ALIGNING CIRCUITS HAVING A. V. C.

RADIO WORLD

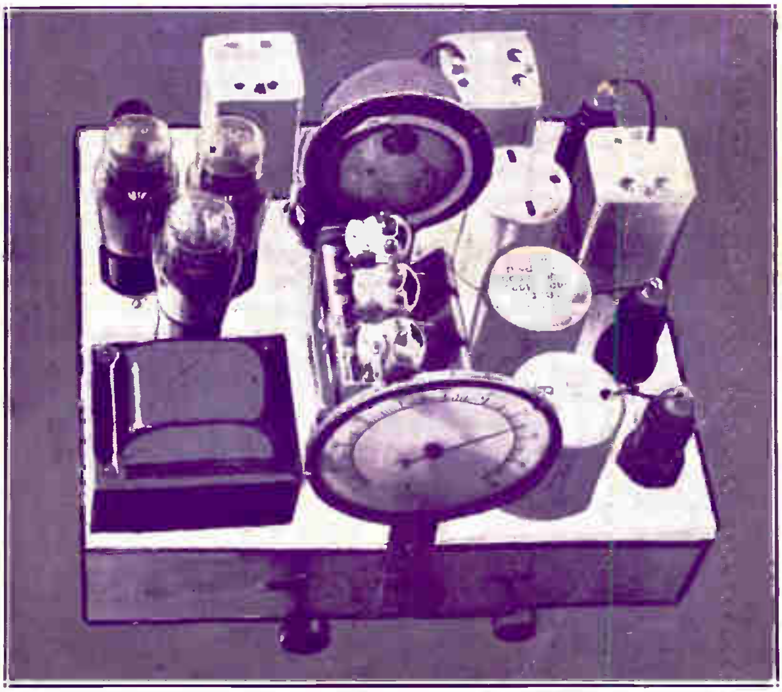
REG. U. S. PAT. OFF.

THE HOW-TO-MAKE-IT MONTHLY—25c Per Copy

12-WATT FIDELITY SUPER

JUNE

1936



NEW TUBES

Greatly improved mixer performance was attained by raising the 6A8 grid current in this nine-tube superheterodyne, and a driver's grid current was eliminated. See article beginning on page 31.

HOW TO IMPROVE YOUR RECEPTION

A VERIFIED THOR VALUE!

POWER plus PORTABILITY At LOW COST!

PORTABLE CRYSTAL P.A.

A GUARANTEED THOR PRODUCT!

COMPLETE 16 WATT SOUND SYSTEM

7 Tube HiFidelity Amplifier in interlocking 3-piece waterproof case, housing 2 Rola, 12" dynamics and amplifier. Each unit completely detachable with base and 25-foot extension for instant placement. Case overall 15x15x21. Fitted with heavy duty corners, hardware and metal screen grilles. All qualifications for an ideal P. A. system, portable or permanent. More power and tone per dollar than ever before.

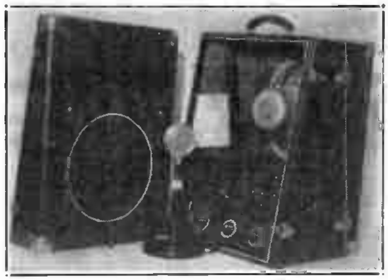
Speaker grilles silk covered with waterproof folding flaps. Rola G-12 speakers supplied in place of the Rola K-12 at additional cost of $5.00 ea.

No. 7HF Amplifier **19.50**

Kit 7 RCA Tubes.. **5.40**

Rola 12" Dynamics. 2500 ohm. ....ea. **3.95**

2 Spkr. Extensions. 25 ft. with plug.... **1.00**



THOR presents in this model a truly compact high quality Portable outfit. Complete with all components. This system is ideal for any application. The sound specialist who requires the finest in tone reproduction can purchase this outfit to fill a multitude of purposes at an exceptionally low price. This outfit presents a perfect sound system for the theatre, dance orchestra, lecturer, entertainer and for all rentals. All units fit together to form one complete unit. Entirely portable. Amplifier contains all controls including speaker supply. Crystal Pre-Amplifier and Selector Switch to operate one or two speakers as desired.

Complete system with all parts as listed. Crystal mike and floor stand included. Ready to operate...... **59.90**

HIFIDELITY OUTPUT DUAL CHANNEL INPUT

High Gain Input for crystal mike, medium gain input for tuner or hi-impedance pickup direct. Individual gain controls permit use of single or dual channels, mixing of one or both. Continuous type tone control finely graduated. Rated gain 125 db. Power output 20 watts peak, 16 watts constant. Tubes—2-6B5, 1-83V, 1-25Z5, 1-6C6, 1-76, 1-6A6. Speaker field supply and output transformer built-in amplifier. All inputs plug in. Crystal mike (shure or astatic) on 6 ft. adjustable floor stand, included in net price.

Triple Section Case.. Complete with handle. **8.50**

Crystal Mike (Shure or Astatic) **13.23**

Shure 6 ft. Adjustable Floor Stand, 3 Section Balanced Base.... **6.50**

Mike Shielded 25 ft. Ext. with plug.. **1.00**

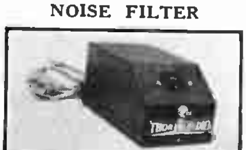
GREEN FLYER

AC 1 Speed Motor, speed controlled, with plate, shpg. wt. 15 lbs...... **7.35**

AC 2 Speed, 33-1/3-78 Motor, speed controlled with plate, shpg. wt., 18 lbs.. **9.41**

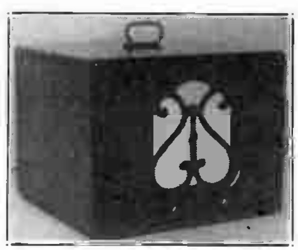
Automatic Stop **1.25**

NOISE FILTER



Efficient filter to eliminate man made static.. Inserts in line between set and outlet. Shpg. wt., 10 lbs. **1.69**

5 TUBE PORTABLE P.A.

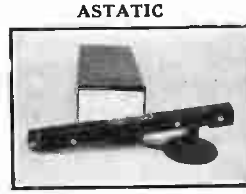


8 WATT P.A. RIG

A powerful 5 tube P.A. system entirely self-contained. Uses push-pull 2A5's, 1-57, 1-56, 1-80. Solid wood case with handle, contains 10" Dynamic amplifier and input mixer. Tuner, pickup or carbon (1 or 2 button). Mike feeds direct as mixer contains mike transformer and battery. Volume and tone control on input and output.

A real bargain on a compact sound system. Complete with 5 Raytheon tubes, 10" Dynamic and mixer ready to operate. Overall size 11 x 14 x 14. Shpg. wt., 30 lbs. Limited quantity **19.95**

ASTATIC



Genuine Crystal Pickup

High impedance. No transformer needed. Feeds direct to grid. Finest of its type. Ideal for P.A. work. Limited quantities............ **6.19**
Shpg. wt., 6 lbs.

UPCO PICKUP

Needs no transformer. Feeds direct to grid. Wide range response. Upco Hi-Impedance Pickup with built in volume control. Finely balanced. **3.95**
Shpg. wt., 5 lbs.

ORDER DIRECT 24 HOUR SERVICE

THOR RADIO

167 Greenwich Street, near Cortlandt Street
New York City

20% DEPOSIT WITH ORDERS OVER $10

SENSATIONAL! New Cathode Ray Radio Tuning Unit

"MAGIC *LION"

"Magic *Lion" is one of the most beautiful pieces of bronze finish metal ornamental statuary you ever laid your eyes on. It houses a complete cathode ray tuning indicator unit. Think what this means to radio owners who want the advantages of this new scientific tuning attached to their present set! Now with "Magic *Lion" they get a superb metal reproduction of the world famed Swiss Lion of Lucerne PLUS an accurate guaranteed radio tuning unit.

NO CABINET BUTCHERING! NO HOLES TO BORE! QUICKLY-EASILY INSTALLED!

EASY TO INSTALL

No risk of ruining a fine radio cabinet or control panel when you install "Magic *Lion"! Five wires quickly connected and the job's done. "Magic *Lion" rests gracefully atop flat cabinets or on a table beside cathedral shaped sets. Quick easy installation spells clean quick profits.

PROFITABLE

The beauty of "Magic *Lion" alone slices sales resistance! Set owners hesitate to have their radio cabinet butchered for ordinary cathode tuning unit installations but when they see how simply "Magic *Lion" is attached they're delighted. Aggressive service experts will like the quick cash sales on "Magic *Lion".

List Price $8.75 Complete with Tube

ORDER A SAMPLE FROM YOUR JOBBER OR WRITE RIGHT NOW!
Specify Cathode Ray Tuning Indicator tube type desired, 2.5 Volt or 6 Volt.
"MAGIC *LION" MFG. CO., 56-60 Gold St., New York, N. Y.

IRON CORE I.F. TRANSFORMERS

NEW Radio Design Company iron core intermediate transformers, as much gain and selectivity with one stage of i.f. as with two stages using ordinary i.f. coils. Shield size: 3½ x 1½ inches. Coils tunable 450 to 470 kc. Price, postpaid................$1.15 each

Coils for Lamb's Noise Silencer i.f. transformer and separate r.f. choke, price, both postpaid—$1.50

RADIO DESIGN COMPANY
1353 Sterling Place Brooklyn, N. Y.
We have coils for all circuits. Write us your requirements.
Send for free circuit diagrams.

METAL CHASSIS

We can supply chassis for any make receiver, experimental or otherwise.
Inquiries should be accompanied with sketch and complete details enabling us to give quick service as to prices and delivery.

KORROL MFG. CO., Inc.
Dept. R.W. 436
232 Greenwich St. New York City

SERVICEMEN AND EXPERIMENTERS TURN TO PAGE 64

ADVT.

You need . . these 2 *books*

PRINCIPLES of PUBLIC ADDRESS SYSTEMS

A practical handbook, full of useful information, fully illustrated, written by M. N. Beitman, an engineer and noted authority on audio amplifiers.
Considers in detail various microphones, radio and phonograph inputs, acoustic feedback, mixing and volume controls, use of vacuum tubes, interstage coupling, power amplifiers, output coupling, loud speaker placement, the decibel, P.A. measurements, power level, and other points of importance, including actual circuit diagrams of tested P.A. systems.

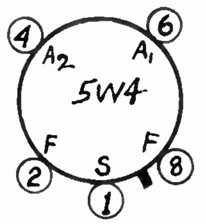
MATHEMATICS of Radio Servicing

Introduces and explains the use of arithmetic and elementary algebra in connection with units, color code, meter scales, Ohm's Law, alternating currents, ohmmeter testing, wattage rating, series and parallel connections, capacity, inductance, mixed circuits, vacuum tubes, curves, the decibel, etc., etc., and has numerous examples.
Plainly written and easy to understand. Only useful data included. M. N. Beitman, author. Size, 8½ x 11 in.

Price, 50c each book.

SUPREME PUBLICATIONS
3727 West 13th St., Chicago, Illinois

New Metal Tube Rectifier, 5W4



Bottom view of the socket.
Pin 1 = Shell (S)
Pin 2 = Filament (F)
Pin 3 = Blank
Pin 4 = Anode No. 2 (A_2)
Pin 5 = Blank
Pin 6 = Anode No. 1 (A_1)
Pin 7 = Blank
Pin 8 = Filament (F)
The key is shown between 1 and 8.

A new all-metal full-wave rectifier is designated 5W4. It is a filament type tube intended for applications where the d-c requirements are moderate.

5W4

Filament Voltage (a.c.)	5.0 Volts
Filament Current	1.5 Amperes
A-C Plate Voltage Per Plate (RMS)	350 *max.* Volts
D-C Output Current	110 *max.* Ma
Maximum Overall Length	3¼"
Maximum Diameter	1 5/16"
Base	Small Octal 5-Pin

Six-Month Celebration of NBC's 10th Birthday

The tenth anniversary of the National Broadcasting Company will be celebrated over NBC Red and Blue networks this Summer and Fall with a six months' period of special broadcasts.

Programs from here and abroad will be presented weekly from May 18 to November 15, the actual anniversary date.

(Continued from preceding page)
necting link between set and speaker. This is done by matching. There is a transformer at the output in the set. It has a certain secondary impedance. A line is used of a certain impedance. The total impedance of line and secondary should match the input impedance of the transformer at the speaker. In this way the energy is conducted from the source (receiver) to the destination (set) with minimum loss. That is true because practically all the energy gets to the speaker, none being dissipated in spurious waves. The rule is that all the energy is dissipated in a resistor terminating a line, when the terminating resistance is equal to the impedance of the line. This is called the characteristic impedance of the line, or the surge impedance. In practice perhaps a 500 ohm line would be used, with transformers at either end to supply the necessary matching. Then almost full realization of the set's output is attained.

* * *

IMITATING INSTRUMENTS

WILL you please state what is the object of these audio devices whereby you can imitate different kinds of music, using the same instrument? For instance, play so that the sound is like that of a piano, organ, violin, clarinet, trombone, etc.?—W. D. S.

The object is to provide instruments for home, studio and auditorium use whereby at will whatever type of instrumental music that is desired may be enjoyed. The principle is in substance the same as that which applies to the electric organ, although in that instance the tones are so treated that only the organ type of music can be produced, with the wide-range selection type of instrument, levers permit the selection of any one of a dozen or so different types of musical renditions. The results are achieved by generating as many fundamentals as will be necessary to cover a specific range, and filtering the harmonics of different orders in such manner as to duplicate the harmonic contents in the type of music desired. Harmonics to the eighth are normally used, with the seventh suppressed, if possible, as this one does not contribute musical values.

* * *

SET CHOKES UP

WHAT can be the cause of my set choking up on loud signals? I have a home-built superheterodyne that uses the 55 as second detector and first audio amplifier. The triode part of this tube is direct coupled to the diode, that is, the rectified voltage is the input to the triode. The cathode of course is grounded.—K. L.

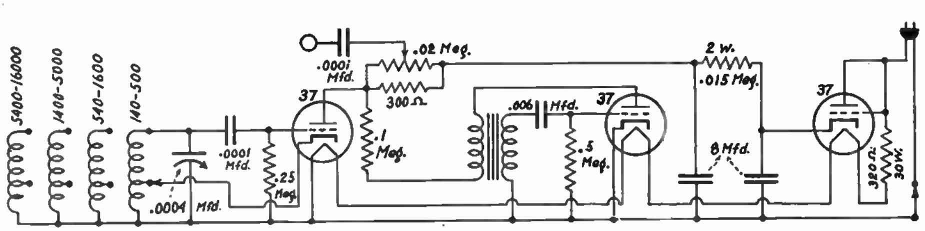
The audio amplitude reaches such a height that the triode of the 55 does not carry enough plate current. In fact, the plate current on peaks may be almost cut off. You probably run second detector output voltages of the order of much more than 20 volts. Besides choking, you probably suffer distortion at signal amplitudes somewhat below the choking level. It is suggested you put a 5,000 ohm resistor in series with the cathode, bypass it with a 8 mfd., and return diode load resistor to cathode, not to ground. Then put a stopping condenser of .05 mfd. between high side of the diode load resistor and grid of the tube, and use a leak at 2 meg. from grid to ground. In that way the grid is negatively biased by the potential drop in the cathode resistor, whereas the diode circuit is not affected as to potential, except trivially. If the volume control is a potentiometer used as diode load, connect the stopping condenser to the potentiometer arm. It is assumed you are using resistance coupling, about 1. meg. plate load resistor, and not a transformer primary in the 55 plate circuit, as diode biasing of a transformer-coupled circuit with primary carrying the direct plate circuit is specifically taboo on account of too-high average plate current, particularly high plate current at no modulation, which endangers tube life.

* * *

EFFECT OF SHIELD

ABOUT what is the inductance drop when a coil is put into a shield? I refer particularly to the type shields used commercially today. —W. E. R.

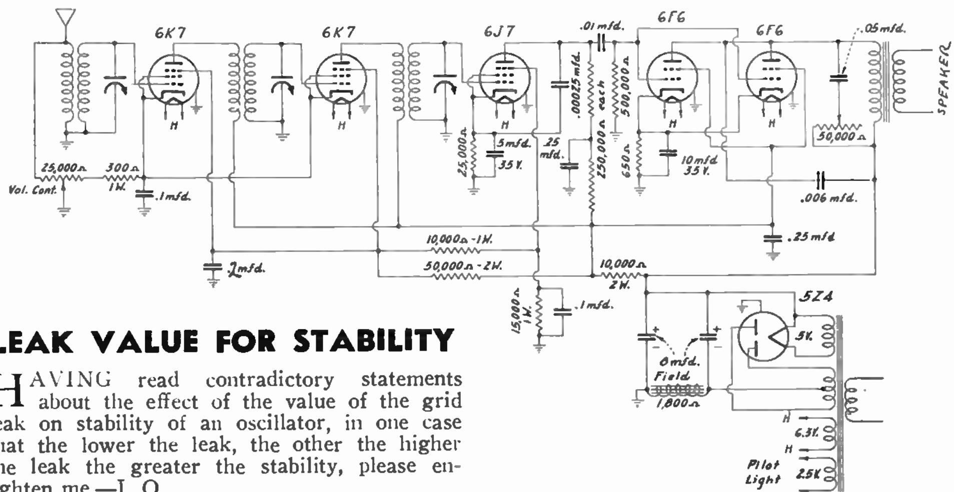
Considering a shield of 2 1/16 inch outside diameter (aluminum or copper), and a coil wound on one inch diameter tubing, centered in the shield, so no part of the coil is closer to the inside shield wall than ⅞ inch, the inductance drop due to enclosure in the shield is about 10 to 13 per cent. The capacity increase is very small, a few micromicrofarads. Coils in the broadcast band were measured. Such results are important to consider when winding coils on data for unshielded varieties and yet the coils are to be enclosed in shields. A good rule is to measure the inductance change and allow for it, otherwise add 12 per cent. to the required inductance and solve for the higher inductance, realizing that shielding will encompass the contraction.



Audio transformer used for modulator (center 37).

RADIO CONSTRUCTION UNIVERSITY

Answers to Questions on the Building and Servicing of Radio and Allied Devices.



Six-tube t.r.f. set.

LEAK VALUE FOR STABILITY

HAVING read contradictory statements about the effect of the value of the grid leak on stability of an oscillator, in one case that the lower the leak, the other the higher the leak the greater the stability, please enlighten me.—I. O.

Depending on the circumstances, either statement may be correct. If any power considerations arise, the lower leak makes for better stability, and low value of leaks are commonly used in transmitters for that reason. The leak should be low enough to result in the same slope of curve for the grid current as for the plate current, though the phases are different, where only voltage is desired, practically no power taken out, the high values of leak may work in the direction of improved stability. The conductance of the tube being rather low, the high leak holds up the oscillation, and thus diminishes the likelihood of abrupt changes. The word *stability* as used here means frequency constancy. In another view of oscillators stability is sometimes intended to mean that the life of the oscillation continues, and instability to mean that the circumstances that originated the oscillation die out.

* * *

HIGH FIDELITY BASIS

CAN the straight characteristic of an amplifier be taken as high fidelity reproduction?—K. L.

No, considerably more than the amplifier has to be considered, for instance, the speaker, the baffle, and the acoustics of the room, auditorium or theatre. A metered test of the amplifier might prove almost ideal amplification, but the reproduction as heard might be far from that.

TWO DIAGRAMS

PLEASE show a multi-band r.f. oscillator modulated with an audio oscillator using a transformer. What kind of oscillation transformer do you recommend for the audio oscillator? I should also like to have the diagram of a tuned radio frequency receiver with bias detection and power pentode output. I should prefer a metal tube set.—F. W. K.

You will find the radio frequency oscillator at the bottom of page 60. It is a four-band Hartley. The audio transformer for the modulation oscillator may be a cheap transformer with low turns ratio. Use no condenser across either winding. A good transformer is likely to generate a frequency that is entirely too low. A one-to-one output transformer could be used to advantage. The circuit on this page answers your requirement for a t.r.f. receiver.

* * *

REMOTE SPEAKER

WILL you please tell me whether it is all right to connect a speaker a considerable distance from the set, without any special precautions, or, if there is some way of avoiding volume drop. please explain it.—W. D.

For distance of more than a dozen feet, say, especially where there is considerable power, it is advisable to minimize the losses in the con-

CATALOGUES

A new 64-page catalog featuring a large assortment of radio receivers, public address amplifiers and systems, radio service replacement parts, electrical appliances and electrical refrigerators, has been brought out by Wholesale Radio Service Co., Inc., of New York. The book measures 7 by 10 inches and is printed in rotogravure in three colors. Wholesale Radio's main office is at 100 Sixth Avenue, N. Y. City, while the following are branch offices: 901 West Jackson Blvd., Chicago, Ill.; 430 West Peachtree St., N. W., Atlanta, Ga.; 219 Central Avenue, Newark, N. J.; 542 East Fordham Road, Bronx, N. Y.

* * *

Catalog No. 131A, listing Electrolytic Condensers made by Cornell-Dubilier Corporation, 4343 Bronx Blvd., New York City, has just been published.

* * *

The Magic Magnet Speaker Catalog of 8, 10, 12, and 18-inch speakers has been issued by Cinaudagraph Corporation, Stamford, Conn.

Tubular Condensers Improved by Cornell-Dubilier Corp.

An improved line of tubular condensers is announced by Cornell-Dubilier Corporation, 4343 Bronx Boulevard, N. Y. City. Outstanding changes are increased impedance to radio frequencies and high internal resistance at high humidity operating conditions. The condensers are recommended for bypassing at radio, intermediate and audio frequencies and a. f. and r. f. coupling, also as tone control adjuncts. The condensers are known as Tigers and Cubs, according to size.

Durham, Nadell and Fischer Appointed

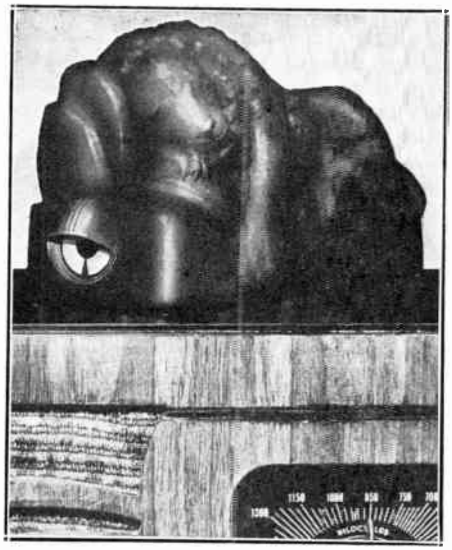
Wholesale Radio Service Co., Inc., 100 Sixth Avenue, N. Y. City, announces the following additions to its forces: Wilson N. Durham, manager of public-address sales for the metropolitan New York area; Aaron Nadell, author, special engineering consultant and correspondent on p. a. problems; Leonard Fischer, design engineer in the high-frequency development laboratory.

Tube Base Diagrams

Tube base diagrams of more than sixty different prong arrangements and connections are shown in a folder issued by the Western Electrical Instrument Corporation, Newark, N. J. Base connection diagrams for octal base tubes, both metal and glass, are included.

A table in the folder classifies more than 300 makes and types of tubes according to their tube base connections as shown on the charts.

Lion Rests, Eye Alert



They say a lion can see in his sleep, meaning he can sense a noise or intrusion and wake up with a snap. The above lion is cast, never wakes up, and the eye that's alert is the electric one (6E5 or 6G5). The device permits resonance and voltage determinations, is self-powered, works on any set and is known commercially as The Magic Lion. The casting duplicates the Lion of Lucerne, famous statue.

Literature Wanted

Readers whose names and addresses are printed herewith desire trade literature on parts and apparatus for use in radio construction. Readers desiring their names and addresses listed should send their request on postcard or in letter to Literature Editor, Radio World, 145 West Forty-fifth Street, New York, N. Y.

F. W. Boland, 181 Frederick Street, Ashfield, N.S.W., Australia.
Oscar C. Kelly, Kelly's Radio Service, Kosciusko, Miss., on radio, radio servicing and construction.
David Salzman, c/o Union Radio Service Lab., 2007 Foster Ave., Brooklyn, N. Y.
James A. Flick, 208 West St., Wilkinsburg, Pa.
Coles Radio Service, Jewell Ridge, Virginia, on construction of radios.
Joe Sabath, 120 Clarion St., Oil City, Pa., diagrams of 80 meter transmitters.
A. Ward Howe, New Hartford, N. Y.
Francis Swanson, 723 Orchard Ave., Chariton, Iowa.
Wilmer E. Brubaker, P.O. Box 176, Cabool, Mo., radios and radio replacement parts.
Harry H. Middleman, 415 West Fifth Avenue, McKeesport. Pa.
S. P. McCoun, 3106 North 10th St., St. Joseph, Mo.
Robert Wold, 3843 Nevada Ave., Fresno, Calif.
Ingwald Haugen, 832 Craire Ave., Rice Lake, Wisc.

nomena. When there is conduction the electrons drift along and it is that drift that constitutes current. In dielectrics the electrons are "bound" to a point of equilibrium and they are displaced a little from this point. It is the displacement that constitutes the current. But are electrons essential to the propagation of electro-magnetic waves? If they are, empty space must be chock full of bound electrons. Of course, it may be that what constitutes an electron in a dielectric constitutes "ether" in free space!

This application of wave guide theory that has come out of Bell Telephone Laboratories and which is discussed elsewhere in this issue is an eye-opener. The claim is made—and it has been proved—that electric waves will travel down a metallic pipe without a return path and also that such a wave will travel down a rod of dielectric material, that is, an insulator, without any metallic conductor. Either type of contrivance is called a wave guide. It appears that both of these guides are the same in principle. In each case there is a bounded dielectric and at the boundary there is a sudden change in the electrical properties. The metal pipe is a good conductor and therefore a good reflector, just as a mirror is a good reflector.

RESONANCE WITHOUT DISCRIMINATION

WHEN we tune a circuit composed of inductive and capacitive elements we adjust either the inductance or the capacity until the current in the circuit is maximum or until the voltage across it is maximum. We then say that the circuit is in resonance with the frequency of the voltage by which it is agitated. We accept as axiomatic that there is only one frequency which will satisfy the conditions. We do that every time we tune a radio set to some desired station. We need not quibble about the fact that the current is maximum at one frequency and that the voltage across the circuit is maximum at another. In all practical cases these two frequencies are very nearly the same.

We could also define resonance as that condition in which the circuit offers zero reactance to the frequency impressed. When the current is maximum in a series circuit the reactance is zero and there is only resistance in series with the impressed voltage. Also, when the voltage across a parallel circuit is maximum the reactance is zero and the resistance is L/CR, where L is the inductance of the coil, R is the resistance in the coil branch, and C is the capacity of the condenser branch. This resistance is extremely high. Practically, there is only one frequency of resonance in either case.

In view of these definitions could there be a circuit which is resonant for all frequencies at the same time? Yes, there could. But surely that answer is a slip of the tongue. It must be a momentary mental aberration. No, it is quite true. That is, it is true if we define resonance as the absence of reactance in a circuit composed of inductance and capacity in parallel. Let us explain.

Suppose the inductance is L and the resistance in the coil branch is R. Also suppose that the capacity in the condenser branch is C. Further suppose that there is a resistance in series with the condenser and that this resistance has a value R. That is, its value is exactly the same as the resistance in the coil branch. Let us make one more assumption. Let R squared be equal to the ratio L/C. What is the reactance of a parallel circuit formed of these two branches? It is zero, and it does not in the least depend on the frequency. That is, it is zero for all frequencies. The resistance of the circuit is $(L/C)^{1/2}$. If the inductance had a value of 250 microhenries and the condenser a capacity of 250 mmfd., the square root of the L/C ratio would be 1,000 ohms. Thus 1,000 ohms would have to be placed in series with each branch, that is, 1,000 ohms present in series with the coil and the same amount of resistance in series with the condenser. The line resistance would then be 1,000 ohms for all frequencies.

Incredible But True

The Returnless Wave Startles Science—Also, Imagine a Circuit "Resonant" to Everything!

—AND NEVER RETURN AGAIN

WE never hesitate to speak of open circuits. Sometimes we mean by an open circuit that there is no circuit where there should be one. That is, we mean that there is a break in the circuit. But at other times we mean a circuit in which there is a condenser. But if there is a circuit it must of necessity be a closed circuit. The closing makes the circuit; the opening of it unmakes it. In one of the Bureau of Standards publications the statement is made that there are no open circuits. That statement is obviously true. If we speak of an open circuit we must do so with a tacit or expressed apology.

