HOW IT WORKS

Special Section of Volume VIII

RIDER'S MANUAL

by

John F. Rider

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Printed in the United States of America

FM TRANSMISSION AND RECEPTION

By JOHN F. RIDER and SEYMOUR D. USLAN

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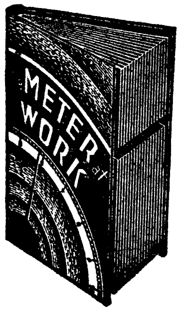

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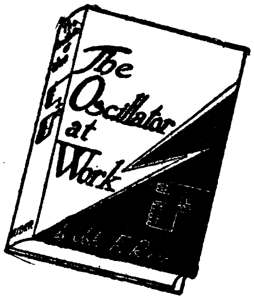

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HOW IT WORKS

Special Section of Volume VIII

RIDER'S MANUAL

CONTENTS

PREFACE

It is characteristic of radio receiver design that developments are constantly being made to improve the performance of receivers. Viewed from a servicing angle, this has meant that the operation of receiver circuits is constantly becoming more complex, and that the serviceman must keep up to date on the new developments in the field.

It is the purpose of this section to analyze some of the more important developments which have taken place, as these innovations are exemplified in the receivers described in Volume VIII. Although for the most part specific receivers are singled out for discussion in this section, the new circuit developments which are explained in connection with these receivers are generally applicable to other receivers which use similar circuit designs. We have felt it preferable to describe specific receivers rather than to generalize because the former procedure makes the information that much more specific, tangible, and usable.

Since many of the receivers described in Volume VIII provide condensed alignment data, we have included in this section a general discussion of conventional alignment procedure. The information contained in this section explains the basic procedure in aligning any receiver, the reasons for the various adjustments, and the manner in which they are carried out. For the most part, the information is generally applicable to all receivers, but it should be understood that the manufacturer's recommended procedure always takes precedence over the conventional alignment procedure.

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CONVENTIONAL ALIGNMENT PROCEDURE

A Description of the General Methods for Aligning Receivers

In this special section dealing with alignment, general information is presented on the subject of alignment technique. To a large extent, this information is generally applicable to all receivers and should be considered as supplementing the specific alignment data included in the Rider Manuals. Realizing the importance of alignment data in service work, we have endeavored in the production of Volume VIII to make this alignment data as complete and comprehensive as possible; however, we have found in many cases that the data provided by the manufacturers are often a skeleton outline of the procedure required, and we therefore believe that the material presented here fulfills a real need.

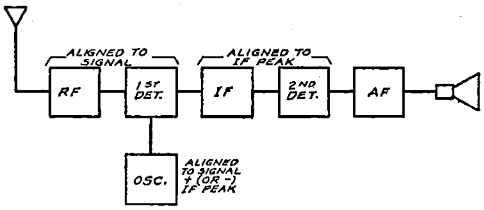
There is a great deal to be said for this policy of condensing alignment data so as to exclude all general information which should be part of the equipment of every well-informed serviceman. For one thing, it releases a considerable amount of space which can be used to better advantage for the inclusion of wiring diagrams, parts layouts, and other pertinent information—and it makes possible the inclusion of receivers which might otherwise have to be omitted entirely from the manual. Even apart from this consideration of the space taken up by elaborate alignment instructions, it has been our experience that most servicemen prefer a more concise exposition of alignment information, such as that provided by the tabular form of alignment data. To the serviceman who knows his job, the tabular form makes possible a more speedy carrying out of the alignment procedure, because spread out in front of him are the steps to be taken and the order in which they must be taken.

Such instructions as "the output of the signal generator must be reduced so as to prevent overloading of the AVC system," "to adjust the oscillator trimmer at the low frequency end of the band, 600 kc, the oscillator trimmer should be adjusted for maximum output, then the adjustment changed slightly, and the dial readjusted for maximum output . . .," etc.—while they are essential to the proper alignment of the receiver in question—are characteristic of the alignment of every receiver. It is therefore just so much wasted space and repetition to repeat these same steps for each receiver. What the serviceman really needs, as far as alignment procedure is concerned, is the sort of information which appears in the tabulated data employed in a number of cases in Volume VIII. This type of data, in conjunction with the physical location of the trimmers, is all that is really required for the proper alignment of a receiver. In some cases, a note may be required to explain some special procedure which differs from conventional alignment practice; such cases are readily handled by including footnotes which explain the departure from conventional procedure.

Since a great deal of alignment information presented in the manual is of the condensed type, we have felt it worthwhile in this section to explain the basic elements of alignment procedure. This information in conjunction with the specific alignment data contained in Rider Manuals is all that is necessary for the proper alignment of any receiver. In the case of those receivers for which the manufacturers have not included alignment data in the service notes, the following discussion of general alignment procedure makes it possible for the receiver to be aligned by examining the schematic, and locating the trimmers on the chassis. There is nothing mysterious about the manner in which these various steps are performed. For the most part, the steps in any alignment procedure are based on logical definite principles of superheterodyne operation; one of the aims of this discussion of alignment is to remove some of the mystery which surrounds the alignment procedure of modern superheterodynes.

What Is Alignment?

It is characteristic of all radio receivers that in general they are able to select a particular signal from among many signals of different frequencies, and that they are able to do this by means of one or more tuned circuits. In the superheterodyne, with which we are concerned in this section, these tuned circuits are located in the radio- and intermediate-frequency amplifiers. In order that the receiver may operate properly and efficiently, these tuned



Block diagram showing at what frequencies the various circuits of a superheterodyne are aligned.

circuits must be aligned or adjusted to certain frequencies. The adjusting of these various tuned circuits according to a definite scheme is what is meant by the alignment of a receiver.

In considering the alignment of superheterodyne receivers, it is convenient to look upon the superheterodyne as consisting of several more or less distinct units. Thus, the signal voltages in the antenna circuit are fed to the *r-f amplifier* section of the receiver; it is the function of this part of the receiver to select the desired signal from among all the other signal voltages present in the antenna circuit and to amplify the wanted signal at the same time. In order to perform both of these functions efficiently, it is absolutely essential that the tuned circuits present in the r-f unit be tuned accurately to the signal.

As far as the *detector-oscillator* sections of the receiver are concerned, the oscillator tuned circuit must be adjusted so that, throughout the entire range, the frequency generated by the oscillator is higher (or, in some cases, lower) than the signal frequency by an amount equal to the intermediate frequency. This oscillator voltage is fed to the first detector circuit where it is mixed with the signal voltage and produces a frequency equal to the resonant frequency of the i-f amplifier, which is commonly designated as the i-f peak.

The original signal is thus converted to a signal of *intermediate frequency* which contains exactly the same modulation as the original signal. It is the function of the *i-f amplifier* to take this signal, amplify it, and at the same time be sufficiently selective so that it will attenuate other signals which are close in frequency to the desired signal. In order to perform both these functions, the tuned circuits in the i-f amplifier must be carefully tuned or aligned to the intermediate frequency for which the set was designed. The greatly amplified signal voltage is then fed to the second detector where the audio voltage is produced, and this audio voltage is then amplified by the audio amplifier and reproduced by the speaker.

The above description is not intended to be very elaborate, but rather is more or less in the nature of a rapid review of superheterodyne operation. For those of you who are a bit hazy on superheterodyne operation, this subject is covered in detail in "Servicing Superheterodynes" by John F. Rider.

When Does a Receiver Need Alignment?

Whether or not the faulty operation of a receiver is due to poor alignment or to some other cause is a difficult question to answer, without in some cases first actually carrying out some part of the alignment procedure. As a general rule, however, this much can be said—that in entirely too many cases there is a tendency to blame poor receiver operation upon the alignment and to upset a perfectly good alignment without first having investigated other obvious defects.

This tendency unnecessarily to turn trimmers and upset the alignment in a complicated multiband receiver is one that should be guarded against, and a preliminary examination of the receiver should always be made in order to determine the cause of the trouble.

An incorrect alignment condition in a receiver is generally accompanied by one or more of the following conditions or symptoms:—low sensitivity, poor selectivity, faulty dial calibration, and distortion. These conditions may occur on one or more of the bands, and may be present to various degrees, depending upon which tuned circuits are out of alignment and the extent to which they are out of adjustment.

A few moments spent in analyzing the trouble will often save a great deal of time. For example, suppose that a receiver shows a fairly low sensitivity on all the bands. Under these circumstances an investigation of the i-f amplifier alignment is in order, because misalignment of this part of the receiver would uniformly drop the sensitivity on all bands. On the other hand, a misalignment of the r-f trimmers would affect the alignment on only one band, rather than on all bands. While it is perfectly possible for all the alignment adjustments on all the bands to be out, the more probable condition is that the i-f amplifier needs realignment, and hence this is the one which should be investigated first.

On the other hand, suppose we take the case in which a receiver operates perfectly on all bands, but shows low sensitivity and poor dial calibration at the low-frequency end of one of the bands. This immediately should indicate to the serviceman that the trouble is due to misalignment of the low-frequency oscillator trimmer on that band, since it is this trimmer which controls the calibration and sensitivity over the low-frequency end of the band.

It may be noted here that low sensitivity is a fault which can be caused by many factors other than misalignment. Therefore the fact that the sensitivity of the receiver is low, is not sufficient in itself to throw suspicion upon the alignment. However, when a condition of low sensitivity is accompanied by poor selectivity and inaccurate dial calibration, then it is probable that the receiver needs realignment both to raise the sensitivity and to restore the dial calibration.

If, as often occurs in practice, an all-wave receiver shows normal sensitivity and operation on one or more bands, and fails to perform properly on the other bands, then the first step should be to check the adjustments common to that band only. In other words, it is quite unnecessary to check the alignment of the i-f amplifier, since the fact that the receiver performs properly on at least one band is direct evidence that the i-f amplifier is operating properly.

So much for the observations as to when alignment is required. The discussion is brought up to emphasize that it is not wise to tamper with alignment just because the receiver is not performing as it should. It should be kept in mind that there are many other factors which can prevent a receiver from delivering the peak performance of which it is capable.

What Causes the Need for Realignment?

There are a number of different factors which operate to bring about the necessity for realignment at more or less frequent intervals. Perhaps the factor which is responsible for more realignment jobs than any other is the change in the characteristics of the components associated with the tuned circuits of the receiver. Due to vibration, the movement of parts, the effects of humidity, temperature, and age,—the capacity and inductance associated with these tuned circuits change their values, and the tuned circuits go out of alignment. In recent years, there has been considerable improvement in the design and manufacture of the components of tuned circuits, so that this change in capacity and inductance over periods of time is being held to a minimum. Among the developments in this connection have been the perfection of compact air dielectric trimmers of various types, the perfection of radio-frequency iron core materials, and improved methods of construction and assembly which tend to make for permanence of adjustment.

Aside from the changes in the tuned circuit itself, there are a number of other factors which operate to cause the need for realignment. Among these can be mentioned the movement of r-f and i-f wiring, since the movement of these leads changes the relative capacities and inductances associated with the tuned circuits. Of special importance is the need for avoiding changes in the relative positions of wiring associated with the high-frequency bands, and especially the ultra high-frequency band, if the receiver is equipped with one. On the latter band, a slight change in the position of the wiring may cause the entire band to be inoperative, since the leads constitute a large part of the inductance and capacitance of the tuned circuits. Particular mention in this connection must be made of the importance of using exact replacement parts where replacement of resistors, condensers, and other parts becomes necessary in or near the r-f unit. The use of a part which has the same electrical characteristics, but which has different physical characteristics or size, will sometimes throw the receiver out of alignment, and in other cases may even cause instability and oscillation.

No discussion of the reasons for realignment is complete without mention of the effect of changing tubes on the alignment of receivers. As far as the i-f amplifier is concerned, it is very seldom that changing tubes will make necessary readjustment of the i-f trimmers. This is true first because the capacity across the i-f circuits is as a general rule considerably higher than the shunt grid and plate tube capacities, and secondly because the tube capacities are held to within fairly close limits in manufacture. On the short wave bands, and especially on the very high frequency ranges, the calibration of the receiver tends to vary somewhat with different tubes, but even here it is the exceptional case where the receiver requires realignment because of a change in tubes.

As a general rule, the replacement of tubes with tubes of the same type will not often influence the alignment of a receiver to the extent that a noticeable change in performance will be noted. However, it should be observed that where a receiver is originally equipped with octal-based glass tubes, these tubes should not be replaced by the corresponding all-metal types, unless the receiver is to be realigned. The reason for this condition is that the capacities of metal tubes are different from those of glass tubes, and this difference in capacity appears across the several tuned circuits and hence causes incorrect alignment. The extent of the difference between the capacities of metal tubes and the glass equivalents is often sufficient to cause an appreciable difference in the performance of the receiver, and it is recommended that the original type tubes with which the receiver was equipped be used when replacement becomes necessary. This statement, of course, does not apply to tubes which are used in the audio amplifier or in the power supply.

General Notes

When the serviceman has satisfied himself that the performance of the set can be improved by realignment, the first step is to consult the manufacturer's instructions relative to the alignment of the receiver in question. Reference to such data is necessary and desirable in order to determine the recommended procedure, the alignment frequencies, and the location of the several adjustments. The importance of reference to the manufacturer's data, as contained in the Rider Manuals, cannot be overestimated; in the last analysis, the proper procedure depends upon the design of the receiver and the manufacturer is best qualified to state the special steps to be followed in aligning his set.

As a general rule the alignment procedure for all receivers should be carried out under conditions which simulate as much as possible the conditions under which the receiver normally operates. This means, for instance, that if any of the coils happen to be exposed, then the alignment should not be carried out with these coils close to a metal-top workbench which will change the inductance of the exposed coils; it means, if the receiver has a metal bottom, that this bottom should be in place before the alignment adjustments are changed; it means that the receiver chassis should be grounded, that all the tube shields should be in place, and that the line voltage should be set at the average value which is encountered in the customer's home (important for AFC-equipped receivers); it means that the receiver should be allowed to reach its normal operating temperature by having been in operation for at least 15 minutes before the final alignment adjustments are made.

"Trimmer" Adjustments

In the course of the following discussion on conventional alignment procedure, there will often be occasion to refer to the adjustment of such and such a "trimmer." By this reference, it is not necessarily meant that the adjustment of the tuned circuit is accomplished by adjusting a trimmer, but rather this designation should be taken to mean the adjustment of any part of the tuned circuit which is effective in changing its tuning.

In some receivers, this will take the form of the usual trimmer condenser which may be of the mica or air dielectric type. If of the air dielectric type, the condenser may be of the type in which adjustment is accomplished by the rotation of one set of plates; or, on the other hand, it may be of the plunger type, where adjustment is accomplished by an axial movement of one condenser plate. In other cases, the tuning adjustment is effected by varying the inductance of the two windings; this latter type of adjustment is generally carried out by the movement of an iron core associated with each of the primary and secondary windings, but in the receivers of at least one manufacturer, the adjustment is made by moving one part of each winding with respect to the other part, each of the windings being in two sections. Regardless of which type of adjustment is provided, the phrase, "the trimmer" should be understood to take in all these various types of adjustments which are effective in changing the resonant frequency of tuned circuits.

Adjusting Trimmers

In the course of aligning a receiver, there is often a marked tendency for the output to drop as the alignment tool is removed from the trimmer. This action takes place because the metal in the alignment tool tends to detune the circuit being adjusted, so that the resonant frequency changes as the tool is removed; it is especially noticeable in the adjustment of the oscillator trimmers on the high-frequency bands. For this reason the alignment tools should contain a minimum of metal, and if the tool is made entirely of fiber or bakelite, so much the better.

Experience is of great assistance in minimizing error from this source. It will be found, if the trimmer is first adjusted for maximum output and the setting then increased slightly clockwise, that the output will rise to its previous maximum value as the tool is withdrawn. If the correct adjustment is not obtained the first time, the adjustment should be repeated until the output rises to approximately the same value, with the tool removed, which was obtained when the trimmer was adjusted for maximum output with the tool on the trimmer.

