURKE HENNESSY
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HERMAN BERNARD
Managing Editor

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THIRTEENTH YEAR

J. E. ANDERSON
Technical Editor

J. MURRAY BARRON
Advertising Manager

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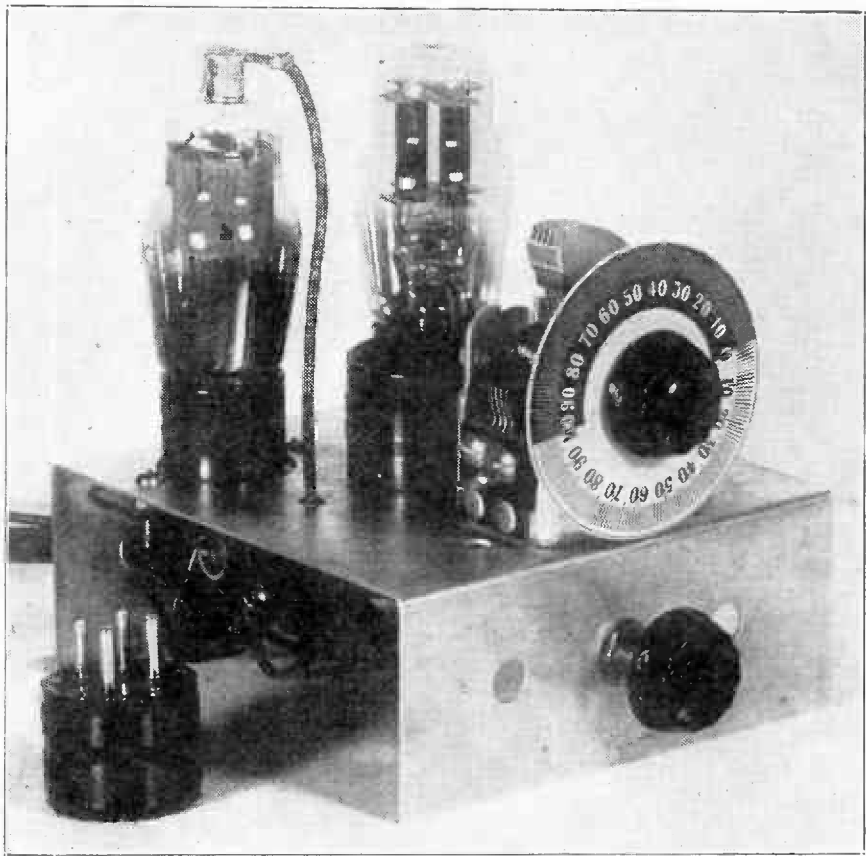
A Short-Wave Converter That Fits in Your Hand

By Steve Erdel

Experimental Radio Laboratories

The two-tube short-wave converter, extremely small in size, that is marked by utmost simplicity of construction, and renders the operation very easy indeed. Plug-in coils are used for covering the various bands.



ANY broadcast receiver, including a superheterodyne, becomes a short-wave superheterodyne when this converter is put in front of it, and as such it will pick up foreign stations, police signals, and amateur chatter. A feature of the circuit is that it is uinversal, that is, that it works equally well on either a.c. or d.c.

As may be noticed on the diagram, Fig. 1, the converter incorporates one 77 tube as mixer and one 37 as oscillator. This is of the tuned grid type and is coupled to the mixer tube by means of a very tiny capacity—two insulated leads twisted together loosely for about one inch. This is C5, which is not contained in the list of parts.

The simplicity of this converter is an outright achievement, for only by study and thought can a circuit be made as simple as this without making sacrifices in quality. Not a thing has been used that is superflous; not a thing has been omitted that is advantageous. The result is an efficient converter that is so small that it could almost be slipped into a coat pocket.

The Mixer

Between the antenna and ground is a resistance of 25,000 ohms, and the grid of the 77 is connected directly to the antenna. It is also connected, through the small condenser C5, to the top of the tuned circuit in the oscillator. A grid leak, R2, of 25,000 ohms is connected in the cathode lead of the 77 and it is shunted by a condenser of 0.002 mfd.

In the output circuit of this tube is a radio frequency choke of 10 millihenries, which is used for coupling to the input of the receiver with which the converter is to be operated. A 0.002 mfd. mica stopping condenser is used to isolate the converter from the broadcast set in so far as the d-c is concerned.

The coils are of the plug-in type, only two coils being used. One is for the reception of foreign station and the other for the reception of police and amateur signals. For foreign signals the coil used contains two windings of ten turns each, the wire being No. 28 enameled. The coil for police and amateur signals contains 19 turns on the tickler and 25 turns on the tuned winding. The coils are wound on tube base forms 1 and 3/8 inches in diameter.

Power Supply

The filaments of the two tubes are connected in series. The necessary ballast resistor is placed in the supply cord and the resistance element is distributed so that heat is not concentrated in any place. The ballast resistance is R5 and has a value of 360 ohms. A snap

(Continued on next page)

A Universal Set for Short-Wave Use

By Louis Passavanti

Harvey's Radio Shop

OF THE many different short-wave receivers that have been devised, the two-tube regenerative circuit leads all the others in popularity. It leads for several reasons. First of all, it delivers the signals even when more elaborate receivers fail to do so. In the second place, it is economical in operation and inexpensive to build. In the third place, it is very easy to operate. When we add to the two-tube regenerative receiver the universal feature and its own power supply, we make it more convenient to use. These features do not in the least detract from its popularity.

The simplicity of this short-wave receiver is brought out by the circuit diagram, Fig. 1. There are really three tubes in the circuit, for one is required for the power supply. The tubes used are a 77 for regenerative detector, a 43 for output tube, and a 25Z5 for rectifier.

The Filament Circuit

The filaments of these tubes are all connected in series, for they are all of the 0.3-ampere type. The order in which they are connected in the series is shown in conjunction with the 25Z5. It will be noticed that the positive side of the line (for d.c.) is connected to the two plates of the rectifier tube and also to the ballast resistor. This has a value of 210 ohms, with a 25-watt rating. This resistance may also be built into the line cord. The other end of the ballast resistor picks up the heater of the 77 tube. Thence the circuit goes to the heater of the 43 tube. From that tube it goes to the double heater of the rectifier tube and then back to the negative side of the power line.

The heaters of the tubes may also be wired in the opposite order, putting the heater of the 77 next to the negative side of the power line, the heaters of the 43 and the 25Z5 next and finally the 210-ohm ballast in the positive lead. A line switch can be put in either side of the line and it is mounted on the 50,000-ohm potentiometer used for controlling the regeneration.

The Tuner

The simplest type of tuner is used, namely, a two-winding coil with a variable condenser across it. The tuned winding is connected in the grid circuit, and it is also connected to the antenna through a small, postage-stamp type adjustable condenser. Plug-in coils are used, a set of four covering the entire short-wave band from 200 to about 10 meters.

The 77 tube is used as detector and regenerator. In the grid lead is a 0.0001 mfd. stopping condenser and from grid to the cathode is a grid leak of 2 megohms. The suppressor grid is grounded, that is, connected to the cathode. Regeneration is controlled entirely by control of the screen voltage. A 50,000-ohm potentiometer is connected between the cathode and the B supply, and the slider of this potentiometer is connected to the screen of the tube. The maximum voltage on the screen is limited by a 10,000-ohm resistor placed between the potentiometer and the high voltage line. Thus the screen voltage is always less than the applied plate voltage.

To maintain the screen voltage at a steady r-f potential a 0.5 mfd. condenser is connected from the screen to the cathode.

The tickler winding is fixed. To insure a low impedance path of the radio frequency currents and at the same time prevent any r-f from passing on to the audio amplifier, a filter consisting of two 0.00025 mfd. condensers in shunt with the line and a radio frequency choke of about 10 millihenries in series is put between the tickler and the audio coupler.

The Audio Coupler

An audio frequency choke of high inductance is used for coupling at audio frequency. If a suitable audio choke is not available, a splendid choke can be improvised out of an audio transformer. If this transformer is good, only the primary need be used. However, in any case better results will be obtained if the secondary is used, assuming that the transformer is of the step-up type. A still higher inductance can be obtained by connecting the two windings of the audio transformer in series aiding. This connection is usually obtained if the two terminals marked for B plus and ground are connected together and the two extremes are used for connection in the circuit. But it is by no means certain that this will result in the series aiding connection. If there is doubt, it is better to use the larger winding of the two alone.

The 0.01 mfd. stopping condenser in the grid circuit of the 43 insures a good amplification on the low tones. This insurance is not invalidated by the use of a 0.5 mfd. grid leak in the circuit. Indeed, the combinaton of 0.01 mfd. condenser and 0.5 megohm is fully effective down to 50 cycles.

The 43 tube is biased by means of a 600-ohm resistor in the cathode lead, and this is shunted by an electrolytic condenser of 25 microfarad. The object of using such a large condenser, of course, is to prevent reverse feedback, especially on the low audio tones.

(*Continued on next page*)

A Short-Wave Converter

(*Continued from preceding page*)

switch is put in series with the heater circuit, and this is placed on the panel directly below the single tuning control and dial.

The supply for the filament is provided by a battery, or the voltage may be taken from the receiver to which the converter is connected.

Of the three terminals at the right of the drawing (Fig. 1) the upper should be connected to the antenna post on the broadcast receiver, the antenna having been removed from that post and transferred to the grid of the 77 tube in the converter. There is a terminal lead for this connection. The lowest terminal should be connected to the ground-post of the broadcast set, the ghound connection being left. If the B supply in the receiver is to be used, no connected to the ground post of the broadcast set, the ground connection. If an external battery is to be used, the negative should be connected to the ground terminal.

The middle terminal, to which R4 is connected, should be connected to the positive of the high voltage battery or to the positive in the broadcast set. A voltage of 135 volts is all right.

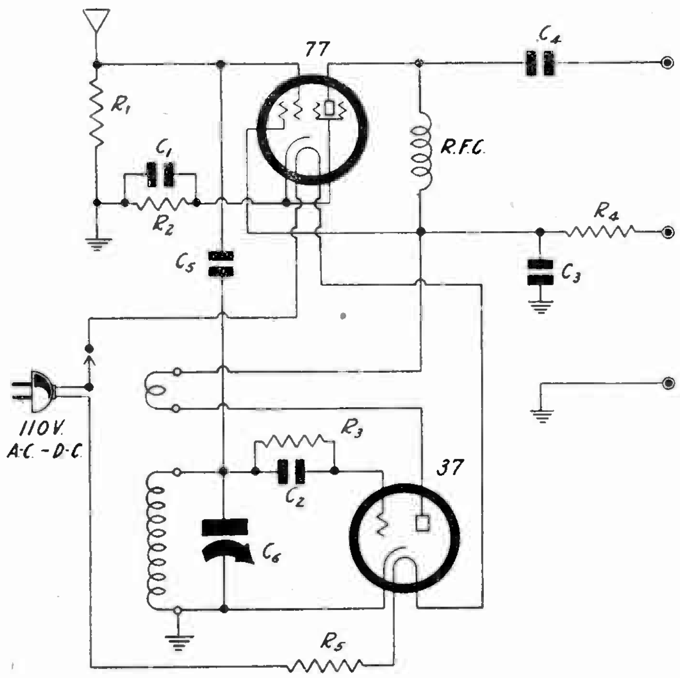


FIG. 2

Circuit of the short-wave, universal converter. Utmost simplicity has been achieved in the design of this circuit.

LIST OF PARTS

One set of oscillator coils
One radio frequency choke coil
C1, C4—Two 0.002 mfd. mica condensers
C2—One 0.00025 mfd. mica condenser
C3—One 0.03 mfd. condenser
C6—One 0.00015 mfd. tuning condenser, with dial
R1, R2, R3, and R4—Four 25,000-ohm, ½-watt resistors
R5—One 360-ohm line cord resistor
One 77 socket
One 37 socket
One four-contact coil socket
One grid clip

LIST OF PARTS

Coils

One set of coils to tune wth a 0.00014 mfd.
One audio choke, or audio transformer
Two filter chokes having low d-c resistance and high inductance
One radio frequency choke

Condensers

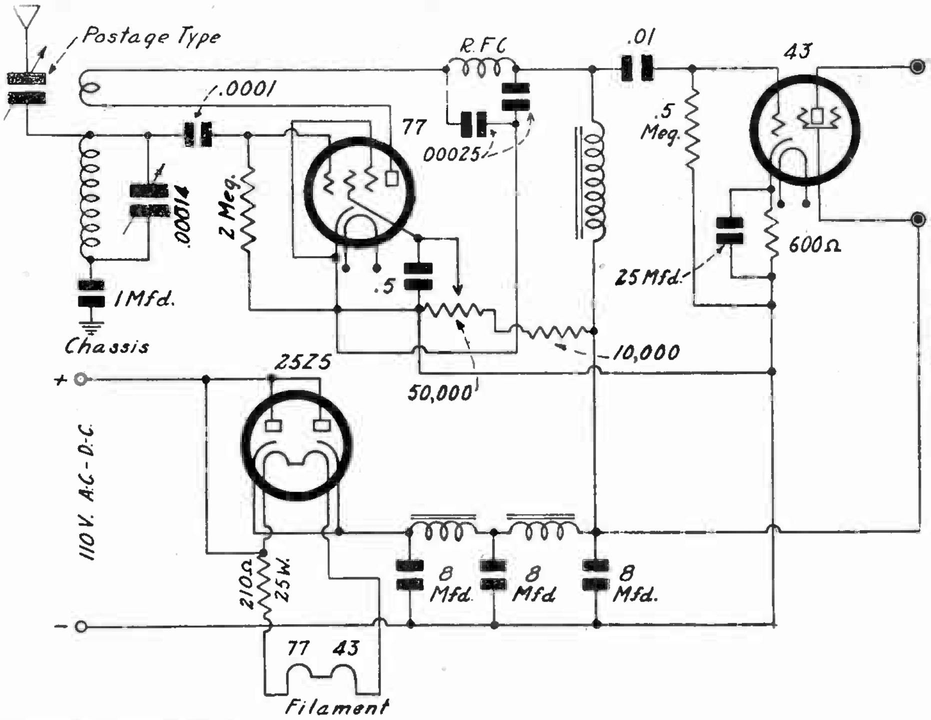
One 0.0001 mfd. condenser
One postage-stamp type variable condenser
One 0.00014 mfd. variable condenser
One 0.5 mfd., 250-volt condenser
One one mfd. condenser
One 0.01 mfd. condenser
One 25 mfd., 35-volt condenser
Three 8 mfd. electrolytic condensers
Two 0.00025 mfd. condensers

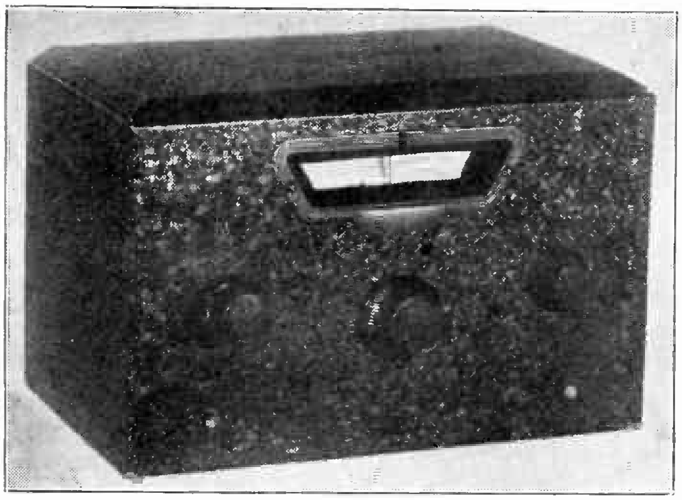
Resistors

One 2-megohm grid leak
One 50,000-ohm potentiometer
One 0.5-megohm grid leak
One 600-ohm, 2-watt resistor
One 210-ohm, 25-watt resistor (or resistance cord.