It has always been axiomatic that there must be a return conductor in an electric transmitting line. It is understood that the earth may form the return. Up to a very short time ago any suggestion that no return conductor was necessary would have been ridiculed. Yet now it has been shown that the return conductor may be dispensed with. Worse than that—or maybe better—it has been shown that even the "go" conductor may be dispensed with. Energy can be sent by electromagnetic waves with only one conductor, provided the shape is right, or without any metallic conductor, provided that certain other requirements are met. At first meeting with this idea it is astounding. After a little thought the possibility of such transmission appears obvious. Simple analogies help to make it so. The idea is intriguing both mathematically and experimentally.

What becomes of the old axiom that there must be a return path? Are we still disposed to laugh at any suggestion that no return is required? No, not quite so ready. But still we might smile, though only after we have made certain that we have left a diplomatic door open for a face-saving retreat. We know we can hurl a jet of water without a return, as long as the water supply lasts. We know also that we could cool an auto engine or heat a room without a water circuit, if we had a steady supply of new water. Simple circulation is involved here. No waves.

Do we have to have a return when we send waves and energy carried by waves? We do not. We can send voice waves down a speaking tube as long as the vocal cords will vibrate. We can do this without circulation of air. It is possible to seal off both ends and still talk through the tube. We do not even have to stand for any back talk from the remote end of the tube. If we had any means of launching sound waves efficiently on a steel wire, we could substitute such a wire for the speaking tube. The wire would then be a sound wave guide. It is clear that no return path is necessary.

In a radio transmission line, either of the concentric or Lecher wire types, is one conductor the "go" and the other the "come"? Heretofore we have thought of transmission line phenomena in such terms. But does thinking in a groove make it so? Hardly.

We are accustomed to thinking of electrons in connection with transmission phetwo hollow copper pipes are used, which are four inches and six inches in diameter and 1,250 feet long.

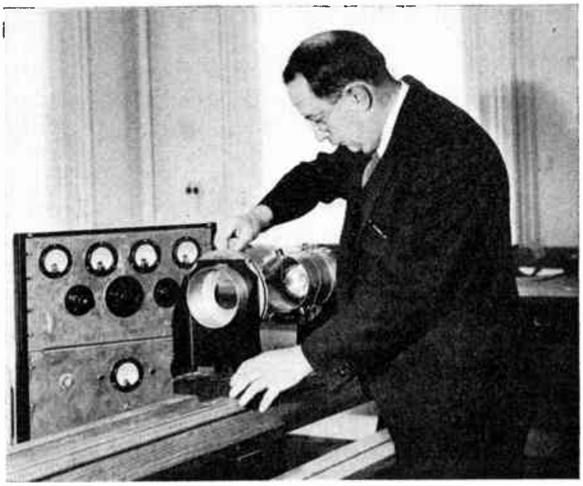
In much the same way that a pair of wires may resonate to waves traveling along their length, or an air column may resonate to certain sound waves, so may a short section of wave guide be made to resonate electrically to the frequencies which it is able to propagate. In its role as a resonator it behaves as if it were a coil and condenser, sometimes in series with an electromotive force, and sometimes in parallel. These resonance effects are very pronounced and may be simply demonstrated by a cylindrical chamber such as that shown in Fig. 3.

The open end of a guide may be made to radiate wave power much the same as sound waves issue from a pipe. To enhance this effect the pipe may be expanded into a cone, thus producing an electrical horn. Tests show that it may function much the same as an acoustical horn, and accordingly may be used as an efficient radiating load for the generator to which it is connected.

The question naturally arises as to what use wave guides may be put. This is a difficult question at this early day. Wave guides have definite limitations. The diameter of the hollow pipe that may be used is directly proportional to the wave length. For a pipe that is at all convenient in size, the frequencies are the highest that have yet been tried out for radio. It is true that the diameter of pipe might be reduced if it could be filled with a suitable insulator.

At this point we are met with a conflicting difficulty of producing at reasonable cost the necessary medium that will incorporate high dielectric constant with sufficiently low losses. It is true too that low attenuation could probably be had with much smaller pipes by the use of H_0 waves, but this calls for an even higher range of frequencies.

For long-distance transmission, the situation is that the art at these extreme frequencies is not yet at a point which permits a satisfactory evaluation of practical use. For transmission over very short distances, however, or for use as projectors of electric waves, or as selective elements under certain conditions, the use of wave guides has definite possibilities.



Some of the experimental apparatus used for the wave guide transmissions. The hollow metal cylinder just below the operator's right hand is a resonator which is being adjusted to resonance with a high frequency signal generated by the oscillator at the left. Another resonator may be seen in the background. A long pipe of the same diameter as that of the resonator constitutes the wave guide. A wave guide is not an electric conductor in the usual sense, but is literally guide in the same way as a speaking tube is a guide for sound waves. In these the air does not move conductively. Only the wave moves from one end to the other. The analogy between sound guides and electric wave guides cannot be perfect.

It's Convention Month, Hence P. A.

This is the year of power amplifiers and public address systems. Nearly everybody in the radio business is "going in for" public address work. Why this sudden interest in a line that has been comparatively dead? Why, it is not a sudden interest. It is merely a simultaneous outburst of interest that has been accumulating for four years. The main reason for the interest is the political activity promised after the nominating conventions this month. Between June and November thousands of politicians will spout political promises and economical panaceas. And much of the spouting will be amplified. Every radio man should be ready to share in the profits of public address amplifiers and accessories.

Of course, public address amplifiers will not be confined to political activity. Many will be used for entertainment purposes. Roadside inns will instal systems in order to supply dance music to their patrons. Small towns will instal systems for the education and entertainment of their citizens.

As a result of this interest there is also an increased interest in phonograph records and in other forms of recorded sound.

(*Continued from preceding page*)

The analytical work of Rayleigh and others has now been greatly amplified. The extensions which have been added to the theory include calculations of characteristic impedance, attenuation, and inductive effects into neighboring wave guides,' and particularly the discovery that, theoretically at least, one of the many waves that may be transmitted through a hollow pipe becomes progressively less attenuated as its frequency is raised. This remarkable property appears altogether unique in the field of electrical transmission.

These electric waves that are guided through hollow pipes and dielectric rods are moving configurations of electric and magnetic fields.

Various Associations

Mathematical theory indicates that in cylindrical guides these two fields may be associated in many different ways to provide a wide range of types of waves. Four of these are shown in Fig. 1. They may be generated by any source of sufficiently high frequency, such as a Barkhausen or a magnetron oscillator. To set up any particular type of wave it is necessary, of course, to provide an appropriate launching mechanism. If the E_0 wave is desired, the source may be connected between the outside shell of the guide and a rather large central disc perpendicular to the principal axis. For H_1 waves the source is connected between diametrically opposite points on the inside of the pipe.

Wave guides behave somewhat like wire lines in that they have a definite characteristic impedance and a definite attenuation. Also waves travel through them with a velocity that may be predicted with considerable accuracy. The calculated attenuations of the four principal waves are of particular interest. They are shown in Fig. 2 for the special case of a five-inch hollow copper pipe.

It will be noted that all waves suffer infinite attenuation at or below certain critical frequencies, and that with an increase in frequency this attenuation decreases very rapidly. For three of the types of waves it approaches a minimum, and then increases for higher frequencies. For the wave that has been designated as H_0 this attenuation appears to decrease indefinitely with increase of frequency.

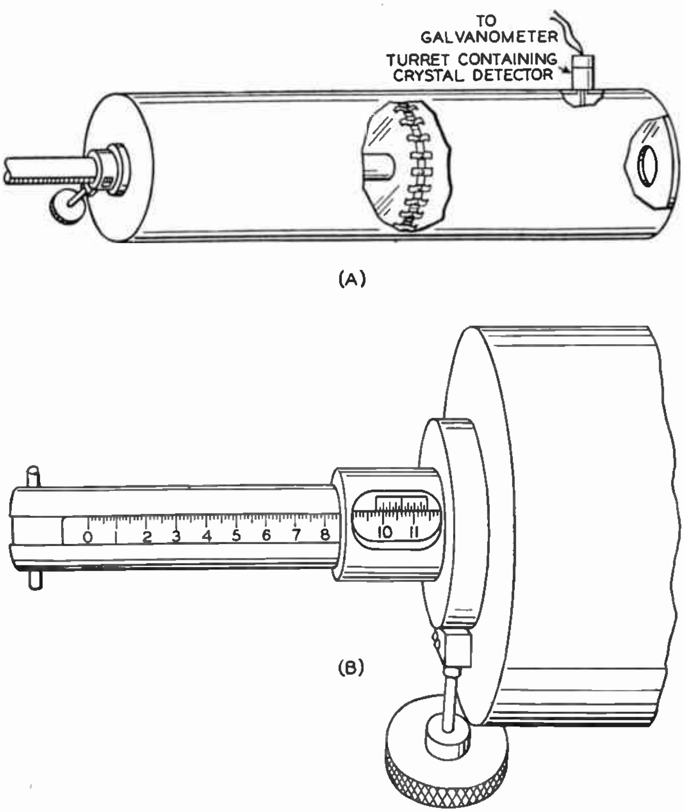


FIG. 3.

Waves that can be transmitted on a wave guide are subject to strong resonance phenomena. Here are two views of a resonator. It consists of a hollow metal cylinder the length of which can be varied accurately. A crystal detector is employed to indicate when resonance occurs.

Hollow Copper Wires

Not all of the calculated characteristics of wave guides have yet been verified experimentally. In particular, no information is yet available on the very interesting H_0 wave except near cutoff. At present, the author, together with A. E. Bowen, A. P. King, and J. F. Hargreaves, is working at the Holmdel Radio Laboratory measuring the attenuations. For this purpose the outer tube forms one side of the circuit and the central conductor the other. If, however, instead of operating such a structure at a frequency of about a million cycles, approximately the average frequency for broadcasting, a frequency of two thousand million cycles were employed, it would be found that the central conductor could then be completely withdrawn and still the structures would be able to transmit power. It would be necessary, of course, to provide a suitable means for launching the waves, and the form of transmission would be radically different.

Dielectric Effect Considered

In this example the pipe would have had to be at least 4½ inches in diameter, but if the pipe had been filled with an insulating material having a dielectric constant of 4 a 2¼-inch pipe could have been used, while if the dielectric constant had been 9, a 1⅛-inch pipe could have been used. As a matter of fact, the outer pipe itself may also be done away with, and the transmission will take place along a wire or rod of insulating material, and the attenuation will be least when the resistivity of the insulator,

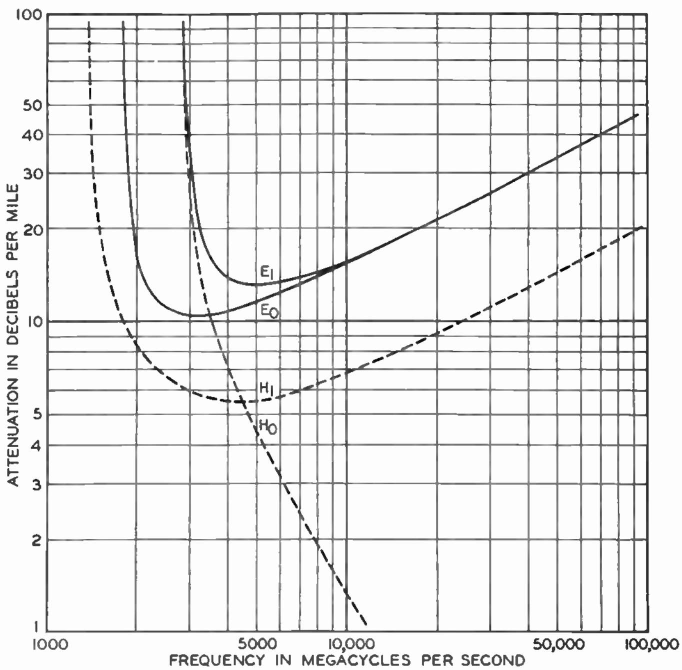
was attempted at that early date. As often happens in science these principles were independently discovered by others. In particular, a group of workers in Germany studied this problem, and published several papers. They were Hondros and Debye in 1910, Zahn in 1916 and Schriever in 1920. Also our own J. R. Carson in 1924 and R. V. L. Hartley in 1931 gave thought to this problem. Both Zahn and Schriever did a small amount of experimental work but it related mainly to the form of wave guide consisting of insulation alone, and dealt with just one of the many types of waves that may be propagated. The published literature indicates that their work was dropped at that point.

Work Amplified

In 1931 the author resumed some experimental work on this subject, which he had started in 1920. This has now been expanded slightly and moved to our Holmdel Radio Laboratory where long wave guides may be constructed. Some details have been given in the April, 1936, issue of the Bell System "Technical Journal." Throughout this experimental research there

FIG. 2.

These curves show the attenuation in decibels per mile of four different types of waves on a wave guide. For all types there is a critical frequency below which the attenuation is infinite. For three of the wave types there is one frequency at which the attenuation is a minimum. For this particular wave guide the frequency is approximately four billion cycles per second. The most interesting type of wave is that indicated by H_0. The attenuation for this decreases indefinitely as the frequency increases.



acting as a guide, is the greatest.

Incredible as these phenomena may seem at first sight, they are readily explicable on mathematical principles that have been known for many years.

As early as 1897 Lord Rayleigh obtained solutions for certain differential equations occurring in electrical theory that indicated that wave power could be propagated through either hollow metal pipes or through dielectric rods. So far as is now known, no experimental work

has been considerable work done by members of the mathematical groups, notably by J. R. Carson, Sally P. Mead, and S. A. Schelkunoff, who also have a paper in the Bell System "Technical Journal" for April. Sometimes experiment has suggested analysis. Sometimes analysis has suggested experiment. As in military operations so in experimental research, greatest progress is made when the efforts of line and staff are complementary.

(Continued on next page)

Electric Wave Guides

Propagation with No Return Circuit

By G. C. Southworth
Radio Research, Bell Telephone Laboratories

IN the early days of electrical communication, it seemed axiomatic that there must be a completed circuit to permit the flow of electric current or power. A return path, either in the form of another wire or the earth, was apparently essential. With the advent of radio this seemingly fundamental law was broken, because for radio transmission no return path in any ordinary sense is required. Radio, however, was very evidently a distinctly different type of transmission. The radio waves simply traveled in all directions through space as does light or radiant heat.

Something New

Researches in Bell Telephone Laboratories have disclosed a new form of transmission for high frequencies. It is unlike radio because the waves are not broadcast through space but follow a physical guide comparable to a wire. No return path, however, is required of the kind that is commonly assumed in the usual case of transmission. With an ordinary concentric conductor, such as is used for feeding a radio antenna,

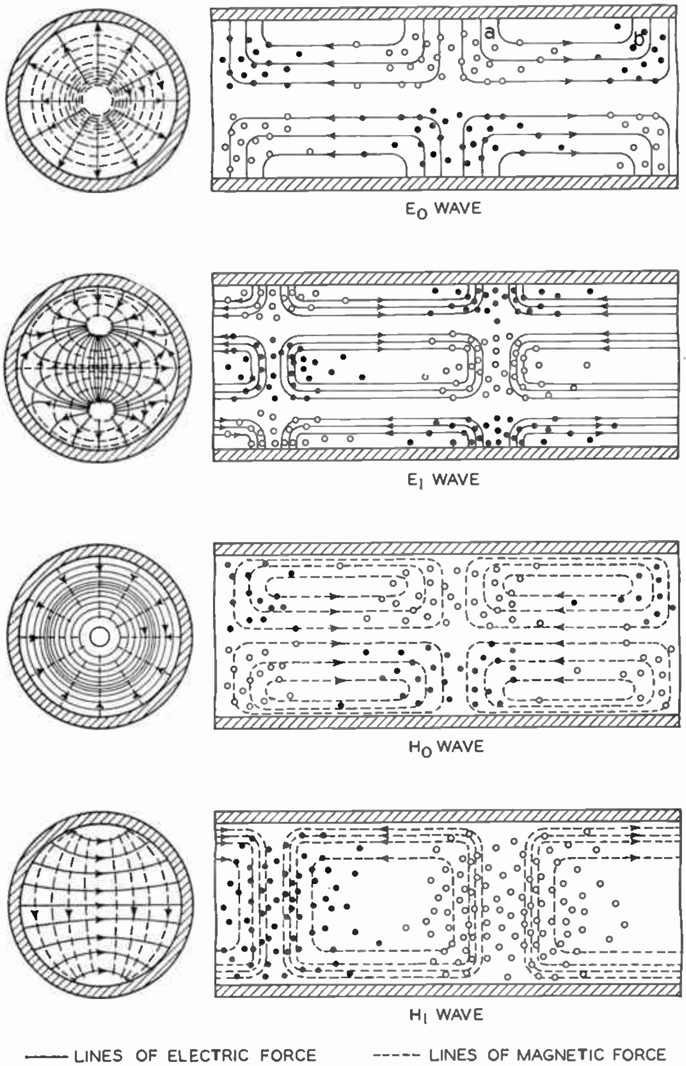


FIG. 1.

Four types of possible waves on a wave guide are illustrated here. In the E_0 wave the electric force is radial and the magnetic force concentric. In E_1 the electric force lines are suggestive of the flux lines about the poles of a bar magnet and the magnetic lines to the equipotential lines. In H_0 the pattern is the same as that in E_0, but with the electric and magnetic lines reversed. In H_1 the electric force lines are similar to parallels of latitude and the magnetic force lines meridians. The distributions of electric or magnetic potentials along the wave guide are shown at right.

when used in this position. This trouble can be reduced, if not entirely eliminated, by installing the potentiometer in the grid circuit of the triode or a. f. amplifier. If increased hum results from this method the grid circuit should be filtered by installing a .1 or .25 meg. resistor from the low potential end of the control to the source of bias voltage, and bypassing the joint of the two resistors to the cathode of the tube by the largest paper condenser that can be conveniently used. Such filtering is recommended in any event for improved tone and reduced hum.

Reduced A.V.C. Voltage

It will be observed that the common a. v. c. filter resistor is often left unbypassed. If loud squawks develop, when the receiver is being tuned to a signal, apparently due to repeats or images from strong stations of higher frequency, it may be necessary to bypass the resistor as shown by dotted lines in the diagram (Fig. 3). The smallest possible capacity should be used at this point to avoid increasing the time constant of the system unduly. Usually .006 mfd. will provide the desired results.

Since there are two diode plates provided there may be a little more volume using them in parallel, but there are advantages in using them separately.

The principal advantage is that a. v. c. may be obtained independently of the demodulator circuit, and control action may be delayed to obtain better sensitivity on weak signals. It will be found that stations formerly almost inaudible may be brought in with respectable volume by delaying the a. v. c. action.

It will be found by a little investigation that often more voltage is being developed in the a. v. c. section than is necessary. This condition may be easily checked by merely shunting various size resistors from the filter resistor to the load resistor, as shown in Fig. 3, thus forming a voltage divider across the load resistor and enabling the experimenter to determine the approximate proportion of voltage desirable. When this is done the receiver should be checked by the signal of the strongest local available, to be sure that the control voltage has not been reduced so much that the first detector becomes overloaded. If the receiver is used largely for the reception of local stations the a. v. c. voltage should not be reduced to a point where the manual volume control would have to be almost fully retarded for customary reception.

The changes are all included in Fig. 3.

Keeping The Soldering Iron Point Clean

By Walter E. Bonham

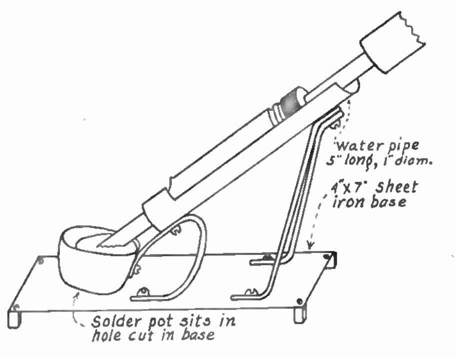
NOTHING is more annoying to the shopman than to have his soldering iron point always dirty, the tinning burned off the point every time a joint is to be soldered or unsoldered. Even a clean, well-tinned iron while heated and exposed to the air becomes oxidized and the tinning burns off, requiring cleaning and retinning.

The arrangement shown is about the best I have ever used to keep the iron always clean and well tinned, ready for use. It essentially is an arrangement which holds the point of the iron in a bowl of solder which the point keeps melted. The point is next submerged in the solder and is thus free from exposure to the air. Besides, the heat is conducted away from the tip.

By building the holder at the proper slope and by regulating the level of the solder in the bowl as much of the point as desired may be kept clean.

Any small iron crucible or the dipper part of a small ladle can be used as the solder pot. A 5-inch length of one-inch inside diameter water pipe cut as shown constitutes the cradle and holder for the iron.

The pipe is cut as follows: One-half inch from one end cut the pipe crosswise, half the diameter. Then cut the pipe lengthwise from the other end, cutting down the middle to meet the first cut evenly. Remove the loose piece. In a piece of 4x7 inch sheet iron and near one end cut a hole to accommodate just the bottom round of the solder pot. Fasten the pipe and the bowl together as shown by a small iron strap of sufficient length to enable bending it around, and fasten to the base when the solder pot is in the depression cut for it and the iron pipe is at the right slant. Two thin iron straps fasten to the other end of the pipe with a small bolt and are spread as an inverted V and fastened to the base. The base is elevated sufficient to clear the bottom of the bowl by any kind of legs or small wooden blocks which may be handy around the shop.



How Walter E. Bonham solved the problem of keeping solder tip clean.

(Continued from preceding page)

power factor condensers, that is, condensers in which the losses are small. These losses are of practically no consequence in the B filter, unless of such great proportions as to indicate condenser breakdown.

Besides leakage, it is desired to test capacity. This is not so readily done, unless one has a meter specially built for the purpose. Capacity testing by a simplified method, using a rectifier type a.c. meter, was discussed in last month's issue. Herewith is given a circuit wherein the capacity of the unknown Cx may be determined on the basis of the quantity of d.c. plate current.

The line voltage is introduced into a transformer that has two separate secondary windings. One secondary feeds one triode and the other secondary another similar triode. Both of these tubes are negatively biased by batteries to just the point where the milliammeter indicates there is no plate current through the upper tube, a 37 or 76 or 6C5 with "unknown" terminals shorted. The tube is then removed and the other intended for similar tube plate current cutoff is put in the socket, to be sure the same condition obtains. In this way two equal or nearly equal tubes are found, and the third is used as B rectifier.

The theory of operation is that when the condenser Cx is connected between the unknown terminals, it will be charged by the B voltage from the rectifier, due to the upper tube becoming conductive when the B potential is applied. Meanwhile the lower 37 remains nonconductive as its negative bias is simply augmented by the a.c. input alternation being negative. However, the phase reversal in the next cycle makes the lower tube conductive, thereby permitting the discharge of the condenser, and the resultant direct current flow is a measure of the capacity of the unknown. If the unknown is Cx, the voltage is E and the frequency is f, the current I = CxEf, so Cx = I/Ef. The frequency f may be considered a constant, 60 cycles, and the voltage E may be a constant, and adjusted to 100 volts, read on the voltmeter. Then Cx = I/6,000. The capacity Cx is in farads, and values in microfarads are desired, therefore Cx is to be multiplied by 1,000,000. However, I is in amperes, while milliamperes are desired, so I is to be multiplied by 1,000. Hence the formula becomes Cx (mfd.) = I (ma) /6000. Hence Cx (mfd.) = Ima/6, or one mfd. equals one-sixth of a miliampere or 167 microamperes. The meter could be shunted so that there would be one milliampere through the meter and five milliamperes through the shunt, total current 6 milliamperes, whereupon full-scale would be read as 10 instead of as one, and represent 10 mfd. Capacities then could be read, from .2 mfd. to 10 mfd. on the usual 0-1 milliammeter with 50 divisions.

The capacity measurement method applies to all types of condensers, including electrolytics.

Remedies for A.V.C. Troubles

By R. K. Wheeler

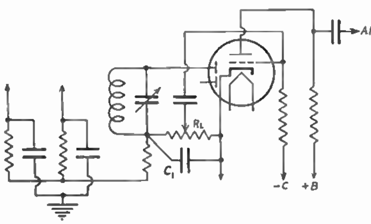


FIG. 1

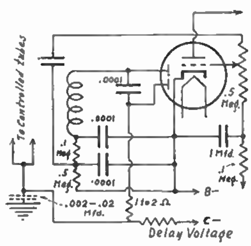


FIG. 2

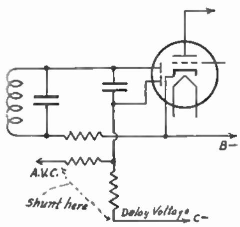


FIG. 3

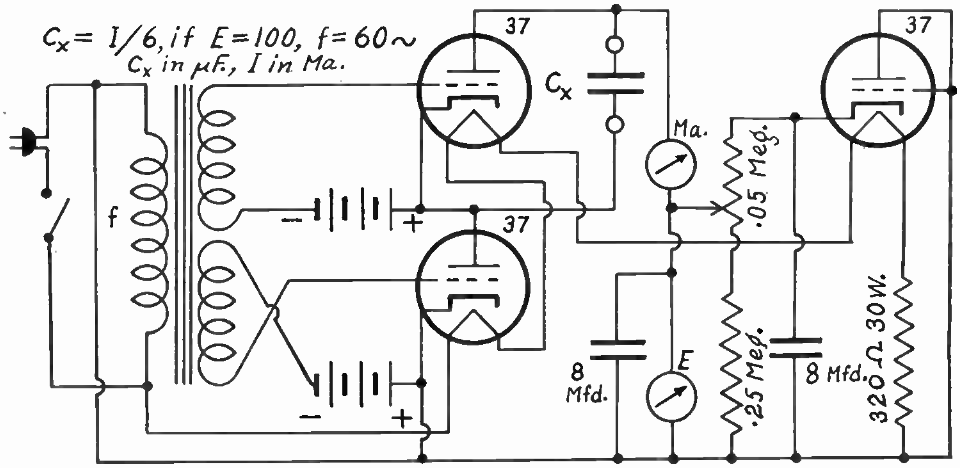
THE automatic volume control circuit most commonly published, and largely used in the smaller receivers, is shown in Fig. 1, and several changes may be made in this circuit for improved operation.

The small condenser C_1, across the diode load resistor, is necessary to help remove the intermediate frequency from the a. f. component of the signal. The goal is not fully accomplished by this method, so further filtering is recommended, by adding small condensers from grid or plate (or both) of the triode section to ground or cathode. This filtering is more effectively done by placing a .1 meg. resistor between the coil and the load resistor, Rl, and bypassing at each end of the added resistor, with a .0001 mica condenser to cathode (Fig. 2). This usually eliminates the need of condensers at the plate and grid of the triode, although the desirability of the inclusion may be checked experimentally.

Relocating the Volume Control

A potentiometer is often used as diode load and manual volume control, and most of the available controls seem inclined to become noisy

SERVICE BUREAU



A method of measuring high capacity (Cx), based on applying 100 rectified volts to the plate (measured at E), biasing the left-hand pair of 37's to cutoff, and reading the current I in milliamperes through the meter Ma. Cx in microfarads equals I (milliamperes) divided by 6, for 60-cycle frequency. If a 0-1 milliammeter is shunted so 1 ma at full scale passes through ma and 5 ma through the shunt, full scale equals 10 mfd. and the meter is direct reading in capacity. Electrolytics may be measured as well as paper condensers.

Capacity Measured, Including Electrolytics

By Barry Walters

THE circuit for testing condensers for leakage by the flash-counting test is shown herewith. A rectifier, small filter and a neon tube are used. The unknown, or condenser to be tested, is put between two open terminals. If the flashes occur once or fewer times per second the condenser may be approved.

All types of condensers may be tested this way, including electrolytics, which usually have the highest leakage. Mica condensers have such small leakage that the equivalent of "no results" may prevail, even if the capacity is very large, which is unusual for the mica types. The test for them, then amounts simply to finding out if the condenser is shorted. There is some value here, nevertheless, as intermittent shorts, a perplexing trouble on the few occasions when it does arise, will show up.

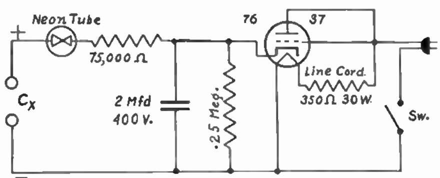
As may be inferred, the circuit is also a continuity tester.

It is easy to memorize the frequency condition represented by one flash a second, and since one will prefer to be too particular rather than not conscientious enough, he will discard condensers that give a quick repetition, obviously more than one a second. No stopwatch or pocket watch is needed in connection with the practical application of the test.