A trimmer should never be left loose in its minimum-capacity position; if necessary, the end plate should be bent so that the plate rests firmly against the nut. When the alignment is completed, it is sometimes advisable to seal the trimmer or tighten the lock nut as the case may be. In carrying out this operation, care should be exercised to see that there is no change in the output meter reading, as the trimmer is being sealed or locked.

Signal Generator Connection

It is good general practice to use a shielded lead in connecting the signal generator to the appropriate point in the receiver, in order to avoid coupling the output of the generator to other points in the receiver. In this same connection, it is advisable to keep this lead as far as possible from the grid leads of adjacent tubes, to further minimize the possibility of stray coupling.

In the early stages of the alignment procedure, where the signal generator is almost invariably coupled to the grid of one of the i-f or r-f tubes, it is considered good practice to couple the output lead of the signal generator directly to the grid cap and to leave the receiver grid lead connected. In this way, the grid of the tube is returned to the proper d-c potential and the voltage distribution in the receiver is not affected. This is of importance where the receiver design is such that the grid is returned to a point in the receiver different from ground, and is of special importance in the case of the newer receivers, where the minimum bias voltage for the r-f and i-f tubes is often fed through the grid rather than through the cathode circuit. In these cases, removing the grid lead, and returning the grid to ground through the signal generator, would leave the tube with zero bias and cause an excessive and undesirable increase in plate and screen current.

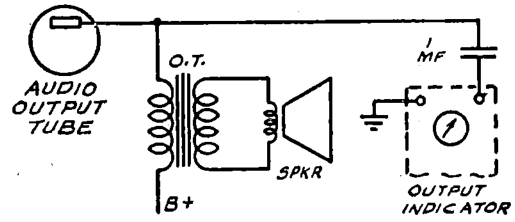
To avoid short circuiting the d-c grid path in the receiver, the output terminal of the signal generator should contain a blocking condenser, the capacity of which is of the order of .01 mf. In many signal generators this condenser is contained internally, but there are a considerable number of signal generators which do not incorporate such a blocking condenser; in the latter cases, the .01-mf. condenser must be connected externally. This condenser is not to be confused with the 200-mmf condenser which is used as a dummy antenna in aligning the antenna stage of receivers for the broadcast range. The latter condenser is designed to simulate the characteristics of the average broadcast antenna and should be connected at the receiver end of the signal-generator coupling lead rather than at the signal-generator end.

Aside from its value in preventing the short-circuiting of the grid bias voltage, the signal-generator blocking condenser referred to in the preceding paragraph is useful when alignment operations are being carried out on a.c.-d.c. receivers. In these cases, it is desirable, although not always essential, that a blocking condenser of about .1-mf capacity be installed in the negative leg of the signal generator to prevent any possibility of short circuits. A ground connection is desirable, but where a.c.-d.c. receivers are concerned, this ground connection should not be made directly to the receiver chassis, but is preferably made through a .1-mf condenser.

Output Meter Considerations

There are many different types of output meters used for alignment work, but as far as the alignment procedure is concerned, they can be divided into two different classes. One group of output indicators, which we shall consider first, measures directly the amount of audio output, while the second group functions through the AVC action in the receiver. It goes almost without saying that the latter type cannot be used on receivers which do not have AVC.

The most common type of output meter is the ordinary a-c multi-range voltmeter of the 1000 ohm-per-volt type. In operation, the voltmeter is preferably connected through a .1-mf (or larger) blocking condenser to the plate of the output tube, and the meter set to the 30- or 50-volt range. The various adjustments are then made so as to obtain the greatest deflection on the meter, or in other words, the greatest output.



By determining the maximum audio output of a superheterodyne with an a-c voltmeter, the correct adjustments of the various trimmers are found.

Other arrangements which function in the same manner are the use of a low range a-c voltmeter across the voice coil, and the use of a neon tube provided with a suitable step-up transformer so that the indicator can be connected across the voice coil.

In using this type of output meter, the action of which depends upon the amount of audio output, the output of the signal generator must constantly be reduced so that the lowest possible value of input signal is used. The point here is that the use of a large input signal will tend to keep the audio output constant, through the AVC action, and thus make it difficult to peak the trimmers accurately. *Under no circumstances should the output meter be shifted to a higher range as the receiver is brought into alignment, but rather the input signal must be continually reduced.* In this connection, the receiver volume control should be advanced fully so as to feed to the a-f amplifier all the audio voltage developed in the second detector. If the audio output is not fully advanced, the input signal required to produce a reasonable reading on the output meter may be sufficiently great so that the AVC system will be operative, and prevent proper peaking of the trimmers.

The second group of output indicators indirectly measures the output of the receiver and the amount of AVC voltage which is developed. Thus, as the receiver tuned circuits are brought into alignment, the signal voltage reaching the second detector and AVC rectifier increase, so that this rectified AVC voltage can be used as an indication of the amount of output. The most direct example of this type of indicator is a vacuum-tube voltmeter connected across the AVC bus.

Or, if more convenient, a milliameter (0-10 ma.) connected in the plate circuit of one of the controlled tubes can be used as an output indicator. The action here is that the amount of AVC voltage increases as the tuned circuits are brought into alignment; since this AVC voltage is applied to the controlled tubes in the form of a negative grid bias, it follows that the plate current of the controlled tubes has its lowest value when the trimmers are properly peaked.

A variation of this same method is to use a high-resistance voltmeter across the cathode resistor of one of the controlled tubes. Clearly, the voltage drop across this resistor has its lowest value when the trimmers are properly peaked because the plate current is then a minimum, so that this can be used as a method of indication. It may be pointed out that the tendency in the newer circuit designs is to dispense with these cathode resistors and to ground the cathodes directly, so that it is not possible to use this method in these cases.

With the AVC type of indicator, it is unnecessary to keep the input signal at as low a value as when the straight audio output type of indicator is used; in fact, it is desirable to keep the input signal at a reasonable value so that the AVC system will function and make it possible to obtain an appreciable deflection on the output indicator. At the same time, too strong a signal should not be used, as this will overload the receiver and make it impossible to peak the trimmers sharply in the overloaded circuits. A modulated signal is not required, since all AVC circuits used in broadcast receivers function on the basis of the carrier strength, and are independent of the degree of modulation.

Which type of output indicator is used is of little importance, provided it is kept in mind that with the straight audio type of output meter the input signal to the set must be kept at a low value; and that with the AVC type of indicator, the input signal must be sufficiently high to render the AVC circuit operative, but not high enough to overload the receiver.

I-F Alignment

The first step in the alignment of any superheterodyne receiver is the alignment of the i-f amplifier. Regardless of the type of superheterodyne, or the frequency range covered, the i-f transformers should be adjusted independently of any tuned circuits in other parts of the receivers. Under no circumstances should the alignment of the i-f amplifier be made secondary to the r-f or oscillator adjustment and it should be understood that whenever the alignment of the i-f amplifier is changed, the alignment of the r-f section of the receiver is affected.

To align the i-f amplifier, the signal generator should be coupled to the grid of the first detector through a .01-mf coupling condenser in the manner previously explained. Harmonics of the signal generator can be prevented from feeding into the r-f amplifier and causing miscellaneous beats by shorting the oscillator section of the variable condenser with a short clip lead. This method of stopping the oscillator is general in that it is equally applicable when a separate oscillator tube is used, or when a combined oscillator-first detector tube is used.

An alternative method of preventing beats and whistles from this source is to tune the receiver to a quiet point near the low-frequency end of the broadcast band. In any event, it is always desirable to have the wave-band switch in the broadcast-band position when aligning the i-f amplifier, in order to avoid the short-circuiting effect of the detector coil. If the range switch is left in one of the short-wave positions, the impedance of the detector coil is often sufficiently small so that it is impossible to drive a signal through to the second detector of the receiver.

If, when this precaution has been taken, the receiver is so badly out of alignment that it is impossible to get a signal through, the signal-generator lead should be shifted to the grid of the last i-f tube. After the trimmers associated with this stage have been aligned, it will be possible to drive a signal through from the grid of the preceding stage, assuming, of course, that the stage is not inoperative for some reason other than incorrect alignment.

Receivers which use i-f amplifiers having variable selectivity must be aligned with the selectivity (or fidelity) control in the *maximum-selectivity* position. In this way, the interaction between the primary and secondary windings, which ordinarily makes a special procedure necessary, is avoided. After the i-f alignment is completed with the selectivity control in the sharp-selectivity position, the overall i-f alignment should be checked with the control in the broad-selectivity position. The variation in the output meter indication should be symmetrical, and the two peaks, which are obtained as the signal generator frequency is varied through about 10 kc either side of the i-f peak, should have the same height.

As a general rule, elaborate instructions are provided in the Rider Manuals for the alignment of high-fidelity receivers, and it is recommended that these instructions be followed carefully in order to insure good receiver performance.

The design of the i-f amplifiers in a number of high-fidelity receivers is often such that the last i-f transformer is of the overcoupled type, and that this coupling remains fixed regardless of the setting of the selectivity control. In these cases, and in fact in all cases of overcoupled transformers, it is desirable that each overcoupled transformer be aligned separately. To carry out the alignment of an overcoupled transformer, the signal generator should be connected to the grid of the tube preceding the transformer, and the primary and secondary windings adjusted for a symmetrical output—for two peaks of equal height, spaced equal amounts from the i-f peak.

It is characteristic of overcoupled transformers of this type that the primary and secondary windings react on each other, so that the conventional method of aligning the two windings for maximum output cannot be used. One method of overcoming the reaction between the two windings is to shunt a 20,000 ohm ¼ watt resistor in series with a .01-mf condenser across one of the windings, while the *other* is being aligned; the principle of operation is to damp one of the tuned circuits of the transformer so that it will not react on the other, and make it impossible to peak the circuit.

After the one winding has been adjusted, the resistor-condenser combination should be removed, and it will then be possible to peak the other winding for maximum output. This completes the alignment of the transformer.

Where the i-f amplifier uses a mechanical system of variable coupling to obtain variable selectivity, the i-f amplifier should be aligned in the conventional manner with the coupling in the minimum-coupling position, that is, the maximum-selectivity position. If this is properly done, then the alignment will be correct and will provide a symmetrical curve for all positions of the selectivity control.

Parallel I-F Alignment

In a considerable number of receivers two i-f channels are provided, the one channel feeding the second detector, and the other channel feeding the AVC rectifier. In cases of this sort, the alignment of the i-f amplifier requires that each channel be separately aligned in the conventional manner. So far as the regular signal channel is concerned, the i-f amplifier can be aligned with the output meter connected to the plate of the output tube, and the trimmers in this channel adjusted for maximum output. The alignment of the AVC channel, which in most cases of this type, means the alignment of only one additional transformer, is most easily accomplished by leaving the output meter connected to the plate of the audio tube, and adjusting the trimmers in the AVC channel for *minimum output.* A fairly strong signal should be used for this adjustment, since the action depends upon the signal being sufficiently strong so that the AVC action will be brought into play. As the trimmers in the AVC channel are brought into resonance, the amount of AVC voltage produced at the AVC rectifier is thus increased; the proper peak is obtained when the maximum AVC voltage is developed, that is, when the audio output drops to a minimum.

In a number of receivers, a separate channel is used to supply the tuning indicator circuit, and in these cases the alignment of the tuning indicator is readily made after the regular i-f channel is aligned. To carry out the alignment of this circuit, the tuned circuits associated with this indicator should be adjusted so that the greatest deflection or indication is obtained on the tuning indicator. Since these circuits are invariably high-selectivity circuits, only one peak is obtained, and there is no difficulty in carrying out this adjustment.

In receivers with more than one i-f stage, difficulty may be experienced as a result of regeneration which occurs because of feed-back to the input circuit of the i-f amplifier; in extreme cases of this type the i-f amplifier may break into oscillation, so that correct alignment is impossible. This effect can be minimized by using a shielded coupling lead to the signal generator and by using a signal generator with a low output impedance, so that the amount of stray voltage fed back to the input of the i-f amplifier is kept to a minimum. While the more expensive signal generators are arranged so as to have an output impedance of the order of 100 ohms and less, there are many service signal generators which employ a high output impedance in order to obtain a high maximum output. For these signal generators—where instability of this sort is encountered—shunting a 100-ohm resistor across the signal generator terminals will reduce the amount of regeneration. Since only a relatively small signal is required from the signal generator, where this effect occurs, the reduction in the maximum signal available from the generator is of no consequence.

Dial Alignment

Following the alignment of the i-f amplifier, it is a good general policy to check the position of the dial pointer with respect to the condenser gang setting. The procedure for doing this varies for different dials, and wherever this data is given by the manufacturers, it has been included in the manual instructions. Where this data is not available, and it appears that the dial needs adjustment, it will often be found that there is an index mark at the low-frequency end of the dial. In such cases, the adjustment should be made so that the dial pointer coincides with this mark when the condenser plates are fully meshed.

Wave Trap Adjustment

After the i-f amplifier has been aligned, the wave trap adjustment should be made, if the receiver is provided with one. It is best to make this adjustment before the r-f alignment is carried out, because in some circuits there is a certain amount of interaction between the wave-trap adjustment and the r-f alignment. With the signal generator connected to the antenna post and the frequency set at the i-f peak, the output of the signal generator should be advanced all the way. The wave-trap adjustment should then be made for *minimum* output; and not maximum output, as are practically all other alignment adjustments. Regardless of what type of wave-trap is used—whether it is of the series or parallel type, whether the adjustment is by means of an iron core movement or by means of a trimmer condenser—it should be noted that the adjustment provided must be set so that the output indication is a *minimum.*

Ordinarily it will not be necessary to again make this adjustment. However, if after the receiver is installed, interference in the neighborhood of the intermediate frequency is present, then the wave-trap should be readjusted so as to minimize this interference. This readjustment should be made while the receiver is connected to the antenna, and tuned to that point on the dial where the interference is most pronounced. With the receiver in this condition and the volume control advanced fully, the wave-trap trimmer should be readjusted for minimum output. This is the correct adjustment even though the wave-trap is resonated to a frequency which is slightly different from the i-f peak.

Change of I-F Peak

In certain localities, it has been found advisable to change the i-f peak of some receivers, particularly those which have very little r-f preselection. In such cases, the i-f peak may be changed by as much as is found necessary in order to find a frequency which is near the recommended i-f peak, but which is furthest away from the interference. The complete realignment of the receiver to the new i-f peak is necessary, in such cases, in order to adjust the r-f and oscillator circuits to the new i-f peak. In particular, the wave-trap should be aligned to minimize the interference, and *not* to the new i-f peak.

Radio-Frequency and Oscillator Adjustments

By far the most important of the adjustments which follow the alignment of the i-f amplifier are those which are located in the oscillator circuit. The adjustment of the oscillator trimmers is of extreme importance because the frequency of the oscillator determines whether or not the difference frequency produced in the first detector will be the correct i-f peak. Improper adjustment of the oscillator trimmers thus prevents the signal from getting through the i-f amplifier "on the nose," and thus impairs the selectivity, sensitivity, and the dial calibration to a marked extent. The other radio-frequency adjustments, while they are important, affect the performance to a much smaller degree. In particular, the dial calibration is controlled almost entirely by the oscillator adjustments, and only slightly affected by the adjustment of the r-f trimmers.

As a general rule, the adjustment of the high-frequency oscillator trimmer follows the alignment of the i-f amplifier. To make this adjustment, the signal generator should be connected to the antenna post of the receiver, and both the signal generator and the dial of the receiver set to the same frequency near the high-frequency end of the band being aligned. The frequency specified in the alignment data given in Rider Manuals should be used for making this adjustment. If the receiver is out of alignment appreciably, it will be impossible to pick up the signal at the correct point on the dial —but it will be found that the signal comes in somewhere near the required point.