Other Requirements

One 77 socket
One 43 socket
One 25Z5 socket
One grid clip



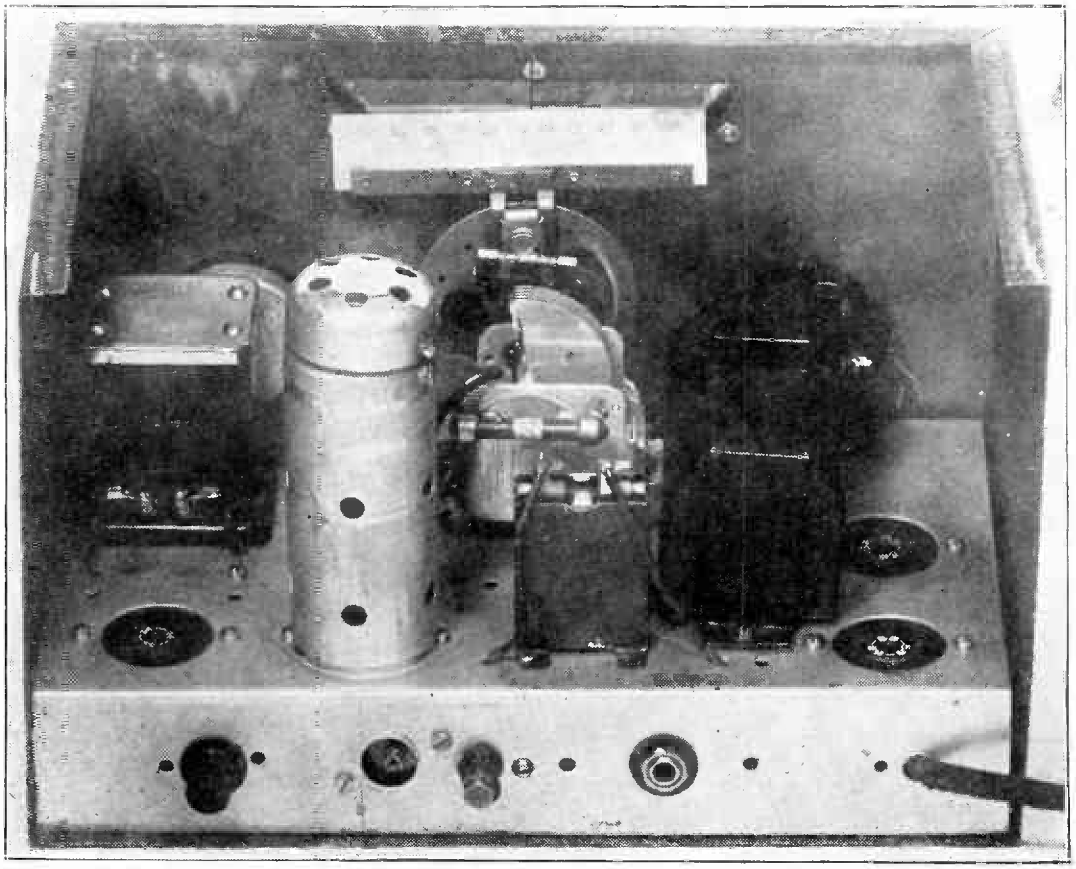


In the power supply a 25Z5 tube is used as rectifier when rectification is required, but it is not removed when the circuit is operated on a d-c line. It is needed as part of the heater circuit ballast even then.

The filtering in the power supply is thorough, as is necessary in a short-wave regenerative circuit. There are no less than three 8 mfd. electrolytic condensers across the line, and two filter chokes in series with it.

Short-Wave Summer Reception

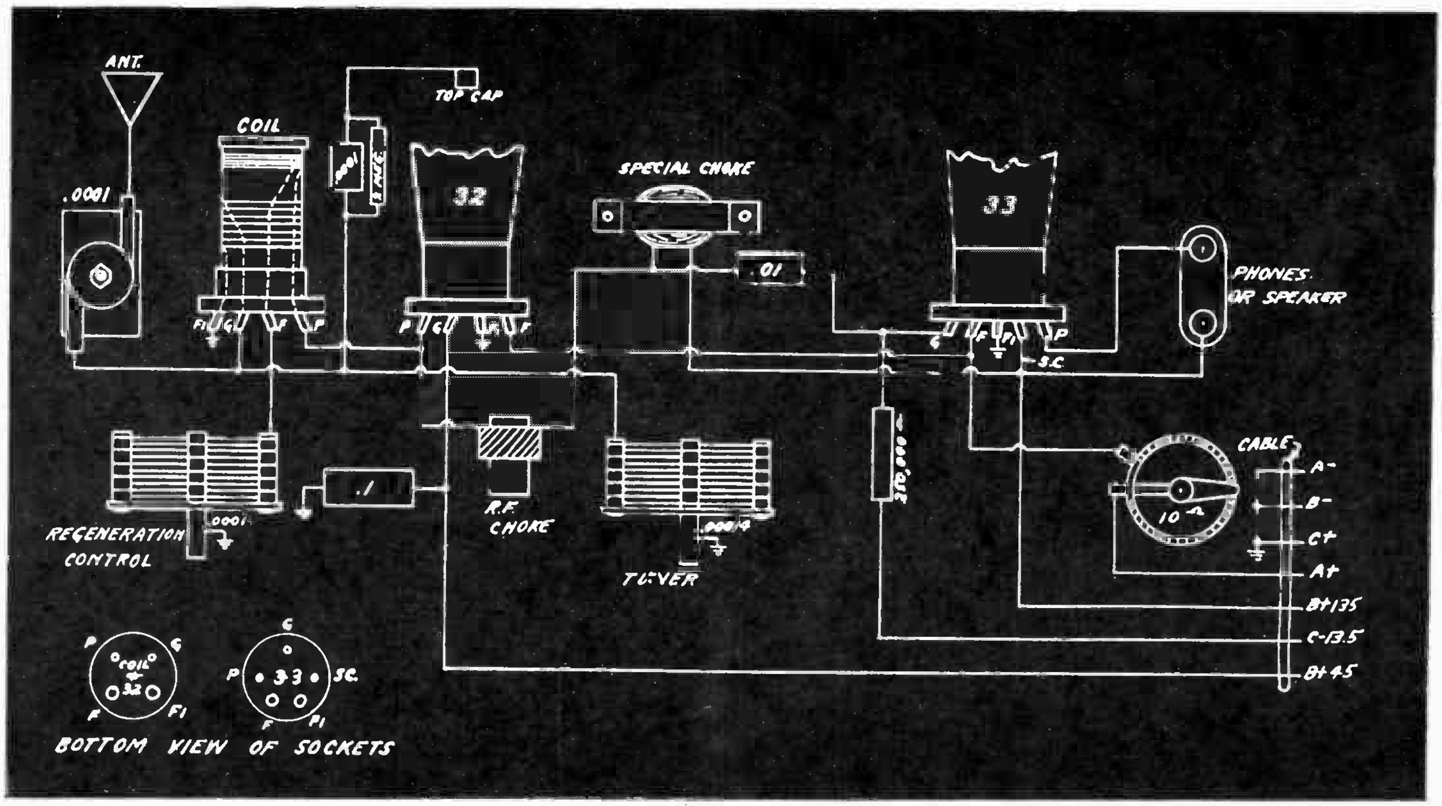
During Summer there is an abundance of static-free short-wave reception. Taking the short waves as a whole, there is clearer reception than from distant stations in the broadcast band. Some band can be selected on which static is low or absent. With broadcasts there is only the one band.



Rear view of the short-wave universal set. The author is employed in a radio store where he demonstrates foreign reception on this receiver.

Detector Feeds Power Tube in
"The Cosman Two"
for Short Waves, Using Batteries

By Herman Cosman
Try-Mo Radio Corporation



THE design and construction of this particular set is unique and simple, the results obtained are remarkable, and a great many short-wave enthusiasts should be interested in building it. Very few constructors realize that some receivers perform much more satisfactorily than others because of consideration given to constructional details. The mistaken impression seems to be that the "circuit" is the important thing, whereas the actual truth is that most receivers employ a circuit whose basic fundamentals were in use when radio was in its infancy. What makes a radio set efficient? How does this receiver incorporate these valuable features?

Choice of Tubes

The first consideration involves the type and number of tubes. Naturally, the most recently developed tubes are far superior in amplification and other characteristics than those of the earlier days of radio. Receivers in those days employed tubes with an amplification factor of about 8, which means that the tube itself can only increase the signal strength that many times. In the present receiver, the first tube can increase a signal to 610 times, not including the tremendous gain from regeneration. Another tube, the 33, a power pentode, is used for great amplification at audio frequencies, to permit loudspeaker reception on most stations.

Also of great importance is the fact that the battery consumption (A and B) is so small that it need hardly be considered. The regular type of A cell and three average B batteries will give over six months of service with this set, because of economy of drain by the tubes employed. Naturally, the expense and consistency of replacement of batteries is an item that all short-wave battery-set constructors should consider.

Mechanical Design

Second in importance, relative to the efficiency of a receiver, is the mechanical construction of the receiver. This includes shielding, parts employed, location of material, chassis rigidity and proper insulation of certain parts with a view towards materially reducing losses that occur at the higher frequencies.

The receiver, in addition to being an all-metal chassis unit which automatically takes care of shielding, is so arranged that all wires are as short as possible to minimize stray feedback and to decrease other possible losses that take place as a result of long wires or other poor layout. In addition, a special shelf which is an inherent part of the panel makes provision for holding all of the plug-in type coils, right in the radio set, where they are convenient and available for quick changeover from one wave band to the other.

The coils employed in a receiver contribute largely to the sensitivity and selectivity. Specially-constructed plug-in coils are used with this set and are the primary reason why it was possible to obtain such gratifying results. These inherent features are low-loss windings and construction. With the five coils it is possible to obtain a complete coverage of from 15 to 550 meters. Thus, even broadcasting can be tuned in when the hour or weather is against short-wave reception.

Color-Coded Coil Forms

A color scheme, relating to the color of the coil form, is employed for differentiating among the bands covered by coils. This method will be found more convenient and satisfactory for selecting the desired coil than attempting to recognize it by the number of turns employed.

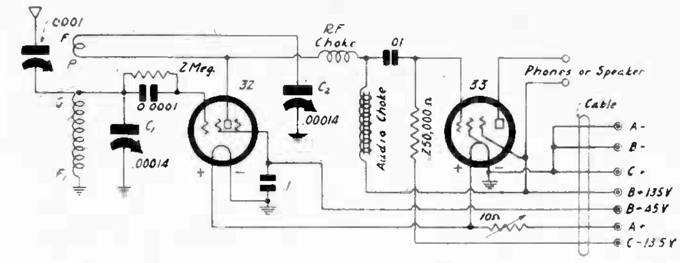
The coil color scheme employed is as follows:

Green	15 to 25 meters
Black	25 to 45 meters
Brown	45 to 95 meters
Red	95 to 200 meters
Blue	200 to 550 meters

The circuit employed is of the conventional Hartley oscillator type. It has been tried and tested by thousands of amateurs for more than ten years, and the fact that it is still in popular use is convincing proof of its efficiency.

Referring to the circuit diagram, it is possible to get a clearer understanding of the salient points. GF, and FP are two windings on the coil form, inductively coupled. GF, is the larger winding for resonance tuning (station selection) when C1, the tuning condenser, is varied. C2 is a variable condenser which, through capacitative coupling, controls the amount of radio-frequency energy fed from the grid circuit (GF, and C1) to the plate circuit (FP).

A high-impedance audio choke is used in the plate circuit of the 32 tube in this regenerative short-wave receiver for battery operation. The detector feeds into a 33 power tube.