The neon tube used is preferably of the type that has no limiting resistor built in. This is not the regular type of night bulb sold in stores, although many radio stores, and practically all the catalogue houses, have the lamps without the built-in-resistors. Even the night lamp type can be used, however, but the limiting resistor will be of somewhat higher resistance than 75,000 ohms, which tends to reduce the frequency of the flashes. Wattage of ¼ watt or less is sufficient.

The tolerance of higher leakage for electrolytic condensers is acceptable, because the circuits in which they are used (principally B filter circuits) are not ones requiring low

(*Continued on next page*)



Using a neon tube without limiting resistor built in, Cx is tested for leakage. Flashes greater than one a second indicate too much leakage.

Distortion Proved in Overloaded Ear

Everyone who listens to music by radio knows that it is possible to "overload" the loudspeaker of his receiver. This is particularly easy when listening to a nearby or very powerful station. If one turns up the amplifier and puts more power into the loud speaker, the quality of the music may be spoiled. The expert says that this is because the amplifier or the loudspeaker has been "overloaded." The receiver, in that condition, gives out some tones that don't belong in the music at all.

The human ear can be overloaded in the same way. When it is, the brain hears sounds that have not reached it through the ear at all. John Mills, of the Bell Telephone Laboratories, tells the story in his last book, "A Fugue in Cycles and Bels." He says:

Music Hashed

"Starting with only two or three strong musical tones in the radio input, a badly overloaded amplifier, or overloaded loadspeaker, can make a veritable hash of music; and too frequently one or the other does just that. When the ear does it, that is different, because there really is a good deal in having hash made at home."

Then he goes on to tell how in the Laboratories it has been proved that when you are listening to a single pure musical note, if that note is made loud enough, you will hear also still higher tones. You will hear the next octave above that note, the G tone above that, and a tone two octaves higher. The louder is the single pure note to which you are listening, the more you hear of these tones which don't exist.

Proximate Tone Used

In the Laboratories, where they carry out fundamental investigations of hearing and speech for the Bell Telephone System, the scientists developed a neat and ingenious method for proving that such higher tones actually exist in the inner ear, even though they do not exist in the air outside the eardrum.

The trick was to use another tone not quite in tune with one of the higher tones, but just enough "off" from it to make a sort of discord. What one then heard was the recurrent swelling of a tone, the "beats" which are evident when two tones are not quite alike but very close in pitch. The presence of "beats" proved the existence in the ear of these higher tones, although only a single pure note had been sounded.

In "A Fugue in Cycles and Bels" the author tells other interesting things which scientists have learned about the hearing of musical tones and also what electricity can do for music.

The words "cycles" and "bels" are borrowed from the vocabulary of telephone engineers. "Cycles" is used to describe, for any complex musical sound, the pitch of a component tone; and "bels," or decibels, to tell how intense or loud the tone is.

WJZ to Bury 85,000 Feet of Copper

Washington.

The National Broadcasting Company filed with the Federal Communications Commission an application for increase of power on WJZ to 500,000 watts. The company also applied for permission to erect a new antenna, a slender steel tower 640 feet high.

"The up-to-date antenna system will increase the efficiency of the present 50,000-watt transmitter, and minimize fading, assuring improvement of reception in the metropolitan New York area from the key station of the NBC-Blue network," said Lenox R. Lohr, president of NBC.

The engineers of the National Broadcasting Company, under O. B. Hanson, Chief Engineer, and Raymond F. Guy, are collaborating with RCA engineers in planning the new antenna system and transmitting equipment, which will be produced by the RCA Manufacturing Company.

"The antenna system proposed," said Mr. Hanson, "is a slender steel tower of approximately 8 feet cross-section from top to bottom, held in position by means of two sets of guy wires. The ground system will comprise a vast buried network of copper ribbon of 85,000 feet. Directly under the antenna there will be a copper screen 150 feet in diameter, to minimize any losses which might occur in the earth at this point.

"The tower structure will be connected with the transmitting apparatus by means of a concentric tube transmission line 10 inches in diameter and 600 feet long. This will provide the maximum efficiency in energy transfer with the utmost reduction in fading and in the radiation of spurious frequencies."

Thick Loom Shielded Wire

WHY is shielded wire of the "thick" type recommended for connection between set's antenna post and antenna coil in the set, as ordinary shielded wire should suffice?

The conductive wire is usually surrounded by small rubber insulation, then a thick serving of cotton, then the braided metallic weave that is to be grounded, which constitutes the outside. Note how by this method the conductor is far enough removed from the grounded part or shield to create very small capacity between them. Hence the loss is small to ground due to capacity, the pickup to the set is greater, and sensitivity is not diminished. This is of particular importance in tuned radio frequency sets, not of moment in big supers.

Tabulated Characteristics of the Sixteen Metal Tubes

Type	Use	Filament Rating Volts.	Filament Rating Amps.	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current ma.	Screen Current ma.	Plate Resistance Ohms	Mutual Conductance Micromhos	Amplification Factor	Load Resistance Ohms	Milliwatts Undistorted Output	Similar Glass Type
5W4	F.W. Rectifier	5.0	1.5	350 RMS.	...	...	110 Max.	...	......	....	....	....	....	None
5Z4	F. W. Rectifier	5.0	2.0	400 RMS.	...	...	125	...	......	....	....	....	....	80
6A8	Converter	6.3	0.3	250	3.0	100	3.3	3.2	500,000	500	....	....	....	6A7
6C5	Amplifier	6.3	0.3	250	8.0	...	8.0	..	10,000	2,000	14	....	....	76
6F5	Amplifier	6.3	0.3	250	2.0	...	0.9	..	10,000	1,500	50-60	....	....	
6F6	Pentode	6.3	0.7	250	16.5	250	34.0	6.5	80,000	2,500	200	7,000	3,000	42
	Triode (screen tied to plate)	6.3	0.7	250	20.0	...	31.0	..	2,600	2,700	7	4,000	850	
6H6	Rectifier	6.3	0.3	100 RMS. Max.	...	...	2.0 Max.	..	......	....	....	....	....	
6J7	Detector, Amplifier	6.3	0.3	250	3.0	100	2.0	0.5	1,500,000	1,225	1,500	....	....	77
6K7	Amplifier	6.3	0.3	250	3.0	100	7.0	1.7	600,000	1,650	1,160	....	....	78
6L6	Power Amplifier (A_1, P-P)	6.3	0.9	250	16	250	120	10	40,000	6,000	135	5,000	1,380	None
6L7	Mixer	6.3	0.3	250	6.0	150	3.3	8.0	1,000,000	325	....	....	....	None
6Q7	Dual Diode, triode	6.3	0.3	250	3.0	...	1.1	..	58,000	1,200	70	....	....	75
6R7	Dual Diode, triode	6.3	0.3	250	9.0	...	9.5	..	8,500	1,900	16	....	....	85
6X5	F. W. Rectifier	6.3	0.6	350 RMS. Max.	...	...	75 Max.	..	......	....	....	....	....	84
25A6	Pentode	25	0.3	180	20	132	40	8	40,000	2,400	95	5,000	2,750	43
25Z6	F. W. Rectifier	25	0.3	125 RMS. Max.	...	...	85 Max.	..	......	....	....	....	....	25Z5

[*See immediately preceding pages for article on the 6L6.*]

6L6

[*Data from RCA Radiotron Division, RCA Mfg. Co., Inc.*]

Heater Voltage (a.c. or d.c.)........6.3 Volts
Heater Current...................0.9 Ampere
Base ....Small Octal 7-Pin

Push-Pull Class A_1 Amplifier

Subscript 1 indicates that grid current does not flow during any part of the input cycle.

Plate Voltage................375 *max.* Volts
Screen Voltage................250 *max.* Volts
Plate and Screen Dissipation (Total) # 24 *max.* Watts

Typical Operation—2 Tubes:

Values Are for Two Tubes

	Fixed Bias	*Self Bias*	
Heater Voltage ##....	6.3	6.3	Volts
Plate Voltage...........	250	250	Volts
Screen Voltage	250	250	Volts
D-C Grid Voltage °.....	—16	—16*	Volts
Peak A-F Grid-to-Grid Voltage	32	35.6	Volts
Zero-Signal D-C Plate Current	120	120	Ma
Max.-Signal D-C Plate Current	140	130	Ma
Zero-Signal D-C Screen Current	10	10	Ma
Max.-Signal D-C Screen Current	16	15	Ma
Load Resistance (Plate to plate)	5000	5000	Ohms
Distortion:			
Total Harmonic	2	2	Per Cent.
3rd Harmonic.......	2	2	Per Cent.
Max.-Signal Power Output	14.5	13.8	Watts

#Precautions should be taken to insure that dissipation rating is not exceeded with expected line-voltage variations, especially in the case of fixed-bias operation. Fixed-bias values up to 10% of each typical screen voltage can be used without increasing distortion.

##The heater should be operated at 6.3 volts. Under no condition should the heater voltage ever fluctuate so that it exceeds 7.0 volts. The potential difference between heater and cathode should be kept as low as possible.

*With no signal.

°The type of input coupling used should not introduce too much resistance in the grid-circuit. Transformer- or impedance-coupling devices are recommended. When the grid circuit has a resistance not higher than 0.05 megohm, fixed bias may be used; for higher values, self-bias is required. With self-bias, the grid circuit may have a resistance as high as, but not greater than, 0.5 megohm provided the heater voltage is not allowed to rise more than 10% above rated value under any condition of operation.

6L6

Push-Pull Class AB_2 Amplifier

Subscript 2 indicates that grid current flows during some part of input cycle.

Plate Voltage................400 *max.* Volts
Screen Voltage...............300 *max.* Volts
Plate and Screen Dissipation (Total) # 24 *max.* Watts

Values Are for Two Tubes

	Fixed Bias	*Fixed Bias*	
Heater Voltage ##....	6.3	6.3	Volts
Plate Voltage...........	400	400	Volts
Screen Voltage	250	300	Volts
D-C Grid Voltage °.....	—20	—25	Volts
Peak A-F Grid-to-Grid Voltage	57	80	Volts
Zero-Signal D-C Plate Current	88	102	Ma
Max.-Signal D-C Plate Current	168	230	Ma
Zero-Signal D-C Screen Current	4	6	Ma
Max.-Signal D-C Screen Current	13	20	Ma
Load Resistance (Plate to plate)............	6000	3800	Ohms
Peak Grid-Input Power °°	180	350	Milliwatts
Distortion:			
Total Harmonic......	**	**	Per Cent.
3rd Harmonic........	**	**	Per Cent.
Max.-Signal Power Output	40	60	Watts

**With zero-impedance driver, plate-circuit distortion does not exceed 2%.

°°Driver stage should be capable of supplying the grids of the Class AB stage with the specified peak values at low distortion.

#, ##, °, *: See notes under Push-Pull Class A_1 Amplifier.

New 1F4 Like 33

A glass type power amplifier pentode, 1F4, has been announced.

The 1F4, having a 2.0-volt filament and an ST-14 glass bulb, is intended for use in the output stage of battery-operated receivers. It is similar in application to the glass type 33, but takes less plate current and filament current. Physical dimensions and connections of both types are identical.

Filament Voltage (D.C.)............2.0 Volts
Filament Current ....0.12 Ampere
Plate Voltage................135 *max.* Volts
Screen Voltage ....135 *max.* Volts
Grid Voltage.....................—4.5 Volts
Plate Current ....8 Ma
Screen Current ....2.6 Ma
Plate Resistance ....200000 Ohms
Amplification Factor.....................340
Mutual Conductance..........1700 Micromhos
Load Resistance.................16000 Ohms
Undistorted Power Output......340 Milliwatts
Maximum Overall Length............4 11/16"
Maximum Diameter..................1 13/16"
Bulb ST-14
Base ....Medium 5-Pin

[*Data from RCA Radiotron Division, RCA Mfg. Co., Inc.*]

what contributes largely to the high efficiency of the tube.

The high power output of course is readily understood as meaning that the output tubes can drive a suitable speaker with a signal with stated wattage behind it when the peak audio volts are delivered to the output tubes' grids, for output distortion level as stated. High power sensitivity means that for a small amount of power expended in the grid circuit there is vastly larger power in the plate circuit, or, a small input power controls a great output power.

Of all the tubes made, the new output tube is alone in the enjoyment of this honor of high power sensitivity, consistent with high power output. In the past tubes might have had one or the other or neither, but never both.

The Beam Circuit

High efficiency means that for the output signal wattage compares favorably to the wattage expended in supplying terminal voltages to the tube for operational requirements, and for the input grid volts. Thus the output signal wattage bears a favorable ratio to the wattage used in all other directions, compared to the case of normal tubes.

As stated, these ends are accomplished by invoking a principle new in power tube design, and in a sense new to vacuum tubes in general. That principle is the beaming of the electron stream, the direction of that stream into a concentrated path, much the same as focusing. The beams are controlled much as if they were rays of light, but of course are not of light frequencies. Fields of potential created by the tube specially located electrodes produce beams of high electron density. Their paths are made to be narrowly continued between the spacing of the turns of which the screen grid is made.

Considered as a single beam confined to a path focused on the screen electrode, naturally the beam develops a space charge, a cloud of electrons. Since the cathode emission intended for a screen is never completely delivered to a screen, due to some electrons returning to the cathode and others remaining for brief suspension just about the screen, there is the equivalent of a steady average value of these delinquents about the screen, though the identities of the electrons is constantly changing. These suspended electrons constitute the space charge and they are limitations on practically all vacuum tubes, since the space charge acts as an obstacle to other and succeeding electrons also seeking the screen or other electrode.

Plate Efficiency Increased

The ingenious accomplishment in the new tube is that the usual drawback of a tube is transformed into an advantage, as the space charge of the screen is made to serve as a suppressor to eliminate secondary emission from the plate. By secondary emission is meant the travel of electrons in the wrong direction, electrons that have been bounced off the plate and thus to limit the plate current, a serious impediment when present. With secondary emission from the plate eliminated plate efficiency soars.

Screen current is likewise reduced, due to focused beam, hence the overall efficiency is increased, as increased efficiency in any single element increases the overall efficiency.

The 6L6 offers much opportunity to the experimenter who has high technical attainments and considerable resourcefulness. Its possibilities are very large indeed. As is true of tubes generally, they are introduced because they serve some distinct purpose, but many other purposes are found, some quickly. Ordinarily a tube does not offer such a vast field of possibilities as the 6L6.

Tonal Effects

One fact well worth considering is that the tube may be classed as a constant current amplifier. Within certain limits of operation, as already set forth, that much could be imagined, since for husky output, nearly 14 watts, the plate current changed so little between maximum and minimum d.c. values. The flat plate current curve removes the requirement of strict ohms loading, since there will be practically no change in the current though there is introduced a considerable change in the load. Also impossible requirements as non-reactive loading of a tube with violent plate current swings is removed.

The effect of working at a very low amplitude level, compared to rated input voltage to the tube, or much lower power output than optimum, is to cause a reactive device like a reproducer to respond more strongly to the high audio frequencies than to the low. If one has a receiver so selective that sidebands are reduced in amplitude, the high audio tones are impaired, and the low-level operation of the 6L6's enables atonement for this discrimination, and an approach to fidelity.

6C5 a Good Driver

The output tubes have to be driven, of course, as a detector alone will not furnish the requirement. A driver should be a 6C5, 6Q7, 6R7 or 6F6 as triode, the 6C5 preferred.

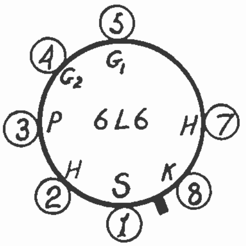
Turns ratios of the push-pull input transformer have an effect. If the 60-watt output is to be utilized the turns ratio should be less than 1 to 3, primary to one-half of secondary. Not more than 1 to 3 should be used for general purposes with these tubes.

Average operating conditions for the 6L6 for Class A_1 (around 14 watts) and Class AB_2 (40 to 60 watts), both push-pull outputs, are given on the following page. Data on single 6L6 output are not given because the method of producing a second harmonic, and none other, is not familiar to us.—EDITOR.

(Continued from preceding page)

and therefore the tubes are better suited for the push-pull output. For Class A_1 push-pull, under given voltage conditions, no grid current, the total harmonic is 2 per cent., made up practically wholly of third harmonic. There is no second harmonic if the stage is balanced.

To capitalize the advantage in the single-ended circuit, i.e., using one 6L6 output tube, is not so easy. It is suggested that the pre-amplifier, or early audio stage, develop sufficient second harmonic and be so coupled to the input grid of the 6L6 that the second harmonic present in this grid circuit is bucked out. This requires, first, a method of generating second harmonic only, and, second, a method of measurement, both of phase and amplitude. The phase must be out by just 180 degrees. These requirements are beyond the ordinary capabilities of experimenters. Moreover, though the suggestion comes from tube manufacturers, the circuit for accomplishing the exclusive generation of second harmonic is not given. The reactive effects of all but tubes heightens the problem. This we state not in criticism but from the frank admission of self-disappointment, as we could not think up the circuit ourselves.



Bottom view of the socket.
Pin 1 = Shell (S)
Pin 2 = Heater (H)
Pin 3 = Plate (P)
Pin 4 = Grid No. 2 (Screen)
Pin 5 = Grid No. 1 (Control Grid)
Pin 6 = Blank
Pin 7 = Heater (H)
Pin 8 = Cathode (K)
The key is shown between 1 and 8.

The best we could do was to assume that even a tiny bit of second harmonic might be present in a supposedly symmetrical circuit, where the supposition was not fully justified (the usual case of push-pull), and to speculate on a way of getting rid of the trouble. This method is to intercept the return to B plus, in the output stage, with the primary of a transformer. No fundamental is present in this primary, the principal voltage is second harmonic, and this is delivered by two secondaries to the power tubes' input grid circuit.

Another Problem

The single Class A_1 tube yields 11.5 watts, 14.5 per cent. total harmonic. Push-pull Class A_1 affords 13.8 watts at total of 2 per cent. distortion. Class AB_1, fixed bias, gives 23 watts, 0.6 cent. distortion, all third harmonic. Class AB_2 enables 60 watts, the third harmonic running up to 7.5 per cent., the second being only 2 per cent., however. The third harmonic, here strong, is one that offers no simple solution. To get rid of it without wiping out the fundamental, which is likewise an odd-order harmonic (the first), is a problem nobody has solved.

Only when one gets above 30 watts do the higher order harmonics than the third appear in this form of operation. Assuming that the requirement is to attain high power output at low distortion, the 50-watt limitation may be imposed, same type circuit, with a third harmonic less than 4 per cent., fifth a bit over 1 per cent. and seventh about .25 per cent. Second harmonic is deemed absent.

It can be seen therefore that the 6L6 beam power amplifier is a tube that is very attractive for a home receiver, especially if worked in a push-pull circuit, where for moderate terminal voltages it affords unexpectedly high power output at very low distortion level.

Constant Current Indicated

Working the system at even less than the maximum output, which is what might be done practically for home use, the power output at 250 volts, self bias, may be nearly 14 watts, 2 per cent. third harmonic distortion, and no other distortion present.

All ratings of power output have significance only when considered in the light of the percentage distortion, and 2 per cent. is the lowest distortion for any receiver ratings. And this low level here is accomplished at only 250 plate volts, 250 screen volts, and a negative grid bias of only 16 volts. The d.c. plate current maximum and minimum for these accomplishments are only 130 and 120 milliamperes, respectively, screen limits are 10 and 15 milliamperes. Note the small change, indicating constant current. The ohms load is 5,000, plate to plate.

The plate impedance is high for such a tube, which rids the high B current requirement of one of its severest rigors, since the high plate impedance removes the criticalness of output ohms loading, and permits operation without any further filtration of the B current than a large condenser next to the rectifier. Hence the large current does not have to pass through a high resistance choke, such as the field of a dynamic speaker, or any other choke. In this way also poor regulation is avoided. When the terminal B and C voltages change considerably with changes of current drawn, due to high resistance in the rectifier line, as speaker field, the regulation is said to be poor.

Where to Put Speaker Field

It is not to be supposed that a speaker field is taboo. Instead the field should carry the B current of the rest of the set, for a receiver of sufficiently high performance to warrant the use of the new tubes will draw enough B current to energize the speaker field when B current other than that to power tubes is passed through the field.

It may have been noted that the screen current is relatively small. This is another way of stating that little power is consumed by the screen circuit. This fortunate development is

Extraordinary Power Tube, 6L6

Quadrode Has Focused Stream, Enables 60 Watts in Push Pull, and is Otherwise Outstanding

By Paul Mallard

THE 6L6, an all-metal power tube quadrode, introduces the principle of the focused beam to the power tube and produces the only power tube that combines high power output capabilities with high power sensitivity. Therefore the tube is one of high efficiency. Considering the voltages used, which are modest, the power output reaches surprising heights, and the percentage distortion is purposely confined to the second harmonic, except for a small third harmonic and negligible higher order harmonics.

Two 6L6 tubes in push-pull, Class AB, afford as much as 60 watts output. Some grid current flows during part of the cycle. Class AB_2 is a customary designation of this type of service. The plate volts are only 400, screen volts 300, negative fixed bias 25 volts, zero signal d.c. plate current 102 milliamperes, maximum signal plate current 230 milliamperes, screen currents, minimum and maximum, 6 and 20 milliamperes, respectively, peak grid input power .35 watt, ohms load 3,800, plate to plate.

At this level there is ratable third harmonic distortion, the third exceeding the second harmonic over part of the cycle of the fully-driven tubes.

When Third Harmonic Goes Up

While third harmonic distortion is particularly disagreeable to the ear, for public address work this might not be considered a serious drawback. For receiver use in the home or in a small auditorium, there would be no incentive to work the output to the limit, and by holding power tube input to lower levels very low distortion will result at power outputs beyond those previously enjoyed with any pair of receiver power output tubes.

Besides the use of the beam principle, the concentration of the distortion on the second harmonic was introduced because, since there had to be a given amount of distortion, if the apportionment could allow concentration on the second harmonic, in the first instance the overtone least objectionable to the ear would be heightened, and secondly a push-pull circuit could be used to eliminate this harmonic from the output. Push-pull has the effect of cancelling from the output the even order harmonics. The second harmonic is the strongest of these by far.

As an example, take the Class A_1 single-ended amplifier, where no grid current flows during any part of the cycle, for given voltaging the total harmonic distortion is 14.5 per cent., of which the second harmonic is 11.5 per cent., so all harmonics other than the second contribute the difference, or 3 per cent. And this 3 per cent. is nearly all third harmonic.

A Splendid Push-Pull Choice

There is no ready method for the single-sided circuit, to eliminate the second harmonic,

(Continued on next page)

Making Wattmeter Calibration Hold

(Continued from preceding page)

one would be used, the phase difference is so small that it may be neglected. Only approximate values are required in a routine test anyway.

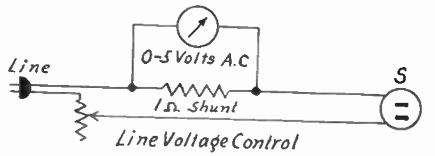
It is well to sound a warning. The resistance in the line across which the voltmeter is connected should never be allowed to open as long as the meter is across it. If the resistance opens, the meter burns out.

The purpose of the rheostat is to adjust the voltage across the measured device to compensate for fluctuations in the line voltage. Some standard of reference is also required for the adjustment. This standard may be a 50-watt lamp. If this is connected in the output socket S and the rheostat is adjusted until the voltmeter reads the same as it did when the device was first calibrated, the calibration will hold for all other values of power within the range of the calibration.

An Improvised Wattmeter

Simple, Quick Measurements Made

By Eugene Kingrey



Circuit of Kingrey's wattmeter improvisation.

A SIMPLE and quick method of measuring wattage is often desirable. Wattmeters are not generally available, but one of sufficient accuracy for practical purposes can easily be constructed. It is based, naturally, on the principle that wattage is the product of current and voltage.

In most instances where we want to measure the wattage we know the voltage and it is only necessary to measure the current. As soon as we have found the current we get the wattage by multiplying it, expressed in amperes, by the voltage.

In the sketch is shown one way of improvising a wattmeter. A heavy-duty, non-reactive resistance is connected in series with the line and across this resistance is connected a low-range a.c. voltmeter. The internal resistance of the voltmeter should be so high that the shunt resistance is neglible in comparison.

Current and Voltage

The small resistance in the line may be one ohm and the voltmeter may have a range of 0-5 volts. This arrangement, the resistance in the line and the voltmeter across the resistance, really constitutes a current meter. Its range, when the resistance is one ohm and the voltmeter has a range of 0-5, is from zero to 5 amperes.

Now we have a means of measuring the current. We should now determine the voltage that exists across the load, in this instance across the output socket S at the right in the figure. The voltage at this point could be measured with the same voltmeter provided that the terminal connected to the line plug could be moved temporarily to the low side of the output plug. Of course, a suitable voltage multiplier resistor would have to be used to protect the voltmeter.

As a rule the voltage of the line is known with sufficient accuracy. If the line voltage control rheostat is set at zero, the line voltage is nearly the same as the voltage across the output socket, for the drop in the one ohm resistance cannot exceed five volts, and in most instances it will be much less. Therefore the power in watts can be computed from the measured, or partly assumed, values of current and voltage.

Lamps as Standards

It is convenient, however, to have a direct reading wattmeter. This can be had by calibrating the voltmeter in watts for a specified line voltage. The specified voltage can be attained by adjusting the line voltage control rheostat, provided the available line voltage is higher than the specified voltage.

For rough purposes the calibration can be done against commercial resistance devices, such as Mazda lamps, heating pads, soldering irons, and others. All these devices are rated in watts and voltage. For example, a lamp may be rated at 50 watts and 120 watts. This does not mean that the lamp takes 50 watts from the line regardless of the voltage of the line. It means that it takes 50 watts when the voltage is 120 volts. If the voltage is less, which it usually is, the wattage is less. But the wattage is proportional to the voltage and it can be computed from the rated wattage of the device and the actual voltage of the line, or rather the actual voltage across the device.

The calibration can be carried out at a standard voltage, say 115 or 110 volts, and every time the wattmeter is used the voltage can be adjusted to that value by means of the rheostat. The power indicated by the wattmeter thereafter is not the power taken by some device when connected to any line, but the power taken when connected to a line having the voltage at which the wattmeter was calibrated.

The Question of Phase

It should be noted carefully that a wattmeter of this type, that is, one in which the voltage and current are multipled together. does not give the true power under all conditions. It only indicates the true power when the current and the voltage are in phase. They will be whenever the load is a pure resistance. But frequently it is required to measure the power taken by a device which is connected to the line by means of a transformer. In that case the current and voltage are not necessarily in phase. When they are not, part of the current flowing in the line does no work and the power indicated by the wattmeter is too high. The excess is greater the greater the phase difference between the voltage and the current. A regular wattmeter will indicate the true power even when there is a phase difference between the current and the voltage. In many instances where a simple improvised wattmeter like the present

(*Continued on next page*)

aerial. Usually an indoor wire will suffice for a sensitive super. Many persons use very short indoor antennas.

The ratio of signal to set-originated noise goes down as the antenna is shortened, so that a hissing sound may accompany reception. The more antenna input, the less this kind of noise, which is due principally to the tubes. The ratio of signal to noise improves. Loud locals may drown out this set-noise, but distant or other weak stations are not likely to do so, although scientific application of a. v. c. tends to equalize the results on strong and weak stations.

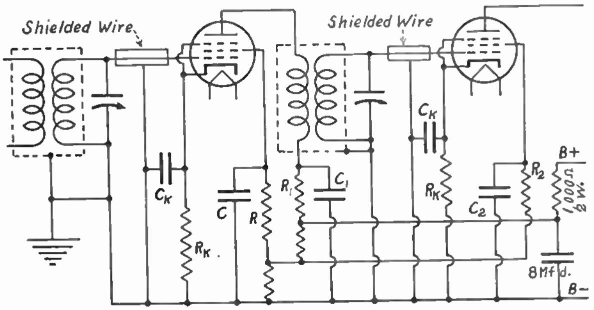
Number of Condenser Gangs

Also, the noise is kept down the greater the selectivity anywhere in the set, the more the pre-selection and the closer the first tube is operated to maximum allowable plate current conditions. Any a. v. c. system for highly selective circuits must work fast enough to give quickly visible indication of resonance, otherwise resonance could be passed over, with abrupt change in audible output, without sufficient or even any indication on the visual device (tube, meter or shadowgraph) of the resonance point that was passed over. A smaller condenser from the controlled circuit's a. v. c. resistor to ground will speed up the action.