If, for example, the signal generator is set at 1400 kc, and the signal appears at 1300 kc on the receiver dial, then the high-frequency oscillator trimmer should be turned clockwise slowly (increasing the capacity) until it is possible to hear the signal with the dial set at the proper frequency, which is 1400 kc in the example chosen. The trimmer should now be adjusted accurately for maximum output with both the signal generator and the receiver dial set at the same frequency. Following this adjustment, the r-f and antenna trimmers should be adjusted for maximum output.

The Low-Frequency Oscillator Adjustment—"Rocking"

Just as the high-frequency oscillator trimmer determines the performance of the receiver over the high-frequency portion of the band, so the low-frequency oscillator trimmer determines the performance over the low-frequency end of the band. The method of making this adjustment is different from the usual manner in which trimmers are peaked for maximum output, in that a procedure commonly designated as "rocking" must be used.

This rocking adjustment is carried out in the following manner. The signal generator and receiver are tuned to the point near the low-frequency end of the band which is specified in the alignment data; to make this discussion more definite and easier to follow, we shall assume that the adjustment is being carried out for the broadcast band, in which case the signal generator would be set at 600 kc. The receiver should be tuned for maximum output, and in general the dial reading will not be exactly 600 kc, but may be off by as much as 10 or more kilocycles on either side. Whatever the dial reading—*even if it is exactly 600 kc,* the next step should be to change the setting of the low-frequency oscillator adjustment slightly and then to tune the receiver for maximum output. If this procedure increases the output, the setting of the oscillator trimmer should be changed a small additional amount in the same direction, and the receiver again tuned for maximum output. On the other hand, if the movement of the oscillator trimmer in this same direction and the readjustment of the tuning control reduces the output, then a slight variation of the trimmer in the reverse direction should be tried, and the receiver tuning control should be readjusted for maximum output. This procedure of alternately adjusting the oscillator trimmer and the tuning control should be continued until no further increase in output can be obtained—that is, until the displacement of the oscillator trimmer in both the clockwise and counter-clockwise directions and the accompanying rotation of the tuning control for greatest output is accompanied by a reduction in the output. The object of this procedure is to arrive at that adjustment wherein the r-f circuits are tuned to the signal, and the oscillator frequency is higher than the signal frequency by the amount of the i-f peak, so that the greatest receiver sensitivity is obtained. It should be noted that in general the dial calibration will not be exactly correct, but that nevertheless this is the best possible adjustment.

Upon completion of this rocking adjustment near the low-frequency end of the band, the adjustments near the high-frequency end should be repeated. Unless the alignment adjustments were initially very far off, it will not be necessary to again repeat the adjustments at the low-frequency end of the band.

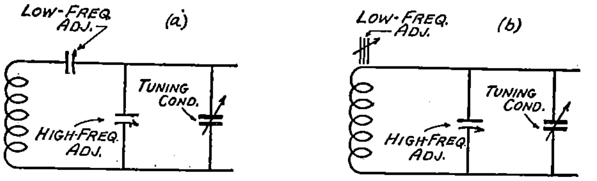
In the case of receivers, which employ band-pass r-f circuits sufficiently broad to pass the wide side-bands required for high-fidelity reception, the application of this conventional rocking procedure will not produce any sharply defined best setting of the low-frequency oscillator trimmer. This is so because the r-f circuits are sufficiently broad so that, for dial settings within a range of about 15 kc, the corresponding setting of the oscillator trimmer for any point within this range will produce essentially the same output. In cases of this sort, the frequency readings of the dial should be noted at the two extreme positions where the output begins to fall off. The dial should then be set half way between these two positions, and the oscillator trimmer should be aligned for maximum output.

For example, if for a particular receiver, with the signal generator set at 600 kc, substantially the same output can be obtained over the range from 580 kc to 610 kc (with suitable adjustments of the low-frequency oscillator trimmer over this range) then the dial should be set half way between these two frequencies—595 kc—and the oscillator trimmer adjusted for maximum output with the dial set in this position *and the signal generator still set at 600 kc.* While the above procedure is recommended as a good general practice to follow in the case of high-fidelity receivers, it is to be understood that the manufacturer's instructions, where available in the manual, should be followed in preference to this general procedure.

Broadcast Band Alignment

In the preceding section, the general alignment procedure required for adjusting any one of the bands was described and shown to consist of adjustments near the two ends of the band. At the high-frequency end of the band, it was stated that these adjustments generally take the form of a shunt oscillator trimmer adjustment, a shunt detector trimmer adjustment, and a shunt r-f trimmer adjustment. These are generally followed by the adjustment of the oscillator series trimmer, near the low frequency end of the band, to assure proper oscillator tracking, the latter adjustment being accomplished by rocking.

While alignment data is included wherever it was available from the manufacturer, the serviceman in the course of his work may be called upon to service receivers for which alignment data is not available. In cases of this sort, it can be stated as a general rule that the high-frequency alignment adjustments should be made at 1400 kc, and that the low-frequency oscillator adjustment should be made at 600 kc (for the broadcast band). On some of the newer receivers, which have an extended range going up to some 1700 kc, better alignment is secured if the oscillator trimmer is aligned at 1700 kc and the shunt detector and r-f trimmers are aligned at 1400 kc. In this way it is assured that the receiver will cover the frequency range indicated on the dial, and at the same time the r-f and detector circuits are aligned to track with the oscillator in the neighborhood of 1400 kc, where this added r-f selectivity is of advantage. Note that to secure the best possible alignment at 1400 kc in these cases, the dial must be rocked while the r-f and detector trimmers are adjusted. This rocking procedure is necessary in order to align the r-f and detector circuits to the signal, and at the same time to produce the correct oscillator frequency.



In (a) the low frequency adjustment is accomplished by means of a trimmer condenser while in (b) a movable iron core is used.

High-Frequency Alignment

The alignment of a receiver on the high-frequency or short-wave bands follows the same general procedure for the broadcast band, but the procedure is somewhat more involved and requires more experience and skill than does the broadcast band or i-f alignment. Primarily, the reason for the greater difficulty of alignment of the short-wave bands arises because there are two frequencies of the oscillator, that is, two settings of the oscillator trimmer, for which the output meter will indicate a maximum output reading. Despite the fact that both of these peaks are equal, only one of them is correct—and only this one will give good receiver performance over the *entire* band.

On the broadcast band, in fact, on all bands, and in every superheterodyne, there are also two adjustments of the oscillator frequency which will give equal performance for a particular dial setting; however, on the lower-frequency bands, only one of these frequencies—the correct one—is within the range of the oscillator adjustment, so that there is no possibility of misalignment. For example, if we take the case of a receiver with an i-f peak of 470 kc, tuned to receive a 1000-kc signal, the oscillator in the receiver is working at 1000 kc + 470 kc or at 1470 kc. The other possible frequency at which the oscillator might work, and still bring in the 1000-kc signal, is 1000 kc — 470 kc or 530 kc. The latter oscillator frequency is said to be the *image* of the 1470-kc oscillator frequency, because it also is separated from the signal frequency by 470 kc. No difficulty in alignment is experienced in this case because obviously the range of neither the series oscillator trimmer nor the shunt oscillator trimmer is sufficient to vary the oscillator frequency by as much as 2 × 470 kc or 940 kc, which is the amount required. However, it should be noted that where a low intermediate frequency is used, such as 175 kc, there is considerable danger, even on the broadcast band, of aligning the oscillator frequency to the image.

A concrete example will illustrate the manner in which the image response of superheterodyne receivers complicates alignment at the higher frequencies. If a receiver is being aligned at a dial frequency of 20,000 kc, for example, then the two possible settings of the oscillator trimmer, each of which will mix with the 20,000-kc signal, are 20,000 kc + 470 kc and 20,000 kc — 470 kc, or 20,470 kc, and 19,530 kc. Clearly enough, these two frequencies are so close together that the range of the oscillator trimmer is such that both frequencies can be produced. One of these oscillator frequencies, the 20,470-kc frequency, is produced with the oscillator trimmer practically all the way out—at minimum capacity—while the 19,530-kc signal is produced with the trimmer set near maximum capacity.

Which one of these settings is the correct one, and which one is to be considered the image, depends entirely upon the design of the receiver. Up until recently, the higher oscillator frequency was almost invariably the correct one, but apparently there are an increasing number of receivers for which the lower oscillator frequency is the correct one on one or more of the high-frequency bands. In cases where no information is available, and two settings of the oscillator trimmer can be obtained, it is recommended that the procedure explained in the next paragraph be followed.

The first step in determining whether the oscillator image should be above or below the signal is to shift the signal generator and dial to the low-frequency end of the band and to see if it is possible to obtain two settings of the oscillator trimmer which will give the same output. In the event that there is only one setting of the oscillator trimmer at the end of the band, then the following procedure will determine whether the oscillator frequency is higher or lower than the signal frequency for the particular band being aligned. Again a concrete example will be used to explain the procedure.

If we assume that only one oscillator setting is obtained when an 8000-kc signal is fed to the receiver, this being the low-frequency end of the band —the high-frequency end is 20,000 kc—then the oscillator is either working at 8470 kc (8000 kc + 470 kc) or at 7530 kc (8000 kc — 470 kc); the problem is to determine whether the higher- or lower-oscillator frequency is correct, in order to properly align the high-frequency end of the band where *two* oscillator settings are obtained.

If the oscillator is working at 7530 kc, then it should be possible to drive a signal having a frequency of 7530 kc — 470 kc or 7060 kc through the receiver; and if the oscillator in the receiver is working at 7470 kc then it should be possible to drive a signal having a frequency of 8470 kc + 470 kc or 8940 kc through the receiver. By varying the signal-generator frequency through each of these frequencies in turn, it is possible to determine the signal image frequency, and hence to determine whether the oscillator should be aligned above or below the signal frequency. By way of summary, it can be noted that if the signal comes through below the dial frequency, then the oscillator is working below the signal frequency on the particular band being considered, and consequently the maximum capacity setting of the oscillator trimmer at 20-mc is the correct one. On the other hand, if the signal comes through above the receiver dial frequency as is more generally the case, then the minimum capacity setting of the oscillator should be taken at 20 mc. To check for both of these image frequencies, it is generally necessary to raise the output of the signal generator, because the r-f circuits are detuned from the incoming signal.

On the highest-frequency band, it will often occur that two settings of the oscillator trimmer are possible at both the high- and low-frequency ends of the band. If no data is available in cases of this sort, then the receiver should first be aligned on the assumption that the oscillator works above the signal, and the minimum-capacity settings of both the oscillator shunt and series trimmer used. If the dial calibration and sensitivity of the receiver are good over the entire range, and more especially at the middle of the range, then this choice is the correct one.

On the other hand, if the dial calibration and sensitivity near the middle of the range are poor, then the band should be realigned on the assumption that the receiver is designed so that the oscillator works below the signal frequency. Whichever of these assumptions gives the better receiver performance is the correct choice.

It should be mentioned that because a receiver is so designed that the oscillator works below the signal frequency on one band, is no indication that this same relationship is maintained on all bands. On the contrary, all receivers almost invariably work with the oscillator frequency above the signal frequency on the broadcast bands, but sometimes shift to below the signal frequency on the higher frequency bands, and more especially on the highest-frequency band. There can thus be no general rule, but where the alignment data is not available, the above procedure should be followed.

Image Check

Even where the data specifies which setting of the trimmer should be used—that is, whether the oscillator works above or below the signal frequency —it is advisable to make certain that the proper oscillator frequency has been chosen. The reason for the test is that in extreme cases the adjustment at the one end of the band may be so far out that it produces a misleading indication at the other end of the band.

If we take the case where the minimum-capacity setting of the trimmer is to be used, and the receiver is being aligned at 20,000 mc (i-f peak equal to 470 kc), then it should be possible to tune the receiver to 20,940 kc (470 kc above the oscillator frequency of 20,470 kc) and at this frequency it should also be possible to pick up the signal from the signal generator. Similarly, in the case where the maximum capacity position of the oscillator trimmer is used, then it should be possible to pick up the signal with the receiver tuned to 19,530 kc. For both these image checks, it will generally be necessary to advance the output of the signal generator in order to pick up the signal.

Ultra Short-Wave Alignment

The alignment of the ultra short-wave ranges, with which a number of receivers listed in this manual are equipped, requires some special mention. For some receivers, as for example, the General Electric E-155 which carries an ultra short-wave range extending as high as 70 mc, the adjustments are fixed and no alignment is required. However, it is of special importance that the wiring in the r-f section of the receiver be maintained in its original position, inasmuch as failure to observe this precaution may decrease the sensitivity of the ultra short-wave range, and in some cases render it completely inoperative.

Some of the receivers incorporating an ultra short-wave range, for example, the Stromberg-Carlson Model 250, make provision for the alignment of this range. Where alignment of this range is attempted, both receiver and signal generator should be tuned to the high-frequency end of the band, which is generally about 60 mc. Since the ordinary signal generator does not provide frequencies as high as this on fundamentals, it is convenient to use the third harmonic of the signal generator output, which in this case would be 20 mc. With the signal generator connected through a 400-ohm carbon resistor to the antenna post,—on some receivers a special ultra high frequency post is provided—the shunt oscillator trimmer should be peaked for maximum output. There is generally no shunt trimmer on the detector coil, so that no further adjustment at the high-frequency end of the band is required.

If the sensitivity and calibration at the low-frequency end of the band are poor, then it is possible that an improvement can be made by adjusting the shape of the loop of wire which generally forms the oscillator coil for this band. Deforming this loop slightly will change its inductance, and thus provide a means for controlling the oscillator calibration at this end of the band. The same type of adjustment can also be made on the detector coil, if the sensitivity of the band is still poor after the oscillator is aligned.

As usual, the high frequency oscillator trimmer should be readjusted, if it is found necessary to change the position of the oscillator coil. It should be emphasized that only a slight change in any one of the wires associated with the tuning system will change the calibration and sensitivity to a marked extent, and that therefore the adjustment of the coils should be very carefully made.

Before changing any of the alignment adjustments, it is a good plan to try the effect of replacing the oscillator and first detector tubes, and to check the several coils, condensers, and switch contacts associated with the band. Poor performance or total lack of operation is often due to one of the causes enumerated above rather than to faulty alignment.

Order of Alignment

The order in which the various bands are aligned is of importance in the case of all-wave receivers which use the tapped-coil system. While the alignment data should be followed wherever available, it is possible to give some general rules which are valuable in cases where no data has been provided by the manufacturer.

There are two types of coil arrangements used in all-wave receivers:—(1) The series arrangement of the coils, wherein a tapped coil is used for the different ranges, and (2) the system wherein a separate coil is used for each of the bands. In the tapped coil arrangement, the highest-frequency band is generally aligned first, and the other bands are aligned in order of descending frequency, with the lowest-frequency band last. In this way, any error which might be present in the alignment of one of the lower-frequency bands does not affect the alignment of the band under adjustment, since the trimmers associated with this band are shorted out of the circuit. With the separate coil system, the adjustments on the several bands are essentially independent, so that the order of alignment is generally not important.

Dummy Antenna

To correctly align the antenna coil, it is desirable that the signal generator be connected to the receiver antenna post through a dummy antenna which is designed to simulate the characteristics of the average antenna. On the broadcast band, a 200-mmf condenser is satisfactory for general alignment work, while on the short-wave bands, a 400-ohm carbon resistor of the half-watt type should be used. Both of these units must be connected at the receiver side of the signal generator lead.

10-KC Filter Adjustment

Receivers which employ a band pass i-f amplifier generally incorporate a tuned circuit in the plate of the 2nd detector or the first a-f stage, the purpose of which is to prevent frequencies and beats higher than 10 kc from getting into the a-f amplifier. The adjustment of this filter is seldom necessary, unless it is tampered with.