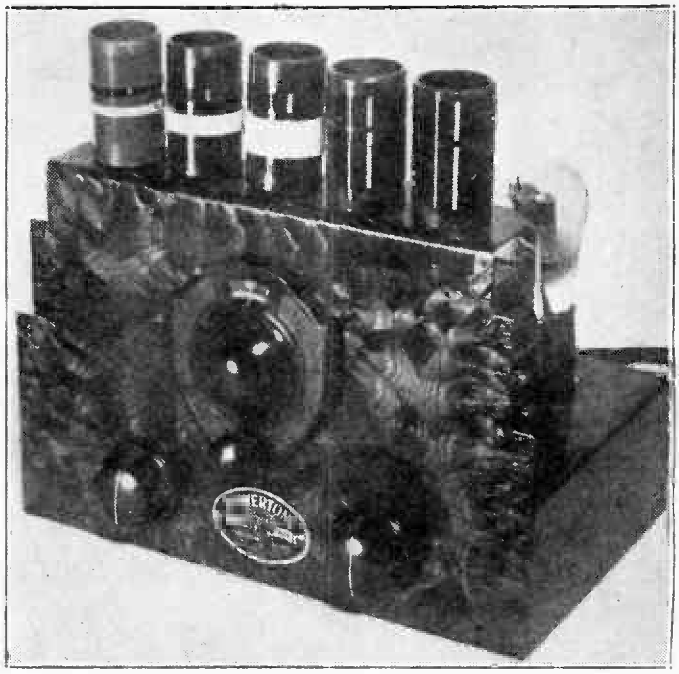
It may be entirely possible that after the constructor completes and tests the set that his skill in tuning is inadequate for obtaining good reception. However, this factor can be overcome only by practice, and learning which control to employ at certain stages of tuning. Also the relative position of C3, the antenna series condenser, is very important when changing from one coil to another, if good results are desired in the wave band which that coil covers. For broadcast reception this condenser should be set for maximum capacity (plates all meshing), and the condenser capacity gradually reduced toward minimum for lower-wave length coils. A few evenings of experimental tuning with this set will make one a skilled operator.

Concerning the receiver's efficiency, besides obtaining all local broadcast stations with loudspeaker volume, over 250 amateurs all over the country were logged in just a few evenings. More than 80 per cent. of them were on phone, and the ease with which they were brought in was gratifying. Besides, foreign stations were heard in plentiful variety.

LIST OF PARTS

One front panel with coil shelf
One sub-base chassis
One wafer socket for 32 tube
One wafer socket for 33 tube.
One wafer socket (UX) for coil receptacle, four-hole.
Two 0.00014 variable condensers
One 0.1 mfd. bypass condenser
One 0.01 mf. fixed condenser
One 85 mH r-f choke
One Powertest audio choke
One 0.25-meg. resistor
One 10-ohm rheostat
One 0.0001 mfd. grid condenser
One 2-meg. resistor (grid leak)
One battery terminal strip
Two vernier dials
One set of five plug-in coils.

Coil Rack is on Top of the Shield Cabinet



The front view of the set, showing rack for holding the plug-in coils.

Condensed News of Corporation Activities

FINANCIAL REPORTS

Keith-Albee-Orpheum Corporation—Net loss for the year 1933, after taxes and charges, $642,293, as against a net loss of $2,477,347 for the year 1932. Cash, $1,676,489, against $1,872,011; notes and accounts receivable, $43,927, against $127,384; current liabilities, $721,046, against $1,712,845.

Howe Sound Company—Net profit after depreciation, taxes and other charges, for the quarter ended March 31, 1934, but before depletion, $488,554, which equals $1.03 a share on $473,791 $5 par capital shares. This compares with a net loss of $125,547 for the first quarter of 1933.

SUIT OF RCA OVER PATENTS

The Radio Corporation of America complained in Federal Court, Brooklyn, N. Y., against the Mackay Radio and Telegraph Company, of infringement of four patents for improvement in radio antenna and electric circuits, issued to Philips S. Carter and Nils E. Lindenblad, and assigned to the Radio Corporation of America. An injunction restraining the defendant from continuing the use of the patents is asked by the plaintiff, also an accounting.

BANKRUPTCY SCHEDULES

Plaza Music Co., Inc., 10 West 20th St., New York City—Assets $292,656 (consisting mainly of accounts, $131,027); liabilities, $201,141. The principal creditors listed are John G. Paine, $6.659; Goldsmith & Co., $12,705 secured; Davis & Cundall, London, $40,750 secured.

A THOUGHT FOR THE WEEK

THE American Society of Composers, Authors and Publishers (ASCAP), which controls the collection for and distribution of royalties to its members, handled a few dollars during 1933, if we can rely on Sigmund Romberg, President of the Songwriters' Protective Association. Mr. Romberg, who is trusted by his brother composers, announces in the association Bulletin that the following figures can be verified:

Cash In Banks In 1933

January	$442,491.58
February	576,919.67
March	565,083.22
April	425,411.40
May	569,830.10
June	689,033.75
July	443,877.50
August	609,047.27
September	746,093.25
October	523,330.41
November	908,259.63
December	577,547.72

Royalties Paid In 1933

April	$389,296.09
July	415,113.15
October	465,066.99
December	499,994.64

Just glance over these figures and then make up your mind that ASCAP is a fairly important element in the world of music and that all authors and composers do not spend their lives in attic rooms.

Literature Wanted

Readers desiring radio literature from manufacturers and jobbers should send a request for publication of their name and address. Address Literature Editor, Radio World, *145 West 45th Street, New York, N. Y.*

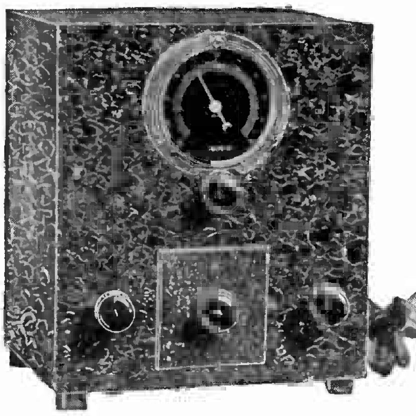
H. S. Varner, Jr., 704 Custer Ave., Brush, Colo.
Donald Elbert (short wave), 421 Bowery St., Iowa City, Iowa.
Eugene Harnagel, c/o Jacob Ihl, Gorham, Ill.
D. M. Bennett, 217 N. Jenison Ave., Lansing, Mich.
C. H. Tanis, 305 Erie Ave., Midland Park, N. J.
Daniel Butler, Gorham, Ill.
Ernel Hiser, Gorham, Ill.
D. S. Garby, 307 West College Ave., Marquette, Mich.
Frank Audette, Tel. Insp., Box 160, Maniwaki, Que., Canada.
T. M. Lysle, 9 Sycamore St., Greenville, Pa.
A. J. Post, Jr., 101 Park Ave., New York City.
Robert H. Clarke, 6764 Lower River Road, Cincinnati, Ohio.
J. H. Edwards, 4237 Huron Ave., R. R. 1, Dearborn, Mich.
Chester L. Masser, c/o Atlantic Refining Co., 5733 Butler St., Pittsburgh, Pa.
K. A. Maxwell, 216 Elysian St., Pittsburgh, Pa.
David Nord, 1108 Gough St., San Francisco, Calif.
Albert V. Greene, Chester Springs, Pa.
L. C. Bennett, 5807 Blackstone Ave., Chicago, Ill.
S. Trinidad, 542 Mason St., San Francisco, Calif.
William A. Temple, 47-13 88th St., Elmhurst, L. I., N. Y.
E. J. Busch, 1115 James Ave., Saginaw, Mich.
M. J. Vaillancourt, 63 Myrtle Ave., Albany, N. Y.
Herman D. McMasters, 3403 So. Center St., Terre Haute, Ind.
S. K. Baker, U. S. Veterans Hpsp., No. Little Rock, Ark.

A SELF-POWERED SHORT-

TWO TUNED R-F STAGES AND RECTI
VASTLY EXTENDING THE PERF

By Samue

Chief Engineer, Posta



Front view of the short-wave booster, showing tuning control and airplane dial at top, coil drawer below, and volume control-switch and antenna switch at corners. The shield cabinet has a black crystalline finish.

LIST OF PARTS

Coils

Four Postal drawer coils (14 to 200 meters)
One 20-henry filter choke
One 7-millihenry choke

Condensers

One dual 140 mmfd. variable condenser
One dual 8 mfd. electrolytic condenser
One 15 mfd., 200-volt electrolytic condenser
Two 0.1 mfd., 200-volt, by-pass condensers
One 0.001 mfd. mica condenser

Resistors

One 12,000-ohm volume control with line switch.
One 300-ohm, 1-watt resistor
One 290-ohm line resistance cord

Other Requirements

One Postal drawer coil socket
One Postal front panel, engraved
One drilled metal sub base
One crystal finished cabinet with rubber legs
One large knob
Two small knobs
Three six-prong sockets
One rotary switch
Two screen grid caps
Five mounting terminals
Two shields and bases
Two 78 type tubes
One 25Z5 tube
One binding post strip
One two-foot shielded cable
Screws and other hardware
One aeroplane dial

The above list applies to the front-cover diagram.

IF THE reader has a short-wave receiver of any kind, sensitive or unresponsive, selective or obtuse, elaborate or simple, he undoubtedly has had the exasperating experience of finding stations on the threshold of audibility. Discovering such stations on the air without being able to "land" them is just as annoying as having only nibbles while fishing instead of real bites.

But there is no longer any need for such exasperating experiences. There is no need of remaining out of range of any station, for any station that is just on the threshold of audibility with the receiver as it is can be brought in with deafening volume, if such volume is desired, by the addition of a very simple device, namely a booster.

The Booster Circuit

What is a booster? It is a pre-amplifier operating at radio frequency and capable of being tuned to the desired station. What does a booster do? It amplifies the weak signals and the strong ones too. It increases the selectivity of the circuit with which it is used, and it eliminates interference. With what set can it be used advantageously? With any receiver whatsoever, t-r-f, superheterodyne, regenerative. However sensitive a receiver may be, it can always be made more sensitive with the booster. However selective it may be, it can always be made more selective with the extra tuners in the booster. And if the receiver is neither sensitive nor selective the booster is necessary to make it both.

We have in mind a particular booster circuit, the one shown on the front-cover diagram. It will be observed that the circuit contains two 78 amplifier tubes and one 25Z5 rectifier. Also, there are two tuned circuits. Although the diagram does not show it, the two condensers are ganged so that the two circuits are tuned by a single dial. That is an essential in a high-frequency tuner for without the ganging it would be practically impossible to find any station.

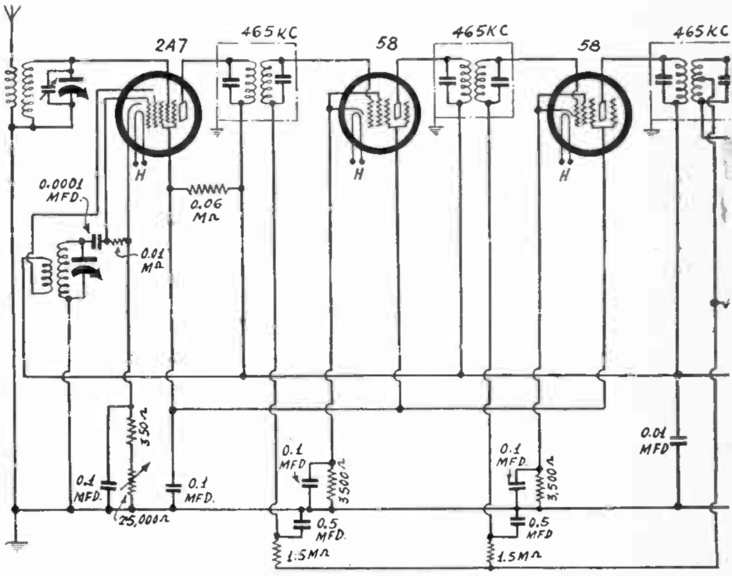
A Particular Booster

The reader might object to ganging a high-frequency circuit on the ground that the two circuits will not track and that consequently no gain in selectivity or sensitivity can be obtained. The proof that ganging is practical even at the highest of the high frequencies ordinarily used for communication is that this particular tuner works. It does increase sensitivity and selectivity remarkably and it does reduce interference. By careful execution of a careful design, satisfactory tracking can be achieved, and the work of adjusting is not as difficult as at first it seems for as the frequency goes up the selectivity of individual circuits goes down. The resonance curve of a single tuner at high frequencies might cover three degrees on the dial. Tracking is quite feasible to within half a degree.

Image Suppression

When the booster is used in conjunction with a superheterodyne there is a very noticeable improvement in the signal-to-noise ratio, and this is striking if the receiver is equipped with a.v.c. There is no appreciable increase in the intensity of the output, for the a.v.c. prevents fluctuation, but there is a marked diminution in the amount of tube noise that is present in the set.

Another noteworthy and strikingly noticeable feature is that image interference is reduced. This, of course, is due to the suppression of the signal frequency by the radio-frequency tuner before the first detector. When there is no radio-frequency tuner in a



The oscillator grid (No. 1) of the 2A7 is shown returne in a multi-wave set diminishes at higher frequencies, tr

-WAVE SIGNAL BOOSTER

FIER IN A UNIVERSAL CIRCUIT FOR ORMANCE IN ALL DIRECTIONS

-l Miller

l Radio Corporation

short-wave superheterodyne, and in most there is none, a booster like the present one is the only means for avoiding image interference. And even when the receiver is equipped with an r-f tuner, the tuner in the booster greatly aids in eliminating the last trace of images and repeat responses.

Switching

The antenna can be thrown either to the booster input or to the receiver input by means of a single pole double throw switch. This switch is mounted on the booster panel. Hence, after the first wiring when the booster is installed it is not necessary to disconnect or connect any wires when cutting the booster in or out. A turn of the knob is all that is required. The knob for this switch appears at the left of panel, there being three equal knobs in a row.

The line switch is at the extreme right in this row of three knobs. This switch is really mounted on the 12,000-ohm variable resistor found in the common cathode lead of the two 78 tubes.