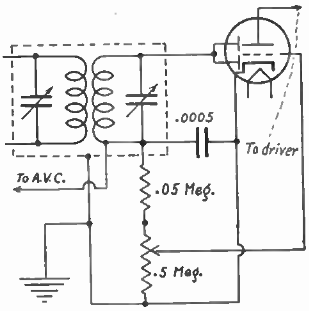
For a super a three-gang condenser is most commonly used. If a four-gang condenser is used in commercial practice, all four sections are not often applied to all bands, except in highest class sets. Practical opinion varies as to the band to which to apply the four tuned circuits.

Difference of Opinion

In one instance only the highest frequency band, about 8 to 25 mgc, is subjected to four-gang tuning because additional pre-selection is needed, the higher the carrier frequency. In a set made by another manufacturer the broadcast standard alone is subjected to four-gang tuning, the other bands to three-gang, to provide enough selectivity without amplification reduction to prevent a strong local from cross-modulating locals or distant stations. In this case the highest frequency band is not subjected to four-gang tuning because the importance of this band is not considered as great. The advisability of pre-selection of course holds. All four gangs on all bands are not used in commercial practice, except as stated in the very finest sets, because of the extra expense and space, and the problems arising from the increase in the number of coils, which might number twenty!



Oscillation cures above. Ck is the cathode by-pass condenser and should be high as practical. A paper condenser of 2 mfd. is suggested. Rk, the cathode biasing resistor, may be raised 50% in resistance if sensitivity drop is not material. R1C1 and R2C2 are capacity-resistor filters. Plate circuits (R1C1) are more important than screen circuits (RC, R2C2). A common B resistor, by-passed, helps (1,000 ohms, 2 watts). Shielded wire aids considerably on overhead grid leads. At right, audio overload preventer in a diode second detector.



If a limiting resistor is placed between the potentiometer and the secondary return, though all the rectified voltage may be used for a.v.c., not all of it can be put into the audio channel.

WBZA to Go It Alone On New Channel, 550 kc

Washington.

The first synchronized operation of broadcasting stations in America will be brought to an end under an application filed by the Westinghouse Electric and Manufacturing Company before the Federal Communications Commission.

The application seeks a new frequency for WBZA, Springfield, Mass., so that it may operate independently of WBZ, Boston, with which it has heretofore been synchronized. Both stations will continue as outlets of the Blue network of the National Broadcasting Company.

Under the terms of the application WBZA's frequency would be changed from 990 kc to 550 kc and its transmitter moved from East Springfield to across the Connecticut river from Springfield. WBZ would continue on 990 kc.

A new high fidelity transmitter and improved antenna system is proposed under the WBZA application.

(*Continued from preceding page*)

suppression is sufficient, and the only way this can be accomplished is by high i.f. and sufficient pre-selection.

How the Image Arises

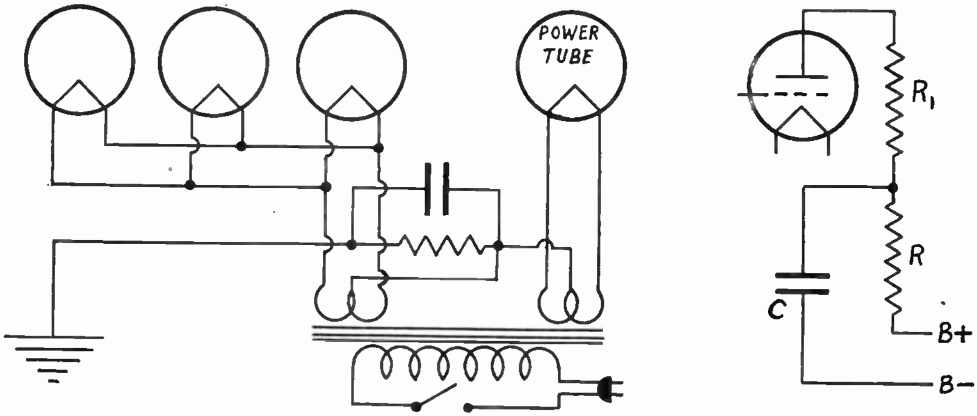
The image arises from the fact that the intermediate frequency is produced by a local carrier mixed with a local oscillator, and the oscillator does not distinguish greatly between a carrier lower than or higher than itself in frequency. That is, for 450 kc i. f., 10,000 kc station desired, the oscillator may be at 10,450 kc, the usual case, or may be at 9,550 kc, both differing from the station by the i. f. Since the oscillator is considered fixed in the example at 10,450 kc, the intended carrier is 10,000 kc, which is 450 kc lower than the oscillator frequency, but an unintended carrier of 10,900 kc is 450 kc higher than the oscillator frequency, so also differs from the local oscillator by 450 kc. Both object and image are received. The image may be a real station, when both signals mix, or simply may be some disturbance in space at that frequency, and there are usually enough disturbances to cause trouble.

The higher the i. f. the better the image suppression, because of the greater absolute frequency difference between wanted and unwanted reception. But the higher the i. f. the less the inter-channel selectivity. Suppose the i. f. is 100 kc and the difference at the r. f. level to be considered is 10 kc. This difference is 10 per cent. of the i. f. Suppose the i. f. is 500 kc. At the r. f. level again the difference considered is 10 kc. This is 2 per cent. at the i. f. It is less exacting on the i. f. channel to reduce by any given amplitude a frequency 10 per cent off resonance than one 2 per cent. off resonance.

I.F. Selectivity Effect Explained

Consider selectivity is the reduction of the amplitude of off-resonant voltages. Assume the frequency difference from i. f. resonance is the same, 10 kc. Assume the selectivity curves are the same for 100 kc and 500 kc i. f. A frequency 2 per cent. removed from resonance would be attenuated only a little, because close to resonance, one 10 per cent. off resonance a great deal. Hence the higher is the percentage difference for the same absolute frequency difference at the i. f. level, the greater the inter-channel selectivity.

In high-fidelity reception systems, using the super, some method of changing the i. f. selectivity is introduced. The inductive coupling between primary and secondary of i. f. coils may be changed, or a tuned circuit may be connected through a variable resistance to present different degrees of loading, to somewhat the same effect. That is, a parallel tuned circuit is either shorted out (no loading highest selectivity) or is coupled to in various degrees, depending on manual control of the resistance connected with this load circuit. When the coupling is maximum the absorption is great enough to broaden the tuning, due to the equivalent resistance load presented by the third tuned coupled circuit. The control therefore is one to get away from fidelity to high selectivity when this is needed for reception clear of interference.



Two hum reducers that usually work well. At left, the receiver tubes, instead of having heater winding grounded, have heater center connected to center of filament type power tube winding. At right, R1, the plate load resistor. This is excellent for aresistor-capacity filter CR. Always R is less than the plate load, R1. C is in microfarads, high as practical.

Choice of Antenna

The inter-channel selectivity is aided of course by the tuning at the r. f. level, but the quantity of such selectivity (thinking of it in decibels) is far less than any good i. f. will provide, but the image suppression is greatly increased by pre-selection, especially as the i. f. can not be increased much above 500 kc for practical reasons.

The front-end selectivity, against both images and adjacent channels, is increased the smaller the antenna. Hence cross-modulation problems often may be solved by using a shorter in amplitude at the transmitter, though of course opposite in phase.

The detector protection is especially significant in connection with high fidelity reception, because the stations use a high precentage modulation. The transmitters will afford 100 per cent modulation.

Percentage Modulation Explained

This means that the modulation amplitude at some time may become as great as the unmodulated carrier amplitude, since at 100 per cent modulation the modulated carrier is twice the amplitude of the unmodulated carrier. Therefore the station's modulator tube or tubes must be of at least the same power capabilities of the transmitter's "final."

In program transmission, for entertainment and instruction, the percentage modulation is ever changing, and 100 per cent modulation simply defines the capabilities, and not the continuous operating condition. Perhaps the average modulation is 30 per cent from a broadcasting station, but at times when there is special dash and vigor to music or speech the transmitter has to be a sort of jetty that will withstand the groundswell; i.e., handle 100 per cent modulation without distortion.

Problems in a Super

The diode therefore will react favorably to deep modulation. If the average modulation percentage is taken as 30 per cent, then the detector tube should be able to produce an output at least three times as great, without distortion, as the average output. This demand is very small on a conventional diode, which could swing in a 10-fold voltage range, and more, without distortion.

The diode statements just made of course apply just as well to a superheterodyne as to a t.r.f. set, but the super has special problems, numerous ones, and there is in sight no complete solution for them. That need not be alarming, since for most problems in radio there is no complete solution, and all operation is more or less on the basis of compromise.

Stability Problem With Two I.F.

The audio channel in a superheterodyne need not be distinguished in any way from one in a super, except that the amplitudes will be greater, and suitable voltaging, biasing and loading have to take care of this properly.

Usually the intermediate channel is considered first. It should be built along with the line rectifier and audio channel, so that alignment is simplified, especially as the detector output (audio) loading has a small effect on the resonant frequency of the i.f. channel.

The general rule is that one i.f. stage is not quite enough and two i.f. stages are too much. The exception to the single-stage i.f. system is that if the two coils are of high Q all requirements for normal reception can be met. The exception about two i.f. stages (three coils) is that by expert design the system may be completely stable, used for its full selectivity, but possibly something less than the full audio output taken off the load resistor, to avoid possibility of overloading the audio channel. Yet the maximum developed rectified voltage may be applied to automatic volume control.

For the two-stage channel the filtration must be of a high order. Usually screen filtration is much less important than plate circuit filtration, but if stages are separately biased by cathode resistors, large capacities across these resistors simplify the stabilization. Again 2 mfd. paper capacities are satisfactory.

Limited Choice of I.F.

What the i.f. shall be is subject only to limited choice under present requirements. For a receiver covering only the broadcast band a low i.f. is preferable, and 175 kc is popular. The inter-channel selectivity is very high this way, compared to use of higher intermediate frequencies, and the image suppression is not difficult. For all-wave coverage, or any inclusion of short waves, the i.f. must be higher than 175 kc if a certain form of interference is to be avoided, or at least minimized. This is called the image interference.

What is the image? It is the response due to an input to the antenna post at a frequency higher than the one to which the receiver is intentionally tuned. How much higher? Consider 450 kc as the i.f. The image always is higher by twice the frequency of the intermediate channel. Thus, to receive 10,000 kc, r.f. level is tuned to that, say the local oscillator is 450 kc higher, or 10,450 kc, and the image is 10,000+(2×450) or 10,900 kc. Hence the image concerns reception of an interfering station. If there is a real station on that image frequency it will come in, unless of course the

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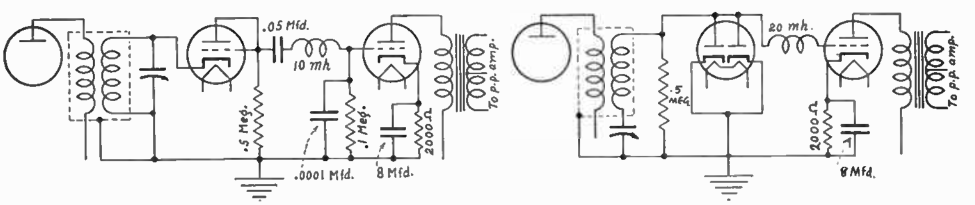

A triode may be hooked up as a diode, as shown at left, for t.r.f. use. The elevated cathode again gets around the difficulty imposed by the grounded tuning condenser. At right a 6H6 dual diode detector has separate diodes paralleled, tuning condenser in series with the secondary as another possible solution of grounded rotor problem.

(*Continued from preceding page*)

The greater the capacity, the greater the reduction of the higher audio tones, and the more the reduction spreads to the middle audio frequencies. Of course the general effect is to lower the average volume or quantity of sound, through bringing out the bass. Reproducers being sluggish at bass frequencies as a rule, the tone control serves a purpose; but more particularly there are times when realism is not so important as reduced interference, and there are interference forms quite pronounced in the high audio frequency spectrum. The tone control helps to reduce such annoyance. Natural static is one of these nuisances. For clarity of speech, however, the high frequency audio tones are essential. They account for the consonants to make for highest intelligibility.

Hum should be kept at a low level. The demand today is for practically humless reception, and it is attainable. Sometimes the improvement in this direction consists merely of encasing an audio transformer in an alloy container, usually a combination of nickel and iron, in certain proportions, to produce high permeability. Moving the audio coils away from power transformers helps, too, and of course B filtration should be excellent.

Resistor-Capacity Filters

Some special troubles arise concerning hum, but all are soluble. One expedient found successful is to connect center tap of winding serving heaters of r.f. and other tubes, to cathode of power tube, rather than to ground. A customary practice is to insert filters, such as resistors across which are large capacity condensers, but these are not normally advisable in audio plate circuits, because of the power expended. If the audio tube is not a driver of the output, but merely feeds the driver, then the expedient may be all right, the filter resistor never greater than the intended load resistor, and the capacity from joint to B minus as large as practical. As a rule, 8 mfd. will be adequate.

If the t.r.f. circuit is taken alone, it is required to afford sufficient selectivity for the location in which it is used, the sensitivity readily will be high enough, depending largely on the coils, the detector should be a proper protector of quality, and an audio driver should precede push-pull output.

It is advisable to have an antenna coil with high inductance primary resonated by virtue of antenna capacity just below the lowest broadcast frequency, to help even out the sensitivity characteristic. Usually the sensitivity is low at the low broadcast frequencies, and the large antenna winding, often a honeycomb coil, either inductively coupled to the secondary, or capacity coupled by a turn or two of wire, favors the low against the high radio frequencies. This applies to a single band.

Feedback Not Wanted

This same method helps a little to solve the feedback problem at radio frequencies. Regenerative effects tend to arise as the frequency is increased, and if these are kept within limits they may be quite favorable, but usually turn out to be a nuisance because of criticalness, so that even t.r.f. sets are constructed nowadays with the view of elimination of feedback and its attendant instability, unless controlled manually. And such manual control has not been in favor for years, except in very small sets, usually of the plug-in coil variety, where only controlled regeneration affords possibilities of practical reception.

There are several methods of providing safety against unwanted feedback. One of them is to provide enough filtration in plate legs particularly, another is to use screen filtration additionally, another is to use shielded wire on the coil leads to plates and grids and ground the sheath. This grounding for the grid leads may be done to a lug fastened to top of the coil shields. The filters often crowd the set with parts, sometimes so much that unless expert pains are taken in placement, the remedy proves worse than the ailment.

Large Bias Bypass Condenser

Various makeshifts consist of altering the usual operating conditions of the tubes, for instance reducing the screen voltage or increasing the grid bias until oscillation is eliminated, or reducing the plate voltage, or the number of primary turns, or putting a resistive load across one of the circuits, principally antenna circuit or plate circuit.

The danger of thus loading the antenna circuit is that in localities where there are numerous stations, or at least where there is a strong local, there may be crossmodulation.

If the bypass capacity across biasing resistors is made much larger than usual, say, 2 mfd. paper dielectric, feedback is often completely eliminated.

The diode detector is recommended for the t.r.f. set for fidelity reasons, but it also is a little help as a safeguard against oscillation, as it does not amplify, hence does not contribute to feedback, though the coil feeding it may so contribute. However, the principal causes of feedback are capacitative and resistive, and not inductive.

Full-Wave Diode Impartial

The diode enables high fidelity detection and stands a larger a.c. input than a t.r.f. set is likely to supply. It detects well because the a.c. (amplified carrier) fed to it is changed to pulsating direct current, the pulses representing the modulation, and the rectified output being proportionate to the carrier input. Hence the audio output is obtained, while the carrier is eliminated.

The diode is distinguished from the usual triode, quadrode or pentode detector by that linearity of response. If both alternations are rectified, the d.c. output is equal for both. Other types of tubes handling full-wave detection will give a stronger output on the positive alternation than on the negative alternation. An alternation, by the way, is half a cycle, and it is assumed that the r.f. alternations are equal plying most of the amplification. The last of the tuned circuits usually feeds the detector, after which comes the audio amplification, which should consist at least of a triode driver, working into the push-pull output, or three audio stages.

Common Problems

Granting that a t.r.f. circuit is well shielded and filtered and therefore is stable at radio frequencies, also at audio frequencies, there are few problems arising in the construction of the receiver to attain superlative results as to quality. For adequate selectivity in all likely locations, a four gang condenser would be used for tuning, in conjunction with four low-gain coils.

More frequently a three gang condenser is used, with three coils instead of four, and results are not of such a high order of selectivity, although for use in rural or other sections where selectivity demands are not so great, the three-gang condenser arrangement is very satisfactory. With high-gain coils the sensitivity is very marked.

It is not advisable to use the band-pass method of tuning, or any equivalent representing two tuned circuits without a tube between them, because the selector or prior tuned circuit is a load on the coil across input of the first tube, and sensitivity suffers.

Some problems are common to all sets. If there is no radio frequency filter in the detector circuit, and yet there are signs of a rasping type of distortion together with incapability of reducing the sound output to zero by adjusting a diode volume control, better r.f. filtering in the detector should be provided.

Unwanted "Double Detection"

Radio frequencies that escape to the audio amplifier may suffer stray detection there and otherwise introduce distortion, especially of that very annoying type due to phase shift. Plural detection of that type, instead of single detection ahead of the audio amplifier, may cause likewise some strange effects, as that of a program in which its echoes are heard, all sound seeming to originate from a pulpit that had surroundings contributing bad acoustical reflections.

The detector filter may consist of an r.f. choke in series with the plate (anode) circuit, condenser across the load directly, or from plate to ground if load return is not to ground, or otherwise connected to the same purpose. A condenser after the choke may be included, but is not essential, except to satisfy the theory of completing the filtration.

The capacity of the condensers is important and refers back to the load. If a transformer or an impedance coupler is in the plate circuit the condenser may be higher in capacity than if a high resistance is used. Since a diode always is loaded with a high resistance in the detector circuit it follows the capacity must not be large, and it is suggested that 100 mmfd. is maximum for a load of .5 meg. A transformer or impedance load may have up to .0005 mfd., and for phones alone up to .002 mfd. may be put across them, provided the 'phones are not of the high impedance type, for which smaller shunt capacities would be more suitable.

Effect of Too Much Selectivity

Condensers mentioned are to act on radio frequencies and not affect useful audio frequencies.

Excessive selectivity's effect is to prevent the full variation of the amplitude of the carrier over the width of the modulation band, and as the higher audio frequencies actuating the carrier are on the outer fringe, the over-selectivity cuts off this fringe. At the audio level, after detection that wipes out the carrier, it is still possible to remove the high audio frequency fringe by too high a capacity across a load resistor or audio coil, because currents of these high audio tones tend to pass through the condenser instead of through the coil or resistor.

Masking Static's Effect

A tone control of the usual sort will act upon these high audio frequencies, and in effect the capacity across a line carrying audio currents is changed by tone control rotation.

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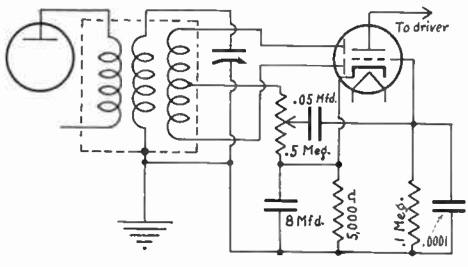
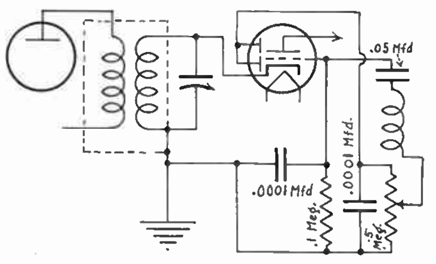


Full wave detection for a t-r-f set. A center-tapped honeycomb coil is inserted in the regular coil form. No bypass condenser is needed across the diode load resistor (.5 meg. pot.) This is because there is no radio frequency across this load for a balanced input, a condition arising from true balance.



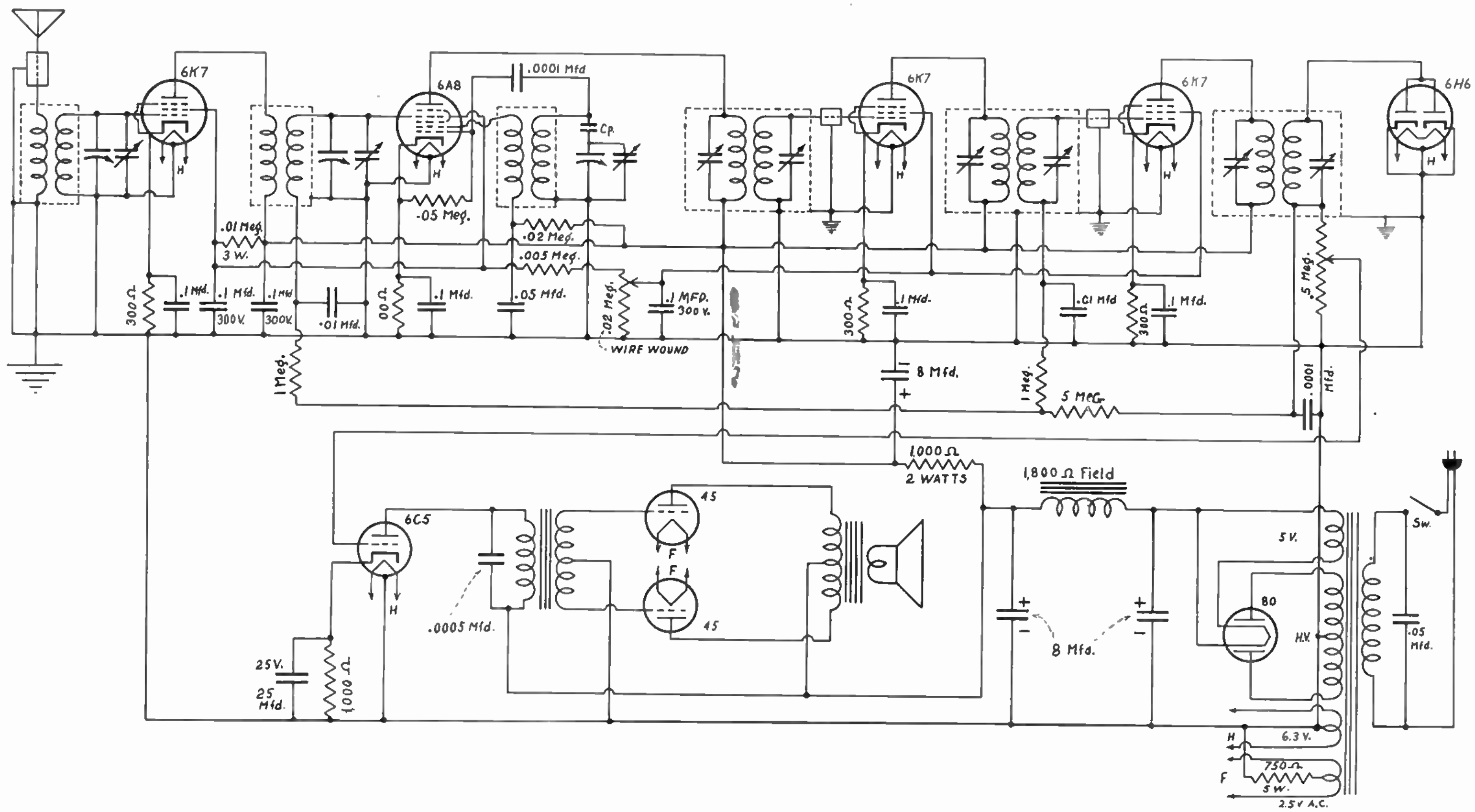
This is a half-wave detector for a t-r-f set, using a very simple method. The stator of the tuning condenser is connected to cathode. Ground is reached conductively through the secondary. The four diagrams presuppose resistance coupling to driver, otherwise the biasing resistor, 5,000 ohms, should be 1,500 to 2,000 ohms.

Quality Super Steps Out, Yet Produces Fine Tone

Temptation

A TWO-STAGE intermediate frequency amplifier always presents the possibility of oscillation at this level, and a ready means of removing the trouble is to detune the middle i.f. transformer slightly. However, this introduces a substitute trouble. The selectivity then is not as good at the i.f. level, also a lopsided tuning curve may introduce some distortion. in the absence of proper instruments with which to make such a special type of adjustment.

It is highly recommended that instead of the reduced selectivity and sensitivity resulting from purposeful mistuning that the i.f. level be stabilized by more logical and more efficient means. Some of these are stated in the text of nine-tube superheterodyne article, others in another article in this issue.



With this circuit a great deal of distance reception was enjoyed, with faithful tone. The audio driver tube is specially circuited, as explained in the text. The biasing resistor for the 6A8 should be 300 ohms. R.f. sensitivity and audio volume controls are included.

The Diode

WHEN the two plates of the dual diode are interconnected, likewise the two cathodes, while the resistance of the tube thus circuited is just half of that of a single unit of the tube, nevertheless it was not to be expected that the volume would go up much, since the load resistor was .5 meg., therefore very high compared to the resistance of the tube when the tube is conducting. Hence the mean current is certainly not doubled.

Nevertheless quite a surprise was in store when the measurement of rectified component was made, using one diode singly, then both diodes in parallel. The increased volume was marked.

One possible reason for this was that an appreciable part of the output is lost due to the voltage developed across the tube when it is a high resistance. Paralleling reduces this loss.

LIST OF PARTS

Coils

One antenna coil one modulator coil, one oscillator coil, all shielded. (See text.)

Three i.f. transformers, 175 kc, primary and secondary tuned; all shielded.

One power transformer; primary, 115 volts, 50-60 cycles; secondaries, 2.5 volts, 3 amperes c. t.; 6.3 volts, 3 amperes, c.t.; 5 volts; 400-0-400 volts, c.t. (120 ma dc.)

One dynamic speaker, 1,800 ohm field; output transformer built in, 5,000 ohms load, plate to plate; five wire cable and plug.

One push-pull input transformer; ratio primary to one-half of secondary not to exceed 3. (1.5 was used in the set as built).

[High ratios produce more volume but more distortion.]

Condensers

One three-gang .000365 mfd. tuning condenser. (Built-in trimmers were removed and Hammarlund 35 mmfd. air dielectric trimmers used, as calibration of receiver was retained better that way.)

Three .1 mfd. 300 volt tubular condensers (Cornell-Dubilier).

Four .1 mfd. 200 volt tubular condensers (Cornell-Dubilier).

Two .05 mfd. 300 volt tubular condensers (Cornell-Dubilier).

Three 8 mfd. 500 volt electrolytic condensers (Cornell-Dubilier).

One 25 volt, 25 mfd. electrolytic (Cornell-Dubilier).

[Electrolytics in cardboard containers.]

Mica condensers: two .01 mfd.; one .0005 mfd.; two .0001 mfd.

Padding capacity for 175 kc is 800-1, 300 mfd. See text.

Resistors

Four 300 ohm. One 1,000 ohm. One .01 meg., 3 watts.

One .5 meg. potentiometer with a.c. switch.

One .02 meg. pot (wire-wound).

One .02 meg. One .005 meg. One .05 meg. One 5.0 meg.

One 750 ohm, 5 watts. One 1,000 ohms, 2 watts.

(Note: resistors not specifically rated may be ¼, 1/3, ½ or 1 watt, as preferred).

To convert to ohms read .01 as 10,000 and .001 as 1,000).

Other Requirements

Line cord and male plug.

Six small octal sockets, three four-hole UX sockets, one five-hole UY socket (five-hole is for speaker plug).

Four miniature grid clips.

Length of shielding wire for connection from antenna post of set to antenna winding of first coil.

One dial. Three knobs. One chassis.

Antenna-ground binding posts (chassis to be grounded).

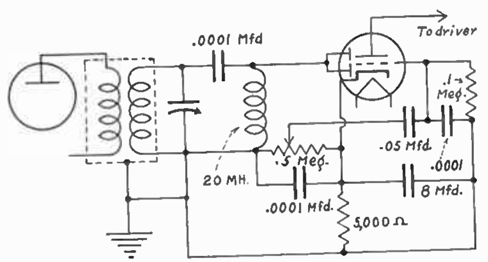
Quarter inch shaft, about 4 inches long, with flexible coupler.

(Note: the shaft is passed through a front panel hole and is coupled to the audio volume control shaft with the coupler, to keep the

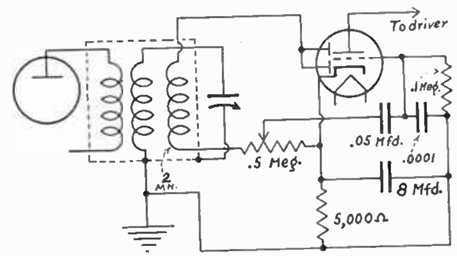
Improving Set Performance

Receivers Apace of Fidelity Transmitters

By Edward Walling Guard



In a tuned-radio-frequency set, since tuning condenser rotor is grounded, the problem is to connect properly to the diode. A stopping condenser and high inductance r-f choke (20 millihenries suggested) afford one solution.