In the event that readjustment does become necessary, it can be carried out most conveniently with an audio oscillator which should be set to produce a frequency of 10 kc. The output of the audio signal generator should be connected across the volume control, and the adjustment of the compensating trimmer should be made for *minimum* output with the output meter connected in the usual position.

In the event that an audio oscillator is not available, this adjustment can also be made by using the 10-kc beat frequency between the signal generator frequency and the carrier of a received signal.

Visual Alignment

Visual alignment methods are recommended by a number of manufacturers to carry out the alignment of the band-pass i-f amplifiers in their receivers. Visual methods are of special value in carrying out the alignment of these circuits, in that the equipment makes it possible to see a trace of the selectivity curve on the screen of the cathode ray tube, and hence to make the various adjustments so as to produce an overall resonance curve which has the greatest height and which at the same time is symmetrical.

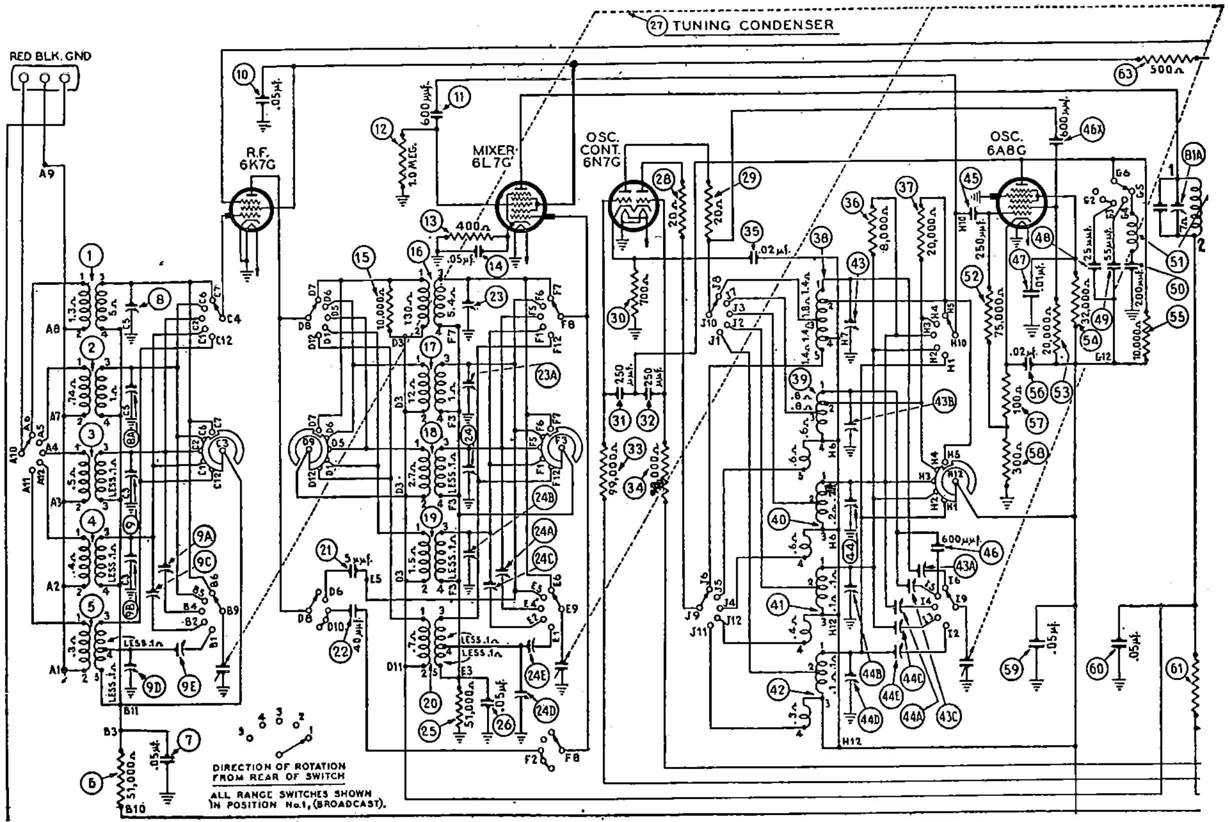
The explanation of the operation of the various types of visual alignment equipment and methods is beyond the scope of this special section. The reader who is interested in this subject will find an unusually complete description in "The Cathode-Ray Tube at Work" by Rider.

RADIO FREQUENCY CIRCUITS

R-F Circuit in Philco 38-116

The schematic in Fig. 1 shows the r-f unit used in the Philco Model 38-116 receiver, which covers the frequency range from 530 kc to 18.2 mc in five wave bands. Referring to the schematic, you will note that a 6K7G is used as an r-f amplifier, a 6L7G as a first detector or mixer, a 6A8G as an oscillator, and a 6N7G as an oscillator control tube.

Considering the fact that five wave bands are used in this receiver, that compensating adjustments are used on all the bands, and that the circuit



Courtesy of Philco Radio & Television Corp.

Fig. 1.—Partial schematic of Philco Model 38-116, showing the r-f, mixer, oscillator, and oscillator control tube circuits.

is further complicated by the presence of the automatic frequency control, the schematic in Fig. 1 is remarkably simple and comparatively easy to follow. However, when defective operation on a specific band is encountered, it is often necessary to break down the circuit for that one band so as to simplify locating the trouble. In Fig. 2, a breakdown diagram of the circuit on Range 1 is shown, and it is evident that the schematic is considerably simplified by redrawing it so as to show only the connections for the specific band being tested.

Range 1

Starting at the antenna circuit, the signal is coupled to the grid of the 6K7G, and the grid is returned to ground through the AVC system. The amplified signal voltage in the plate circuit of the r-f tube is coupled to the grid of the 6L7G mixer tube through the r-f transformer 16, and the signal grid returned to ground through a 51M-ohm resistor which is by-passed with a .05-mf condenser. The plate circuit of the 6L7G connects directly to the first i-f transformer, and since we are not here concerned with the i-f amplifier, the signal path will not be traced further.

The oscillator circuit in this receiver is more complicated than usual because of the presence of the automatic frequency control circuit. The oscillator coil is identified in the diagram by the number 38, and has five connections running to it. The lower connection on this coil is connected to the plate of the oscillator control tube through a 20-ohm resistor. The first tap from the bottom is connected directly to the positive voltage supply and it is through this lead that voltage for the oscillator control tube is supplied. The next tap on the coil is connected to the plate of the other triode section of the 6N7G control tube and is also connected to the oscillator grid of the 6A8G oscillator tube through a 600-mmf condenser; this tap supplies the feedback voltage so as to maintain oscillation in the circuit, and also supplies one of the points across which the reflected reactance of the push-pull control tube is introduced. The next tap connects to the grid through a 250-mmf grid condenser, so that the impedance of the tuned circuit as seen by the grid is lower than the impedance of the entire oscillator grid tuned circuit. The tuned circuit is completed, tracing the circuit from the upper coil connection, through the low-frequency oscillator padder 43A and the tuning condenser; trimmer 43 constitutes the high-frequency oscillator trimmer adjustment.

Although automatic frequency control circuits are described in more detail elsewhere, it will probably be worthwhile going over the method of operation of the oscillator control circuit used in this

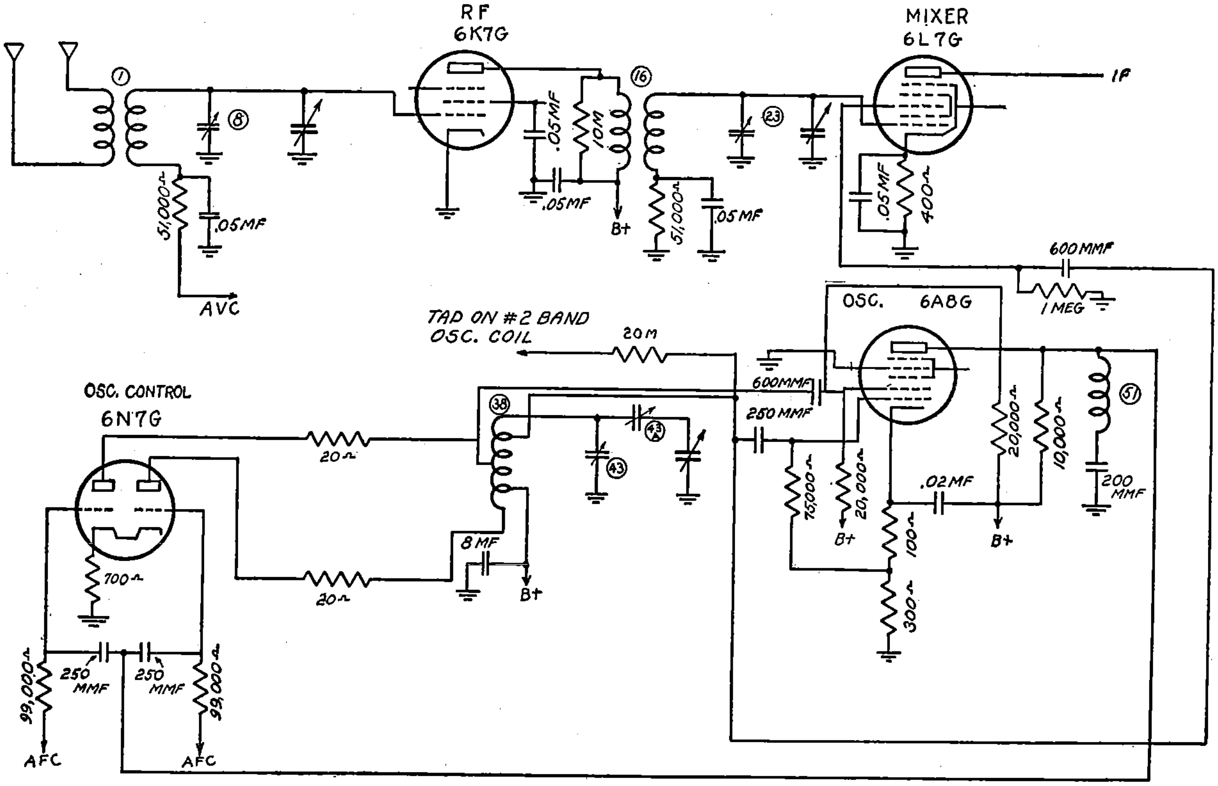


Fig. 2.—How the components of the Philco 38-116 are connected for Range 1.

receiver rather briefly, considering that the circuit has already been broken down. However, we are going to take it for granted that you are familiar with the general principles of AFC, so that the description will be quite brief.

The lagging grid voltage which must be fed to the grids of the 6N7G oscillator control tube is obtained by inserting a so-called *control impedance* in the plate circuit of the 6A8G oscillator tube. For Range 1 the control impedance consists of coil 51 in series with a 200-mmf condenser, the combination of these two forming a series circuit resonant at a frequency above the broadcast band. The plate voltage for the 6A8G is fed through a 10M-ohm resistor which shunts this control impedance, as far as r-f is concerned.

Since the r-f plate current in the plate circuit of the oscillator tube is in phase with the oscillator grid voltage, the voltage drop across the control impedance lags the oscillator grid voltage by approximately 90 degrees, so that a corresponding amplified current flows through the two sections of the oscillator grid coil which are connected to the plates of the 6N7G through two 20-ohm resistors. The action of the currents flowing through the oscillator grid coil is such that the oscillator frequency is either increased or decreased in accordance with the d-c voltage from the discriminator, which is applied to the grids of the 6N7G through the two 99M-ohm filter resistors. This action is discussed in more detail in the section which deals with AFC circuits.

The oscillator voltage is fed to the oscillator grid of the 6L7G through a 600-mmf condenser and the grid is returned to ground through a 1-megohm resistor. A combination of cathode and grid-leak bias is used in the oscillator circuit, since you will note that the #1 grid of the oscillator tube is returned to the junction of the two cathode resistors through a 75M-ohm resistor.

There are a number of actions which take place in this circuit which are not indicated on the breakdown diagram of Fig. 2. In the first place, all the coils which are not in use on Range 1 are shorted by separate sections on the wave-band switch; thus the contacts C3, D9, F3, and H12 short circuit the antenna secondary windings, the r-f primary windings, the r-f secondary windings, and the oscillator windings which are not being used for the particular band in operation. Note that the construction of the aforementioned switch wafers is such that not only the band immediately higher in frequency than the one in use is short circuited, but that the remaining coils are also shorted.

It should be noted, as indicated in Figs. 1 and 2, that a 20M-ohm resistor is connected between the

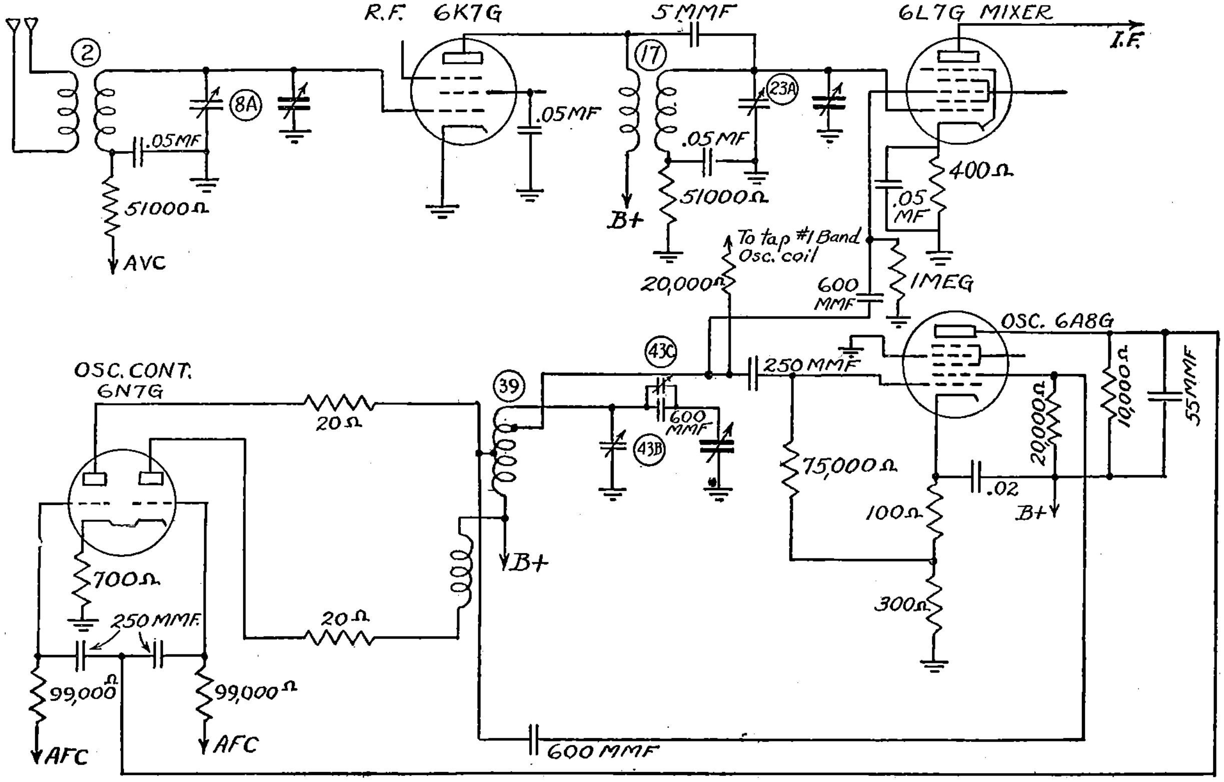


FIG. 3.—Connections of the Philco 38-116 when the band switch is set on Range 2.

Range 1 and Range 2 oscillator grid coils. Effectively this shunts a 20M-ohm resistance, in series with the comparatively small reactance of the Range 2 oscillator coil, across the Range 1 oscillator grid coil.