The middle knob on the panel controls the coil drawer, or the coil switching scheme, which is a unique feature of this booster. The two coils are mounted in a metal box measuring 5x2.5x2.5 inches with a metal partition between them. The top of the box is a bakelite strip on which are mounted two rows of four contact points. As the box is eased into position these contact points connect with phosphor bronze springs. Since the condensers are mounted directly over the coil box, the leads are exceedingly short.

Coverage of Coils

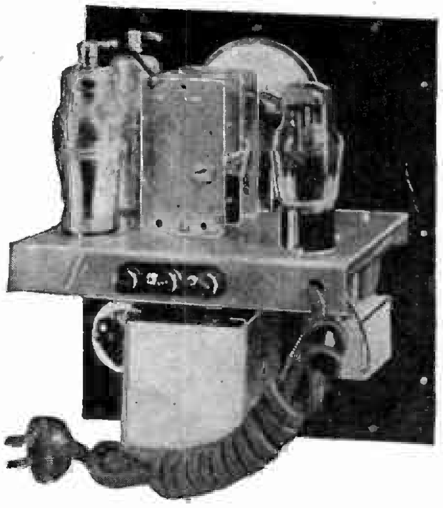
There are four short-wave coil drawers and the coil inductances have been selected so that the band covered is from 14 to 200 meters. The coverage of the different coils are:

A, 90-200 meters.
B, 59-90 meters.
C, 29-61 meters
D, 14-31 meters.

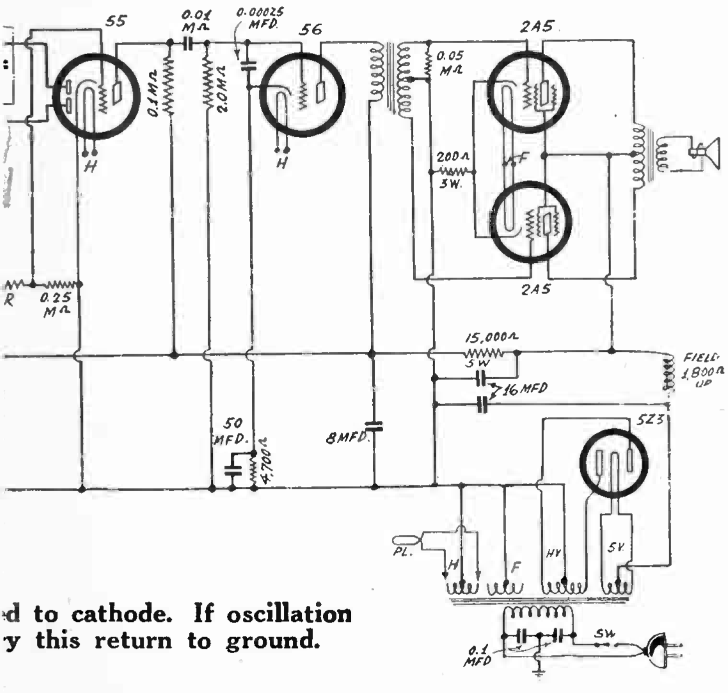
In terms of frequency the coils have the following ranges:

A, 1,500-3,330 kc.
B, 3,330-5,080 kc.
C, 4,920-10,340 kc.
D, 9,670-21,400 kc.

In addition to these short-wave coils there are two for the broadcast frequencies. No. 1 covers the range 1,500-857 kc and No. 2 the range 857-540 kc.



Back view of the short-wave booster, showing the gang condenser, the tubes and the coil drawer (below the subpanel). The two antenna and one ground connections permit the use of a doublet antenna.



-d to cathode. If oscillation -y this return to ground.

The Power Supply

The circuit contains its own power supply and it is arranged so that it works equally well on either alternating or direct current. The two cathodes of the 25Z5 are connected together to lower the resistance. On a.c the tube functions as a half-wave rectifier and the output voltage is somewhat higher than 100 volts. On d-c the tube acts as a conductor only but of comparatively low resistance. Even on 110 d.c. the output voltage available for the tubes is around 100 volts. The tubes work very well on this voltage. It will be noted that plate and screen voltages are all the same.

The filter in the power supply consists of one 30-henry choke coil and two dry 8 mfd. electrolytic condensers. And that is all the filtering that is needed in the B supply filter.

In shunt with the second 8 mfd. section and connected from the screen of the first 78 to ground is a 0.1 mfd. condenser of the paper dielectric type. The object of this is to pass the radio-frequency currents, for an electrolytic is not good at high frequencies. There is another 0.1 mfd. condenser from the cathode of the tube to ground, which serves to by-pass the bias resistor.

May Use Doublet Antenna

Provision is made for a doublet antenna in case that is to be used. At the rear of the booster chassis is a strip containing three binding posts. Two of these are marked "ant." and one is unmarked. When a doublet is employed the two leads are connected to the two posts marked "ant" and ground is connected to the unmarked post. When an ordinary antenna is used in it it is only necessary to connect it to one of the antenna posts and to connect the other "ant" post to the ground post.

GRID RETURN TO GROUND

It is unusual to short the return of the oscillator grid through a resistance to cathode, as in the receiver diagram at left. This is all right for the broadcast band. But if the receiver covers short waves, since the oscillation intensity diminishes finally, it may even disappear, due to too much grid current. A remedy is to return the grid leak to negative B (ground in this instance). The oscillator plate voltage then may be reduced, if desired.

Low-Pass Filters

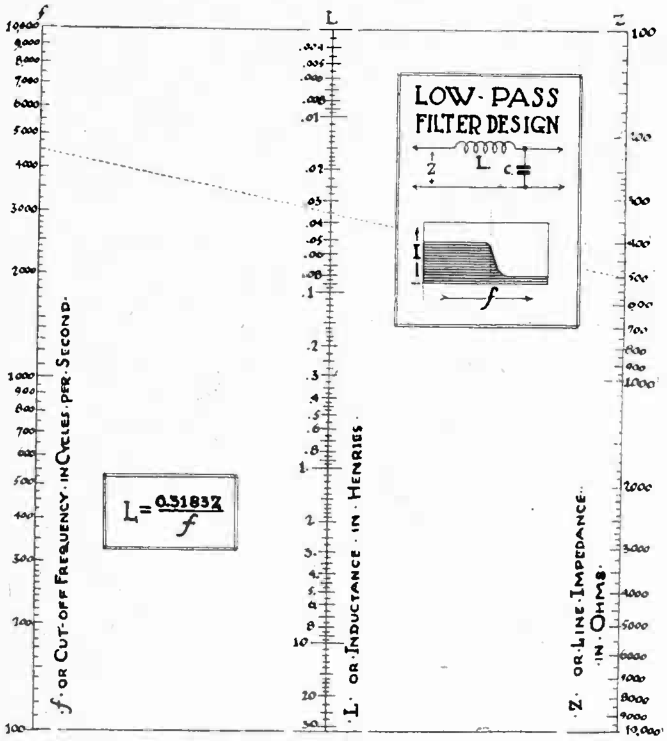


FIG. 1

Straight-edge chart for solving low-pass filter problems. The scales relate the inductance, the cut-off frequency, and the characteristic impedance.

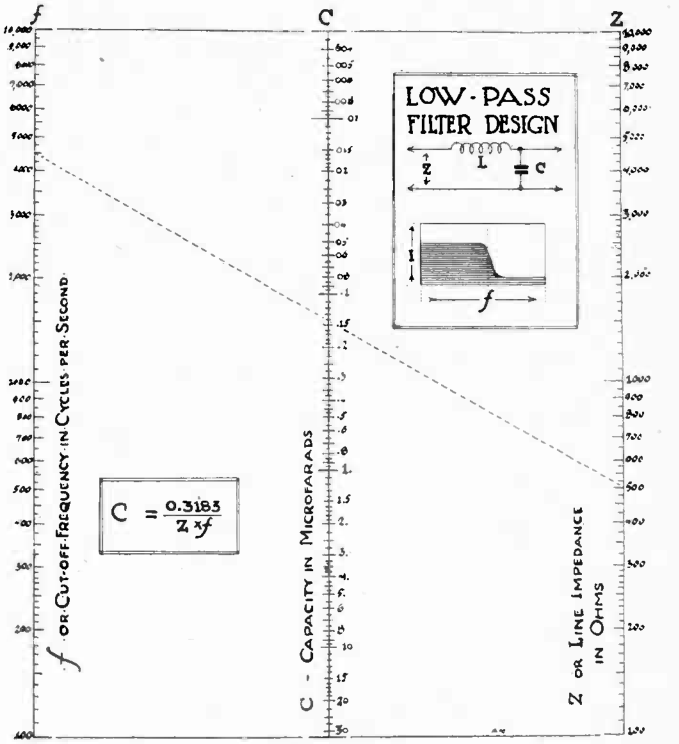


FIG. 2

Straight-edge chart for solving low-pass filter problems. The scales relate the capacity, the cut-off frequency, and the characteristic impedance.

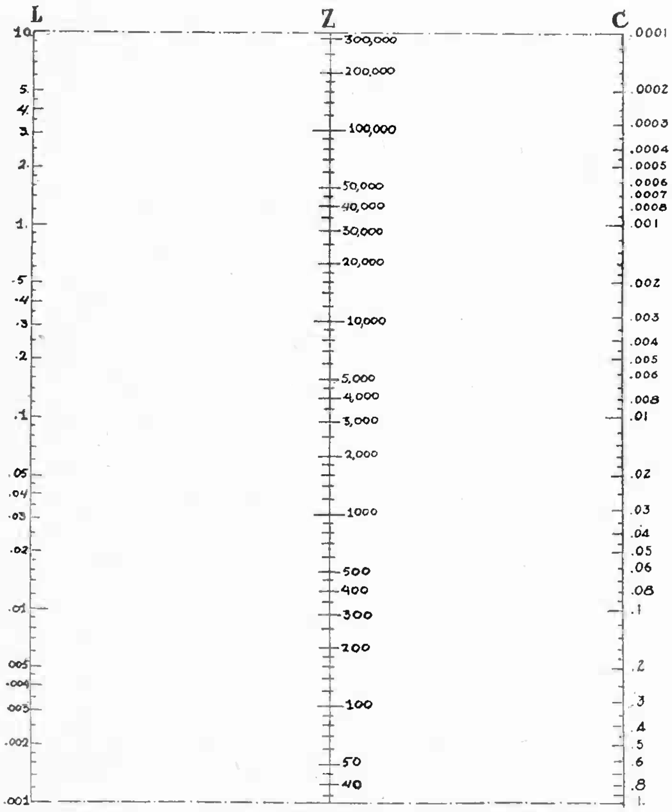


FIG. 3

This chart relates the series inductance, the shunt capacity, and the characteristic impedance of a low-pass filter. If any two are known, the third can be read from the chart.

Evaluations on Charts for Straight-Edge Solutions

By Alan Mannion

Mannion Radio Laboratories

THE design of low-pass filters to accomplish definite objectives can be reduced to a straight-edge operation, thus saving a great deal of time and computation. In a low-pass filter there are four factors, one of which is usually unknown. The most important factor is the cut-off frequency. The next is the characteristic impedance of the filter. The remaining two factors are the inductance in series with the line and the capacity in shunt with it.

Application of Formulas

Let the cut-off frequency be represented by f, the characteristic impedance of the line by Z, the inductance by L, and the capacity by C. In terms of L and C the cut-off frequency is $f=0.3183/(LC)^{1/2}$ and in terms of L and C the characteristic impedance is $Z=(L/C)^{1/2}$. From these relations we can get three design formulas, one giving the inductance in terms of the cut-off frequency and the characteristic impedance, another the capacity in terms of the same factors, and the third the characteristic impedance in terms of the inductance and the capacity.

In Fig. 1 is given the straight-edge construction for the case of the inductance in terms of the impedance and the cut-off frequency. The cut-off frequency is laid off along the left-hand scale, the characteristic impedance along the right-hand scale, and the unknown inductance along the center scale.

Suppose we want to determine the inductance when the cut-off frequency is to be 4,500 cycles and the characteristic impedance is to be 500 ohms. We place a straight-edge across the scales so that it passes through 4,500 cycles on the f-scale and 500 ohms on the Z-scale. The point on the L-scale where the straight-edge cuts gives the required inductance in henries. In the illustration the reading is 0.035 henries.

Capacity Ascertained

In a similar way we can find the capacity required. In Fig. 2 the center scale has been replaced by a capacity scale, the other scales being in the same relative positions except that the Z-scale has been plotted in the opposite direction. Now suppose we want to finish the problem started, namely, to find the design of a low-pass

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Tuned Coupling Methods

for Radio-Frequency Amplifiers

By J. E. Anderson

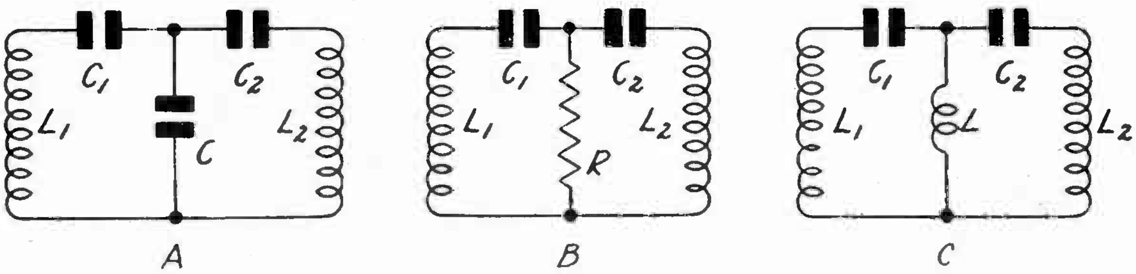


Fig. 1

Three types of coupling between circuits. A, direct capacitive; B, direct resistive; C, direct inductive.

EVERY structure is made up of units—building stones, so to speak. The unit of which every electrical network is composed is the circuit, or mesh. While the term circuit is applied to complex networks composed of two or more simple circuits, this use of the term is a somewhat illogical extension. When we speak of coupled circuits we mean simple circuits or meshes, and the coupling of these result in a network.