Another diode connection method for a t-r-f set, this one utilizing a third winding, 2 millihenries. This is a honeycomb and fits inside the regular coil form. This and the previous diagram are for half-wave detection.

IMPROVED results from radio receivers depend largely on increased possibilities of tubes. However, some betterment is achieved independent of the actual tubes used, although not always so readily.

Only now are radio receivers becoming instruments of notable musical worth, in keeping with the capabilities of the better transmitters. For a long time transmitters have been ahead of receivers as to performance. Naturally this would be true in a country having a ratio of 66,000 receivers for each standard broadcast transmitter. But it has been true also throughout the world. Many transmitters were bad but the average of the receivers served would likely be just as bad or worse.

Evils present in the receiver, or in the medium through which the radiated wave passed, have been blamed on the transmitter as a chronic opinion.

It is therefore fitting to consider the principles guiding the construction of better and better receivers.

Why Superheterodyne is Used

The predominant circuit of the day is the superheterodyne. This is because the public wants to tune in short waves, and also waves longer than broadcast waves. For wide frequency coverage of that type, or all-wave reception as it is called, the superheterodyne circuit is essential for all save laboratory receivers. For certain measurement purposes tuned radio frequency circuits may be used, with equally wide wave coverage, but separate and shielded plugin coils are advisable, the selectivity is not constant, nor the sensitivity, and the chief advantage of such a laboratory set is to be able to identify responses readily, as to frequency of stations. The superheterodyne would not produce measurement results quite so definitive.

The tuned radio frequency set is readily of the type that does not introduce more selectivity than high fidelity permits. Too selective a set, and a superheterodyne readily easily could be made so, reduces the intensity of the high audio frequencies, all but removing the upper registers of string and wind instruments and speech.

Maintaining Tone Quality

Since there is a growing interest in high fidelity, and some possibility that programs of that type will be widely transmitted, the sets should keep pace with the transmitters. Therefore if one desires to listen only to the standard broadcast band, he may select a t.r.f. receiver, introduce a diode detector, and use high-grade audio coupling, preferably with a driver and push-pull output. As a rule the triode output tube or connection is to be preferred, though less sensitive. The "connection" refers to triode use of a quadrode, pentode, etc., by interconnecting the externally accessible elements other than grid and cathode. The result is in general reduced quantity of distortion, especially small third harmonic, which overtune may be accentuated in a pentode. The even order harmonics are not so important because, though triode generated, they are practically eliminated from the output by the push-pull circuit.

The t.r.f. set may be as sensitive as the superheterodyne, will not likely be as selective, and is much simpler to understand and construct. A group of shielded coils is tuned by a gang of variable condensers, the tubes in between sup-

and after several trials it was considered sufficient to confine a.v.c. to the circuits as shown in the diagram.

300 Ohms for 6A8 Cathode

The alignment was done on the basis of a 0-6 voltmeter placed across the 300 ohm resistor in the cathode leg of the last 6K7, the tube ahead of the diode. The meter was temporarily fastened to rear of the tuning condenser.

By the way, the resistor in the cathode leg of the 6A8 should be 300 ohms, also, as the number 3 disappeared during the engraving process, and the designation now reads 00 ohm in the diagram.

The finished circuit produced results on a par with the best of receivers, attaining a sensitivity of about 3 microvolts per meter.

The only trouble encountered in any direction other than what has been set forth concerned oscillation at the intermediate frequency level. The use of shielded wire, sheath grounded, for the overhead grids of the i.f. tubes, was found necessary, and the insertion of the 1,000-ohm, 2-watt resistor in the B feed to these tubes, with 8 mfd. as bypass, helped. Not all 8 mfd. condensers were useful, because some had too high an impedance even at the intermediate frequency, but the Cornell-Dubilier condenser did the trick nicely.

The i.f. channel was single peaked but there was no sideband cutting of useful audio frequencies.

Coil Winding Directions

The tuner coils used were of commercial manufacture (Delta Radio Co.), but those desiring to wind their own shielded coils may do so from these data:

R.f. coil, secondary 130 turns of No. 32 enamel wire on one inch diameter; primary, 35 turns of same wre, wound over secondary, near one end, two turns of insulating material between. This may be wrapping paper or Empire cloth.

Modulator coil, same as r.f. coil.

Oscillator coil, for 175 kc, if i.f., secondary, 100 turns No. 32 enamel wire on one inch diameter; tickler, 40 turns of same kind of wire, wound nearer the center over the secondary, nearer the center of the axial length of the secondary, one turn of insulation material between.

The padding condenser for 175 kc should be 800-1,300 mmfd. adjustable, or may be made up of a fixed condenser with a variable across it of smaller capacity, to strike this range.

For 465 kc i.f. the r.f. and modulator coils are the same as for 175 kc, but the oscillator coil consists of 85 turns of No. 32 enamel wire on one inch diameter, and the tickler of 30 turns, placed as was done with the other tickler. The padding condenser would be .0003 mfd. fixed and 140 mmfd. adjustable across it.

However, the direction for both ticklers are subject to the grid current test previously set forth. If more tickler turns are put on the oscillator parallel trimmer has to be reset.

The image suppression is of course better if

New Oscillator Powerful, Stable Near One Meter

Cleveland.

A radically new type of radio oscillator, powerful around one meter, was demonstrated here before the convention of the Institute of Radio Engineers by P. D. Zottu, of the RCA tube research and development laboratory, Harrison, N. J.

Mr. Zottu produced 80 watts of power on a wavelength of 120 centimeters with eight commercially available tubes. The design is such that twenty or more might be used.

The new oscillator permits the use of tubes in parallel without "adding up" their internal capacity. In microwave circuits, the internal capacity of the tube, governed by the size of the tube's elements, is a definite part of the tuning circuit. The smaller the elements can be kept, therefore, the shorter the wavelengths on which the tube may be effectively employed. But the problem has been complicated by the fact that production of greater power necessitated large tube elements to dissipate the increased heat.

The new multiple oscillator employs standard tubes of conventional design. The tuning circuit between the grid and plate of each tube is like a miniature horseshoe. The eight tubes used are disposed radially around a common "tank" circuit and connected to the tank so each tube contributes its utmost power without appreciably influencing the tuning of the main circuit. Thus, if one tube will produce ten watts, ten will generate 100 watts. It is believed that this is the first time that more than two tubes have been used together as oscillators at such short wavelengths with directly proportional increase in power. Moreover the separate units can be replaced without shutting down the oscillator.

If one tube should have a tendency to stray from the wave all the others, acting through the common "tank" circuit, pull it back. This is regarded as an important advantage in any possible commercial application as a transmitter, since crystal control, effective on short waves and in the broadcast band, does not lend itself readily to micro-wave work.

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a short antenna is used. It was not found necessary in New York City to use more than ten feet of wire, as aerial, and any outdoor antenna would undoubtedly afford lesser selectivity, unless a doublet is used, but this is not intended for the present circuit. The change required for a doublet would be to avoid grounding the return of the antenna winding, and instead bring that out, as well as the present antenna lead, to a binding post.

[*List of parts and schematic diagram will be found on following two pages.*]

(*Continued from preceding page*)

300 volts applied to the 6C5 through the primary of the push-pull input transformer, there will be grid current even if the grid is about one volt negative. That means even with a signal that carries the grid negative by one volt there will be distortion.

Gets Rid of Bad Distortion

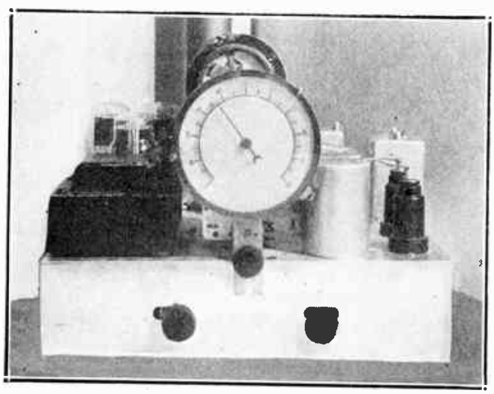
This form of distortion is particularly annoying and is present when receiving weak stations. Really the case becomes that of mixing second and third detection. If the modulator part of the mixer tube is considered the first detector, the 6H6 the second detector, for small signal inputs the 6C5 would be the third detector. If there is grid current there is inevitable detection, and it so happens the grid current has to flow through the diode load resistor and is out of phase. The resultant speaker sound is rasping.

So the simple device of introducing a biasing resistor in the cathode leg was applied, and this got rid of the trouble. It is usual to have a biasing resistor if indirect coupling is used, say, stopping condenser between diode load resistor and 6C5 grid, and then the addition of triode grid leak returned to the grounded lead. When that is done a little self-rescue work is performed by the driver circuit, because the higher the amplitude of the rectified component of the carrier (that is, the stronger the audio frequencies), the greater the plate current through the 6C5, and the greater the negative bias, since the plate current must flow through the cathode resistor to complete the return circuit to B minus.

The Other Extreme

The author is partial to direct coupling, because the frequency characteristic is better, and the difficulties arising can be solved. The circuit is nearly non-reactive and the reduced plate current for increased signal improve audio transformer results on low notes.

The cathode resistor eliminates grid current, beecause at low signal level the 6C5 current is greatest and the negative bias as developed through the cathode resistor is highest.



The front view.

Next, if too much signal is put into the 6C5 the plate current will be reduced practically to zero, and this introduces another form of distortion, due to operation of the tube at or near cutoff, the other form of rectification. Again there would be distortion.

The total voltage across the secondary of the push-pull transformer may reach 60 volts, delivering 30 volts to each tube, for loading up the power tubes. If the ratio of primary to one-half of secondary is 1 to 3, as much as ten volts of signal may appear across the primary before the push-pull input and output are overloaded. The working mu of the 6C5 is about five for very strong signals, therefore as much as 2 volts may be put into the 6C5 before output distortion results from power tube overload.

Strong Stations

The rectified voltage across the diode then may reach 2 volts safely, as viewed from effect on the 45's output. The current through the diode resistor load then may be 4 microamperes with audio volume control all the way on, for maximum output. The diode current could be 250 times as great and still be within the maximum current allowable for the diode, so that is not overloaded.

So for strong stations, say one or two that may be tuned in by persons operating the receiver in large cities, the audio volume control or the r.f. sensitivity control would have to be adjusted so that the output would not be overloaded, or the 5,000-ohm resistor (.005 meg.) in series with the 20,000 ohm i.f. screen potentiometer may be increased to such a value that no distortion appears even on the strongest local. However, it is recommended that the values imprinted on the diagram be followed, since then weak stations come in stronger, and that also is important.

A.V.C. Helps Out

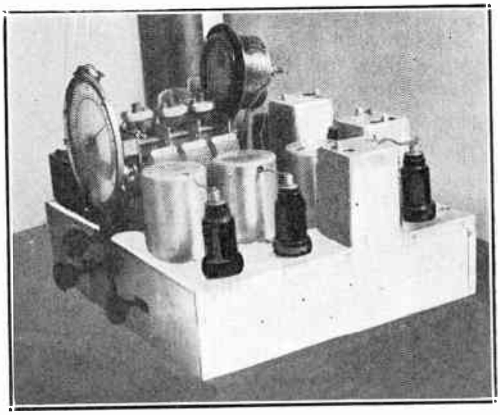
The question may arise whether the biasing resistor that is the novelty in the direct-coupled driver circuit hastens the cutoff of plate current due to strength of signal. Practically it does not. Since the plate current runs very low indeed on loud signals through the tube, the voltage drop across the cathode resistor becomes less, so that if the plate current is reduced to zero, there is no biasing due to the cathode resistor. Also there is no output, since no audio signal appears across a primary through which there is no d.c.

Therefore the cutoff condition is practically unchanged, and while it is something requiring consideration, it is not a real trouble. Automatic volume control does or can correct for it, and such control is introduced in the second i.f. stage and in the station carrier input circuit of the pentagrid converter. If for reasons of preventing distortion due to strong locals the a.v.c. action is desired to be more effective, then the first i.f. stage also may be subjected to a.v.c., using the same constants of filter resistor and capacity as in the second i.f. stage. However, a.v.c. is at the expense of sensitivity,

More Pep, Less Distortion

Precautions in Super's Mixer and Driver Circuits

By Frank Barker Reynolds



Side view of the nine-tube superheterodyne. Front to back the tuning coils are r.f., modulator as oscillator.

HEREWITH is a nine-tube superheterodyne for covering the standard broadcast band. The circuit may be built with intermediate transformers of low frequency, around 175 kc, or with i.f. up to 485 kc. The lower the inter-intermediate frequency the greater the inter-channel selectivity, so it is assured the constructor will select 175 kc, as the higher i.f.'s would be necessary only if short waves were to be tuned in, which would require more coils and also switching.

Two particular factors concerning the receivers are the mixer circuit and the audio driver. As metal tubes are used, except for rectifier and power tubes, the pentagrid converter is the 6A8, which requires special attention, and the audio driver is a direct-coupled 6C5. Standard practice is followed in the rest of the circuit, so attention will be paid to the mixer and the driver.

Pentagrid Converter Tips

It has been found that for optimum conversion there should be an abundance of grid current, although there is an upper limit. Let us fix the upper limit as half a milliampere (500 microamperes). So, too, there is a lower limit, which we shall select as 100 microamperes. But since we have only one band to consider, the standard broadcast band, where the difficulties are least, let us imagine the circuit is complete and functioning and we are desirous of finding out simply whether the translation is as great as it should be.

Most tests for this factor are difficult and some of them lead to contradictory or inaccurate results, but since there is grid current, we may rely on this, therefore put a 0-1 milliammeter in series with the .05 grid leak. This is done by cutting the connection of grid leak at the cathode of the 6A8 and interposing the meter between the open side of the leak, and the cathode. The optimum grid current is half scale on the meter and this we shall not desire to exceed.

By turning the set's dial we shall note that the grid current changes. Usually it is greatest at the higher frequencies of tuning. We shall watch the maximum current and the minimum current. Since the minimum will occur near or at the low frequency end of the tuning (padding condenser assumed nearly right, though not critical for this purpose), does the current dip below 100 microaperes If so there is not enough tickler winding, and even if the job is slightly irksome we shall have to add tickler turns until at or near the low frequency terminal of tuning the grid current comes to 100 microampeers or more.

Establishing Correct Grid Current

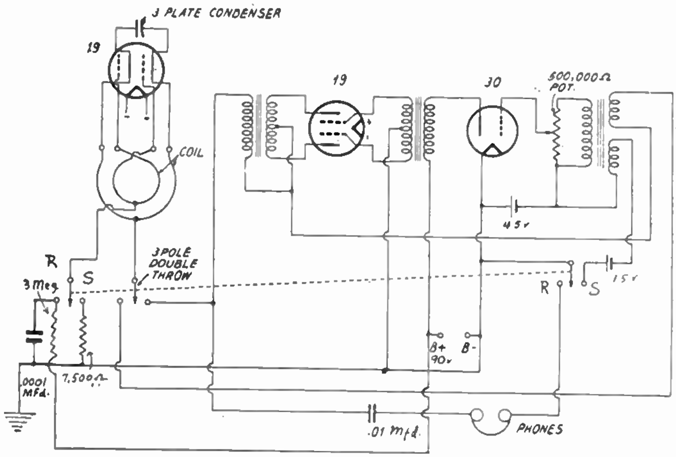
The test for how much more lies in comparing the current rise at the other frequency extreme. No more than 100 microamperes should flow at the low frequency end if that causes the grid current to be driven beyond 500 microamperes at or near the high frequency end. So at some part if the tuning 500 microamperes are reached and at the other end it will follow that 100 microamperes will be exceeded or at least equalled. Small departures from these values are permissible if circumstances require.

By establishing high enough grid current the oscillator modulates the other part of the tube sufficiently. Besides increased sensitivity there is a greater ratio of signal to noise.

Now as to the driver. This is the 6C5, ahead of the push-pull output tubes. The grid of the 6C5 is directly coupled to the diode load resistor. The diode is a 6H6 used with two sections paralleled, as it was found volume was greater that way. Now, if there is no biasing resistor in the cathode leg of the 6C5 there will be some grid current even when there is no signal, because the negative bias would be zero, or nearly zero. It so happens that for the conditions deemed to exist, with around

(*Continued on next page*)

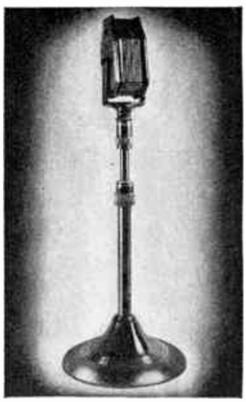
BATTERY-OPERATED TRANSCEIVER



This circuit is that of a typical short-wave transceiver. An unusual feature, however, is that the grids of the oscillator are returned to 90 volts plus when the circuit is set for detection or reception. This is not an error, for it was found that the receiver operated better this way than when the grids were given the more conventional bias in values. There is a slight error in the diagram, however. Just above B plus join the two lines.

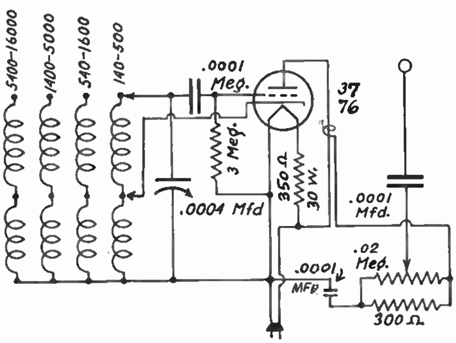
DIRECTION AS FUNCTION OF MICROPHONES

Directional as well as "broadcast" microphones are in use. A directional microphone is one which is sensitive in certain directions and not in others, whereas a "broadcast" microphone is equally sensitive in all directions in the horizontal plane. The directional microphone has many applications. Its main advantage is that it is able to pick up weak sounds from one direction and exclude all sounds coming from other directions. This property is useful in recording out of doors in the midst of many extraneous noises. For example, some celebrity is interviewed by talking film reporters when a ship arrives. There are countless noises about which cannot be suppressed. But only the voice of the celebrity is desired. The directional microphone solves the problem easily. There is also use for this microphone for public address purposes. Only the direct voice of the speaker is desired. If the amplified voice of the speaker also affected the microphone the entire amplifier would start oscillation quite independently of the speaker's voice. If the loudspeaker is placed on the insensitive side of the microphone, oscillation is easily avoided.



HOW TO GET SMALL CAPACITY COUPLING

The coupling between the plate circuit of an oscillator and the output binding posts must be very loose if the output is to be controlled. A simple way of obtaining loose coupling is by use of a tiny capacity, and the simplest and least expensive way of getting a tiny capacity is to wrap one wire around another without connecting the two conductively. As an example of this, one No. 16 push-back wire was wrapped around another of the same kind and the capacity, the two forming a twisted pair. The capacity was then measured and it was found to be 3 mmfd. per inch of the resultant twisted pair.



For 100,000 ohms I equals 1,580,000/101,580 ohms, equals 30.6 microamperes.

Differences likes .5 microampere can not be read on the meter. In fact, the 1,000 microammeter may have a total of 50 subdivisions, or 20 microamperes per division, and while half and quarter divisions may be estimated, it is still difficult to get close readings for differences of 5 microamperes. That, again, is why the crowded parts of the scale, particularly high resistance and low resistance, can not be so closely determined. Still, the information is often adequate when one ascertains the resistance "more than 300,000 ohms" or "less than 50 ohms."

Notice that even resistance values purposely have been obtained. From this information a table may be prepared, or a curve run. From the curve in particular in-between resistance values may be found. The current is read when the unknown resistance is inserted, and then the current divisions on the up-and-down part of the curve are consulted, and the point found where a horizontal line on this axis intersects the curve. Then the line is traced downward to the base where the resistance value in ohms is read.

Even Divisions on Meter Used

If it is desired to calibrate the resistance values of unknown for the even divisions of the meter this may be done from the formula

$$Rx = \frac{E}{I} - Ro$$

where Rx is the unknown resistance, E is the potential in volts, I the current in amperes and Ro the limiting resistance (1,580 ohms in this instance). Rx and I change, E and Ro do not.

For 20 microamperes per division, assume readings to one-quarter of a division, or 5 microamperes, and use 5, 10, 15, 20, 25, 30, etc., microamperes. Again, it may be found simplier to consider I in microampere units, whereupon E is multiplied by 1,000,000:

$$Rx = \frac{1{,}000{,}000 \times E}{Imca} - Ro$$

where E is potential in volts and Imca is current in microamperes. Ro is 1,580 ohms.

Thus for one division, if it equals 20 microamperes, the total resistance is 1,580,000/20 or 79,000, and subtracting 1,580 ohms, the answer is 77,420 ohms. Because the series resistance always has to be subtracted from various total resistances, the current does not change proportionate to Rx, except perhaps for high values of Rx, and then one only relatively.

From the foregoing data assembled for the full sweep of the scale the same general basis of running a curve is provided, and the curve should be exactly the same in either instance. Slight transcription inaccuracies are to be expected because of the odd curve shape, and mark the curve herewith.

The object of going into the method is to enable the use of any meter one has, within reason, remembering of course that the range becomes less acceptable to general practice in radio as the meter is less and less sensitive. However, find the full-scale current, divide it into 1, yielding the ohms per volt, and arrange the series limiting resistance on the bases of that many ohms per volt, for 1.58 volts. Then apply the formulas, either one.

Those possessing a 0-1 milliammeter may follow the curve given herewith, therefore do not have to perform the computation, although the curve range is only 100 to 10,000 ohms, because excellent readings are obtainable, also because the cross-section paper is two cycle semi-logarithmic.

When one range is calibrated, unknown resistances of any multiple of that range may be read if the same multiple is used for ohmage range, applied potential and the limiting resistance.

This is true, for the limiting resistance is the *total* limiting resistance. We found that the meter's own resistance was of consequence on the low range. On the high range it is not, and may be neglected.

Multiplying the Scale

Suppose nominally 1.5 volts were applied originally, with 1,580 ohms; if we now use 45 volts we are multiplying by 30, and to have the current scale reflect unknown resistance values 30 times as great we need 47,400 ohms, or, say, a fixed resistance of 40,000 ohms and a variable of 10,000 ohms. It is possible to use a single rheostat for both purposes, by using 45,000 ohms fixed for the high range, 1,000 ohms fixed for the low range, and have around 3,000 ohms as the variable.

The off-curve resistance values for 0-1 milliammeter are seven below, 100 and 10,000 ohms repeated, and current values ascribed as accurately as they can be read:

Rx (ohms)	*Current (Microamperes)*
10	995
20	987
50	970
75	950
100	940
10,000	135
15,000	95
20,000	75
25,000	60
50,000	30
75,000	20
100,000	15
150,000	10
300,000	5

The meter has been considered as a current-read device. When the scale divides the current evenly for separate divisions that is a handy way to work the formulas. Sometimes the scale reads 15 for 0-1 ma, and then the voltage readings are handier. Then the formula is

$$Rx = (E/e - 1)\, R_0$$

where Rx is the unknown resistance in ohms, E is the cell voltage in volts, e is the apparent voltage as read when Rx is interposed, R_0 is the voltmeter resistance. If the meter is a milliammeter deflections may be use for E and e, while R_0 would be the limiting resistance.

(*Continued from page* 26)

When one solves for the total resistance the unknown limiting resistance must be subtracted, since the difference is the value of the unknown.

So the sensitivity of the meter, either in terms of full-scale current or ohms per volt, must be known. It is usually imprinted on the meter scale. Of course it may be measured. Or it may be obtained from the manufacturer's catalogue. Look up the model number of the instrument (not the serial number), and the voltage range or ranges, and a notation likely will be found that reveals the information on sensitivity.

If one sets up a circuit for full-scale deflection as outlined, preferably using a higher voltage than 1.5 volts, and then puts a rheostat across the meter terminals only, the rheostat may be turned until full-scale is reduced to half scale, and the resistance of the meter equals the resistance of the rheostat at this setting. The rheostat is removed and is measured in a circuit through which considerable current passes, say, 100 milliamperes. Then if the rheostat may be measured for voltage drop at 100 ma by a low range 1,000-ohms-per-volt voltmeter, and the rheostat resistance equals ten times the voltage read. Usually a 6-volt source, consisting of dry cells, will be sufficient voltage, as the meter resistance of a 0-1 milliammeter may be expected to lie between 27 and 100 ohms in practice. This suggests a 10-volt scale on the voltmeter.

Use of Rheostat

The meter resistance is of importance only for low voltage or ohmage range, as then it may be a ratable part of the total required series resistance. So if 1,500 ohms are required and the meter resistance is 100 ohms, the limiting resistance should be the difference, or 1,400 ohms.

It is common practice to have a rheostat as limiting resistor for the low ohmage range, or a fixed resistor less than the required total resistance, and a rheostat much more than the difference. A good combination would be to use 1,000 ohms fixed and 1,000 ohms variable. Then the cell could be used until its resistance has risen to about 400 ohms.

It is to be expected that the cell or battery resistance will change, hence the compensator, if the meter is zero adjusted (no current through meter, needle made to read zero), then if full-scale voltage is applied, the rheostat is turned until full-scale needle deflection prevails. There is no need then to know intimately what is the apportionment of the components of the total series resistance, even if the cell or battery voltage is a little different in reality than the nominal value.

The Cell Potential

This point is made because numerous measurements of single 1.5 volt cells, also small dry batteries, using an electrostatic voltmeter (one that does not draw any current) indicate that the true potential of each cell is about 1.58 volts, rather than 1.5 volts. It is true that voltmeter readings taken with current-drawing instruments usually show closer to 1.5 volts, but this is because of the resistance of the cell. The current flowing through this cell resistance accounts for the voltage potential difference. It may be surmised that the cell potential actually does not change, only the cell resistance changes, and that the difference in voltages read from time is due exclusively to the cell resistance increasing.

For any close work, therefore, it may be well to regard the cell potential as 1.58 volts, rather than 1.5 volts, hence for a 0-1 milliammeter there would have to be 1,580 ohms per volt instead of 1,500. The difference is small, however, whichever way the subject is considered.

The usual setup for an ohmmeter is to use a 0-1 milliammeter, with suitable limiting resistance and rheostat, as explained, and for 1.5 volts full-scale deflection. Then resistance may be measured very well between 100 and 10,000 ohms. Also, lower values of resistance, and higher ones, may be measured, but the limits are debatable. It becomes necessary to define measurement as compared with estimate.

Formula for Selected Resistances

For a 0-1 milliammeter, then, consider the limiting resistance Ro as 1,580 ohms, when the cell is taken as E = 1.5 volts. If it is desired to coordinate the current scale with ohmage values of selected resistors, then selected resistance values, R, will be measured by the current I as follows:

$$I = \frac{E}{R} - Ro$$

where I is current in amperes, E is potential in volts, R is the selected resistance and Ro is the limiting resistance (1,580 ohms).

I and R will vary, E and Ro will remain fixed.

By this formula we obtain the current values as read on the meter, corresponding to known resistances, hence applicable to unknown resistances by current measurement, and we may select as many resistance values as we desire, say, from 10 ohms to 300,000 ohms. The very low and the very high resistance readings can not be closely made, because the meter scale does not enable such close distinctions.