Range 2

The breakdown diagram for Range 2 (1.58—4.75 mc) is shown in Fig. 3. Essentially the circuit on this band is the same as that on the previous range, and all the remarks which were made above are equally applicable for this band. There are, however, a few minor changes in the oscillator circuit, which are as follows: The G6 wafer disconnects the tuned control impedance and a 55-mmf condenser is substituted in its place. In the grid circuit of the oscillator, the series condenser consists of a fixed 600-mmf condenser in series with an adjustable condenser; the same 20M-ohm resistor which connects the two grid coils on Ranges 1 and 2, and which was mentioned above, here serves to shunt the Range 2 oscillator grid coil through the reactance of the Range 1 oscillator coil (and its trimmer condenser). As before, the coils which are not in use are short circuited by the several sections of the wave-band switch.

Range 3

On Range 3, Fig. 4, which covers the band of frequencies between 4.7 and 7.4 mc, the most apparent change is in the arrangement of the antenna and r-f tuned circuits. Thus the antenna transformer secondary is tuned at both the low- and the high-frequency end, as is also the r-f transformer secondary. In addition to providing an adjustment at both ends of the band so as to assure perfect alignment of the signal circuits, the use of the series condenser and the shunt trimmer provides a band spread action which is evident in that the frequency range covered on this band is less than 1.6 to 1. On the first two ranges, on the other hand, the frequency band covered is approximately 3 to 1.

The automatic frequency control circuit on this band is essentially the same as on the two previous bands, with the exception that a 25-mmf condenser is used as the control impedance in the plate circuit of the 6A8G oscillator.

A lower value of shunt resistance is used across the oscillator tuned circuit, since you will note from the breakdown diagram that the 20M-ohm resistor is replaced by an 8M-ohm resistor which shunts the tuned circuit through the reactance of the Range 4 oscillator circuit. An additional circuit modification on this band is the use of a 40-mmf condenser

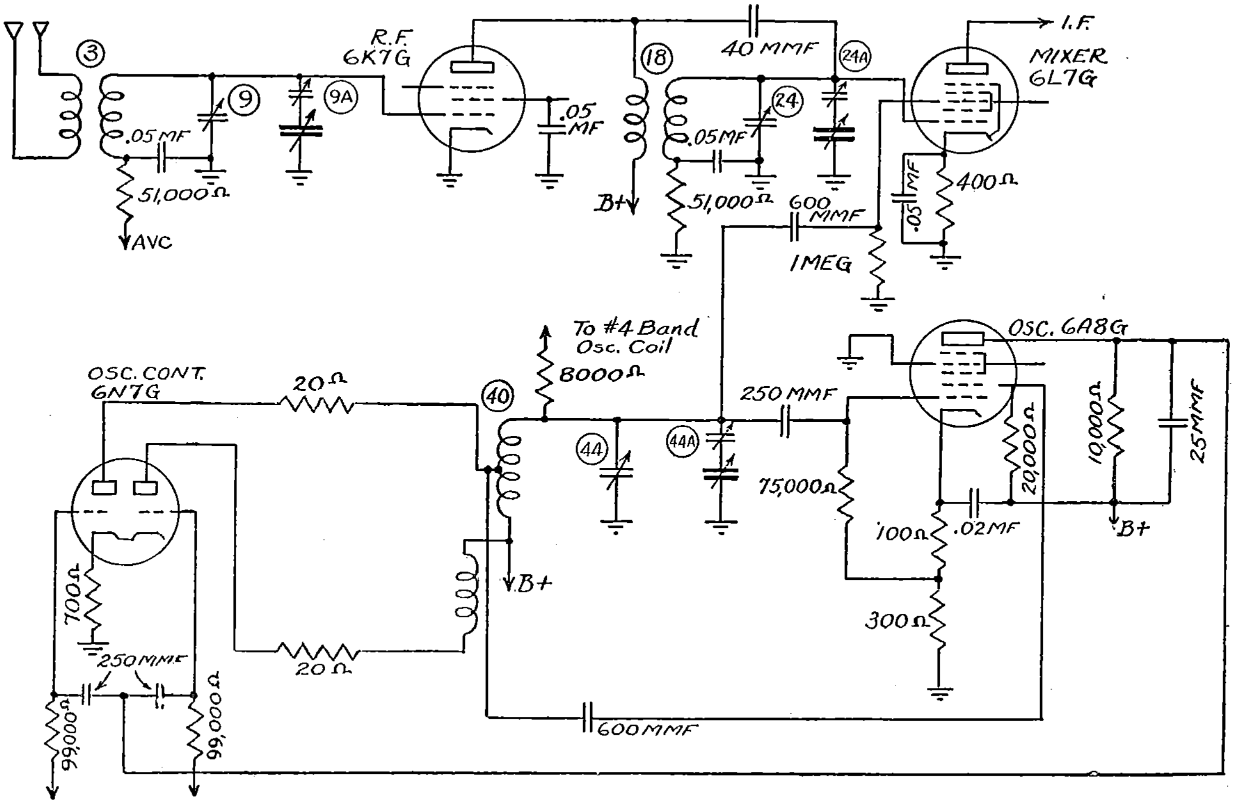


Fig. 4.—Connections for Range 3 (4.7-7.4 mc) of the Philco 38-116.

between the primary and secondary windings of the r-f transformer, whereas a 5-mmf condenser was used in this position on Range 2.

Although it is not indicated in Fig. 4, all the coils which are not in use on this range are short circuited by the shorting switch sections, as we saw to be the case for the other ranges.

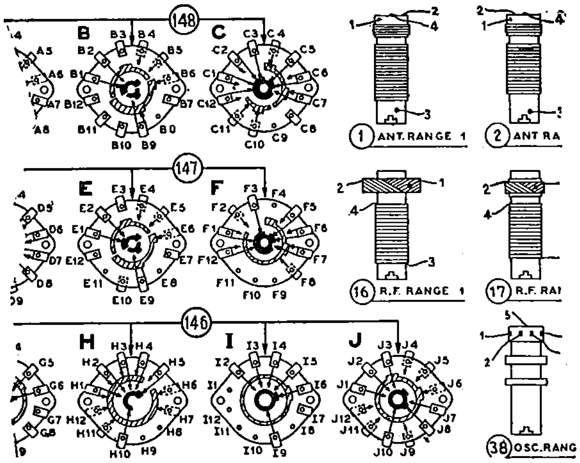
Range 4

This range, which covers from 7.35 to 11.6 mc, makes use of the same arrangement of series and shunt trimmer condensers in order to obtain electrical band spread and at the same time makes possible the accurate tracking of the antenna and r-f circuits. Essentially the circuit is the same as on the preceding range so that no further discussion is necessary.

Range 5

On the highest frequency range, Fig. 5, covering from 11.5 to 18.2 mc, the same basic circuit arrangement is still retained. However, both the antenna and r-f secondary windings are tapped, so that the tuning condenser appears across only a part of the respective grid coils. In the plate circuit of the control tube, the 25-mmf control impedance condenser is eliminated, since the plate-to-cathode capacity of the tube is sufficiently great on this band to provide the desired amount of lagging voltage for the grids of the 6N7G control tube.

To enable quick identification of the various leads which are connected to the several switch wafers, a separate diagram shown in Fig. 6 is provided, which shows a detailed view of each section used in the wave-band switch. Each wafer on this diagram is identified with a characteristic letter, and the contacts numbered consecutively around the switch. Since the schematic carries these same



Courtesy of Philco Radio & Television Corp.

Fig. 6.—How the band switch wafers and coils are identified in the Philco 38-116.

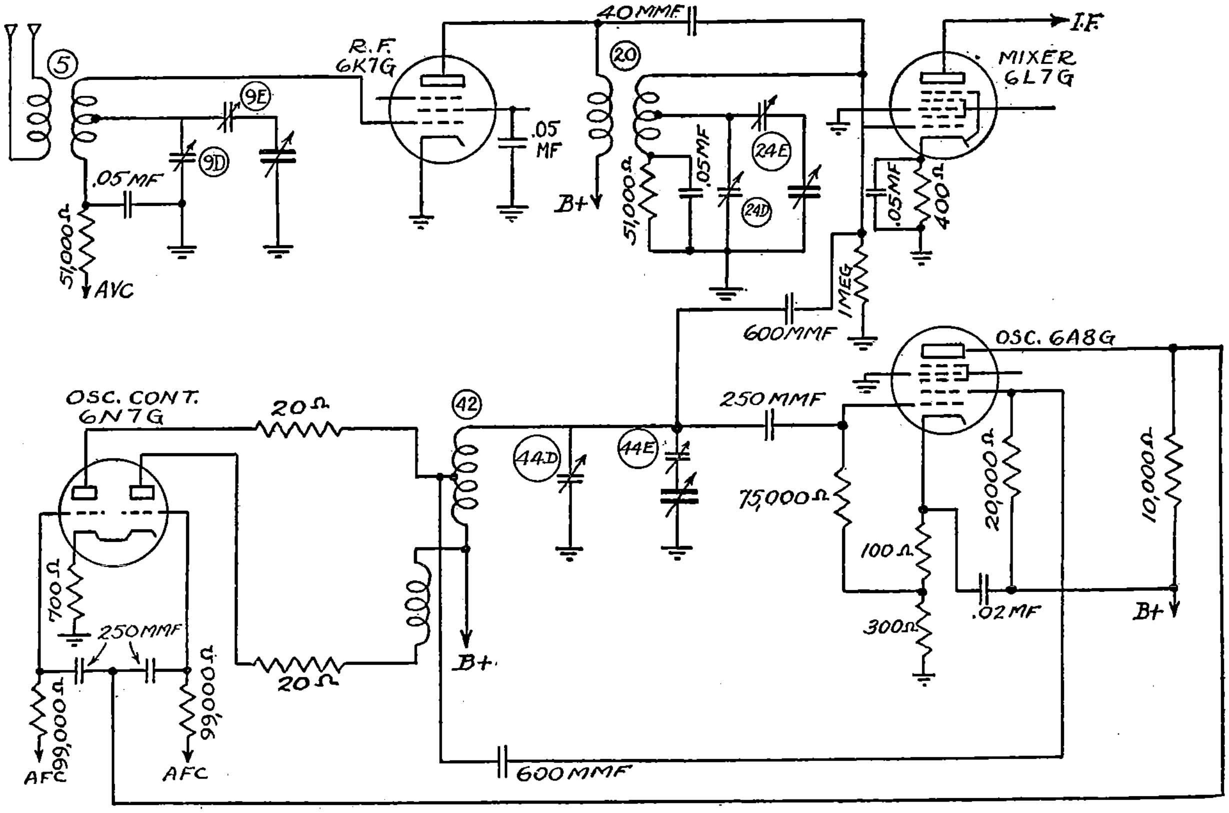


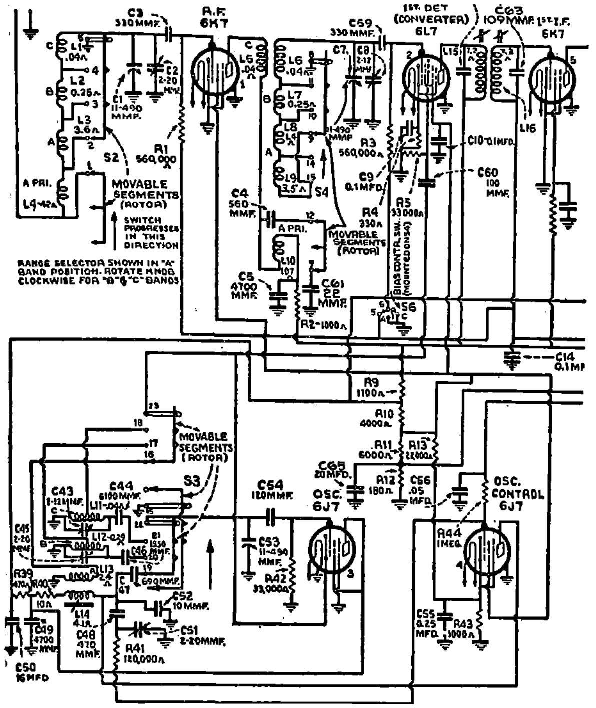
Fig. 5.—The Range 5 connections for Philco 38-116.

identifying letters and numbers, it is a relatively simple matter to identify each lead wire in the schematic with its actual position on the wave-band switch. This is of great value in making continuity checks and in general troubleshooting work.

A drawing of the individual coils is also supplied with the service data; this diagram shows a pictorial view of the several coils and identifies each lead with a number which corresponds to the number used to identify the coil terminal in the schematic. The provision of this data makes for an appreciable saving of time whenever it becomes necessary to conduct testing operations which involve measurements at any of the antenna, r-f or oscillator coils. The resistance of each section of the various coils is specified in the schematic, and to make the most of this data an ohmmeter capable of reading low resistance values should be used.

R-F Circuit in the RCA 811K

The accompanying illustration shows the three-band "Magic Brain" circuit used in the RCA Model 811K and in a number of other 1938 RCA receivers. This circuit embodies several distinctive features which are of interest both because they indicate the trend in modern r-f circuit design, and as well because the data supplied with this circuit illustrates the type of data which the manufacturer is supplying to the serviceman for servicing the more complicated multi-band receivers.



Courtesy of RCA Mfg. Co., Inc.

Fig. 7.—The "Magic Brain" circuit used in the RCA Model 811K.

As the schematic in Fig. 7 shows, a 6K7 is employed as an r-f amplifier, a 6L7 as a frequency converter or first detector, and a separate 6J7 tube is used as an oscillator. The frequency range covered is from 530-1720 kc on the A band, from 2100-6800 kc on the B band, and from 6800-23,500 kc on the C band. Even a first inspection of Fig. 7 shows that the circuit arrangement in this r-f unit is different from the circuits heretofore used, the most apparent of these differences being the series arrangement of the coils, with the absence of separate primary windings, and the distinctive and unusual way of representing the switch contacts. Although not apparent from the schematic, the antenna coils are all wound on a single form and connected in series. The A, B and C sections of the detector coil are likewise wound on a single form, and although separate coils are used in the oscillator circuit for each band, these are also wound on the same form.

We can best analyze this circuit by breaking it down into the connections which exist for each of the wave bands in turn. By so doing, the complicated switch connections are eliminated from the circuit and only those parts essential to the operation on one band are shown. Breakdowns of this type are necessary in order to locate trouble in the r-f unit when defective operation occurs on one or more of the wave-bands.

"A" Band Breakdown

Working from the schematic, Fig. 7, let us first draw a breakdown diagram of the circuit when the receiver is operating on the A band. This is relatively simple to trace out, since the schematic has been drawn for this condition, and the breakdown diagram is shown in Fig. 8. Note that on this band, L4 functions as the antenna primary winding, while the secondary winding of the antenna coil consists of L1, L2, and L3 in series. The signal voltage induced in this secondary winding is coupled to the grid of the 6K7 r-f tube through the 330-mmf coupling condenser, so that the amplified r-f current flows in the plate circuit of the tube through L5 and L10. The switch S4 connects a 22-mmf condenser in series with the 560-mmf condenser, so that essentially the capacity across L10, the A band primary winding, is less than 22-mmf. As a result of this connection, the signal voltage is transferred into the secondary winding, consisting of L6, L7, L8, and L9 in series, because of the coupling between L10 and these windings. This voltage is transferred to the grid of the 6L7 frequency converter through a 330-mmf condenser.

We might note here that this rather unconventional use of a grid condenser and grid resistor in both the r-f and detector sections of this receiver is to permit grounding the coil and switch assembly without at the same time grounding the grids of the respective tubes. The AVC voltage for these tubes is then supplied through the 560M-ohm grid resistors. No grid current normally flows through these resistors since the grid is at all times biased negatively with respect to the cathode.