A circuit is itself made up of units, or elements. These are condensers, inductors, and resistors, and these elements possess, respectively, the properties capacitance (capacity), inductance, and resistance. The terms condenser, inductor, and resistor suggest that the elements are lumped or concentrated. That is, a condenser is an element that possesses capacitance, an inductor an element that possesses inductance, and a resistor is one that possesses resistance. But it is not always possible to regard the elements as lumped, and seldom in ultra-short wave circuits. All the elements are distributed more or less, and then it is preferable to speak of distributed properties rather than of distributed elements.

Coupling

Two circuits are said to be coupled when they have an element in common. The property of the element may be resistance, capacitance, or inductance. When the common element has resistance the two circuits are resistance coupled. Similarly they may be inductively or capacitively coupled. In Fig. 1 we have coupled circuits in which the coupling is capacitive (A), resistive (B), and inductive (C). All these are said to be directly coupled. The coupled circuits are L1C1C and L2C2C in (A), L1C1R and L2C2R in (B), and L1C1L and L2C2L in (C).

Indirect inductive or magnetic coupling is illustrated in Fig. 2. The two circuits in this case are L1C1 and L2C2, the source of e.m.f.,E, being in circuit L1C1. The coupling is effected by mutual inductance between the two coils L1 and L2 and this mutual is indicated by M. The arrow signifies that the mutual is variable, but it may also be fixed. In (A) the magnetically coupled circuits are drawn in the customary fashion. In (B) the same circuits are shown in equivalent direct coupled form. Thus the mutual inductance is the common element but the inductances in the two meshes are diminished by M. In this case M is supposed to be positive. If it is negative, the common element changes sign and it is also added to each of the mesh inductances.

In Fig. 3 is a network in which the coupling is sometimes referred to as indirect capacitive. It seems preferable to regard the network as having three meshes with direct capacitive coupling between each two adjacent circuits. Another way of regarding the network is to consider it as composed of one simple circuit and one complex, for example, L2C2 the simple and C(L1C1)C the complex.

Function of Coupling

The function of coupling is to transfer energy from one circuit to another. The object, however, is not always to get the greatest energy transfer in a given time. Sometimes the object is to get the greatest current in the secondary at a particular frequency, or the greatest potential difference across an element in the secondary. Occasionally the object is to transfer energy at the greatest rate, that is, to make the power transfer greatest.

The coupling may have different degrees, depending on the proportion of the energy in the primary, or first circuit, that is transferred to the secondary, or second circuit. If a large proportion is transferred the coupling is said to be "tight" or close and if a small proportion is transferred it is said to be loose. The degree of coupling is usually expressed as the coefficient of coupling. If L1 and L2 are the two inductances in two circuits coupled by a mutual inductance M, as in Fig. 2, the coefficient of coupling, k, is defined by the relation $M=k(L1L2)^{1/2}$. That is, the coefficient of coupling is the ratio of the mutual inductance between the two circuits to the geometric mean of the inductances in the two. The coefficient of coupling may have any value between zero and unity. If its value is near zero, the coupling is loose; if

(Continued on next page)

How to Check Up on Filter Design

(Continued from preceding page)

filter that cuts off at 4,500 cycles and has a characteristic impedance of 500 ohms. We place the straight-edge across the scales in Fig. 2 so that it passes through 4,500 cycles on the f-scale and through 500 ohms on the Z-scale. The edge crosses the C-scale at 0.14 mfd.

A check on the design can be done by means of the scales in Fig. 3. In this figure the inductance is plotted on the left scale, the characteristic impedance on the center scale, and the capacity on the right hand scale. If our previous work is correct the straight edge should pass through 500 ohms on the center scale if it is laid so that it passes through 0.035 henry on the inductance scale and 0.14 mfd. on the capacity scale. The check is as good as could be expected with this method.

Of course, the curves in Fig. 3 can be used directly for determining any one of the three when the other two are known. For example, we might want to know what the characteristic impedance of a low-pass filter is when the inductance is one henry and the capacity is 0.01 mfd. The straight-edge shows 10,000 ohms. Or, having the inductance, we might want to know what capacity should be used to make the characteristic impedance 5,000 ohms. Let us assume we have 0.5 henry for the inductance. The straight-edge tells us on the C-scale that the capacity should be 0.02 mfd. The inductance can also be found when the impedance and the capacity are known, hence these curves should prove highly valuable to experimenters and students.

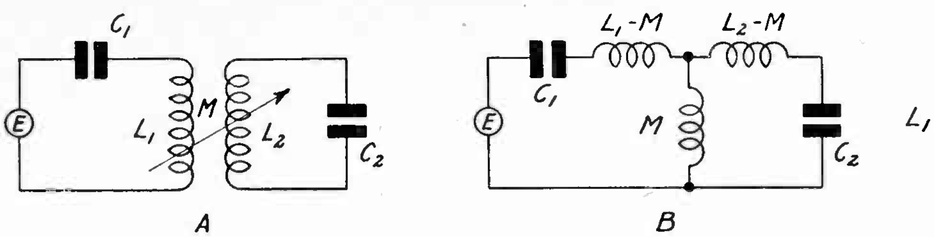


FIG. 2
Indirect inductive or magnetic coupling between two circuits. A, the usual method of representing it. B, the equivalent coupler when reduced to direct inductive coupling.

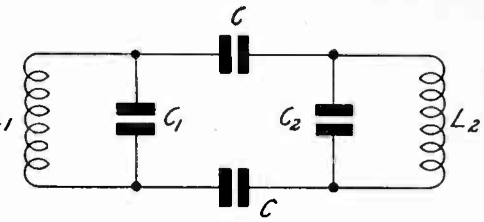


FIG. 3
This is sometimes called indirect capacitive coupling, but the network may be viewed otherwise.

(Continued from preceding page)
it is near unity, the coupling is "tight." There may be any degree of coupling between these limits, theoretically at least, but it is practically impossible to obtain unity coupling.

The case in Fig 1C comes directly after that of Fig. 2 provided that the coefficient of coupling is obtained from the equivalent circuit (B). In Fig 1C the total inductance in the primary is L1+L and the total inductance in the secondary is L2+L. The common inductance is L. Hence $L=k[(L1+L)(L2+L)]^{1/2}$ defines the coefficient of coupling. In case the two circuits are coupled capacitively the coefficient of coupling is defined by the ratio of the common capacity reactance to the geometric mean of the total capacity reactances in the two circuits.

In any case of coupling, the smaller the impedance of the common element the looser is the coupling; and conversely, the larger the impedance of the common element the tighter is the coupling. It is not the absolute value, however, of the common element that determines the coefficient of coupling between two circuits, but rather its relative value to the other elements of the same kind in the circuits.

Computation of Coupling Coefficients

Let us compute a few coefficients of coupling to illustrate what has just been said. Suppose we have a transformer in which the primary inductance is 50 microhenries, the secondary is 250 microhenries, and the mutual between them is 75 microhenries. What is the coefficient of coupling? The total inductance in the primary is 50 and the total in the secondary is 250 microhenries. If we multiply these together and extract the square root of the product we get the geometric mean between the two inductances. This is 112 microhenries. The common or mutual inductance was assumed to be 75 microhenries. Therefore the coefficient of coupling is 75/112, or 0.67. This is comparatively close coupling. Suppose the mutual inductance had been only 5 microhenries. This would have made the coefficient of coupling 5/112, or 0.0446, which represents loose coupling.

Suppose now we have a circuit such as that in Fig. 1C. Let the inductance L be 10 microhenries and let L1=L2=250 microhenries. What is the coefficient of coupling in this case? The total inductance in either the primary or the secondary is 260 microhenries. Hence the geometric mean has the same value. Therefore the coefficient of coupling is 10/260, or 0.0385. This is loose coupling. If we had made L equal to either of the other coils, the coefficient of coupling would have been 0.5, because the common inductance would have been 250 microhenries and the total in either circuit, and hence the geometric mean, would have been 500 microhenries.

When the coupling is capacitive as in Fig. 1A, the coefficient of coupling can be computed by the relation

$$k^2=C1C2/(C+C1)(C+C2).$$

Suppose C1=500 mmfd., C2= 250 mmfd., and C=1,000 mmfd. What is the coefficient of coupling? With substitution in the formula above we obtain k=0.258, which represents medium coupling. To make the coupling looser the common capacity C would have to be increased. It is interesting to note that when C in the above formula is zero the coefficient of coupling becomes unity. That means that the network degenerates into a single circuit, and that this is so is obvious from the figure.

Series and Parallel Circuits

Two or more elements are in series when the same current flows through all of them. Two or more elements are in parallel when the same potential difference exists across the terminals of all of them. Thus in Fig. 4A we have a series circuit composed of three elements L, R, and C. The electro-motive force E is placed so that the same current must flow through all the elements if any current flows at all. The potential difference across the elements are not the same in this case. The e.m.f. may be induced in the inductance in the circuit, as in Fig. 4B. An alternating current is supposed to flow in coil L1 and there is supposed to be mutual inductance between L1 and L. The induced e.m.f. is placed so that the three elements L, R, and C are in series.

In Fig. 4C we have a parallel circuit consisting of two branches, R, L and C. R and L are in series but these two are in parallel with C. The same potential difference, E, exists across C as across L and R. A practical occurrence of this connection is illustrated in Fig. 4D, in which L and C are in parallel in so far as the signal e.m.f. is concerned. The resistance R is supposed to be in the coil L and the by-pass condenser is supposed to be so large that its effect on the potentials across C and L can be neglected.

Resonance

Suppose we have a simple series circuit such as that in Fig. 4A. If the frequency of the alternating e.m.f. is varied, C, L, and R being constant, or if C is varied, E, R, and L being constant, there will be one combination at which the current in the circuit will be very high. When this occurs the reactance of the coil L is equal to the reactance of condenser C and the two reactances cancel each other, for inductive and capacitive reactances always have opposite signs. When this condition obtains the only obstruction to the flow of current in the circuit is the resistance R, and the value of the current is E/R, where E is the e.m.f. in the circuit and R is the resistance. If the e.m.f. is measured in volts and the resistance in amperes, the current E/R is given in amperes.

When the inductive and capacitive reactances are equal for the frequency of the driving e.m.f. the circuit is said to be in current resonance with that frequency. When this obtains the frequency, f, is related to the capacity, C, and the inductance, L, by the equation

$$f=0.1593/(LC)^{1/2}$$

in which f is given in cycles per second if L is in henries and C is in farads.

High Impedance

When the e.m.f. is connected as in Fig. 4C in respect to the circuit elements and either the frequency or the capacity is varied, there will be one combination at which the impedance offered the electro-motive force is exceedingly high and when the line current, that is, the current from the generator E, is very small. When this occurs the circuit is said to be in voltage resonance with the driving e.m.f. If the current is measured by connecting a suitable meter in series with either the condenser or the coil, it will be found that the current is maximum when voltage resonance obtains. Therefore it is the line current only that is small.

The frequency at which voltage resonance occurs is obtained by the same formula as that for current resonance, provided that the resistance in series with the coil is small. When this is large the formula does not apply but if the resistance is so large that its effect on the frequency must be taken into account, the circuit is not suitable for a resonator in a receiver or transmitter.

Resonance Curves

If the electromotive force applied to either a series or a parallel circuit containing resistance, inductance, and capacity is kept constant but its frequency is varied, the current in the series circuit and the impedance of the parallel circuit will vary according to the curves in Fig. 5. For frequencies much lower than the resonant frequency the current will be low. Then, as resonance is approached, it will increase rapidly to a maximum value. As the frequency increases still more, the response will decrease and for frequencies very far above resonance it will be about the same as it was for frequencies much below resonance.

The value of the response, that is, the current in series or the impedance of parallel circuit, at resonance will depend on the resistance in the circuit. If the resistance is high, there will be only a slight increase in the response at resonance, as indicated by curve A. If the resistance is less the rise will be greater, as indicated by curves B, C, and D. For good radio-frequency tuners, the rise would be much higher than for curve D in Fig. 5. The height to which the curve rises determines the effectiveness of the circuit as a tuner, or its selectivity. The selectivity is the property of the circuit by which it discriminates between the frequency of resonance and all other frequencies.

The Measure of Selectivity

The selectivity of a circuit is commonly measured in terms of the ratio of the inductive reactance to the resistance, and it is usually assumed that all the resistance is concentrated in the coil, or in the coil branch of the circuit. This ratio is usually called the Q of the circuit and it can be expressed symbolically as follows:

$$Q=2\pi fL/R.$$

The Q of a circuit may have any value from zero to 30,000, provided in circuits we include quartz crystal resonators. For low

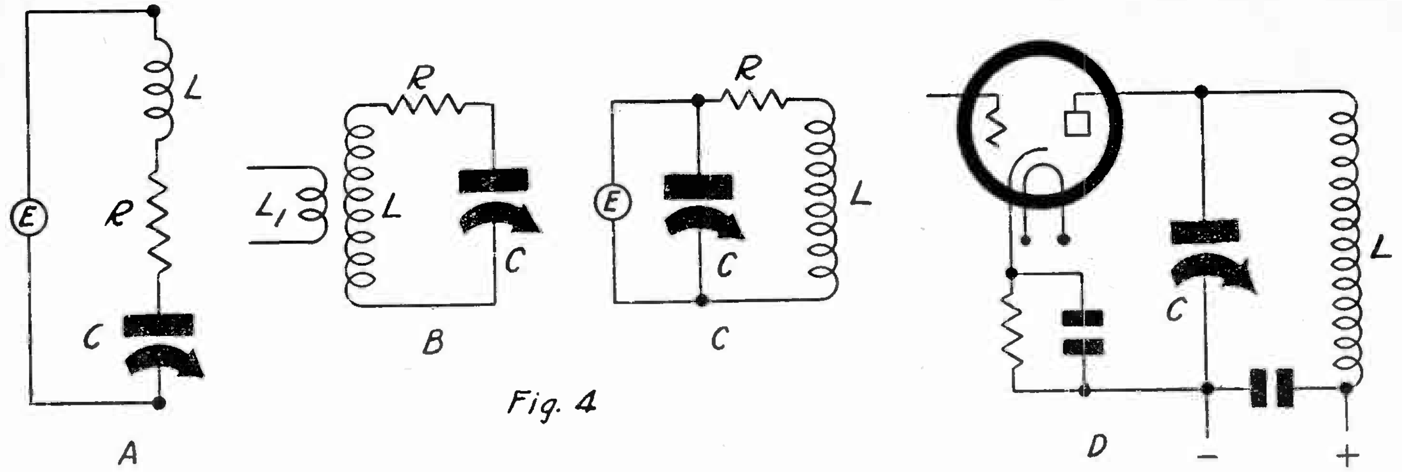


Fig. 4

These illustrate the difference between series and parallel circuits. A. A series circuit in which the same current flows through L, R, and C. B. A series circuit of the same type as A except that the e.m.f. is applied inductively. C. A parallel circuit. The same potential exists across the two branches but not the same current flows in these branches. D. A parallel resonant circuit used as load on a triode.

frequencies, those for which iron-core chokes can be used, the Q may be as high as 500. In the broadcast band of frequencies a Q as high as 200 may be attained, but for the lower amateur frequencies a Q of 100 is considered good. Quite often the Q of a single circuit in the broadcast band is not more than 60.