Let us solve for 10 ohms, 100 ohms, 1,000 ohms, 10,000 ohms and 100,000 ohms, to illustrate. Perhaps it will facilitate matters if we note that current in amperes is to be considered, whereas readings will be in microamperes, hence if we want I in units, we multiply the voltage by 1,000,000 and use the formula

$$Imca = \frac{1{,}000{,}000\ E}{R} - Ro.$$

Values Computed

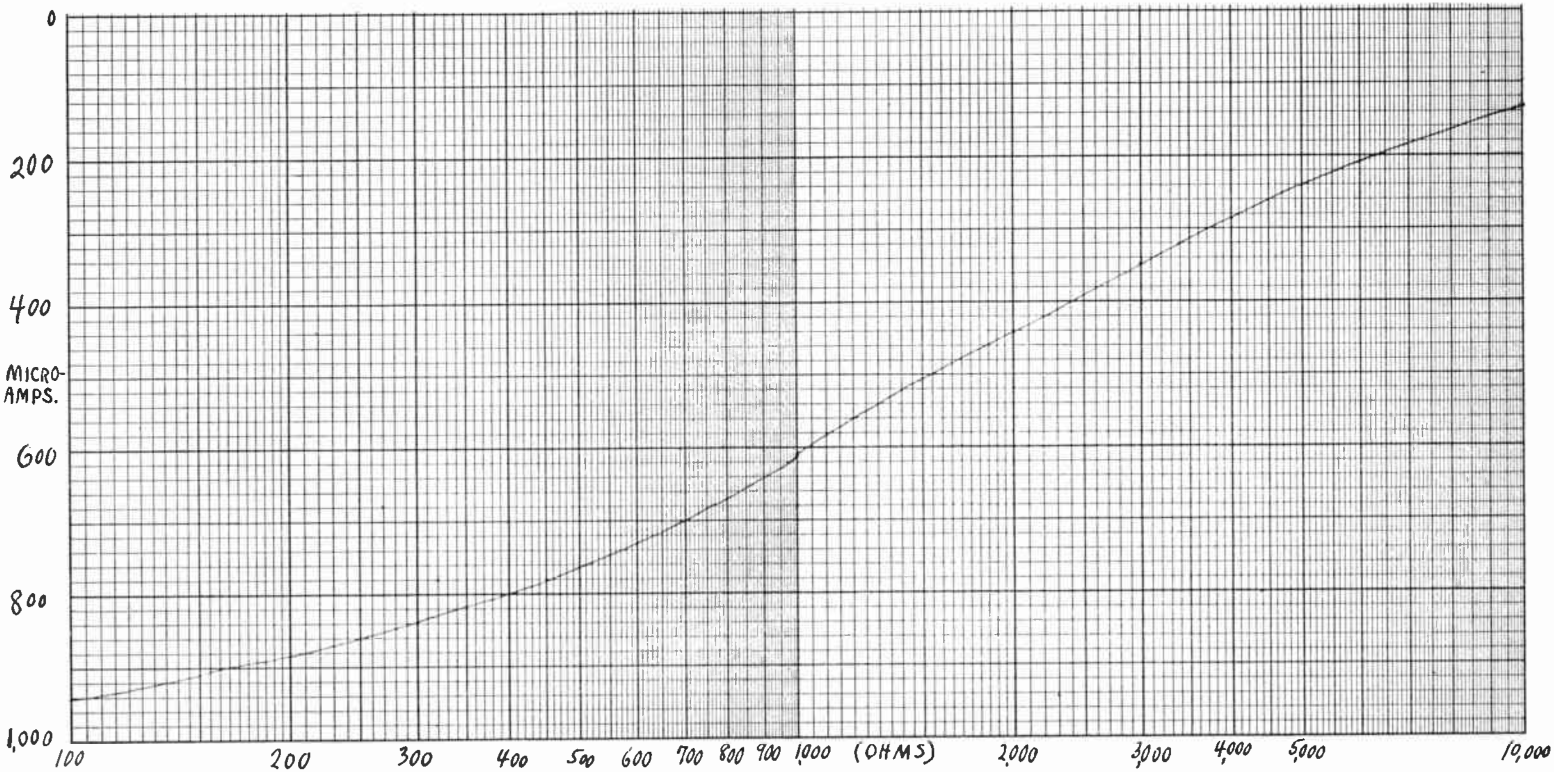
For 10 ohms, I equals 1,580,000/1,590 or 994 microamperes. (The 10 ohms have been added to the 1,580 ohms.)

For 100 ohms I equals 1,580,000/1,680 or 940 microamperes.

For 1,000 ohms I equals 1,580,000/2,580 or 611 microamperes.

For 10,000 ohms I equals 1,580,000/11,580 ohms, equals 136 microamperes.

Resistance Curve for 0-1 Milliammeter and Single Cell



Any 0-1 milliammeter becomes an ohmmeter when the 1.5-volt cell and limiting resistor are used and the above curve followed, 100 to 10,000 ohms. Higher and lower values will be found in the text.

Improvising an Ohmmeter

Current Scale Related to Resistances

By Neal Fitzalan

REGULAR ohmmeters are direct reading. Meters serving multiple purposes often include an ohmmeter scale. However, beginners sometimes want to measure resistance, using a meter they have. The instrument may be calibrated for current or voltage. The problem is to calibrate the readings in terms of ohms, when the circuit is properly set up for this purpose. In this connection it is well to appreciate some fundamental facts concerning the meter and its use.

In all instances the meter is a current-operated device. The needle moves because of the change in current. In a voltmeter there is a limiting resistance in series with the meter, so that when the intended maximum voltage is applied the needle reads exactly full scale. Since the current scale in direct current instruments is linear, the voltage scale is linear. However, the ohmmeter scale, or the equivalent ohmage for different current settings, is not linear.

Series Circuit Used

The ohmmeter therefore is a meter set up as for voltage, that is, with limiting resistor, and presupposes that the intended maximum voltage is applied when the circuit is closed. This circuit would consist of the meter, the limiting resistor and the voltage source in series.

If instead of simply closing the circuit as described, an unknown resistance also is put in series, then there will be less current, because when the voltage is constant the current decreases with increased resistance. Hence the higher the unknown resistance the smaller the current.

The more sensitive the meter the higher the resistance that may be read. The sensitivity of the meter is greater, the less the current required for full-scale deflection. For a current meter useful for resistance measurements in the ranges desired in radio practice the rating would be in milliamperes. If possible, a meter that has a sensitivity of one milliampere (.001 ampere) should be used, or a more sensitive one, if that is at hand. Then the range is well suited to radio practice.

Rating of Sensitivity

If the meter is a voltmeter the sensitivity may be expressed in ohms per volt. This quantity is equal to the total ohmage of the limiting resistance divided by the full-scale deflection voltage. Thus if the full-scale voltage is 1.5 and the limiting resistance is 1,500 ohms, the current is 1,500/1.5, equals 15,000/15 or 1,000 ohms per volt. Or, statement of ohms per volt enables computation of the full-scale deflection current, which is the voltage divided by the resistance, or 1.5/1,500 or 15/1,500 equals .001 ampere. If the full-scale current is known, the ohms per volt for any voltage range equals the number one divided by the full-scale current in amperes. Hence for a 0-1 milliammeter, the full-scale current is .001 ampere, so 1/.001 or 1,000 equals the ohms per volt.

If the ohms per volt and the full-scale deflection voltage are known, then the limiting resistance is the voltage divided by the current, or 1.5/.001, hence 1,500 ohms.

Getting Meter Information

It is necessary to know, or to be able to compute, the limiting resistance for turning a current or voltmeter into ohmmeter practice, because the resistor intended to limit the current at a given voltage to full-scale deflection always is in circuit, along with the unknown.

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by avoiding conducive contact of generator output wire, and wrapping a few turns of this wire around the plate lead of the tube concerned.

6. Remove generator output wire from its present position and connect it instead to grid of the modulator tube. The receiver being peaked is assumed to be for standard broadcast band reception, and if a multi-band set, the switch is turned to standard broadcast position, lowest receiver frequency setting.

7. Retune to the plate condenser of the transformer feeding the diode. Adjust this for minimum meter reading. If the reading is too low, meaning too close to zero, reduce generator output. Hereafter do not molest this condenser, Now adjust the condenser across the other winding of the same transformer. If either adjustment does not reduce the meter reading, return to the original setting affording minimum deflection. This holds throughout. Now repeat the realignment process on the next transformer. If there is a third transformer do the same work on that. Once the plate condenser is adjusted for minimum meter reading on any transformer do not disturb but make all further changes, if any, in the grid circuits, or in the diode circuit for the last transformer.

If there is no audio volume control and therefore there can not be ready elimination of sound output, the speaker voice coil may be shorted to accomplish this. Due to the low impedance of voice coils it is necessary to make this short with stout wire. Even so a slight audible response may be expected.

Remedy for Disastrous Sluggishness of A.V.C.

While it is necessary to use a tuning meter with a circuit having automatic volume control, if one is to facilitate tuning with minimum of interference, maximum of sensitivity and best tone, nevertheless circuit conditions may render even this aid difficult to use properly unless the actuating circumstances are understood.

One outstanding fact about a. v. c. is that it may act quickly, moderately or slowly. Rather the action should be quick, not slow. If it is too slow it is called sluggish, and the effect lags appreciably behind the cause, so that the diode rectified current, and consequent voltage for a. v. c., become maximum before the meter reads maximum. Thus turning the receiver dial one may pass over a station, or fail to tune it in correctly, despite aural aid, because the meter finally is relied on, and it does not follow the rectified voltage quickly enough.

Remedying Time Constant

This sluggishness is due to a time constant in the resistor-capacity filter that is too high. This filter comprises the resistor in series with the grid return, and the bypass condenser from coil end to B minus (usually ground). The action may be speeded up either by making the resistor smaller or the condenser smaller, or reducing both. The product of the resistance in megohms and the capacity in microfarads should lie between .04 and .09. The action under the .09 time constant condition is slower than that under the .04 condition, but both values and those between are fast enough, yet not too fast.

For audio-frequency reasons it is favorable to tone to have the resistance high and the capacity low, yet of course attaining time constant values within the prescription. The reason is that the diode has a load resistor of high resistance, usually .5 meg. No less than .25 meg. should be used there. Since the filter resistors just mentioned are bypassed they are substantially in parallel with the diode load resistor, and thus the audio impedance is reduced in the diode circuit. For .5 meg. diode load, filter resistors of 1 meg. bypassed by .05 mfd. would be minimum from the resistance viewpoint.

Tuning to I. F. "Depression"

If the i. f. channel is single peaked, then the meter action, with time constant proper, is abrupt. But if there has been double peaking for band-pass filtering, then resonance is not always denoted by the actual peak, but by the position between the two peaks. If the channel has been carefully aligned and the a. v. c. time constant is right, the receiver dial at low frequencies can be turned to work the i. f. channel on the "depression frequency" over most of the broadcast band, particularly for low intermediate frequencies. For short waves, when the i. f. is high anyway, distinction is not so readily made. An exception exists if there is mechanical or electrical r. f. bandspread, when the valley can be tuned to instead of either peak. For constant ratio of bandspread this possibility diminishes as frequency increases. It is usually sufficient in flat-top i. f. that the minimum reading "holds" though the r. f. dial is turned a trifle.

3. Turn on the set. The r.f. and i.f. sensitivity controls should be turned all the way up (maximum volume). If there is an audio-frequency level volume control it may be turned all the way down, as the alignment may be made in silence. If a selectivity control is present it should be at the position for maximum selectivity.

4. Use a signal generator, set at the frequency at which the intermediate channel is to be peaked. Connect output wire of the generator to plate of the last i.f. tube. Note the reading on the voltmeter. Adjust the condenser of the i.f. transformer winding feeding the diode until meter reads minimum. Usually the signal generator will have to be at largest output for this purpose.

5. Remove connection of signal generator output wire from plate of the tube ahead of second detector to plate of the previous tube. Adjust the condenser across the plate winding of the transformer feeding the diode. Adjust the condenser across the grid winding of the next transformer. The minimum meter reading, sharply defined, is the sole test. If meter reads too low, or if two positions of any condenser give minimum readings, reduce the output of the signal generator. This may be done by adjusting the attenuator, or, if there is no attenuator,

(*Continued on next page*)

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quency, or 1,100 kc for a 175 kc i.f., and if no sensible meter effect is produced, the oscillator is tentatively right.

How Long an Aerial to Use

Next connect an antenna and note carefully the response from 1,400 to 1,000 kc, with signal generator shut off. If there are many whistles and squeals and birdies, used a shorter antenna, even only six feet of wire, and if the birdies disappear, then everything is all right. You may increase the antenna length to that point where the birdies come back, but reduce it a bit to get rid of them again, and then you know just how much antenna you may use with the set.

Now remove the antenna from the receiver post, turn on the generator, now adjusted to afford 600 kc output, and turn the series padding condenser all the way down, maximum capacity.

Unless the padding condenser is of wrong maximum capacity, or by accident just right at that capacity, as you turn the receiver dial to somewhere near the full capacity setting of the tuning condenser you will get a deflection somewhat lower than the no-input value.

Now step by step, tiniest possible adjustments made one at a time, turn the padder's setscrew with a screwdriver or alignment tool, and turn the receiver dial to a higher capacity position. The meter reading should decrease slightly, or at least, not increase. Finally a considerable drop in the voltage reading will take place.

Keep noting the voltage. Soon it will begin to read higher, disclosing that the right point has been passed. Remember each time to move the receiver dial to higher capacity settings, just trivial mechanical movements all of these. Having noted the minimum voltage read, readjust the padder until this reading is restored, and the alignment is complete.

Short-Wave Alignment

If the dial is frequency calibrated, though 600 kc is the true frequency for the receiver dial setting now existing, the dial may read some other frequency not far removed, but there is no control over this, without remaking the oscillator coil, so it is perhaps wise to accept this as the best that can be done without embarking on any redesign of a receiver.

For higher frequencies of reception, assuming a two-band or other set, such as all-wave, intended to bring in short waves, the parallel trimming, if any, is done at the high frequency end, and the dial position used for the broadcast band may be selected, and a frequency injected that yields response. If there is to be low-frequency padding of a short-wave band, then about the same receiver dial position is selected as was used for 600 kc, and the adjustment made the same way. Many receivers have no low frequency adjustment, or rely on fixed condensers for short-wave padding. Some refinement may be introduced by using more series padding capacity (by paralleling with small fixed capacity) to check for better tracking and then trying large series capacities, connected to the padder itself, to the same effect, but this is again in line with receiver redesign.

So far we have considered the superheterodyne. We have assumed a diode detector used for detection proper (audio development) and the same detector for a.v.c. Sometimes a separate a.v.c. tube is used, or a separate section of a diode. No matter which way it is done, there is an a.v.c. line. In rare instances there may be two such lines, one from the regular detector to effect a.v.c. on some tubes, the other from the a.v.c. rectifier to effect control on other tubes. Also, the a.v.c. may be applied to modulator tube control grid circuit, or also to the r.f. tube or tubes, but never to the local oscillator. The principles just set forth, and the method of application, remain the same.

If the conversion takes place in a single tube, e.g., a pentagrid converter, there is still no difference in the procedure. The modulator and oscillator sections must be separately identified, but this is easily done. Any tube manual will give the necessary information.

Tabulated Sequence

Although a.v.c. is not used much in tuned radio frequency sets, nevertheless where it is used the same procedure may be followed, where the r.f. tube ahead of the only detector is the one used as tube voltmeter, the adjustment being made, however, at only one frequency, which may be nearly the highest frequency to which the set tunes, since such sets are usually single band. There is no adjustment for the low frequency end, except perhaps for tuning condensers with slotted plates. It is hardly practical to get high-grade results this way, and the high-frequency adjustment is always upset by the low-frequency adjustment, so perhaps reliance on the high-frequency peaking will suffice. Better grade condensers are made with tolerances so close that here is no real need for monkeying with slotted plates. Preferably install a high-grade tuning condenser.

The procedure for peaking an intermediate amplifier subject to automatic volume control will be tabulated. A tube subject to control is used as a vacuum tube voltmeter. The representative diagram assumes that the last i.f. tube is so controlled. Many sets have only one i.f. tube and if there is a.v.c., of course that tube is controlled.

1. Short the antenna winding of the antenna coil. Do this preferably at the coil, not at the antenna and ground binding posts of the set, because there may be pickup due to the wire leading from antenna post to antenna winding.

2. Unless you are working on a wooden table or bench free of metallic covering, turn the chassis so that it stands on one end, preferably where supported by the power transformer. Put a 0-5 or 0-6 d.c. voltmeter across the cathode biasing resistor of the controlled i.f. tube, or if more than one are controlled, across the biasing resistor of the last i.f. tube. If the chassis in its console has open bottom no further precaution about this is necessary, but if the chassis has a metal bottom piece, solder voltmeter leads to the cathode resistor and bring them through the chassis somewhere, and affix the bottom piece. Alignment must be made under the conditions of actual use of the set.

what more than the band width. That is, for 175 kc mean, start generator at 175 plus 5 or 180 kc, and slowly tune it through to 175 minus 5 kc, or 170 kc. A direct reading signal generator in the 175 kc range ordinarily will not permit readings to 1 kc. Or, if the divisions at best are 5 kc apart, then extend the theoretical band to 20 kc, starting at 165 kc and running to 185 kc. When the frequency and voltage readings have been taken a curve may be drawn so that the selectivity and fidelity of the intermediate amplifier may be examined. Any lopsided result will indicate that the double peaking has not been done properly.

The foregoing concerned the intermediate amplifier, which is not always the most exacting circuit to adjust in a superheterodyne. Since we have the simple indicating system, the voltmeter M, we may use that to advantage for the radio frequency and local oscillator adjustments, i.e., tracking. Suppose we select the standard broadcast band, and describe the process, which for other bands would be repeated the same way, so far as necessary. For high frequency bands there might be no series padding condenser, or if there is one, it may be fixed, so that only the parallel trimmers have to be adjusted, unless tracking can not prevail because of oscillator inductance error.

The Tracking Method

Remove antenna from the receiver, connect signal generator to the antenna post, set signal generator going at 1,450 kc, and turn the receiver dial to read 1,450 kc, if frequency calibrated; otherwise to read 8 or 92, depending on whether a 0-100 dial reads low or high numbers for low capacities of tuning. If little response is noted on the meter, turn the parallel trimmer on the oscillator tuning condenser section one way and the other for minimum deflection on the meter. This adjustment is critical, and if one passes the desired point care must be observed that one returns to the minimum reading exactly. If minimum is too low to be read easily, reduce the input, say, by wrapping the signal generator output wire around the antenna binding post for six turns or so, at the conductive part, end of output wire left free. All r.f. or i.f. manual volume controls are assumed to be at position of greatest volume, maximum sensitivity, and if any selectivity control exists, it is set for maximum selectivity.

Next adjust the modulator trimmer, for reduction of the voltage read on M. Then adjust the antenna trimmer of the modulator. The oscillator adjustment produces greatest change, the modulator next greatest, the antenna trimmer least change. For strongly coupled oscillator and modulator circuits there may be interdependence between modulator and oscillator trimmers at this part of the broadcast band, so do not be surprised if any adjustment of the modulator trimmer only makes the voltage read higher. Simply restore to the original setting for minimum reading.

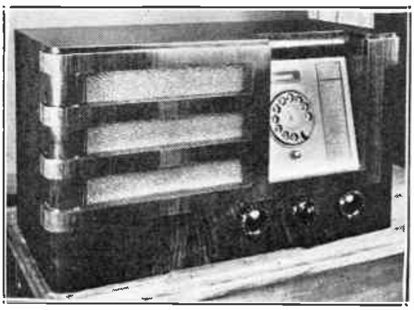
Check Against Wrong Setting

The high-frequency tiedown for the standard broadcast band has been completed, except for a check on the oscillator frequency being higher or lower than the intended carrier (1,450 kc) frequency. In practice the oscillator is intended to be higher, thus for 175 kc the oscillator should be at 1,450 plus 175 kc or 1,625 kr, or for 456 kc should be at 1,450 plus 456 kc, or 1,915 kc. But if the oscillator were lower, instead of higher, more likely if the i.f. is low frequency (175 kc) there would be reception just the same, but the tracking could not be accomplished. So now turn the oscillator trimmer all the way down (assuming it was not all the way down originally and see if the same response can be picked up. If so the local oscillator is now lower than the signal generator frequency and the first setting was right, so return to it. If the repeat can not be tuned in, this way, for lack of capacity leeway on the trimmer, or because the i.f. is too high, both expressing the same idea, restore the oscillator trimmer to the original position of minimum deflection, and change the signal generator frequency to some value higher than 1,450 kc by about twice the intermediate frequency. Watch for needle deflection. Thus, if the intermediate frequency is 175 kc, twice that is 350 kc, so turn to 1,450 plus 350 kc, or 1,800 kc, and if a response is noted, though a weak one, the oscillator is properly higher in frequency. As a check, turn the signal generator to a frequency lower than 1,450 kc by about twice the intermediate fre-

(Continued on next page)

Phone Dial Method for Set Tuning

A radio receiver tuned with a telephone type dial was exhibited at the Trade Fair in Leipsic, Germany. Any desired station is dialed in just as a desired telephone number is selected. The dial controls relays and a motor which drives the tuning condenser around. The number dialed determines where the motor is to stop. The tuning



is always exact for it has been determined previously by precise instruments. The illustration shows a modernistic set equipped with one of the new tuning devices. The sloping feature of the tuning panel helps selecting and reading the numbers. The lack of symmetry in the cabinet design enhances the modernistic effect.

Selectivity Measured by Small Voltmeter

It is not to be expected that operators will possess signal generators that give the equivalent of bandspread tuning, but if they are that fortunate they may run a selectivity curve of the intermediate channel, by peaking the i.f., noting the meter reading, and then turning the signal generator to equally spaced frequencies up to 7.5 kc on one side and 7.5 kc on the other side, nothing the meter reading for each of the equally spaced frequencies. Then a curve may be prepared, using cross-section paper, with frequencies written at the base, and voltages on one side. After the points are registered on the paper the curve is completed by extrapolation. Thus a result somewhat like that obtained from a cathode ray oscilloscope is produced.

If the channel is not to be singly peaked, but doubly peaked to band-pass effect, then the shape of the curve may be viewed, also the width of the band passed may be noted, and a critical examination made of whether both sides of the curve are equal. If they are not equal, the double peaking has to be done over again to make them equal, as lopsidedness produces a form of distortion.

If the task of tuning the transformers for double peaks, using one winding and its condenser for one peak, the other winding and the other condenser for the other peak, all constants of one transformer, proves too difficult, one transformer may be peaked as to both windings at one frequency and the other transformer at the other frequency. Then if there is a third transformer it is necessary to peak one of its windings at one frequency and the other winding at the other frequency.

(*Continued from preceding page*)

governing a single transformer. The plate condenser settings in the final checkup should not be disturbed on rechecks, but only the secondary condensers.

The condition will be encountered by some wherein the voltage reading on M is reduced practically to zero. This denotes too much input, so reduce it. Using a 0-15 volt voltmeter of 66.6 ohms per volt, Rk with no signal input read 3.3 volts across 380 ohms, whereas at resonance for completely aligned channel read .5 volt. If possible use a voltmeter of smaller full-scale deflection, say 0-6 volts, or thereabouts. This is the same recommendation as previously given, that the reading on the voltmeter be as near maximum deflection as possible at no-signal input.

When Beats Are Troublesome

If any circuit is desired to be adjusted, as plate circuit, when the signal generator is connected to it, put a resistor between of 20,000 ohms to 50,000 ohms between signal generator output lead and plate of the tube. This applies also to the modulator tube, though connection is then made to the control grid.

In case there are beats, causing confusion in alignment, short-circuit the antenna winding at the coil (not at antenna-ground posts), or if need be, remove the local oscillator tube, if it is separate from the modulator, or short the local oscillator grid to ground with a piece of wire. These references have nothing to do with the oscillator in the signal generator. All final peaking should be done with local oscillator functioning.

Thus the peaking of the intermediate amplifier is completed. The work performed is the establishment of resonance at a selected frequency, to afford the maximum sensitivity and selectivity of which the i.f. channel is capable, also maximum performance in the absence of oscillation. By all means the oscillation must be stopped before any final alignment is attempted. It so happens that when the circuits are exactly in tune the presence of oscillation is less likely, but close peaking must not constitute a makeshift cure. Stop the oscillation before final peaking.

Double Peaks for Bandpass

Besides absolute peaking, which has just been described, there is double peak alignment, required for some band-pass i.f. channels. The amplitude is made of equal height a two points each removed from the mean frequency by half the band width intended to be passed. Suppose that the mean intermediate frequency, or depression frequency it may be called, is 175 kc. Suppose the band width is to be 8 kc. Then the frequencies 4 kc removed from 175 kc in both possible directions are 175 minus 4, or 171 kc, and 175 plus 4, or 179 kc. A signal generator is required that has sufficient bandspread tuning to enable the selection of the two peak frequencies, each closely identified. The condenser across one winding of an i.f. transformer is turned until there is minimum deflection on voltmeter M at one of the frequencies. and, with generator next set at the other frequency, the other condenser across the other coil is adjusted until there is minimum deflection for the second frequency, 8 kc removed from the first. The same sequence is followed as for single peaking, starting at the last coil, and the same connections are made.

Care must be taken that the reading is exactly the same for one peak frequency as for the other, both minimum readings on M. In the final realignment the two frequencies are repeated and the proper circuits tuned to their intended frequencies, so it is well to keep a record of which condenser was used for each frequency on each transformer.

Possible to Run a Curve

When this double peaking is attained it is well to note the minimum voltage reading on M for one of the two peak frequencies, recheck that the same voltage is read for the other peak frequency, and then, all alignments having been completed, to turn the generator through some-

Mechanical Aspects of Tuning I.F. Channel

Most superheterodynes have intermediate frequency transformers with mica dielectric condensers, one tuning the primary, the other tuning the secondary. These condensers have a spring tension, and one of the plates is worked against this tension by adjusting a setscrew, using a screwdriver. If the usual metallic driver is employed there may be body capacity effects, and even with a neutralizing tool this is a possibility. Thus the meter reading will change when the driver is removed. Test carefully for body capacity. If it exists, then the adjustments must be made bit by bit, meter read when the transformer is free and clear of this extra metal or dielectric through which the body capacity becomes effective.

Some transformers, particularly those in the best sets, have air dielectric condensers. These also are usually adjusted with screwdriver turning a setscrew. There is one distinction: capacity is increased for the mica dielectric condenser almost always when the rotation is in a clockwise direction, decreased when rotation is in an anti-clockwise direction. Thus "turning to the right" lowers frequency, turning oppositely increases frequency. With the non-end-stop air dielectric condensers there is no guide as to whether capacity is being increased or decreased, and either may be true of either direction, although the point is merely academic. The right setting is attained just as readily.

Some transformers have three tuned circuits. Uusually it is advisable to align on the basis of adjusting the two extreme condensers, leaving the center one intact, until possibly the final checkup, when the center ones alone would be adjusted. As a rule it is recommended that the center one be not molested for high-class transformers peaked at the factory.

from the signal generator, especially for the two-stage i.f. amplifier, and most especially if high-grade i.f. coils (high Q) are used, with their relatively loose coupling.

The Retuning Process

A good first approximation is reached, and when one is close to the required peaking condition the accomplishment of the final close result becomes easy. For instance, if the work has been tentatively performed, and the generator is positioned at the modulator grid circuit, a good plan is to identify the plate and grid tuning condensers of the last i.f. coil. There is B voltage between the plate condenser and the chassis or the coil shield. Therefore now carefully retune the plate condenser of the last i.f. coil for minimum deflection on M. Then slowly turn the diode condenser to determine if you can get a lower reading, and if not, reverse the direction of turning, as a renewal of the attempt. If you can not get a lower reading, return to the diode condenser setting that restores the minimum reading. For compression type (mica dielectric) condensers, turning the condenser setscrew to the right usually increases capacity, therefore lowers frequency. Turning the setscrew to the left does the opposite, lowers capacity and raises frequency.

Now go through the same process for the coil ahead of the one just peaked, and then, if there is still another i.f. coil, again repeat the process.

Plate Settings Stay Put

Due to interaction between plate tuning of one tube and grid tuning of the next (or anode tuning for the detector), for strong coupling there may be no single setting for each condenser that will be just right. Of course the two windings that are tuned are inductively coupled, constituting the same coil. Capacity change in one circuit is reflected a little in the other, and the object therefore is not to establish just a particular capacity setting but to get the two capacities set so that the transformer is tuned to a single frequency. There is not a great leeway, and one capacity can not be far off, and the difference made up by adjustment of the other, however the operator should not be mystified by getting true resonance at different pairs of settings for the two condensers

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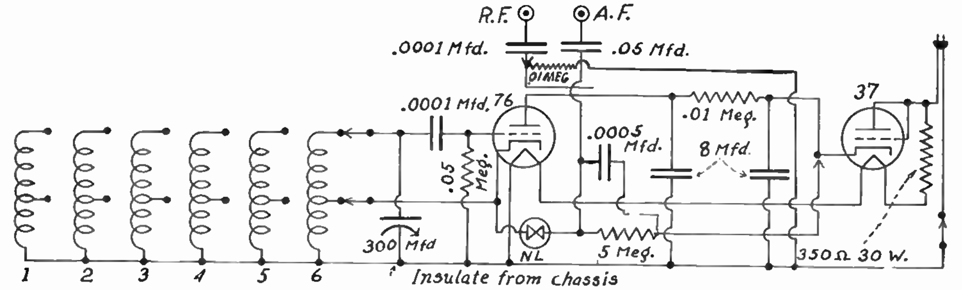
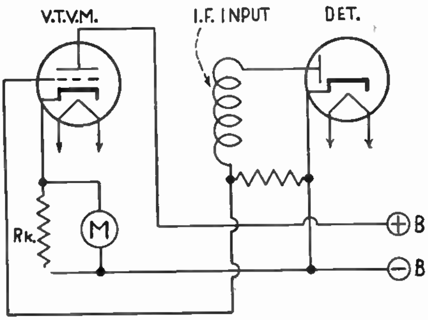


At right, close to cathode of the 37, is a switch that when "on" energizes the neon tube NL for modulation of the signal generation. If modulation does not exceed 100% the a.v.c. alignment method described should show no difference in meter reading whether modulation is on or off.