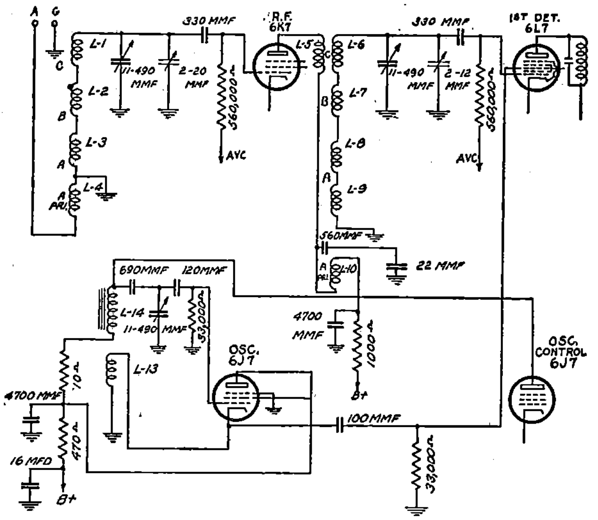


Fig. 8.—Breakdown of RCA Model 811K for the A Band connections.

Turning our attention to the oscillator circuit on the A band, as broken down in Fig. 8, we note that an iron core inductance L14 is used as the secondary winding, and that the feedback is in the cathode circuit through L13 which is coupled inductively to L14. In this breakdown we have omitted showing the connections of the oscillator control circuit, since this circuit is discussed elsewhere in this section. The oscillator voltage is taken off across the cathode coil and coupled to the oscillator grid of the 6L7 through a 100-mmf condenser; the 33M-ohm resistor supplies a d-c return path for this grid.

"B" Band Breakdown

The manner of operation on the B band is not so easily interpreted, since the tracing out of this breakdown necessitates visualizing the circuit connections which are made and broken as the several switch sections are moved up into the next waveband position. Fortunately, there is a definite tendency on the part of manufacturers to make these drawings as simple as possible, and the schematic in Fig. 7 represents, we believe, an example of the simplification which can be introduced by the proper layout of the schematic.

Beginning again at the antenna, the lower section of S2 shorts L4, and the upper section of the same switch grounds the junction of L3 and L2. The breakdown diagram of Fig. 9 is made in accordance with these observations, and it is evident from this figure that L3 functions as the primary winding for the antenna coil on this band. In other words, the coil arrangement is such that part of the secondary winding on the A band (L3) becomes the primary winding for the B band. Thus the same winding performs a dual function in this circuit.

As the breakdown of the detector circuit for the B band shows, the effect of switch S2 moving up one position is to disconnect the 22-mmf condenser, to connect the 560-mmf condenser to the lower end of L9, and to ground the junction of L7 and L8. In this way, the r-f current in the plate circuit of the 6K7 flows through the 560-mmf condenser and through the coils L8 and L9. On this band the relatively high inductance of L10 prevents the r-f current from flowing through it, so that effectively L10 acts as an r-f choke, and L8 and L9 together constitute the primary winding for the detector coil on the B band. Again you will note that as in the case of the antenna coil, part of the secondary on the A band (L8 and L9) becomes the primary winding on the B band.

In the oscillator circuit, movement of switch S3 into the B-band position, connects the tapped coil L12 into the circuit; at the same time, the lower section of the switch shorts the A-band coil to ground so as to prevent resonance in the A-band coil from interfering with the operation of the B-band oscillator. The switch is so placed with respect to the circuit that the B-band coil is switched

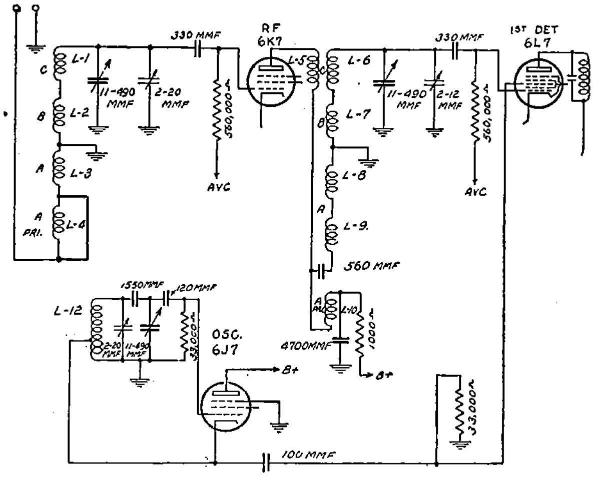


Fig. 9.—B Band connections of RCA Model 811K.

into the circuit with its own high frequency trimmer condenser and series padding condenser in order to secure proper tracking. The cathode of the 6J7 oscillator tube is connected to the tap on L12 so that, unlike the A band, no separate coil is used to obtain feedback for the oscillator.

"C" Band Breakdown

This completes the breakdown diagram for the B band and in Fig. 10 we show the breakdown of the circuit when the receiver is operating on the C band. In the antenna circuit the effect of moving the switch S2 up to the C-band position is to short circuit both L3 and L4 and to shift the ground point to the junction of L1 and L2. It is thus apparent that L2 serves as the primary winding of the input transformer, while L1 becomes the secondary winding. In other words, L2 performs a dual function, in that it is part of the secondary winding on the B band and also becomes the primary winding on the C band.

In the detector input circuit, the movement of the S4 contacts to the C-band position results in L9 being shorted and the ground being moved up to the junction of L6 and L7. As the diagram shows, L5 functions as the primary winding, while L6 is the secondary winding. The short circuit which is placed across L9 is sufficient to prevent undesirable reaction among the several coils mounted on the detector coil form over the frequency range covered by the C band.

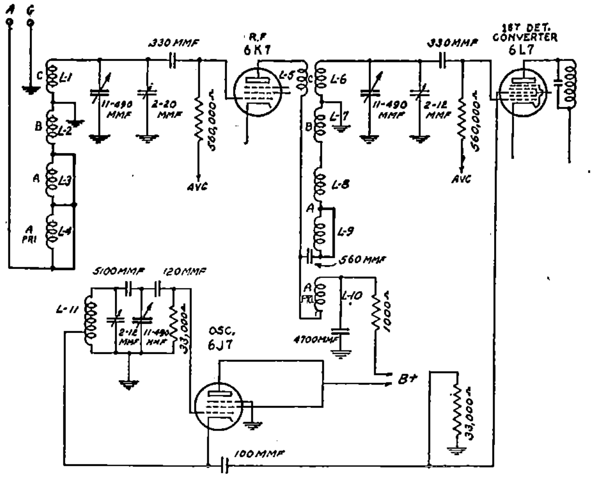
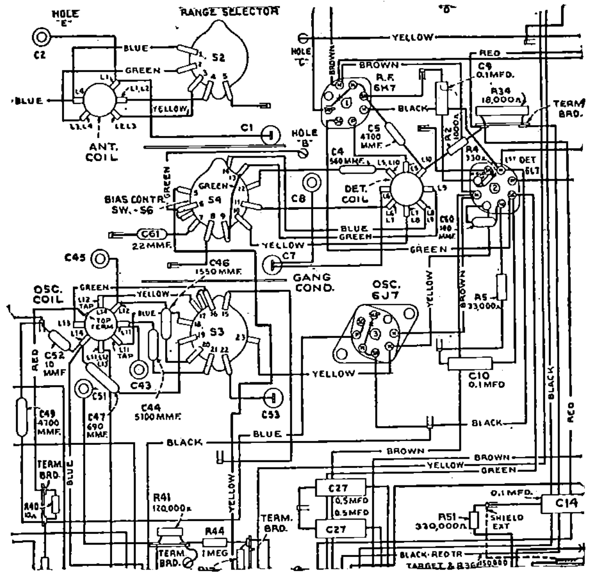


FIG. 10.—Connections of the "Magic Brain" when operating on the C Band.

In the oscillator circuit on the C band, the action of the switch S3 is such as to short circuit the B-band coil L12, to introduce into the circuit the C-band coil L11 with its associated trimmer condenser and 5100-mmf series tracking condenser, and to connect the cathode of the 6J7 to the tap on L11. The oscillator circuit on this band, as the figure shows, is essentially similar to the circuit shown for the B band.

As the breakdown diagrams indicate, the switch S6 in Fig. 7 functions to connect the grid of the detector tube to the AVC line on the broadcast band, and to ground the grid of this same tube on the two short-wave bands. This arrangement is used so as to permit more effective AVC action on the broadcast band and at the same time to allow increased sensitivity for operation on the B and C bands where large signal strengths are not ordinarily encountered.



Courtesy of RCA Mfg. Co., Inc.

FIG. 11.—A portion of the chassis wiring diagram showing how the switch contacts are numbered.

Additional Data

To further simplify and facilitate servicing of the radio-frequency section of the receiver, the service notes for this receiver incorporate a chassis wiring diagram, a section of which is reproduced in Fig. 11. Of particular interest is the consecutive numbering of the contacts on each of the wave-band switch sections to correspond with the designations in the schematic. In analyzing the circuit, this makes it possible for you to identify any lead on the schematic with its corresponding contact on the switch assembly by reference to the chassis wiring diagram. In addition to the switch designations, the terminals of each coil unit are identified to indicate the coil which is joined to the terminal. Thus the several terminals on the antenna coil are identified in Fig. 11 as "L1," "L1, L2" (meaning the junction of L1 and L2), "L2, L3," etc. Although not absolutely essential, the individual diagrams of the internal coil connections, as shown in Fig. 12, are of further assistance in speeding up service work on these units.

For those of you not familiar with the notation used to designate movable iron cores, it should be pointed out that the arrow through the iron core in L14 (Fig. 7) indicates that the inductance of this coil can be varied by movement of the iron core associated with this coil. This adjustment, by the way, is the low-frequency oscillator padding adjustment and replaces the conventional series padding condenser which is used in receivers not having an adjustable iron core.

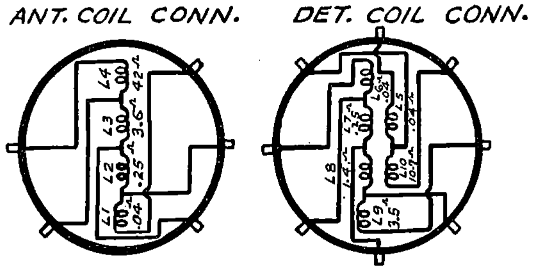


Fig. 12.—Examples of the schematics that show how the coils are connected internally.

The schematic shown in Fig. 7 contains in addition to the other information which has been mentioned, the capacity and resistance values of the various condensers and resistors used. The indication of the various coil resistances directly adjacent to the units is of great value in checking the circuit.

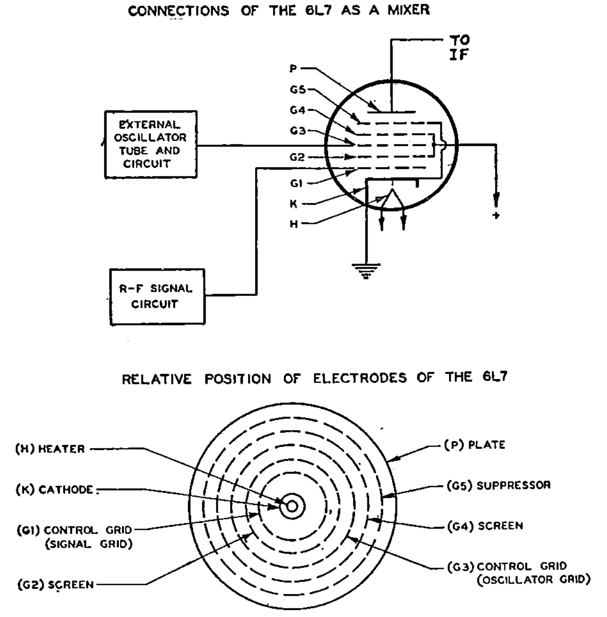
The 6L7 Mixer

A considerable number of receivers listed in Volume VIII of the Rider Manuals use the type 6L7 tube in the first detector stage to accomplish the conversion of the signal to the intermediate frequency. This is especially true of the more elaborate multi-band receivers, where the use of the 6L7 makes possible improved performance by minimizing the coupling between the oscillator and signal circuits at high frequencies.

Fig. 13 shows the relative position of the several grids used in this tube, and also shows how these grids are connected in the basic mixer circuit used with the 6L7. Referring to this figure, the first grid (G1) of the 6L7 is the radio-frequency or control grid to which the incoming signal is supplied. By making this grid of the remote cutoff (variable mu) type, distortion and cross-modulation are minimized and it is possible to apply AVC voltage to the signal grid. The second grid (G2) operates to accelerate the electrons and also acts as a screen between the signal grid and the remaining grids. The third grid (G3) is the oscillator grid, which receives the voltage developed by a separate oscillator tube in a conventional circuit. Since the amplification factor of this grid is relatively high, it is possible to secure good conversion efficiency with a relatively small oscillator input.

The fourth grid, which acts as a screen and is internally connected to the second grid, functions to increase the plate resistance of the tube. This high plate resistance is desirable so as to reduce the damping effect on the first i-f transformer into which the mixer plate is coupled. The fifth and last grid is connected internally to the cathode and acts to suppress the secondary emission from the plate. In this way operation at low plate voltages is made possible and, as well, the plate resistance is maintained at a relatively high value.

Because of the fact that the oscillator signal applied to grid number 3 is large in comparison with the signal voltage, a large component of the plate current is at the oscillator frequency. Furthermore, since there is a small signal voltage applied to number 1 grid, the amplification of the tube for the oscillator component of the voltage applied to grid number 3, varies at a rate equal to the signal frequency. In other words, the oscillator component of the plate current can be said to be modulated by the voltage applied to the signal grid, so that a frequency equal to the difference between the



Courtesy of RCA Mfg. Co., Inc.

Fig. 13.—The relative positions of the elements of the 6L7 tube and how they are connected when the tube is used as a mixer.

signal and oscillator frequencies is produced. This, of course, is the intermediate frequency.

The 6L7 has been shown to possess a number of advantages over the 6A7. One of these is of particular importance from a servicing viewpoint: decreased reaction between the oscillator and signal circuits which simplifies the proper alignment of the circuits. However, the 6L7 does not displace the pentagrid converter type which is still very widely used, since the 6L7 requires a separate oscillator tube while the 6A7 type does not. The two tubes really provide alternative methods of converting the signal to the intermediate frequency.

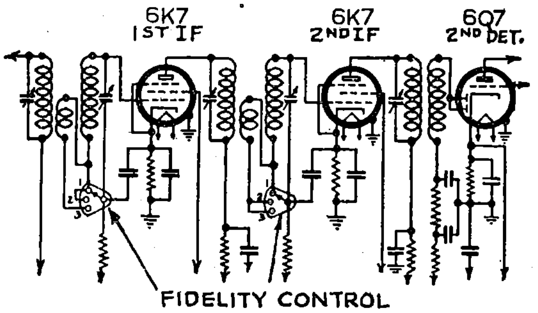
Because of its other properties, the 6L7 has been used in some applications as a radio-frequency or intermediate-frequency amplifier in receivers where the voltage available for automatic volume control is especially low; in these applications the AVC voltage is applied to both the signal and oscillator grids.

We shall not discuss commercial circuits employing the 6L7 at this point, since several modern receivers using a 6L7 mixer tube have been broken down in a preceding part of this section dealing with r-f circuits.

INTERMEDIATE-FREQUENCY CIRCUITS

Many of the high-fidelity receivers described in Rider's Volume VIII Manual use various arrangements in the i-f amplifier to approach the ideal selectivity curve which shows a flat top over a range of approximately 10 kc on either side of the i-f peak, and which drops sharply on both sides of resonance. Something approximating this broad degree of selectivity is required in order to avoid the attenuation of the higher audio frequencies.

However, the conditions within the various wavebands and in fact within the broadcast band itself are such that it is not always possible to use a broadly peaked i-f amplifier. This arises as a result of interference between adjacent channels which are separated by only 10 kc, so that the sidebands of one carrier frequency interfere with those of an adjacent channel. For example, where it is desired to receive a comparatively weak signal on a channel which is adjacent to one that is strong, it is especially desirable to have a selectivity which is considerably greater than that necessary for faithful reproduction of the upper audio frequencies.