The reason why the Q of a circuit is not so high at the higher frequencies is that the ratio of L to R is low. L is small by necessity to resonate with the condenser in the circuit and R is large because of the skin effect and because of losses by radiation and absorption in insulators around the coil.

Picking Up Signal

Coupled circuits, usually resonant, are employed for picking up radio signals from space. One of the circuits is the antenna-ground and another is usually a simple circuit consisting of a coil and a variable condenser. There are two common methods of coupling, the direct method illustrated in Fig. 6A and the magnetic method shown in Fig. 6B.

That (A) represents a coupled network appears from Fig. 6C. Here C is the same condenser as C in (A). C1 is a small variable condenser that is often placed in series with the antenna for purposes of tuning and for varying the coupling, and Co represents the capacity of the antenna to ground. It is this capacity that makes the primary circuit, that is, closes it. One element in this circuit has been omitted, namely, the self inductance of the antenna. This might be imagined to be in series with Co between that condenser and C1.

The signal induces an electro-motive force in series with Co, and therefore in series with the self capacity of the antenna, C1, and C. C is the common element between the primary and the secondary circuits. When C is small, the coupling between the two circuits is likely to be very close, and when it is the selectivity of the tuner is not good. Neither does the greatest potential difference appear across the tuned circuit LC. The main function of C1 is to loosen the coupling between the two circuits. The smaller C1, for a given value of C, the looser is the coupling.

In Fig. 6B we have magnetic coupling between the primary and secondary circuits. While only the small winding L1 is shown in the primary circuit, it is understood that the antenna capacity Co and the self inductance Lo are present and that they are in series respecting the signal e.m.f. picked up. In this case the coupling coefficient can be made small by reducing the mutual inductance between L1 and L.

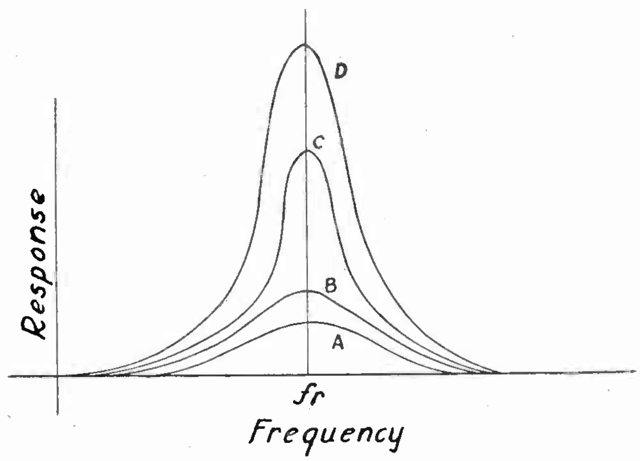


FIG. 5

Resonance curves showing variation of current in series circuit or impedance of parallel circuit as the frequency varies, the applied e.m.f. being constant.

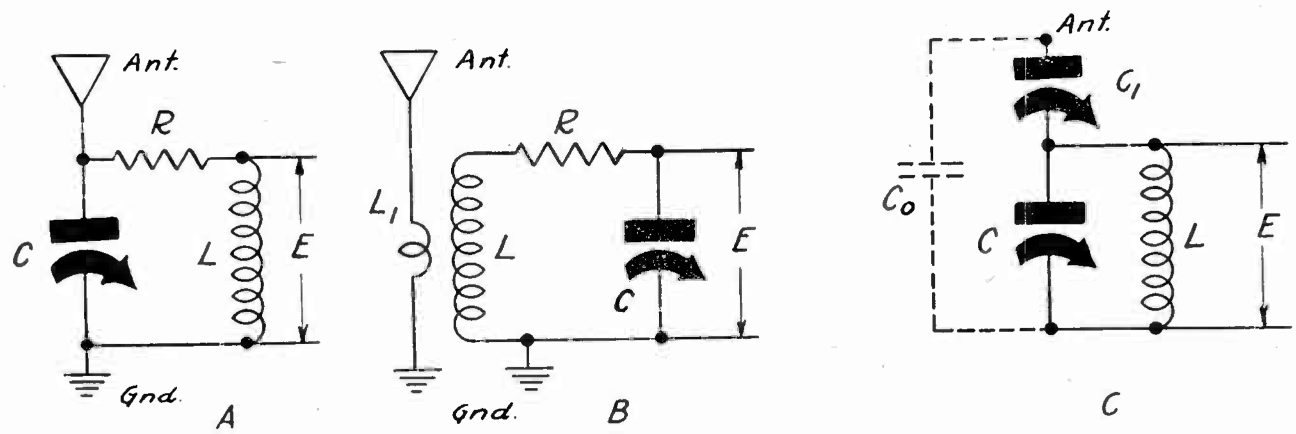
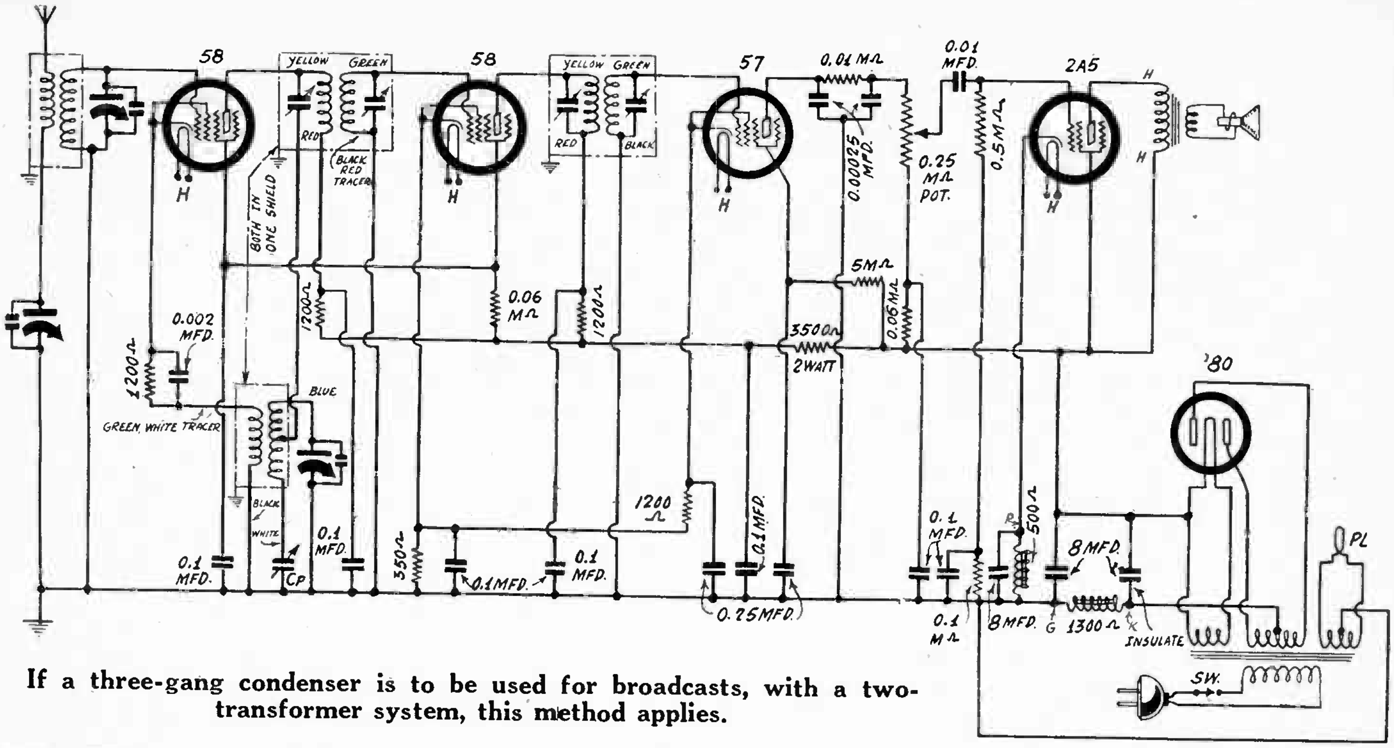


Fig. 6

Methods of picking up signals from space. A. This shows direct capacitive coupling between the antenna circuit and the resonator. B. This employs magnetic coupling between the antenna and resonant circuits. C. This shows how the capacity to ground of the antenna closes the primary circuit.



If a three-gang condenser is to be used for broadcasts, with a two-transformer system, this method applies.

Radio University

Answers to Questions of General Interest to Readers. Only Selected Questions are Answered and Only by Publication in These Columns. No Correspondence Can be Undertaken.

Intensifying Ground Wave

YOU HAVE DISCUSSED methods whereby the radiated power from an antenna is directed into a beam in any direction, especially upward toward the Heaviside layer. Has anything been done to intensify the ground wave to increase the reliable service range of a station? It seems to me that this is more important than directing the beam upward where there is nobody to receive the signals.—W.E.R.

A vertical half-wave antenna insulated from the ground intensifies the ground wave. It is used on some of the more modern transmitters.

* * *

Best Audible Range

WHAT FREQUENCY does the human ear respond to most easily? In other words, at what frequency can the weakest sound be heard?—R.E.H.

The threshold of audibility is lowest in the octave between 1,024 and 2,048 cycles per second. If an oscillator is to be modulated by a tone for the purpose of providing an easily distinguished sound, that frequency of the tone selected should fall in this range.

* * *

Power Detection

IS THE DIODE rectifier a power detector? What are the characteristic features of a power detector?—T.Y.L.

A power detector is not a power detector at all. It is, usually, a high signal detector, that is, a detector that can handle high signal voltages without overloading. From this point of view the diode detector is a power detector because even a small diode such as the 55 cannot be overloaded without first overloading the amplifiers following it. A true power detector would work directly into the loudspeaker.

* * *

What Vacuum Means

WHEN A RADIO TUBE has been exhausted well so that there is no appreciable gas left in the glass envelope, about what is the gas pressure? How many gas molecules are left per unit volume? —F.R.T.

The pressure may amount to one-millionth of a millimeter of mercury, but quite often it is only one-tenth as good as that. Even with the higher vacuum there are millions of millions of molecules of air in every cubic centimeter of space. The distance between the molecules is about 0.0001 centimeter in the ordinary vacuum tube used in receivers. Even when the vacuum has been made as nearly perfect as possible with present methods, there are still an inconceivable number of molecules per unit volume in the space supposed to contain no molecules.

* * *

Smoothing-Out Filter

IF A HALF-WAVE rectifier is used to supply a current pulse every cycle and nothing between these pulses, how is it possible to get pure d. c. out of the circuit? I understand how the choke in the filter takes out variations in the current but I cannot see how it supplies current when there is none. What part does the condenser in the filter play?—W.G.L.

The pulses of current flow into the condenser next to the rectifier. During the time that the rectifier conducts, only a part of the pulse flows through the coil and the load. More than half of the pulse goes into the condenser. While the tube is not conducting the condenser discharges through the coil and the load. Hence, although the rectifier sends only pulses, a steady unidirectional current flows through the coil and the load. An alternating current flows in the condenser, for current flows both in and out of it.

* * *

Regeneration Control

IF THERE IS a suppressor grid in a regenerative circuit, is it possible to control the regeneration by controlling the potential on the suppressor and to do this so that the frequency of resonance is not affected?—R.T.

The answer to the first part of the question is affirmative but to the second it is negative. However, the dependence of the frequency on the regeneration control is about as slight as it can be, so we are nearly justified in making the answer to the second part of your question affirmative as well.

* * *

Measuring Inductance of an Antenna

IS THERE a simple way of measuring the inductance of an antenna, using a calibrated oscillator, a calibrated condenser, or a calibrated variable inductance?—W.H.J.

One way of measuring the inductance of the antenna is to measure its natural wavelength, with the oscillator, for various added inductances in series with the antenna. Plot wavelengths squared against added inductance and continue the line until it cuts the axis for zero wavelength. The intercept between the origin and the point where the line cuts the inductance axis is the self-inductance of the antenna. The slope of the line is the self-capacity of the antenna. Another way of measuring the inductance of the antenna is to measure the natural wavelength without added inductance and then again with a known inductance added. The self-capacity of the antenna can then be computed in terms of the added inductance. This is really a special case of the intercept method.

* * *

Parasitic Oscillations

IN A RADIO AMPLIFIER or oscillator parasitic oscillations are supposed to occur under certain conditions. Just what are these oscillations and how are they produced?—W.E.H.