"Visual" Has Special Meaning in Testing

The single meter method of alignment at d. c. values is of course a method that is based on use of the eye and therefore visual in a true sense. However, formerly there were two methods of alignment: one concerning audio frequency results, as read on an output meter, and the other for results viewed on the cathode ray oscilloscope as applied to receivers in production. The test made with the oscilloscope is known as a "visual," and to avoid confusion of terms it is well to retain the word visual for the cathode ray method, and one therefore may refer to the meter method as the silent test.



The basic tube voltmeter circuit. The last i.f. tube is used as such, in fact it may be the only i.f. tube in the set. The detected voltage affects the meter M. Rk is the cathode resistor for safety bias.

(Continued from preceding page)

the r.f. end representing some position in the broadcast band, the remaining i.f. windings may be peaked at the i.f. level.

Completion of I.F. Peaking

All activities will influence the voltmeter M, and since the added tuning will raise the amplitude at the detector, the rectified voltage is higher, and the Rk voltage drop is reduced more and more.

With the signal generator at C the peaking is completed, except for refining the adjustments in an effort to get the voltmeter reading still lower. Always the aim is to establish the lowest possible voltmeter reading.

The process just described does not require that the signal generator used for supplying the intermediate test frequency be modulated. Whether it is modulated or not, the quantity of the rectified voltage, or drop across the diode load resistor R4, is about the same for modulation percentages 100 per cent or less, as the diode rectifies the mean a.c. The actual voltage across the diode load resistor is .636 of the r.m.s. (a.c.) input to the diode, assuming perfect rectification.

For the foregoing reason it is not necessary to pay any attention to audio, not even to listen to any reproduction, because we are depending solely on reading a d.c. voltmeter, and it is being influenced by conditions arising solely from ratification of the i.f. carrier.

Anti-Noise Method

To put it differently, if there is a volume control that works at the audio level, as in the representative diagram, the voltmeter reading, taken on M, is independent of the setting of this control. If you like, you may listen to the output, as well as read the d.c. voltmeter, although only the d.c. voltmeter is the real guide. In fact, the present silent method enables peaking without annoying fellow workers or family with screeches.

It is not necessary therefore to rig up a tube voltmeter to attain a guiding deflection, because there is really a tube voltmeter, though uncalibrated, present in the set.

The reason why the present method works on as strong a signal as you may prudently feed to the i.f. channel within the limits of overloading is that it is solely a measure of the quantity of the i.f. amplitude in terms of the i.f. carrier's rectified voltage. And the more closely the circuits are to resonance, the greater will be the i.f. input to the detector and the consequent rectified current and resultant potention difference across the diode load resistor. The a.v.c. action does reduce amplification, but we are now using a method that in point of time is prior to the effect on amplification.

First Movement Small

There are some factors to consider concerning the signal generator connection. Depending on the signal generator, the connection may be made by putting the signal generator output wire directly to plate of the second i.f. tube for the first adjustment (secondary feeding diode). If the generator output is very strong and can not be attenuated sufficiently to yield a closely definitive response, reduce the coupling by avoiding direct connection, wrapping a few turns of wire around the plate lead of the second i.f. tube. Usually for the first adjustment, concerning only the winding supplying the diode, the input should be husky. It is not to be expected that the voltmeter needle will move much, but it will be a recognizable deflection. The accompanying plate winding, also intended to be tuned, need not be adjusted at this particular time, especially if the signal generator is closely coupled to the second i.f. plate, for then the loading effect on this plate circuit by the signal generator is pronounced, and what looks like tuning, with generator connected, turns out to be mistuning when generator is advanced to the preceding plate circuit. For the second measurement, the indication will be pronounced.

The reason for working backward, from last i.f. coil to first, is that gross misalignment is frequently encountered, and it is hard to get much through the i.f. amplifier at any frequency it attains a direct current value directly proportionate to the mean i.f. amplitude. So the more i.f. voltage put into the second detector, the greater the rectified current, hence the greater the potential difference across the diode load resistor.

How Extra Bias Arises

Since the high side of this resistor is negative, if the grids of the controlled tubes are returned through an exclusive d.c. path to the high side of the diode load resistor, zero rectified voltage across this resistor will add nothing to the bias otherwise present on the controlled tubes, any finite rectified voltage will increase the negative bias on the controlled tubes to the extent of the rectified voltage.

To afford standard negative bias at no input to the i.f. channel, the usual biasing resistors are placed between cathode and B minus of the controlled tubes, and are bypassed by fixed condensers.

Of course, more than merely i.f. amplifier tubes may be controlled, but we shall confine ourselves at present to a.v.c. in the i.f. channel because it is always the first channel to be aligned, and any other alignment depends on the i.f. channel being right.

The circuit may consist of fewer i.f. stages, or different connections, nevertheless the principle remains the same, and the simple alignment process holds, using only the modest voltmeter, and without breaking any connections whatever.

The Action Analyzed

In the representative diagram, note the tube identified as "2d I.F." The principle of operating the alignment method will be described in connection with this tube and the diode, so that the reader will comprehend what goes on when he performs the simple process of adjustment.

Looking at the representative diagram, if an i.f. input is made to the detector and the rectified voltage is developed across R4, this voltage is referred back to the second i.f. tube as additional negative bias. Remember that the sole effect on the second i.f. tube is that provided by d.c. voltage, as there is assumed to be no a.c. left, the condenser across R4 in the set removing the i.f. For an i.f. input at A, therefore, there will be a ratable voltage developed across R4 that increases the negative bias on the second i.f. tube. The more negative the bias, other voltages constant, the less the plate current in the controlled tube, therefore the smaller the voltage drop across the biasing resistor in the cathode leg of the second i.f. tube. Although triodes are indicated, the tubes would naturally be pentodes of the remote cutoff type, and the sum of the plate and screen currents would flow through the cathode biasing resistor.

Because only d.c. is now influencing the grid of the second i.f. tube, the input coil to the second i.f. tube has no effect. Resonance is not now involved in the second i.f. tube and its input.

Tube Voltmeter Practice

Fortunately, even the remote cutoff tubes, which are the only ones well suited to a.v.c. provide substantial reduction of B current in the controlled tube for small changes of grid control bias voltage. Therefore the voltmeter will show changes readily.

The second i.f. tube therefore is being treated as if it were a vacuum tube voltmeter, uncalibrated. The negative grid bias increase due to a.v.c. reduces the voltmeter reading, and therefore it is well to use a voltmeter of a range affording voltage reading across the cathode biasing resistor Rk near full scale for no-signal input to the detector.

Now any circuits that are tuned to an input frequency will reduce the voltage reading across the second i.f. tube's cathode biasing resistor Rk. There will be a sharp indication of resonance. This method is known as peaking, because the tuning is done only to produce the highest amplitude and only one peak.

Now if we move the signal generator connection from A, the second i.f. plate, to B, the first i.f. tube's plate, we may adjust two succeeding hitherto untouched circuits, for greater reduction of the voltage across the second i.f. tube's cathode resistor Rk. The meter's circuit position is not changed. Then if the connection is moved to grid of the modulator tube, with

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Small D.C. Voltmeter as Tuning Indicator

The inexpensive voltmeter with which the measurement is made for peaking by the silent, no-broken-connection method may be used as a tuning indicator. Such a meter can be bought for 60 cents. All a.v.c. systems require some visual method of verifying resonance, otherwise resonance becomes hit or miss, and when there is a miss, which is often, there is distortion. The meter should be panel mounted.

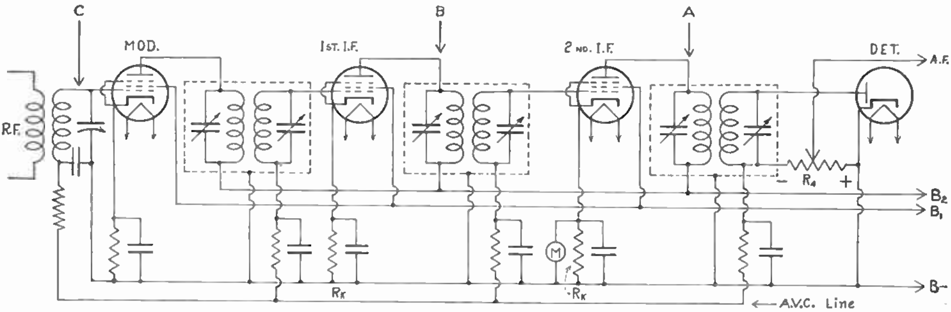
Since the actual voltage readings are not important, but only minimum deflections are watched, the meter used need not be calibrated, although it preferably should have some gradations, to aid the eye in discerning minimum deflection, particularly noting small differences.

Since a low resistance voltmeter may be used, its effect on the steady bias of the controlled tube with which it is used should not be ignored. The biasing resistor normally would be 250 ohms but often 300 ohms are used for a.c. sets with remote cutoff tubes. No actual substitution of biasing resistor need be made, but an aural response (if used) may be expected to be weaker, especially on faint signals, when the voltmeter is removed, due to the steady bias being higher when the meter is out of circuit. The actual biasing resistance, hence bias, is less when the meter is across this resistor, as it is a case of two resistors in parallel.

Silent Peaking with A.V.C.

Single D.C. Voltmeter Used and No Circuit Connection Broken

By Herman Bernard



Representative diagram of an intermediate amplifier with two stages subject to automatic volume control. The tubes, left to right, are modulator, first and second i.f. and detector. Rk is the diode load resistor, M is the d.c. voltmeter (about 0-5 volts) used as sole indicator.

OUTPUT meter alignment of a circuit using automatic volume control is more difficult because the very levelling effect for which a.v.c. is used tends to mask resonance. Instead of resonance denoting greatest quantity of sound output the set may produce equal quantity at frequencies slightly removed from resonance, because the off-resonant voltages nearly remove the extra negative bias that functioning a.v.c. contributes. The increased gain on weak signals makes up for the reduced gain on strong ones.

Therefore if a conventional output meter, which is an a.c. instrument of the rectifier type, 1,000 ohms per volt, is placed across the primary of the power tube's output transformer, a strong signal fed to the i.f. amplifier will defeat practical alignment. The same would be true if an a.c. meter were put across the voice coil, a connection which permits the use of a low resistance meter. It is clear that all that gets through the audio channel is audio frequency, and what is being measured is audio frequency, therefore if a signal generator is used it must be of the type including modulation.

Inexpensive D.C. Meter Used

Realizing that many radio experimenters and students have low-range direct-current voltmeters, especially of the low resistance type, a circuit was built, and peaking of the intermediate channel, as well as alignment of the oscillator and r.f. radio frequency section, was accomplished with the use of such a small, inexpensive meter.

The i.f. channel is assumed to exist with proper continuities and voltages. It feeds a diode detector. The i.f. voltage is impressed on this detector and develops a rectified output across the diode load resistor, R4 in the representative diagram. The signs at the terminals of this resistor denote the polarities of the d.c. potential across this resistor. The left-hand, or negative side, is called the high side, the cathode or positive end the low side.

The number of controlled tubes is immaterial. Two i.f. tubes are shown controlled as follows: When the i.f. input to the detector is rectified

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For Particular Receivers Take Maker's Advice

Although a specific method of alignment of a superheterodyne at all channels has been set forth, the data are intended for application to the general case, and are not to be construed as contradictory of manufacturers' directions. If a particular make of set is to be aligned there is no better authority than the manufacturer. Then follow manufacturers' directions in preference to those given herewith, for the manufacturers have in mind special needs applicable to their own receivers.

unmodulated carrier and a few per cent higher with complete modulation. This represents a reduction in the plate power consumption of the final stage of a radio transmitter by nearly a factor of two, as compared with the power required by an amplifier of the conventional type.

A 50-kilowatt amplifier, for example, with 33 per cent. efficiency, would require a d.c. plate input of 150 kilowatts, of which 100 kilowatts would be dissipated at the anodes of the water-cooled tubes.

Gaited to High Fidelity

With the new circuit the power input for unmodulated carrier is 83 kilowatts, and the dissipation accordingly only 33 kilowatts, permitting a considerable saving in the water cooling system as well as in power requirements. These items are of great importance in modern high-power broadcasting, where the cost of apparatus and power constitutes a large part of the operating expense.

By the application to radio transmission of another Laboratories development, the feedback principle* of H. S. Black, to reduce the effects of non-linearity in the amplifier characteristics, the new high-efficiency equipment has been made to perform with a quality of transmission which satisfies the most rigorous requirements of high-fidelity broadcasting.

Finally, the new circuit, being purely an amplifying scheme, can be applied to special types of transmission, such as the single-side-band transmission employed in the transoceanic service of the Bell System. Other schemes that have been proposed for improving the efficiency of broadcasting radio transmitters do not appear to be of such broad applicability.

*Bell Telephone Record, June, 1934, p. 290.

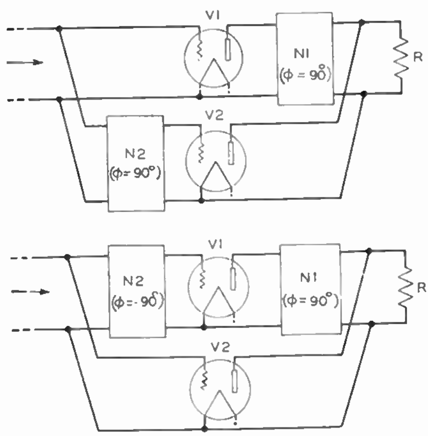
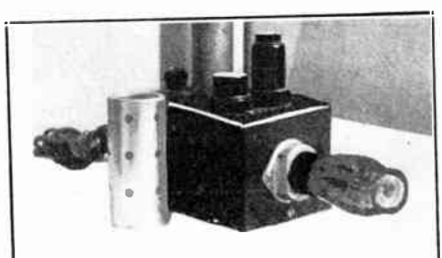


FIG. 8
With a 90° phase shift in the plate circuit of one tube, a compensating phase shift must be inserted in the grid circuit of one of the tubes so that both tubes may be excited from the same source.

I.F. OSCILLATION CURES

WHAT can be done to stop oscillation at the intermediate frequency level of the superheterodyne you build, which has two i.f. stages at 465 kc? When you tune the amplifier on the nose the oscillation is pronounced. Whenever you pick up a carrier a squeal comes with it, although by closely tuning to resonance with the carrier you can get rid of this squeal; indeed, attain very high order of sensitivity.

When three i. f. coils are used that way the circuit requires careful treatment, as oscillation troubles is a frequent complaint. Assuming that the filtration in this circuit is as good as you can conveniently make it, the first and easiest method is to use shielded wire on the leads to control grids of the i. f. tubes. If it is almost impossible to remove the coils so that the shielded lead wire can be readily attached in place of the present wire, wind thin wire around the present lead, being careful to protect the grid clip from what otherwise would be a grounded wire and thus by shorting stop reception. Affix a lug to the shield coil with a self-tapping screw and solder one end of the wound overlay of wire to this lug. The coil shield is assumed grounded to the chassis. Do this to the two overhead leads, or the three leads, if a screen grid tube is second detector. Also it is permissible to raise the negative bias on the i. f. tubes somewhat, using resistors of half again as much resistance as the present ones. Then retune the i. f. and if trouble continues (although it will be less), use much larger paper bypass condensers across the biasing resistors in cathode legs of the i. f. tubes. If any enduring oscillation can be traced to a particular tube, put a resistor across the plate winding connected to that tube, of such a value that oscillation just stops. A 50,000 ohm rheostat may be tried, turned until oscillation stops, measured externally, and duplicated with a fixed value.



A 6E5 or 6G5 ray indicator tube may be inserted in a socket at side of a box. The other tubes are 6C5 (as diode line rectifier) and 6H6, as test signal rectifier. The rectified signal is fed to the ray tube, over which the tube shield is put.

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behaves similarly, as shown in Fig 5(a); whence, in order to have the total load current I_4 linear with respect to grid excitation, the current I_2 fed into the load from tube V2, which is zero at the carrier point, must rise linearly beyond this point and be equal to I_3 at the peak of modulation.

From this same property of network N we also deduce that if the voltage E_2, across the load and the second tube, is linear with respect to grid excitation, then the current I_1 fed into network N by tube V1 must also be linear. Figs. 5(a) and 5(b) therefore give the complete picture of the conditions existing at the plates of the two tubes for all values of radio-frequency grid input voltage to the amplifier, and the behavior of each tube during the modulation cycle may be studied by considering the grid excitation to vary at audio frequency about its average value e_0, to the extent corresponding to the percentage modulation.

Phase Shifting

When samples of the radio-frequency plate potentials on the two tubes during modulation are viewed on the screen of a cathode ray oscilloscope the patterns are of the shape shown in Fig. 6. Patterns (a) represent the envelope of the plate potential of V2, which, being directly associated with the load, is required to be sinusoidal when the modulating signal is a pure tone. Patterns (b) show the envelope of the plate potential of V1, which, though sinusoidal over the negative half of the modulating cycle, is twice as high as that of V2 over this range, and being unable to increase appreciably beyond its carrier value, remains flat during the upper half of the cycle of modulation.

The network N employed to obtain the impedance inversion may be one of a number of networks of which an example is given in Fig. 7. They always have a 90-degree phase shift, which means that the plate potentials on the two tubes are always in quadrature. This requires the insertion, in the grid circuit of one or the other of the tubes, of another 90-degree network in order that both tubes may be excited from the same source. The complete amplifier then assumes one of the forms indicated in Fig. 8.

The numerous tests conducted on the high-efficiency amplifier at various power levels have been uniformly successful, and the new circuit is being incorporated in the new high-power broadcasting equipment of the Western Electric Company The overall efficiency obtained in the tubes and output circuits is 60 per cent for

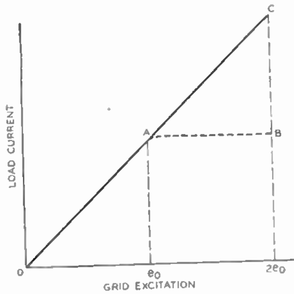

FIG. 4
If the second tube were not permitted to come into action at the carrier excitation e_0, the load current could not increase and would follow the path OAB.

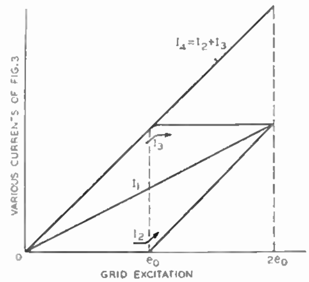

FIG. 5A
The current I_2, furnished to the load by tube V_2, supplements I_3 to make the total load current linear with respect to the grid input voltage.

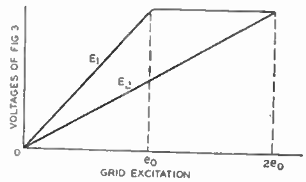

FIG. 5B
As the grid excitation is modulated about its carrier value e_0, the plate potential of tube V-1 does not respond to the positive half-cycles of modulation, since it has reached its maximum value at the carrier output.

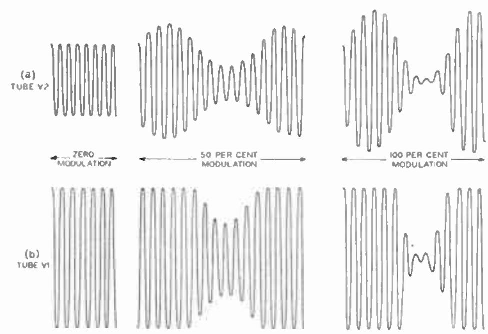

FIG. 6
Cathode ray oscillograms of the plate potentials of the tubes.

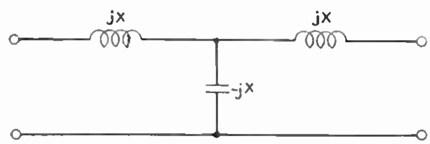

FIG. 7
A section of simple low-pass filter at 0.7 times the cut-off frequency consists of three equal reactances, and has a 90° phase shift and the desired impedance-inverting characteristic.

unmodulated carrier must not be more than half of its peak value.

The efficiency of the conventional power amplifier, then, is but 30 to 35 per cent when the carrier is unmodulated, and only slightly more for the average percentage modulation of the usual broadcast program.

How the Idea Started

An efficiency of 33% means that the d.c. power supplied to the plate circuit of the amplifier must be about three times the carrier output, and two-thirds of this input power has to be dissipated at the anodes.

With power levels of 50 kilowatts and higher becoming almost commonplace in radio broadcasting, it has become very important to find means for increasing efficiency to reduce the cost of power. Since early in 1934 a succession of tests has been conducted at the Whippany Laboratory on a new power amplifier circuit in which the usual practice of dividing the load equally between the tubes at all times was discarded.

The idea was conceived that by obtaining the power from a reduced number of tubes up to a certain point—in particular, the carrier output—these tubes could be operated at this point at their maximum plate voltage swing, and consequently at high efficiency; then if the remaining tubes were brought into action in a certain manner they would not only contribute to the output, but would so change the operating conditions for the original tubes as to permit the latter also to increase their output power without having to increase their output voltage.

Connections for New Circuit

Fig. 3 shows schematically the method of connecting the tubes to the load in the new high-efficiency circuit. V1 and V2 are two tubes that in the conventional amplifier might have been connected in parallel with a circuit whose impedance, for the fundamental frequency, may be represented by the resistance R. In the new circuit a network N is interposed between R and V1, the tube which is to deliver the carrier power. This network is the equivalent of a quarter-wave transmission line, and like such a line has the interesting property that its impedance as measured at one end is inversely proportional to the impedance which is connected at the other end.

For all values of grid excitation from zero up to the carrier level, V2 is prevented by a high grid bias from having any plate current, and the power is obtained entirely from V1. The network N is so designed as to present to V1 an impedance so high as to require this tube to operate at nearly its maximum possible radio-frequency plate voltage swing in order to deliver the carrier power. The efficiency at the carrier output is accordingly high, and may be from 60 to 70 per cent.

How the Impedance is Changed

If we were to plot the current in the load impedance R against the radio-frequency voltage applied to the grids of the tubes, as in Fig. 4, the curve would be quite linear up to the carrier point A and then, if V2 were not allowed to come into action, would flatten off along a path AB because the plate voltage swing on V1 has attained its maximum value.

By permitting V2 to begin coming into play at point A we obtain a twofold action: V2 not only contributes power to the load, but in coming into play in parallel with R it effectively increases the impedance in which the network N is terminated. This increase in terminating impedance, by virtue of the inverse characteristic of this type of network, results in a decrease in the impedance presented to V1, so that the radio-frequency plate current, and hence the power output, of V1 may increase without any increase in its alternating plate voltage, which was already at maximum at point A.

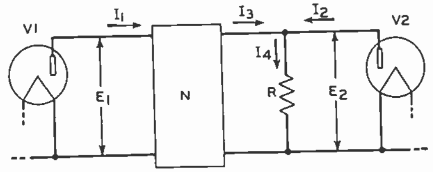

FIG. 3
In the high-efficiency circuit, an impedance-inverting network, N, is inserted between one of the tubes and the load.

As the grid excitation on the tubes increases beyond its carrier value e_0, V2 contributes more and more power to the circuit and thereby permits V1 also to supply more power, until at point C, which corresponds to the instantaneous peak of a completely modulated wave, half of the power in R is being contributed by V2.

Output Power Doubled

The network N is at that instant effectively terminated in 2R ohms instead of the original R ohms, and the impedance presented to V1 is half of its original value, permitting V1 to deliver twice its original output power with no increase in its output voltage. The total power in the load, then, at the peak of modulation is the required value of four times the carrier power, corresponding to an increase in load current to twice its carrier value.

It is a characteristic of networks having the impedance-inverting property of network N that a definite current at either pair of terminals is associated with a definite voltage at the other pair of terminals, entirely without regard to the terminating impedances. From this rather remarkable property we may deduce that if the output voltage E_1 of tube V1 is linear with respect to the grid excitation up to the carrier excitation e_0, of Fig. 4, and then remains constant up to the peak excitation $2e_0$, then the current I_3 fed into the load from network N

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A New R.F. Power Amplifier

First Solution of High Efficiency Transmitting

By W. H. Doherty

Radio Development, Bell Telephone Laboratories

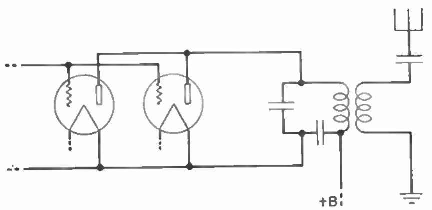


FIG. 1
Radio-frequency power amplifiers are coupled to the load by tuned circuits which present a very low impedance to the tubes at harmonics of the carrier frequency.

THOSE accustomed to operating vacuum tubes at the low power levels employed in wire transmission or in radio receiving systems are frequently startled to learn of the extremes to which one must resort in the operation of power amplifier tubes in radio transmitters.

The transmitting tube, far from being operated over a small and linear part of its characteristic, is subjected to large alternating grid voltages which cause the plate current to be zero over approximately one half of the radio-frequency cycle, and frequently to reach the saturation value determined by filament emission on the other half-cycle, with accompanying large grid currents. This extreme mode of operation makes possible much larger power outputs than could be obtained if operation were confined to the linear part of the tube characteristic.

Fig. 1 shows the circuit of a simple form of the conventional radio-frequency power amplifier, in which two tubes are connected in parallel and coupled to the transmitting antenna.

How Harmonics Are Minimized

The coupling circuit is so tuned as to be equivalent to a pure resistance load of the desired value over the relatively narrow transmission band occupied by the carrier and the side-frequencies due to modulation, while for frequencies much lower or much higher than the carrier, the impedance of the circuit is very low.

Hence, although the radio-frequency plate current wave contains large harmonic components due to the extremely non-linear operation of the tubes, only the fundamental component encounters any appreciable impedance, so that the plate voltage wave is very nearly sinusoidal. The power delivered by the tubes to the circuit is therefore almost entirely at the fundamental frequency.

High-quality amplification of a modulated wave then requires merely that the fundamental component of the plate current be proportional to the radio-frequency grid voltage. It turns out that if the tubes are biased nearly to the cut-off point, so that plate current flows only during the positive half-cycle of the alternating grid voltage, a close approximation to this requirement of proportionality is readily obtained.

Plate Swing vs. Efficiency

Under these conditions, represented in Fig. 2, most of the plate current flows while the plate potential is near its minimum value, and if this minimum value is sufficiently low, i.e., if the amplitude of the plate voltage wave is sufficiently great, the power lost in the tubes—which is proportional to the product of instantaneous plate voltage and current—will be small, and the efficiency correspondingly high. The efficiency is, in fact, very closely proportional to the amplitude of the plate voltage swing.

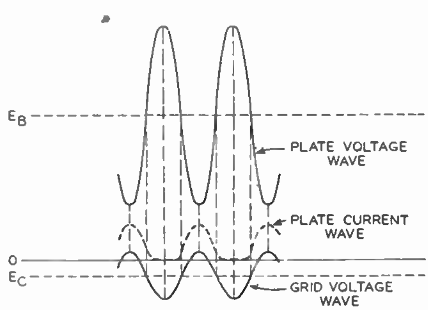


FIG. 2
Most of the plate current of a power amplifier flows while the plate potential is in the vicinity of its minimum value, so that the tube loss can be made small by using a plate voltage swing of large amplitude.

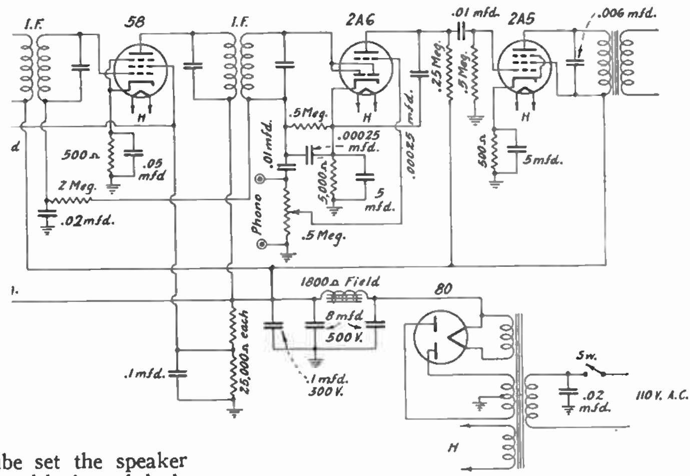
By permitting the plate voltage to swing down to a value as low as 10 or 15 per cent of the applied d.c. plate potential, large power outputs may be obtained at an efficiency of 60 to 70 per cent; but unfortunately such large amplitudes correspond only to the peaks of modulation, and since these peaks at 100 per cent modulation have amplitudes of twice the carrier amplitude, the plate voltage swing for

Speaker Field Ohmage

Wide Option for Small Receivers

By Capt. Peter V. O'Rourke

What shall be the ohmage of the speaker field? Is there much leeway? May one use a 2,500 ohm field, as he has such a speaker, instead of the 1,800 ohms specified at right? Can a dynamic speaker handle greater output wattage than the d.c. wattage across the field?