Courtesy of Fada Radio & Elec. Corp.

FIG. 14.—The selectivity of the Fada Model 312 is changed by varying the coupling of the i-f transformer windings.

The need for an i-f amplifier capable of meeting the diverse conditions encountered has resulted in the production of numerous types of i-f amplifier circuits which provide a variable degree of selectivity under the manual control of the listener. Thus a broad degree of selectivity is provided for high-fidelity reception, and at the same time a turn of the selectivity control makes it possible to increase or sharpen the selectivity when the conditions warrant it. A number of representative methods used for effecting a control over the selectivity are described in the following paragraphs.

Variable Selectivity in the Fada 312

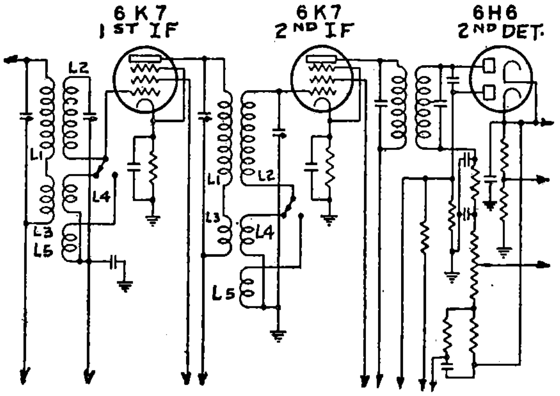
The circuit used to provide three degrees of selectivity in the Fada Model 312 receiver is shown in Fig. 14. Essentially, the variation in the selectivity of the i-f amplifier is effected by varying the coupling between the primary and secondary windings on the first and second i-f transformers. As the circuit shows, each of these transformers employs an auxiliary winding which is closely coupled to the primary winding, so that switching this winding into the circuit increases the net coupling between the two main windings. This increase in coupling is accompanied by an increase in the band-width of the frequencies passed by the transformer and hence by a decrease in the selectivity.

With the switch in the #1 selective position, the auxiliary windings are disconnected from the circuit in both the first and second i-f transformers, so that the i-f selectivity is sharp. With the switch in the #2 broad position, the auxiliary winding of the second i-f transformer is switched into the circuit, so that the selectivity is decreased somewhat. Throwing the switch into the #3 high-fidelity position leaves the second i-f transformer in the overcoupled position, but in addition provides a further decrease in selectivity by connecting the auxiliary winding on the first i-f transformer into the circuit.

At all times the selectivity of the last i-f transformer is sufficiently broad so that the desired band-width is passed into the second detector.

Variable Selectivity in the Fairbanks-Morse 12C6

This receiver employs a slightly different variation of the same principle used in the preceding receiver. Reference to Fig. 15 shows that the secondary winding of both the first and second i-f transformers is composed of three sections—L2, L4, and L5. L1 and L2 are loosely coupled to each other and constitute the major position of the primary and secondary inductance respectively. L3 and L4 are tightly coupled, while the coupling between L5 and the primary is loose. With the switch in the broad position L5 is out of the circuit and the secondary winding consists of L2 and L4. Since L4 is closely coupled to L3, the coupling between the secondary and primary windings is sufficiently great so that a broad response is obtained. With the switch in the sharp position, the closely-coupled L4 is replaced by L5, which has the same inductance but is loosely coupled. Thus, in this position the overall coupling between the primary and secondary is low and the frequency response is sharp. The tuning is not disturbed when changing from the sharp to the broad selectivity position, because L4 and L5 have the same inductance.

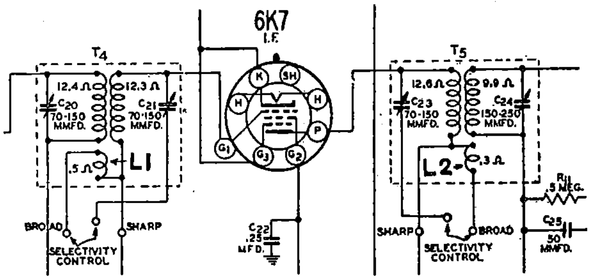


Courtesy of Fairbanks Morse & Co.

Fig. 15.—The method of varying the selectivity in the Fairbanks Morse Model 12C6.

Variable Selectivity in the Gamble-Skogmo 47LL

As Fig. 16 shows, this receiver employs an auxiliary winding in both the first and second i-f transformers to provide two degrees of selectivity in the i-f amplifier. In the sharp selectivity position, the closely coupled windings L1 and L2 are out of the circuit, while in the broad selectivity position, the double pole selectivity switch connects the auxiliary windings into the circuit in both the first and second i-f transformers. It is important that the complete alignment procedure be carried out with the selectivity control in the sharp position.

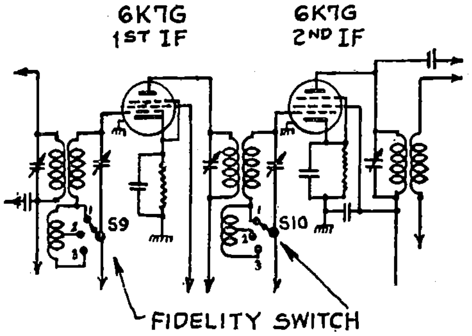


Courtesy of Gamble-Skogmo, Inc.

Fig. 16.—Two degrees of selectivity are obtainable in the Coronado 47LL.

Variable Selectivity in the Garod 1650 Series

A three-position selectivity control is provided in this receiver, Fig. 17, in order to make possible three degrees of selectivity in the i-f amplifier. As in the preceding circuits the variation in selectivity is effected by switching a closely-coupled auxiliary winding into the circuit. In the sharp selectivity position, this winding is entirely out of the circuit, while in the medium or #2 selectivity position, a section of this closely-coupled winding is used to broaden both the first and second i-f transformer. In the #3 or broad position, the entire closely-coupled winding is used in both transformers, so that the coupling is still further increased and the selectivity further decreased.



Courtesy of Garod Radio Corp.

Fig. 17.—How the three degrees of selectivity are made possible in the i-f amplifier of the Garod 1650 series chassis.

In the sharp selectivity position, an automatic tone control circuit is used and is switched into the action by a third section on the fidelity control switch. The operation of this tone control circuit, which functions to reduce the high-frequency audio response in accordance with the carrier level, is described in another part of this section.

Three-Winding I-F Transformers

To obtain a more desirable i-f selectivity curve, a number of the receivers described in this manual use one or more three-winding i-f transformers in the i-f amplifier. In the Grunow Model 941, for example, the first i-f transformer is of the three-winding type, in which a tertiary tuned circuit is interposed between the primary and secondary windings. In the adjustment of this particular transformer, it is recommended that the tertiary winding be peaked for maximum output before the primary and secondary trimmers are adjusted.

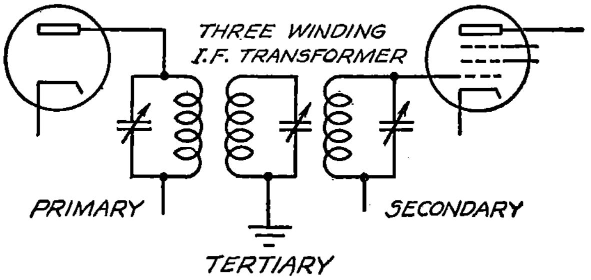


Fig. 18.—Three winding i-f transformer in Crosley receivers.

In another type of three winding i-f transformer, specifically that used in a number of Crosley receivers, Fig. 18, the trimmer of the tertiary winding must be screwed down all the way (but not so tightly as to strip the threads), and with the tertiary trimmer in this position, the primary and secondary windings are peaked for maximum output. When this is completed, the tertiary winding should also be peaked for maximum output. Under no circumstances should the primary or secondary trimmers be disturbed again, as incorrect alignment will result. If the alignment is initially very far off, then the adjustment of the complete transformer must be repeated in the original order specified in the alignment instructions for the receiver.

Variable Mechanical Coupling

In addition to the numerous i-f circuits which employ closely-coupled auxiliary windings to obtain variable selectivity in the i-f amplifier, it should be noted that there are some receivers which use a mechanical arrangement for physically varying the separation, and hence the coupling, between the primary and secondary windings of the i-f transformers. Receivers using this arrangement, of which the Philco Model 38-116 is representative, generally vary the coupling in two of the i-f transformers simultaneously. In addition, this control is often ganged with a high-frequency tone control so that maximum attenuation of the higher audio frequencies is obtained with the selectivity control in the sharp position, while with the control in the broadcast or maximum coupling position, the tone control is adjusted automatically for the greatest high-frequency audio response.

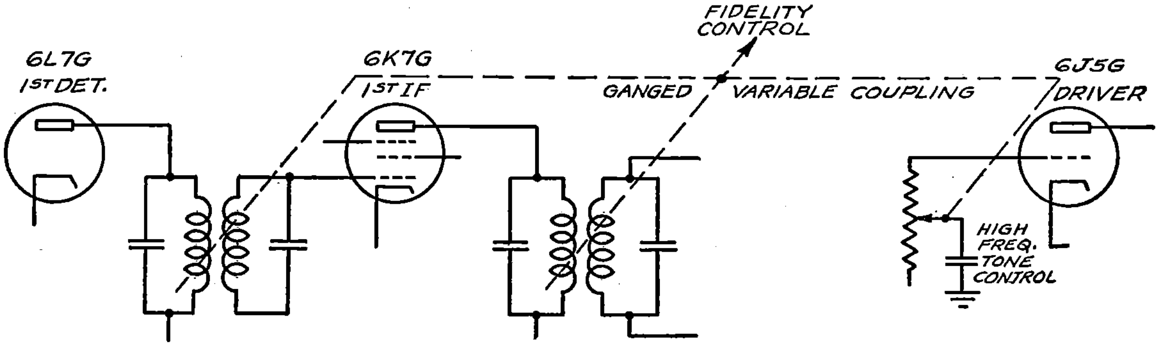


Fig. 19.—Variable coupling in i-f transformer ganged with high-frequency tone control.

AUDIO DEGENERATION

Negative feedback or degeneration is somewhat of a new thing to the serviceman, since this year's receivers mark the first time that this feature has been used to any extent in the audio amplifiers of radio receivers. In a sense, this new development bears a certain resemblance to neutralization, with which you are more familiar as a method of feeding back an out-of-phase voltage so as to neutralize the undesirable effects of r-f regeneration. Just as neutralization makes possible more stable operation of radio-frequency circuits, so does degeneration or negative feedback make possible more stable and distortion-free operation of audio amplifiers. More specifically, degeneration makes possible an improved frequency response, reduces both harmonic and phase distortion, and in some circuits which we will discuss later, lowers the plate resistance of the output tubes so as to provide a desirable damping action on the loudspeaker.

It is not entirely obvious why feeding back a portion of the output signal to the input of an amplifier stage should accomplish all the enumerated effects, but nevertheless such is the case. Let us see why this is so by taking the case of a single stage resistance-coupled amplifier, and investigating in a general way the effects of negative feedback. Fig. 20(a) shows a single audio stage without degeneration, while in Fig. 20(b) there is illustrated an audio stage which incorporates degeneration. The operation of this circuit is as follows: A signal voltage Es is applied to the grid of the tube, and an amplified voltage Eo appears across the output; a fraction of this voltage, determined by the relative values of R1 and R2, is fed back to the grid, so that the total voltage on the grid is not Es alone, but Es in series with the voltage across R2. The path of the voltage fed back to the grid circuit is indicated in heavy lines.

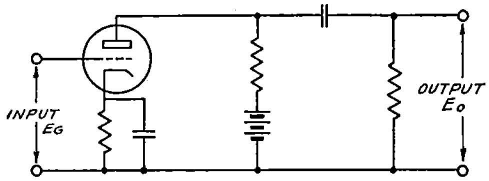


FIG. 20-A.—Resistance coupled stage without degeneration.

Since a 180-degree phase reversal takes place in a single stage of amplification, the voltage across the output—and hence also the voltage across R2—is 180 degrees out-of-phase with the applied voltage Es and therefore it cancels part of Es. This phase reversal of the signal can also be explained by noting that an increase in the signal voltage Es, during part of the signal cycle, is effective in causing a decrease in the a-c plate voltage, and since part of this plate voltage is fed back to the grid, the net increase in grid voltage is less than the actual increase in Es. This is simply another way of stating that in the circuit of Fig. 20(b), the voltage fed back from the plate to the grid circuit is 180 degrees out-of-phase with the signal Es.

So far we have demonstrated that negative feedback reduces the net signal voltage on the grid and therefore reduces the output of the stage. This feature in itself, of course, is not very desirable, but the desirable features which accompany this reduction in gain more than offset the reduced gain. This is especially true since amplifier tubes of both high voltage and high power sensitivity are available at the present time.

Why this reduction in output should be accompanied by more stable operation can be seen from this line of reasoning. Suppose we assume that a signal voltage is applied to the grids of the stages in Fig. 20(a) and Fig. 20(b), the one circuit being a conventional amplifier stage and the other circuit incorporating degeneration. In the circuit without feedback, any change which would bring about a lowered gain in the circuit would result in the same relative change in the output voltage. However, in the circuit with negative feedback, the same change is accompanied by a decrease in the amount of bucking voltage fed back to the grid, so that the *effectively increased value of signal voltage* tends to compensate for the decrease in the gain of the stage. This decrease in gain may have occurred, for example, as a result of the increase in the plate resistance of the tube, or a decrease in the mutual conductance of the tube.

In the same way, negative feedback compensates for the effect of any change in the circuit which tends to raise the output voltage from its normal value. Thus if any factor should tend to raise the output voltage by affecting the gain of the stage, assuming again that the input signal is constant, then the increased amount of bucking voltage fed back to the grid would tend to reduce the effective signal voltage on the grid and therefore to reduce the output, and hence to compensate partially for the increased gain of the stage.

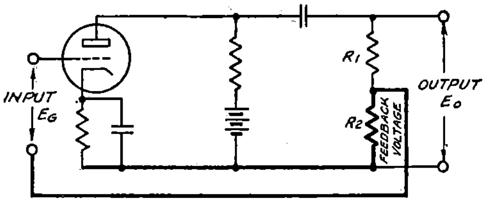


FIG. 20-B.—Resistance coupled stage with degeneration.

The above explanation explains in a qualitative way why the use of negative feedback tends to make the output of an amplifier independent of changes in the tube and circuit constants. It also explains why the use of negative feedback is effective in leveling the frequency response characteristic of an amplifier, since any change in the constants of the circuit with frequency tends to be offset in the manner explained above.

In somewhat the same way, both distortion and hum are reduced through negative feedback. This action is brought about by the fact that a portion of the hum and distortion in the output is fed back in reverse phase to the input of the stage, so that when this component arrives at the output of the amplifier, its phase has been reversed and it tends to cancel the hum and distortion in the output. For obvious reasons this cancellation cannot be complete, for if there were no distortion left in the output, there would be no distortion component to feed back to the input. However, a considerable improvement can be effected through negative feedback, and in general, the higher the percentage of feedback, the greater is the reduction in distortion and hum. (By percentage of feedback is meant the ratio between the voltage fed back to the input of the amplifier, and the output voltage. In the circuit of Fig. 2 this would be equal to R2 divided by R1 + R2.)

Degeneration in General Electric E-155

The degenerative audio amplifier circuit used in the G.E. E-155 receiver (similar systems are employed in a number of other G.E. receivers) is shown in Fig. 21. A 6C5 is used in the 1st a-f stage and a 6F6 in the 2nd a-f stage, the latter being transformer coupled to a pair of 6L6's in the output.