Parasitic oscillations are those which occur in an accidental circuit, that is, in a circuit that was not intended to be the oscillatory circuit. The oscillator, for example, might be a Hartley and intended to oscillate at 5 megacycles, but actually it may be an oscillator of some other type generating a frequency of the order of 50 megacycles.

* * *

Idea for Third Section of Gang

CAN ANY ACTUAL advantage be derived from a three-gang condenser I have, which is to be worked in a two-transformer circuit, comprising a mixer in a small superheterodyne? Ordinarily one section would tune the modulator and one the oscillator, but as there is a third section I would like to get some advantage out of it, if possible, and not merely let it ride unused.—J. E. X.

Yes, you may connect the third section in series with the primary of the antenna coupler, if the receiver is to be used for broadcast frequencies. In this way the actual coupling of the antenna is reduced at the higher frequencies, which tends to level the response in the modulator stage, and also increases the selectivity. However, if short waves are to be received, this method of ganged series condenser does not work out practically, because, first of all, the capacity should be smaller, and second, it is critical for any given freqency, and there would be no means of introducing the necessary variation to effectuate the critical coupling condition. The circuit of a complete receiver along the lines indicated is shown on the opposite page. The circuit is of a very simple sort, comprising a five-tube superheterodyne, with 58 used as both modulator and oscillator, with another 58 as the sole intermediate-frequency amplifier, a 57 as the second detector, and resistance coupling used between that detector and the pentode output tube, a 2A5. The 280 rectifier is the fifth tube. The circuit is useful for reception of local stations.

* * *

Key Clicks

I HAVE BEEN listening on certain amateur stations and have been hearing plenty of key clicks. Now I have also heard similar noises in my receiver which were not caused by amateurs. Just what gives rise to the clicks?—W.J.L.

The key clicks are the result of sudden growth of oscillation in a circuit when the key is closed. The amplitude attains full value in a burst rather than gradually. Any sudden change in the current will produce the same result, for example, the starting or stopping of current in any circuit. The remedy for key clicks and similar disturbances is to put a choke in series with the circuit where the surges take place. This does not mean, of course, that the choke should be put in the oscillating circuit where the oscillations build up rapidly. The choke might be put in series with the plate supply.

* * *

Transceivers

WHAT IS a transceiver? Is it a receiver, a transmitter, a combination of the two, or something that is not related to either? —R.L.C.

A transceiver is a combination of a receiver and a transmitter. Usually it is portable and is very simple. Often there are only two tubes in the circuit, but these can be used either as a regenerative receiver or a transmitter. Airplanes use them.

* * *

Starting and Stopping Oscillations

DURING MY EXPERIMENTS on oscillators I have found that the same conditions do not obtain for starting as for stopping oscillations. It requires more feedback to start oscillations than it requires to keep them going. In some cases a shock of some kind is required to start the circuit, but when once started the oscillations keep right on. Please explain why the conditions are different from starting and stopping.—L.A.

The condition exists but there is a question whether it can be explained. Perhaps an analogy will suffice. Suppose we start to pull a loaded wagon. It takes a strong effort to start it moving. But once started it does not require much effort to move it, or to keep it moving. There are two factors which enter into this. First we have inertia. It took work to start the wagon moving a certain speed, but after it had attained that speed, no more work needed be done on the inertia. In fact, the inertia would keep the wagon moving. All that is required after the start is to overcome friction. The other factor is that before starting the friction was greater than after the start. The oscillator is similar. There is friction and inertia. Friction must be overcome to keep the circuit going, but inertia need be overcome only when starting, or stopping.

* * *

Lissajous' Figures

IS THERE any simple way of utilizing Lissajous' figures that does not involve the use of a cathode ray oscilloscope? If so, please explain it.—R.N.L.

You might arrange two tuning forks with a small mirror attached to a prong of each and have a ray of light be reflected first by one to the other and then to a screen. But this device, or any similar one, is good only for frequencies to which the forks respond. Only the oscillograph or scope is applicable to variable frequencies. It does not necessarily have to be a cathode ray oscilloscope. But the cathode ray oscilloscope is good for all frequencies. There is really no substitute for it.

* * *

Function of Beat Oscillator

IN ANY short-wave receivers a beat oscillator is incorporated. What is the purpose of this oscillator? Are there short-wave signals which cannot be received without it or is it merely an aid in receiving ordinary short-wave broadcast signals?—R.E.M.

The beat note oscillator serves two functions, first, to make audible continuous waves, and second, to located short-wave signals on the dial. An unmodulated carrier could not be heard even though it were very strong at the second detector because when it is detected, or rectified it consists of directly current. It is the function of the beat note oscillator to modulate the unmodulated carrier and thus to make it audible in the output of the receiver. It takes a comparatively weak beat note signal to make the unmodulated carrier audible because of the strength of that carrier. The other use of the beat note oscillator is to locate station carriers while tuning. If the carrier is weak it may not be "spotted" when first passing over it, but if the beat note oscillator is going there will be a whistling sound in passing over the carrier. This will occur at every carrier and therefore a large number of stations can be spotted that would be too weak to make themselves heard without the beat note aid.

* * *

Radio Frequency Resistance Variation

ABOUT HOW MUCH does the resistance of a broadcast coil vary with frequency? That is, how much greater is the resistance at the high frequency end than at the low frequency end? I realize that no two coils are alike in this respect but all I want is a rough idea.—R.L.J.

A certain coil wound with No. 20 wire with 46 turns had a radio frequency resistance of about 1.8 ohms at 550 kc and 3.2 ohms at 1,500 kc. Thus in this case the resistance was 1.78 times greater at the high frequency than at the low. This happened to be a good coil. In coils not so good the resistance is much higher and the change is more rapid.

* * *

Losses in Condensers

ARE THE RADIO-FREQUENCY losses in condensers of appreciable magnitude or are they entirely negligible in comparison with the losses in the coil? Are the losses greater or less at the higher frequencies? That is, how does the effective resistance of a condenser vary with the frequency?—T.H.M.

The apparent resistance of a condenser varies inversely as the frequency and also inversely as the capacity. Therefore at very high frequencies the resistance of a good condenser is negligible whereas at low frequencies it may not be. This rate of variation of the resistance of a condenser assumes that the insulation of the condenser is perfect. If it is not perfect and the leakage is considerable, the resistance varies inversely as the square of the frequency, inversely as the square of the capacity, and inversely as the leakage resistance, not as the square of the leakage resistance. To avoid high resistance due to leakage the insulation should be made as good as possible and the capacity should be made large. For a given frequency this means that the inductance will be small and this in turn that the total losses in the circuit will be low.

* * *

Compensating Capacity Changes in Oscillator

CAN YOU SUGGEST a method of making compensation for variations of frequency due to changes of capacity and inductance in an oscillating circuit due to changes in temperature? I want some means for compensating that does not require a temperature oven. —T.R.N.

There is always the possibility of using a thermo-element to vary either the inductance or the capacity. It would be easy to contrive a compensator that would just offset the combined effect of inductance and capacity variation, that is, over a certain range of temperature. It will first be necessary to know just what the temperature coefficient of frequency of the oscillator is then to design the thermo-element to have the opposite effect. Perhaps the easiest way would be to vary the capacity by means of the thermo-element.

* * *

Best High Frequency Conductor

WHAT IS THE BEST shape for a conductor of high frequency current? I have in mind solid copper wires, solid round rods, stranded wire, copper tubing, square rods, flat strips. Please give reasons for your choice.—E.R.H.

Round conductors are better than any other because only in round conductors is the current distributed uniformly on the surface. In a flat strip the current concentrates at the sides, or edges, in a square rod it concentrates at the four corners. Stranded conductor is not good above about 500 kc. Round copper tubing is just as good as round solid rod of the same diameter, because high frequency currents concentrate near the surface, and there is just as much surface on a tube as on a rod, the diameter being the same in the two cases. There is no current at the center of the rod, the frequency being high enough, and therefore the center might as well be removed. For the same weight of copper it is obvious that copper tubing is much superior to solid conductor, for there will be much more surface.

* * *

Choice of Audio Amplifier

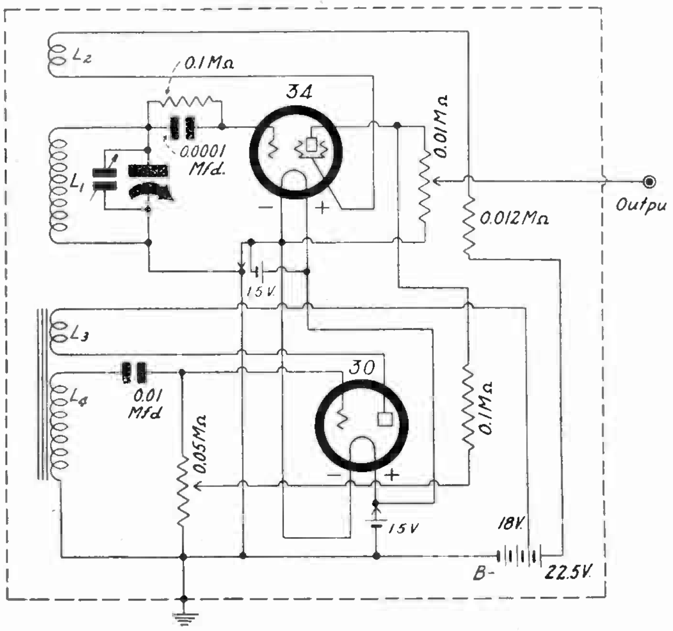
WHAT KIND of audio amplifier would you recommend for use in conjunction with radio, phonograph playing, and microphone operation?—G.H.

Push-pull output with 2A3 tubes, fed by a 56 with a first-rate transformer. This is enough for radio and phonograph playing. For microphone work more amplification is required, but how much depends on the sensitivity of the microphone. Two stages would be required for a condenser and ribbon microphone. It would be best to use two stages of preamplification in any case for the gain can always be controlled.

A Portable Precision Type
Signal Generator

An Electron-Coupled, Frequency-Stabilized Test Oscillator, with Separate Oscillator Audio—Direct Reading of Frequency, Percentage Modulation and Decibel Attenuation of Output—Fundamentals 132 to 380 Kc and Harmonics Used—Services Intermediate, Broadcast and Short Waves

By Herman Bernard



Circuit of Model 3430-S Signal Generator. See picture diagram on back cover.

TUNE the grid circuit, use a tickler, apply the voltages to a tube, and you have an oscillator. Provide some modulation, calibrate the generated radio frequencies and you have a test oscillator. Grid blocking may be used for modulation. What is the oscillator, then, but a one-tube set used not for reception but for transmission? If there is a separate modulator tube, as there is in the better type devices, you have a two-tube set. Everybody knows that one-tube and two-tube sets are for beginners. And yet the leading radio scientists are concentrating their best efforts on such one-tube and two-tube "sets" and in the accompanying analysis develop formulas as long as your arm. The publications of the learned radio societies in this country and abroad contain more data on oscillators than on any other topic. Why? Are our best minds in their second childhood, or is there something esoteric about even the simplest oscillator?

There is certainly an underlying motive of great consequence. The need has arisen for an extremely high order of frequency accuracy and stability in variably-tuned oscillators. The precision already accomplished approaches that of a crystal. Generally speaking, the crystal is limited to a single frequency, multi-frequency response from a crystal being a misfortune, with the single exception of a special beat oscillator.

United States Takes Lead

The United States has taken the lead in the development of frequency-stabilized oscillators, and within the past two years accuracy to a few parts in a million has been achieved. Starting with the usual complex solutions, the development has been so far advanced toward simplification that excellent stability is attained by the insertion of a single resistance, a method that the author developed and now offers to the science for the first time.

It may be well to define the goal. The oscillator, to be stable, must not have its frequency influenced by terminal voltages. Although use and age may change the effective battery voltages, still the same frequencies should obtain as when the oscillator was calibrated. Thus the oscillator is frequency-stabilized when the tube is so loaded, connected and voltaged that the behavior of the circuit is like that of a pure resistance. The tube, as we find it, is wobbly, and practically any voltage change will change the plate current.

When we have frequency stability, or generation and maintenance of the same frequency at the same setting every time, we also have amplitude stability. That is, the oscillation voltage is the same throughout the tuning range. Ordinarily the intensity is much greater at the higher frequencies of tuning, the most unstable region and the one presenting the real problem. Amplitude stability results in a constant voltage delivery to the output load. Lesser values may be taken off, by the usual attenuation methods, but what the load receives is always the same; only the amount taken off may be selected.

Steady A-F Output

An incidental advantage of an amplitude-stable system is that, though we may not know just what the output voltage is in absolute value, at least we are assured that it is always the same, so we may test a receiver's sensitivity simply from observation of a receiver output meter. The output of the oscillator does not have to be measured each time and then compared with the receiver output, for we are using a uniform system.

The simplest circuit for achieving some kind of frequency stability is the grid-leak-condenser type of oscillator. For the middle and lower frequencies of tuning the results are good indeed, but at the higher frequencies instability is about at its worst. The oscillator has as usual a rising characteristic, that is, amplification is greater the higher the frequency, although there is considerable flattening in the specified regions.

Numerous methods have been shown for stabilization of oscillators, most of them rather complicated, requiring an extra coil or two, an extra tuning condenser or tube, and closely-held constants. Since a simpler method was deemed necessary if frequency-stabilization was to be extended to less expensive laboratory and servicing equipment, this was one of the first subjects considered in the design of a test oscillator. Three men spent two years on the circuit shown in the diagram. The experimenting was done in my laboratories, and I was assisted by J. E. Anderson, former instructor of physics in the University of Wisconsin, and former Western Electric engineer, and by Edward M. Shiepe, author of "The Inductance Authority," and graduate of the Massachusetts Institute of Technology and of Polytechnic Institute of Brooklyn.

Series Resistor Stabilization

It was my good fortune to develop the simplest method of stabilization, consisting merely of a series resistor in the plate circuit. For electron-coupling purposes it will be noted that the orthodox screen of the 34 tube is used as the plate. The series resistance might, instead, be in the grid circuit, but in some formations it is easier to stabilize in the plate circuit, and such was true of the present device.