IN the four, five or six-tube set the speaker field ohmage is not very critical, and it is practical to substitute a larger field resistance for a lower one specified, or even use a lower resistance field than is recommended, and still results may be good. The speaker field, when used as series B choke, as is assumed, acts as a sort of regulator, because if the resistance is made higher than recommended, the current through the field is reduced, the actual voltage drop across the field may not change much, whereas if the field is of smaller resistance, the current is greater, and again there may not be considerable change in voltage drop.

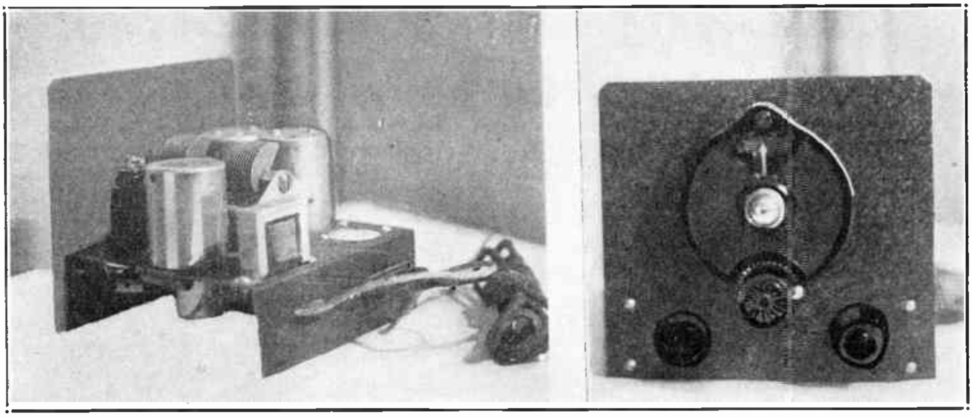
Of course it depends on the amount of current the receiver is intended to draw, and on the difference between the recommended resistance of the field and the actual field resistance used. If one takes two rather wide differences, 1,800 ohms recommended, 2,500 ohms used, there will be lower B voltage available, because though the current is reduced due to the higher resistance field, the drop across the field is disproportionately greater, due to the wide divergence of resistance.

When the field is made lower than recommended it should not be much lower, say, if 1,800 ohms are called for, 1,500 ohms would be as low as one should go, for the tubes have to be considered, and too great a voltage may shorten their lives. Since self-bias is used so much, the negative bias is increased also, but usually not quite apace.

The voltage delivered by the power transformer, and the regulation of the transformer, have a bearing on the results. Another fortunate circumstance arises. The power transformer output from the high voltage winding will be less, as the drain is increased due to lower field resistance, therefore nature come along to give assistance, as it were, and perils thus are minimized though one does resort to substitution.

Perhaps the main reason for adherence to a particular resistance field winding is that a certain rating power transformer is used, therefore the rated voltages will be applied to the tubes. If the B voltage is too high though self-bias and other factors tend to reduce the peril of it becoming too high if field resistance reduction is not severe, perhaps a blue glow will appear in the power tube. That is a warning. The quality may be impaired as well as tube life shortened. Some pentodes have a natural blue glow, not to be confused with the gas effects that create bluishness all around the plate. The harmless blue glow is concentrated and is due to the rapid acceleration of converging electrons.

The field wattage is the product of the voltage in volts and the current in amperes. Assume 100 volts and .06 ampere, the wattage is six watts. The output tube, say, is rated at five watts. Suppose the speaker field wattage is reduced to three watts, can the output tube still be distortionlessly supported by the speaker, or does the field limit the tube's, hence set's, distortionless output? There is no necessary limitation on the set even if the d.c. wattage of the speaker field is reduced, as several circumstances control the results. For instance, the permeability of the core on which the field is wound, if high, would enable greater power output from the set than the d.c. power dissipated in the field. With cores as commercially present in the fields of dynamic speakers, very high permeability is not to be expected.

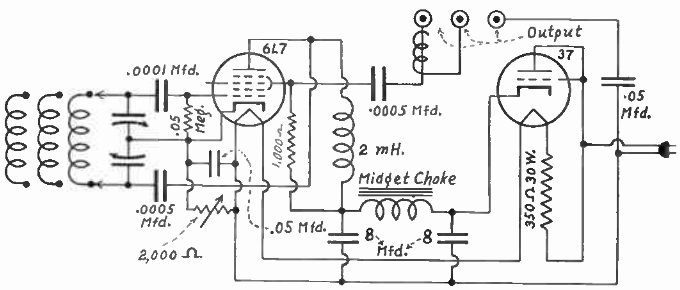


Front and side views of the Colpitts oscillator. The dial may be read with extraordinary closeness, as it is a National dial with true vernier scale.

(Continued from preceding page)

The circuit is universal. That is, it may be used on either a.c. or d.c. lines. The fact that all three output binding posts are insulated from the high voltage and from the line, it is safe to use the oscillator on all types of circuit.

The mechanical features of this Colpitts oscillator can be seen from the three photographs. One shows a top view of it. In this the three shielded coils are easily distinguished. Likewise the two-gang tuning condenser can be seen in the center. The oscillator tube, a 6L7, may be seen back of the panel at the extreme right. The rectifier tube socket is seen in the diametrically opposite corner of the chassis and the filter choke at the right rear corner. The remaining parts are below the subpanel. A panel view of the oscillator shows the control dial in the center, the coil selector switch at the left and a output volume control at the right. The rear view gives additional pointers on the assembly of the oscillator.



The circuit of the Colpitts oscillator. The output is electron coupled to the screen of the oscillator tube. All three output posts are insulated against direct current. The output level is controlled by means of bias variations on grid No. 3. See text for directions on connecting this grid.

LIST OF PARTS

Coils

One set of three shielded coils to cover three tuning bands.
One midget filter choke.

Condensers

One National Co. dual gang 335 mmfd. tuning condenser.
One .0001 mfd. grid condenser.
Two .0005 mfd. fixed condensers.
One .05 mfd. condenser.
Two 8 mfd. electrolytics.

Resistors

One 0.05-megohm grid leak.
One 2,000-ohm variable resistor, with knob.
One 1,000-ohm resistor.
One 350-ohm, 30-watt ballast resistor.

Other Requirements

One two pole, three stop switch for selecting coils, with knob.
One vernier dial.
One octal socket.
One small grid clip.
One five-contact socket.
Three binding posts.
One line cord and plug (with built in resistor, 350 ohms, 30 watts).
One small chassis.

Rigging Up a Colpitts

Good Stability for Signal Generators

By J. E. Anderson

THE Colpitts oscillator has always been one of the favorites among designers of quality signal generators. Only one other oscillator has enjoyed equal popularity, or possibly greater popularity, and that is the Hartley, which is the exact opposite of the Colpitts in so far as coils and condensers are concerned.

Theoretically the Colpitts should have less harmonics than the Hartley. Therefore when the object is to produce a relatively pure wave the choice should be a Colpitts, whereas when the object is to get as many strong harmonics as possible the choice should be a Hartley. Of course, practically there will be strong harmonics in the Colpitts.

One of the objections to the Colpitts is that it requires two variable condensers in the tuned circuit. But there is no difficulty in getting such condensers, for a two gang tuning condenser is suitable for the purpose. The common rotor of such a condenser could be connected to ground, and thus body capacity effects would be eliminated.

Single Winding Coil

A decided advantage of the Colpitts oscillator, especially when it is to cover many bands, is that only one coil, and that one not tapped, is required for a single band. Thus while the switching problem is not simplified, the unused coils are readily kept entirely outside the functioning circuit. Winding is easier.

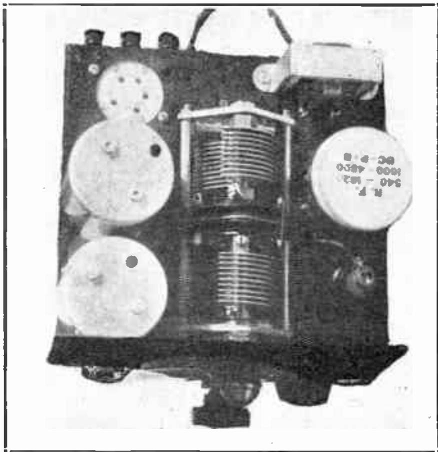
One way of wiring up a Colpitts oscillator is shown in the drawing. Three coils are indicated. These may be separate coils or they may be three windings on the same form. In the present case, as will be seen on one of the photographs, there are three separate coils, each individually shielded, the better practice of course.

Several details call for attention. There is a grid condenser of .0001 mfd., for instance. This is not absolutely essential because even when it is shorted there is no shorted path to the cathode. The grid leak, however, is essential whether or not the grid condenser is used. A value of 50,000 ohms is satisfactory and this is suggested.

What to Do with G3

The 6L7 tube used has an injector grid (No. 3), not shown connected. Normally this would go to B minus. Then the rheostat in the cathode leg can be used as attenuator, and the scheme also works if G3 is connected to the slider, if the cathode resistor is a potentiometer.

Between the plate and the lower side of the tuned circuit is a .0005 mfd. condenser. This is not essential when the grid condenser is used. But if grid condenser is omitted, as it may be, the plate condenser must be used. Its value is not critical.



Top view of stable signal generator, using National Company's straight frequency line double bearing condenser.

The output coupling deserves special mention. It will be noticed that it is similar to that of the Dow oscillator. In this instance, however, the plate is used for feedback and the screen for the output. In the Dow electron coupled oscillator the arrangement is the reverse. A stopping condenser of .0005 mfd. intervenes between the screen and the output binding post. This insulates the post from the high voltage. The other output posts, the one on the extreme right, is connected to ground through a .05 mfd. condenser. One side of the supply line is used for ground. Therefore both binding posts are insulated for the power supplies and only a.c. appears at the output posts. There is a third, or middle, post. This is coupled loosely by a small capacity to the screen-connected post. When the output required is very small, the two right hand posts should be used. When maximum output is required the two extreme posts should be employed.

Mechanical Factors

A 37 tube used as a diode is employed as a B supply rectifier. A good filter consisting of a midget choke and two 8 mfd. electrolytic condensers is used to remove ripple voltages. This filter is entirely satisfactory because the current required by the plate and screen of the oscillator is very low, and under such conditions any filter is most effective.

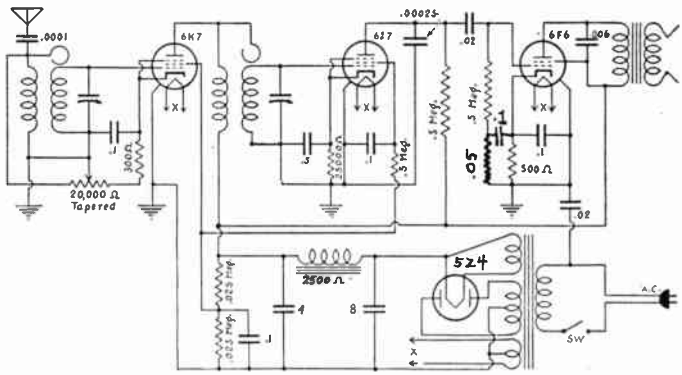
(Continued on next page)

to get full filtration from this condenser. The B supply filter consists of one 8 mfd. condenser, next to the rectifier tube, a 2,500-ohm speaker field coil, and a 4 mfd. condenser next to the voltage divider. Of course, a 2,500-ohm filter coil may be substituted for the field coil in case the speaker has its own field supply.

Tapered Volume Control

The voltage divider consists of two 25,000-ohm resistors, the screens being connected to the junctions of these two resistors. The .1 mfd. condenser across the bleeder section of the voltage divider serves to maintain the screen voltage on the 6K7 steady in respect to radio frequency fluctuations.

The volume is controlled satisfactorily in this receiver by means of a 20,000-ohm potentiometer in the cathode circuit of the first tube. Since the potentiometer is connected between the cathode return and the antenna, with the slider grounded, the control is doubly effective in controlling the volume. In addition, the resistance element is tapered so that the proper degree of control is obtained gradually at all volumes within the range of the circuit.



A good four-metal-tube t.r.f. set, using a two-gang condenser. If the volume control is tapered, as suggested, the change of sound quantity will be more gradual. The slow change in resistance should be toward the cathode.

Readrite's Direct-Reading Tube Tester Is Improved

New improvements add to the effectiveness of the 1936 Model 430 Readrite tube tester in checking all glass, metal and metal-glass tubes under actual load conditions. The manufacturer is Readrite Meter Works, Dep't W, Bluffton, O. It is an emission type tester. A unique shadow type a. c. meter for line voltage adjustment is a feature. Besides indicating the actual line voltage setting, it also is a pilot. Model 430 has five sockets for receiving every type of tube. It contains a direct reading Triplett model 221 meter with good-bad scale. Testing requires only four operations. The cover is removable.

LIST OF PARTS

Coils

Two high gain unshielded radio frequency tuning coils for 360 mmfd. condensers.
One power transformer to give a 250-volt output.
One dynamic speaker with output transformer for 6F6 and a 2,500-ohm field.

Condensers

One .0001 mfd.
One .00025 mfd.
One .006 mfd.
Two .02 mfd.
One 4 mfd. electrolytic.
One 8 mfd. electrolytic.
Two .05 mfd.
Four .1 mfd.
One .5 mfd.
[*Above condensers are Cornell-Dubilier.*]
One two-gang, 360 mmfd. tuning condenser.

Resistors

One 20,000-ohm tapered potentiometer, with line switch.
One 300-ohm bias resistor.
One 500-ohm bias resistor (three watts).
Three .025 megohm resistor.
One .05 megohm resistor.
Three .5 megohm resistors.
One 1 megohm resistor.
(All resistors not otherwise specified may be as small as half watt.)

Other Requirements

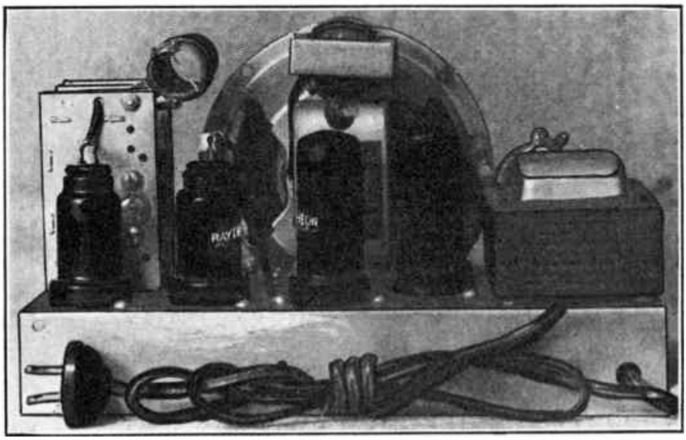
One tuning dial with lights.
One line cord and plug.
Four octal sockets.
One four tube chassis.
Two grid clips, small size.

receiver these two can be tracked perfectly at all settings. Therefore the selectivity is higher than one would suppose and it may be as high as that of a three-tuned-circuit set in which the tracking is not perfect. Indeed, it might be higher. The selectivity will be greatly improved if a short antenna is used with the receiver. Also, the omission of the coil shields makes the selectivity higher.

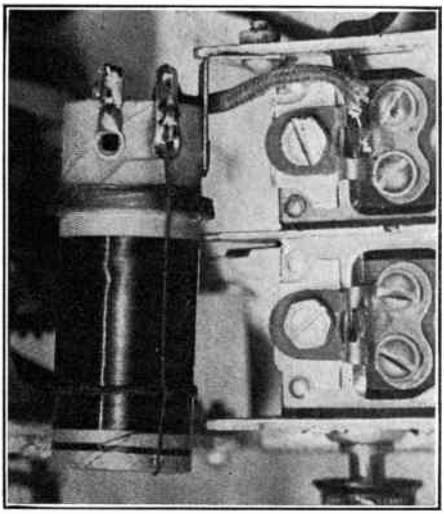
High Detection Efficiency

The 6K7 working into a high gain tuner yields an extraordinarily high voltage gain. This gain is considerably boosted by resonance in the second tuner. Therefore a strong signal is delivered to the detector grid even though the input to the receiver be comparatively low.

The detector tube, which is operated as a self-biased transrectifier, is a 6J7, and this tube has a very high detecting efficiency. The bias is supplied by a 25,000-ohm cathode resistor, which is shunted by a .5 mfd. condenser. For best detection the screen voltage on this tube should be much lower than that on the 6K7 and for that reason a .5 megohm resistor is connected between the 6J7 screen and the screen voltage tap on the voltage divider. A .1 mfd. condenser connected between the screen and ground is sufficient to keep the screen steady in respect to audio and radio frequency voltage fluctuations.



Rear view of the four-tube midget receiver showing tuning condenser at left, the speaker in the middle, and the power transformer at right. A midget speaker is used in this instance.



A close view of the top of the tuning condensers, with the trimmers and one of the unshielded high gain coils.

The resistance-capacity coupler between the detector and the power tube is designed to transmit all frequencies equally down to the lowest essential audio frequency. The plate load resistor and the grid leak are both .5 megohm and the coupling condenser is .02 mfd. The remaining parts associated with the coupler are for filtering. Thus the .00025 mfd. condenser connected between the plate of the 6J7 and ground serves to prevent transmission of radio frequency voltages to the power tube. The .05 megohm resistor in series with the grid leak and the .1 mfd. condenser between the cathode of the 6F6 and the junction of the two resistors serves to suppress hum and also to prevent reverse feedback. This .1 mfd. condenser is much more effective than the condenser of the same value that is connected across the 500-ohm grid leak alone.

In the plate circuit of the power tube is a condenser of .006 mfd. capacity. Its function is to suppress a certain type of high frequency noise which is sometimes associated with pentode power tubes. The .02 mfd. condenser connected across the primary of the power transformer is also for the purpose of filtering. It aids in suppressing line noises. As will be noted, it is not connected directly across the line but from one side to ground. Therefore it may be necessary to reverse the power plug in order

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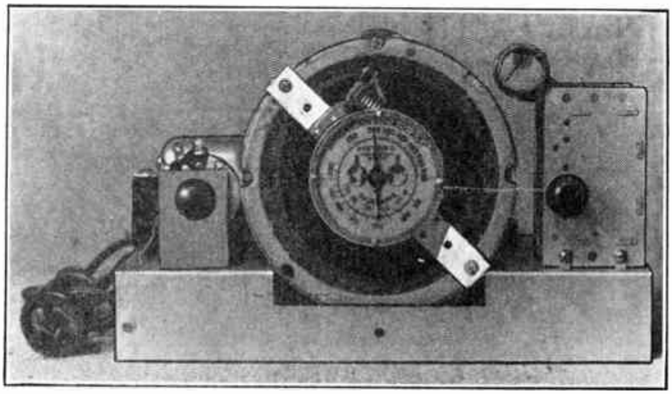
The Dial's on the Speaker

In Four-Metal-Tube T.R.F. Set

By Jack Goldstein



Front view of the four-tube midget receiver, showing the volume control at left, the dial in the middle, and the condenser at right. A belt connects the dial to the condenser.

THIS is in truth the era of midget sets. Receivers have been brought down almost to vest pocket size. This reduction in size has been made possible by the increase in the sensitivity of the tubes, as well as by the reduction in the size of tubes. Two or three tubes will now do more than half a dozen tubes used to do.

Unfortunately, the decrease in size of receivers has been accompanied by a decrease in performance, not so much in sensitivity and selectivity as in output quality and quantity. This is partly due to the necessity of using a small speaker to confine the receiving unit within the specified diminutive dimensions.

It is not necessary to have the speaker built into the chassis, provided that we are willing to devote more room to the speaker. If necessary, the speaker may be put outside the receiver proper, in which case the tuner and amplifier can be confined in an extremely small space.

Metal Tube Set

There are many places in a home where a speaker of large size could be placed to better advantage. Of course, if the receiver is to be portable—easily movable from room to room in a home—the speaker should be an integral part of the radio receiver and in that case it is necessary to sacrifice tone quality to a certain extent. However, in the interest of realism the speaker employed should be as large as possible, consistent with the space devoted to the portable receiver.

In the present example we show the speaker built into the chassis as that is the vogue of the day for such small sets.

There is no trouble in getting a large output from a midget receiver, for the output tube may be a 6F6 power pentode, the tube that is used in many large receivers, and this tube may be operated under the same conditions in a midget as in a large console receiver.

High Gain Coils

The midget receiver here presented is a t.r.f. circuit of the high gain type. It has four tubes. The radio frequency amplifier is a 6K7, the detector a 6J7, the output tube a 6F6, and the rectifier a 5Z4. All of these tubes are of the metal type and all are of small size. Because of the small number of tubes, and the small size of each one, this set can be assembled into a very small cabinet.

Two so-called high gain coils are used in the tuner. Perhaps it would be more nearly correct to say that they are equal gain coils, for the coupling between the primary and the secondary circuits is such that there is just as much gain at 550 kc as at 1,500 kc. And this equality of gain over the entire tuning band has not been attained by suppressing the usual high gain at the higher frequencies but by boosting gain at the lower frequencies. This has been effected by a fixed resonance in the primary circuit of each coil below the lower end of the tuning range. The coils are unshielded and mounted so that there is no stray coupling. One coil is atop the chassis, the other below.

Belted Dial

Looking at the speaker one notes that the dial is in front of it. The tuning condenser, knob attached to its shaft, is at right. The common mechanical connection between condenser shaft and dial is made by a belt. This solves the mystery why the dial turns, though relatively far from the condenser.

Since there are only two tuned circuits in the

RADIO WORLD

The How-to-Make-It Monthly—Fourteenth Year

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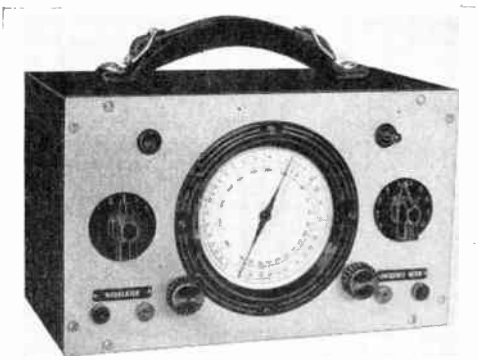
NEW! "RACO" PORTABLE SIGNAL GENERATOR



The Model 339-B Portable Signal Generator in a handle-equipped black wrinkle finish shield cabinet, the front panel finished in "Raco Wrinkle Illuminite," wired, complete with A and B batteries, two 30 tubes, r.f. attenuator, variable audio frequency control, selector switch, r.f. and a.f. output jacks. (Shipping weight, 11 lbs.)......... **$15.10 NET**

Model 339 B Kit, less tubes and batteries $11.50

OUTSTANDING FEATURES

(1)—Frequencies are direct reading to an accuracy of 1 per cent., using Raco's own calibrated dial and precision inductances, and a precision variable condenser (54 kc to 17,000 kc).

(2)—Radio frequency output has an attenuator that does not molest the frequency generated, no matter where the attenuator is set.

(3)—A tone is impressed on the radio frequency generated, or not, as you prefer, to allow for both methods of alignment. A throw of a switch introduces or removes the tone.

(4)—The audio frequency generated may be varied by adjustment of a control marked in arbitrary graduations, 1 to 10. This enables measurement through interference.

(5)—Besides the radio frequency output jacks, there are separate jacks for the audio frequency output, and since this audio frequency may be adjusted, tests may be made of response characteristics of audio amplifiers.

(6)—Stabilization of the radio frequency oscillator.

(7)—Stabilization of the audio frequency, and independence of the audio frequency from any setting of the radio frequency tuning condenser.

(8)—Modulation is about 50 per cent., when introduced in the r.f. oscillator, double peaks are thus completely avoided.

Don't be Misled! "RACO" Pioneers of Quality

THE IDEAL BEGINNERS' TWIN TUBE TRANSCEIVER

AT LAST ! ! !

An inexpensive 1 tube 5 and 10 meter Transceiver.

This extremely efficient transceiver is recommended for one short wave enthusiast who is interested in exploring the fascinating 5 and 10 meter bands.

The circuit utilizes the type 19 two-volt twin tube, and is exceedingly sensitive since the super-regenerative principle is employed when the receiving position is switched on. A double pole single-throw switch is the means by which the instrument may be switched to either receiving or transmitting. Dimentions: 5" x 6" x 9".

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- 10-Meter Coils .... .50
- R.C.A. Lincensed Tube .... .65
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- Wiring diagram and complete instructions included in every kit.

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A powerful oscillator with class B modulation provides sufficient power for excellent portable-mobile work. Completely self-contained unity coupled 5 meter transceiver using two 19 tubes and one 30. The maximum practical power for a portable rig.

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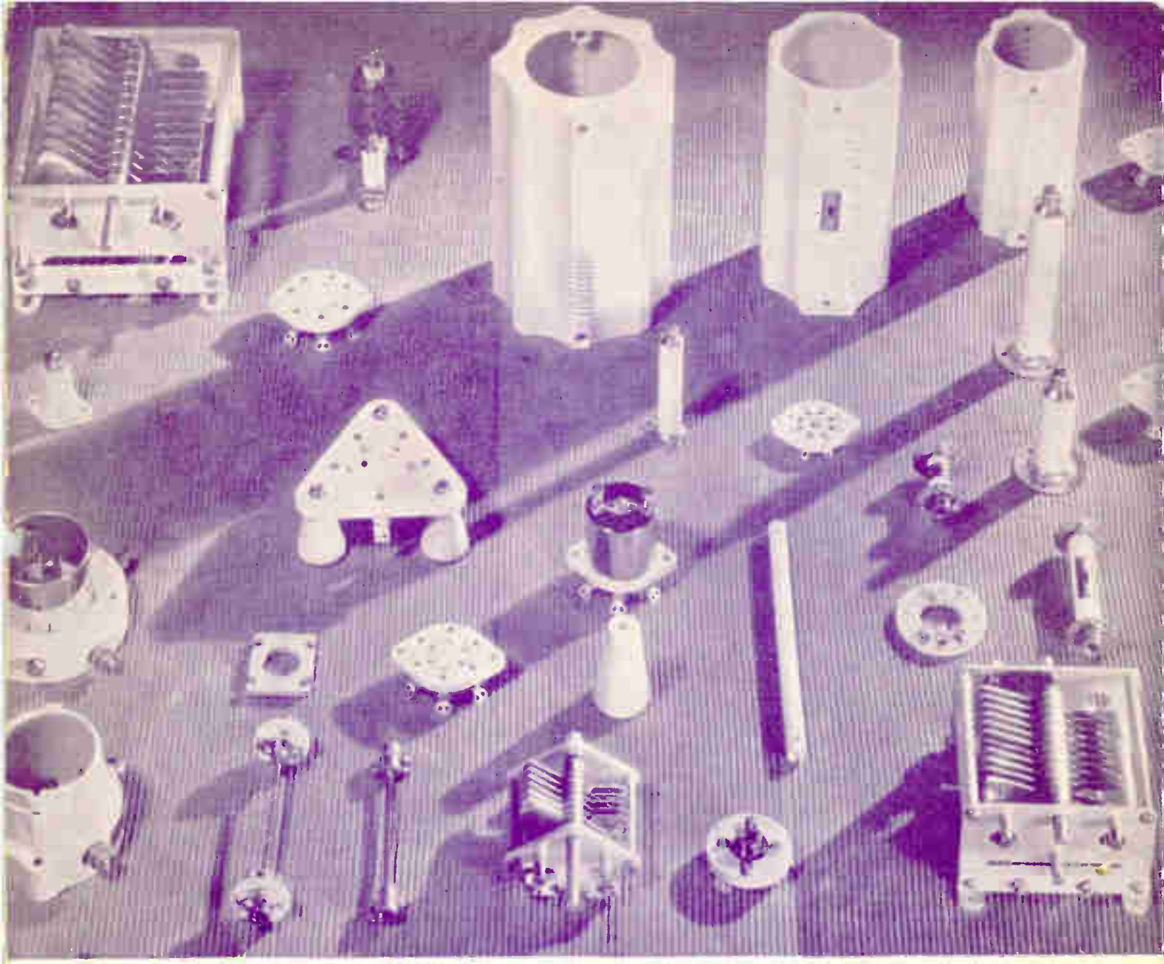

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