The general principle of the introduction of stability in this easy manner is to counterbalance the normal behavior of the circuit. The series resistor is most effective at the high frequencies and has little effect at the low frequencies. A grid-leak-condenser type oscillator itself produces good stability in the region where the series stabilizing resistor is of little effect, so if the new resistor is chosen of exactly the right value it will introduce a falling characteristic equal to the rising characteristic of the rest of the circuit.

A ready means of checking up on this assertion is to put a current meter in series with the plate leg of any unstabilized oscillator and note the unbearable violence of change of that current, especially at the high frequencies of tuning. If the oscillator is of the grid-leak-condenser type the showing is quite pronounced, because the unstable region is sharply compared to the stable region by the sudden and wide fluctuation of the needle which previously had not moved much. Since the leak-condenser type oscillator is in a sense a vacuum tube voltmeter yielding relative values, the amplitude or strength of oscillation obviously varies greatly. The greater the intensity of the oscillation the less the current in the plate circuit, for the grid voltage has risen accordingly, and developed a higher d-c drop across the leak. If the needle could be made to stand still we would be assured of amplitude stability and then might investigate whether also we have frequency stability.

12,000 Ohms in Series

For the circuit shown, the plate resistor was selected experimentally at 12,000 ohms, and a plate reading that changed 50 per cent. without stabilization changed less than 10 per cent. with stabilization. By a still more exact selection of resistance value the plate current change may be held to 2.5 parts in 1,000.

At least the input was relatively stable, the same voltage of oscillation present at all frequencies, and as nothing but the input affects the output, the output is the same at all frequencies. A vacuum-tube voltmeter check corroborated this. With a uniform output we could calibrate a potentiometer as to its resistance at certain positions, and then the calibration could be communicated to a circular scale, and we could enjoy direct-reading output attenuation in decibels, say, in steps of 2 decibels down, from 0 attenuation to 20 decibels attenuation.

The current through the total potentiometer being held constant, the decibel calibration holds, for only the resistance ratios need be considered, using the power formula, since the oscillator's output will be delivered to a system in which the power output is the main consideration:

$$-DB = 20 \log 10 \left(\frac{R1}{R2}\right)$$

where R1 is 10,000 ohms as a base and R2 is the resistance between plate and arm.

On the foregoing basis, therefore, the resistance values are as follows for steps of 2 DB down, from 0 to 20 DB:

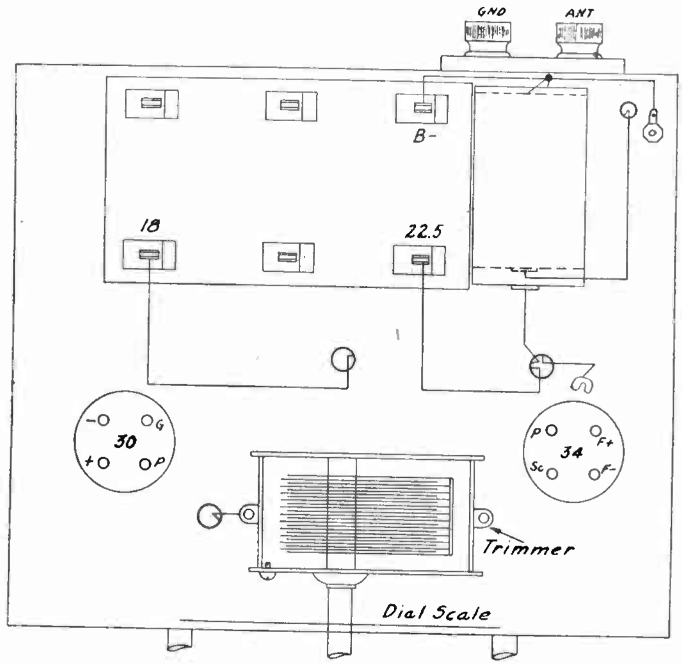
Ohms-Resistance Between Pointer and Filament	*DB Down*
10,000	0
7,940	2
6,300	4
5,000	6
3,970	8
3,160	10
2,504	12
1,990	14
1,580	16
1,250	18
1,000	20

For 50,000-ohm potentiometer, multiply left column by five, for 100,000 by 10, etc. The circuit uses 50,000 ohms.

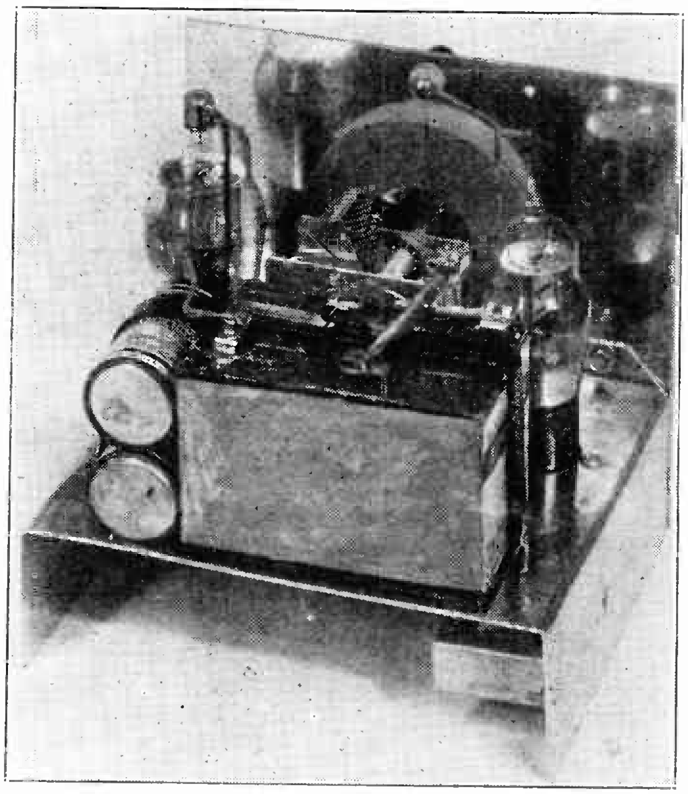
Now, as to a determination of whether frequency stability exists, without recourse to any expensive apparatus. Two tests are proposed. Beat the supposedly stabilized test oscillator with some broadcasting station that uses a high carrier frequency, let us say 1,500 kc, as the rule against deviations exceeding 50 cycles imposes a greater absolute accuracy on such stations, in this instance an accuracy of one part in 30,000. If the test oscillator generates lower frequencies, use an harmonic of the test oscillator to beat with the station, or even select the much more accurate transmissions of the Bureau of Standards on Tuesdays, on a 5,000 kc carrier, transmission accurate at all times to better than one part in 5,000,000.

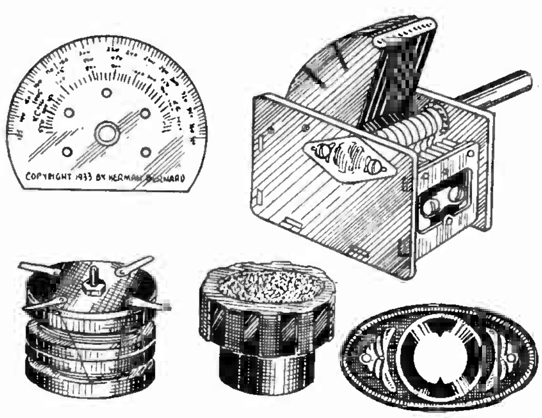
Frequency Change Noted

The test oscillator is made to beat with the station so that the resultant note is any audio frequency you can hear well. Then the B voltage is moved from 22.5 volts to lesser values for the entire voltage range in which r-f oscillation continues, and by ear one notes whether the pitch changes. The change in audio frequencies in cycles is compared to the frequency of the transmitter in cycles, and the frequency stability is thus evaluated. The change should not exceed 100 cycles at 1,500,000 cycles, or a frequency



Rear View of Model 3430-S





The tuning unit consists of dial scale, condenser, oscillation transformer, knob and escutcheon.

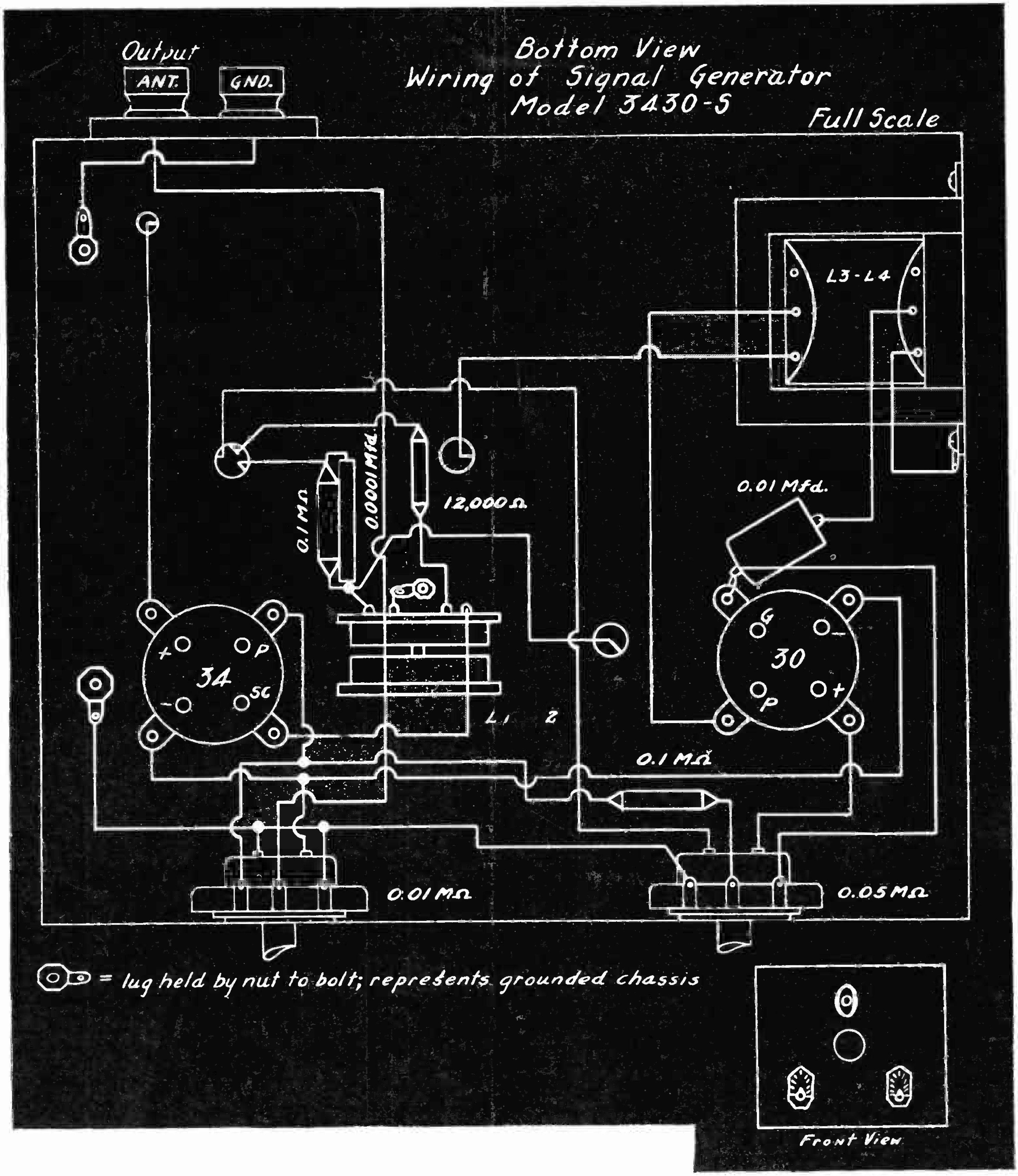
stability of one part in 15,000. This is not a high order of stability, but represents what a home constructor can duplicate, and the ear test just outlined, although barren of absolute values, is as sound a test as to whether the oscillator is unstable as any means known to the science.

The second method provides closer results. A beat is struck with a standard carrier and adjusted to zero, or as near so as possible. The test oscillator's output is connected in the detector circuit of a tuned-radio-frequency receiver and attenuated so that that station carrier at the detector is of about the same amplitude as that of the oscillation from the device being tested. A vacuum tube voltmeter is used. Now a d-c milliammeter is put in the receiver's detector plate circuit and the station tuned in more carefully and the oscillator readjusted in another attempt to establish zero beat. If there is a frequency difference of 5 cycles to a fraction of 1 cycle, then the meter needle will oscillate at the frequency of this difference and the oscillations can be counted.

Less Than 100% Modulation

For the frequency stability to be maintained it is necessary that

(Continued on next page)



A series condenser of 0.00025 mfd., in the output leg, omitted from above, but shown on page 18, is preferably included if the cabinet is to be grounded externally.

(*Continued from preceding page*)

the modulation be considerably less than 100 per cent., and as thus far no modulation has been considered, it is suggested that for purposes of fairly high accuracy the modulation percentage should not exceed 30 per cent. in critical testing. However, the modulation attenuator should be capable of permitting 100 per cent. modulation, and the attenuator may be calibrated on that basis. A series resistor is used between the arm of the audio attenuator and the customary plate of the radio-frequency oscillator, which plate is here used only for coupling purposes. Although the plate is returned to negative filament through a resistor, space current flows through this resistor, that is, there is electron coupling between test oscillator and r-f output, and between audio oscillator and radio-frequency oscillator. The audio oscillation also is limtied by using 18 volts on the plate of the 30 modulator, instead of 22.5 volts. This likewise raises the pitch of the audio note to a pleasanter frequency.

Since a single tone is concerned, the formula for percentage modulation is

$$\%M = \frac{100\,A}{a}$$

where A is the difference between the modulated and the unmodulated radio-frequency voltage and a is the unmodulated radio-frequency voltage alone.

The result may be put on a circular scale and a pointer knob will indicate the percentage modulation used.