The path of the feedback voltage is indicated in the figure in heavy lines, and it is apparent that the audio voltage across the voice coil is fed back to the cathode circuit of the 6F6 2nd a-f tube through a 2-mf condenser and a 180-ohm resistor. The voltage fed back in this manner is impressed across the 50-ohm resistor in the cathode circuit, which is not by-passed. It is the function of this resistor to introduce the feedback voltage into the cathode circuit, while it is the function of the 1000-ohm cathode resistor—which is by-passed for audio frequencies by a 10-mf condenser—to provide self-bias for the tube.

As a result of the feedback voltage developed across the 50-ohm resistor, the net signal voltage between the grid and cathode of the 6F6 is decreased so that a degenerative action is obtained. Because of the characteristics of the feedback circuit, the amount of degeneration which is obtained varies for the different audio frequencies and is smallest for the low audio frequencies. Thus at 50 cycles, the 2-mf condenser offers a reactance of approximately 1600 ohms so that the percentage of voice coil voltage which is introduced into the cathode of the 6F6 is approximately 3 per cent. At 500 cycles, the reactance of this same condenser is about 160 ohms and, as a result, its limiting action over the feedback voltage is considerably less than at the lower audio frequencies; the percentage of feedback at this frequency is readily computed to be slightly over 10 per cent. Jumping to 5000 cycles, which is representative of the higher audio frequencies, the reactance of C is so small as to be negligible, as a result of which the feedback increases to about 20 per cent.

This circuit has the desirable characteristic that an effective bass compensation action is secured because of the lower percentage of negative feedback at the lower audio frequencies. This increases the gain at the low audio frequencies, and produces a better overall characteristic. Since the feedback circuit is operative between the input to the 2nd a-f stage and the voice coil, it follows that distortion and hum originating between these points is reduced, although the effectiveness of the feedback circuit is decreased somewhat at low frequencies

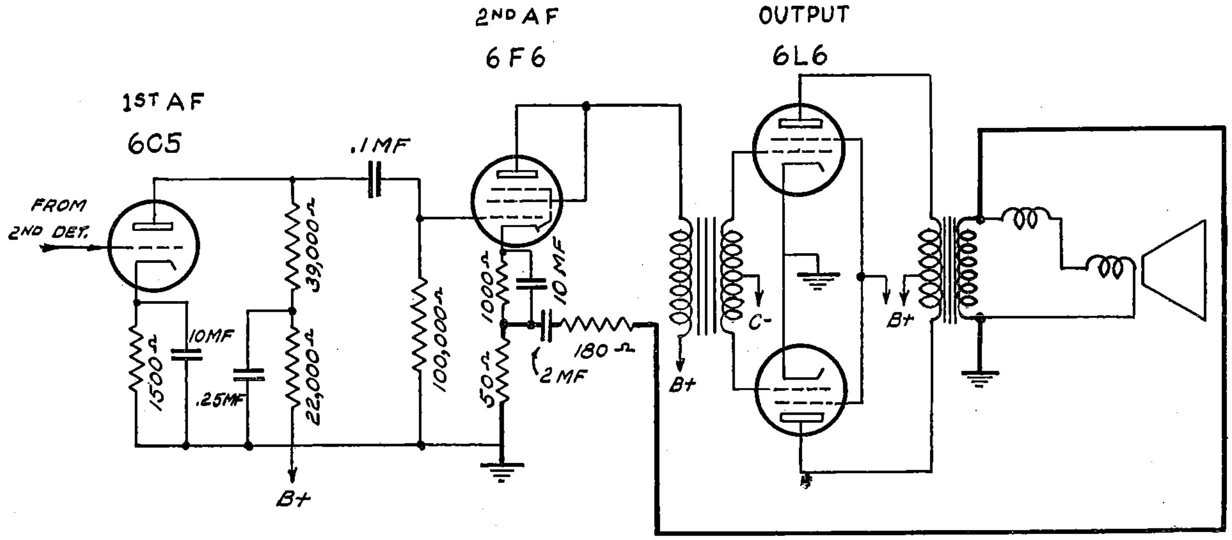


FIG. 21.—The degenerative feedback voltage is fed from the output circuit to the cathode circuit of the 2nd audio stage.

because of the lower percentage of feedback which is used for these frequencies. Note that characteristics of both the input and output transformers are included between the points of feedback, so that whatever frequency and amplitude distortion may be introduced by these transformers is minimized.

Degenerative Amplifier in Philco 38-116

The audio amplifier used in the Model 38-116 Philco receiver illustrates the use of negative feedback or degeneration in both the driver stage and the push-pull output stage of the audio amplifier. Although the specific circuit discussed is that used in the receiver referred to above, similar circuits are used in other receivers in the 1938 Philco line, so that the discussion to follow can be taken as generally applicable to other receivers using the same basic circuit.

Referring to Fig. 22, the signal is amplified in the first audio stage, which uses the triode section of a 6R7G and develops an audio voltage across the plate load resistor R1. The condenser C1 acts as a filter condenser and the tube receives its plate voltage through the decoupling and filter resistor R2. As you will note from the circuit, R3, C2, and R4 form a voltage divider across the plate load resistor R1, so that practically all of the signal voltage developed across R1 is fed to the grid of the 6J5G driver stage. The signal is amplified in the ordinary way, so that an amplified signal voltage is developed across the primary L1 of the input transformer.

So far we have not mentioned the degenerative part of the circuit, which is indicated in heavy lines in Fig. 22. Starting at the plate of the driver tube, we can trace the feedback voltage through the 500M-ohm resistor R5, through the blocking condenser C2, and finally across the grid resistor R4. Remembering that the voltage across the plate load L1 is approximately 180 degrees out-of-phase with the voltage across the grid of the driver tube, it is clear that the voltage developed across R4 as a result of the feedback path through R5 and C2 cancels parts of the signal voltage, so that a degenerative action takes place.

We can get an idea as to the amount of feedback voltage which is developed across R4 by considering that the output voltage divides across the grid of the driver tube in accordance with the impedance between the grid and ground. Since the grid is effectively shunted by the 50M-ohm plate load resistor R1 and the plate resistance of the first audio tube, it is evident that the percentage of output signal which is fed back to the input is of the order of 10 per cent. For the lower audio frequencies the percentage of feedback present is considerably lower, since the reactance of condenser C2 begins to become appreciably large.

We have now traced the signal as far as the plate circuit of the driver stage and shown that negative feedback is used between the plate and grid circuits of the driver stage to improve the characteristics of that part of the audio amplifier included between these points. Tracing the signal from this point on, we note that a voltage is induced in the split secondary windings L2 and L3 of the push-pull input transformer. This voltage is coupled to the two grids of the 6L6G's used in the power output stage, and the low potential sides of L2 and L3 returned to the bias point in the power supply through two 10M-ohm resistors. The plates of the 6L6G tubes are transformer coupled to the speaker in the conventional manner.

Again we have indicated the path of the negative feedback voltages in heavy lines. Considering first the upper tube in the push-pull stage, you will ob-

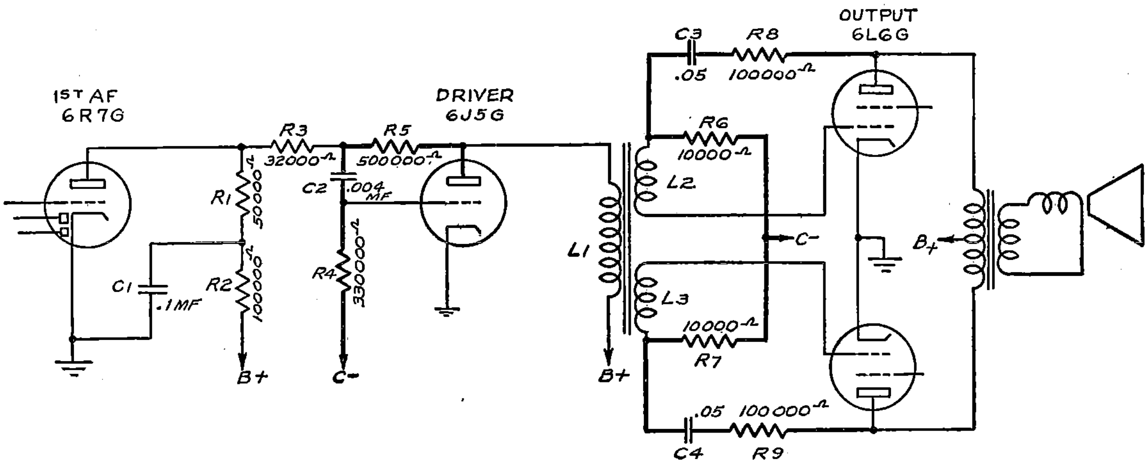


FIG. 22.—The degenerative feedback voltage is fed from the plate to the control grid circuits as shown by the heavy lines. Philco 38-116.

serve that the signal at the plate of the 6L6G is fed back to the grid through the 100M-ohm resistor R8 and the .05-mf blocking condenser C3, so that a percentage of the signal present in the output is developed across the 10M-ohm resistor R6. Since this resistor is in series with the grid winding L2, it is evident that approximately 10 per cent of the output voltage is fed back to cancel part of the applied signal voltage across L2. Exactly the same circuit is used for the second or lower tube in the push-pull stage, so that symmetrical operation of the output stage is secured.

The negative feedback circuit which has just been described for the power output stage functions independently of the negative feedback circuit used in the driver stage, and reduces hum and distortion of the signal between the grid and plate circuits of the 6L6's. In addition to decreasing hum and distortion, this circuit has the desirable effect of reducing the plate resistance of the output stage, that is, the impedance into which the loud speaker works. As a result, a beneficial damping action on the speaker is produced, so that the speaker is prevented from producing sounds after the signal voltage causing the initial motion of the voice coil is no longer present.

Phase Inversion and Audio Degeneration in the Philco 38-2

The audio amplifier in the Philco Model 38-2 receiver incorporates an interesting phase inversion and degenerative circuit. Referring to the breakdown diagram in Fig. 23, the output of the second audio stage is applied to the grid of the 6J5G phase inverter. This phase inverter operates on the principle that the audio voltage developed across the cathode resistor of a resistance-coupled amplifier is 180 degrees out of phase with the voltage across the plate load resistor. Since a 180-degree phase difference is the required condition for push-pull excitation, it follows that this is a convenient method for exciting the grids of push-pull tubes.

In accordance with this principle, the audio voltage developed across the 50M-ohm plate load resistor is applied to the grid of one of the 6F6 push-pull output tubes. The voltage developed across the 50M-ohm cathode resistors (45M + 5M) is applied in the same way to the grid of the other 6F6 output tube. Since these voltages are 180 degrees out of phase with each other, true push-pull excitation of the output tubes is obtained without the necessity for an input transformer.

It is worth noting that the d-c voltage drop across the 5M-ohm resistor supplies the bias voltage for the phase inverter tube, since the grid return is tied to the negative end of this resistor, i.e., to the junction of the 5M- and 45M-ohm resistors. Since this resistor is not by-passed for r.f., a certain amount of degenerative action is present; however, this does not affect the operation of the phase inversion circuit, but rather tends to reduce distortion.

An overall degenerative action is incorporated between the voice coil and the input circuit to the second a-f stage. This is effected by returning the cathode of this tube to ground through the voice coil winding of the output transformer so that the full value of voice coil voltage is fed back to the second a-f cathode. As in the other degenerative circuits discussed in this section, the circuit functions to reduce distortion, hum, and to increase the stability of the audio amplifier.

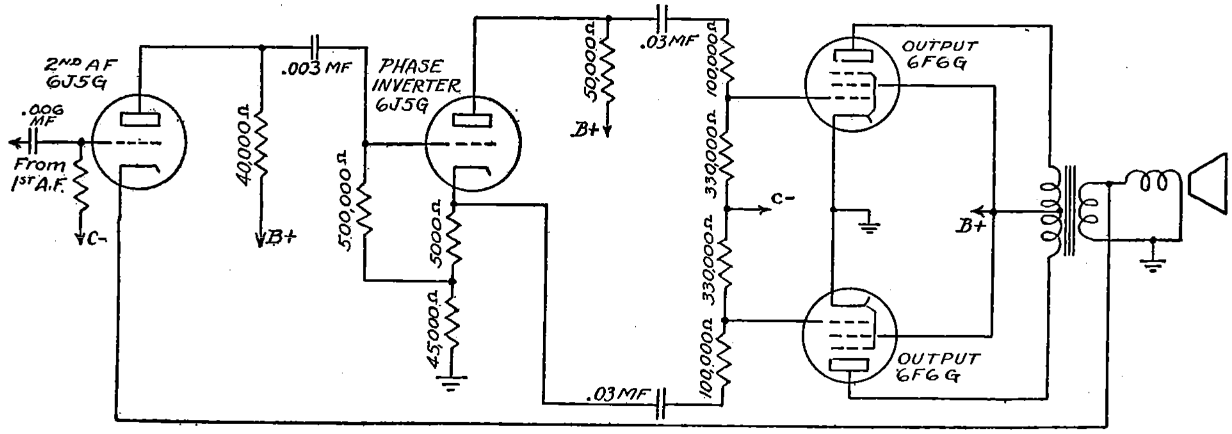


Fig. 23.—The out of phase voltage is secured from the cathode circuit of the 6J5G phase inverter tube. The degenerative feedback voltage is fed from the output circuit to the cathode circuit of the 2nd audio stage. Philco 38-2.

Phase Inversion in the Pilot Model G-584, G-585

The circuit used in this receiver to accomplish phase inversion uses only one tube to amplify the signal and at the same time to split the phase in order to permit push-pull excitation. As Fig. 24 shows, the circuit operates on the principle that when load resistors are placed in both the plate and cathode circuits of a vacuum tube, the voltages across the two resistors are 180 degrees apart in phase, which, of course, is a requirement for push pull excitation. Advantages of this circuit, variations of which are used in a number of other receivers in this manual, are that phase inversion is accomplished without the degeneration characteristic of the older circuits which employed this principle.

Referring to Fig. 24, the signal voltage from the secondary winding of the last i-f transformer is fed to the diode section of the 6Q7G, where it causes a rectified current to flow from the diode plates through the filter resistor R1, the diode load resistor R2, and back to the cathode. As a result of this rectification, an audio voltage is developed across the 250M-ohm resistor R2, and this voltage is fed over to the volume control through a .05-mf condenser C4. It is important to note that the low side of the volume control is returned to the cathode through a 10-mf electrolytic condenser C3, so as to complete the audio path to the cathode of the tube.

The grid of the triode section is connected to the volume control rotor, and returned to the junction of the 2500-ohm bias resistor R3 and the 100M-ohm cathode load resistor R4 through the 250M-ohm filter resistor R5. It should be noted that there is no audio voltage across R5, and that this resistor functions only to filter the d-c voltage applied to the grid. Because of the manner in which the control grid is returned, the bias voltage on the grid of the triode section is equal to the voltage drop across the 2500-ohm cathode resistor R3; this is of course the same as the conventional method of self-bias, the only difference being that the bias resistor is not returned to ground, but rather is returned to a cathode load resistor which is above ground potential.

So much for the manner in which the triode section receives its bias voltage. As far as the phase inversion of the signal is concerned, the plate of the tube is connected to the 100M-ohm resistor R7, which serves as the audio plate load and which is connected to the B+ supply through the 20M-ohm filter resistor R8. Since the cathode load resistor R4 is equal to the plate load resistor R7, it follows that audio voltages of equal value but opposite phase are developed. These audio voltages are fed to the grids of the push-pull output tubes and accomplish the desired phase inversion.

Ordinarily in the phase inverters of this type, it is important to keep the capacity between the cathode and the ground of the phase inverter tube as low as possible. This capacity is reflected across the audio load in the cathode circuit, R4 in this case, and tends not only to shift the phase of the cathode audio voltage, but also to lower the gain on the cathode side for the higher audio frequencies. In this particular circuit, however, a capacity balance is achieved on the plate and cathode side by shunting the cathode to ground through a 100-mmf condenser C2, and likewise shunting the

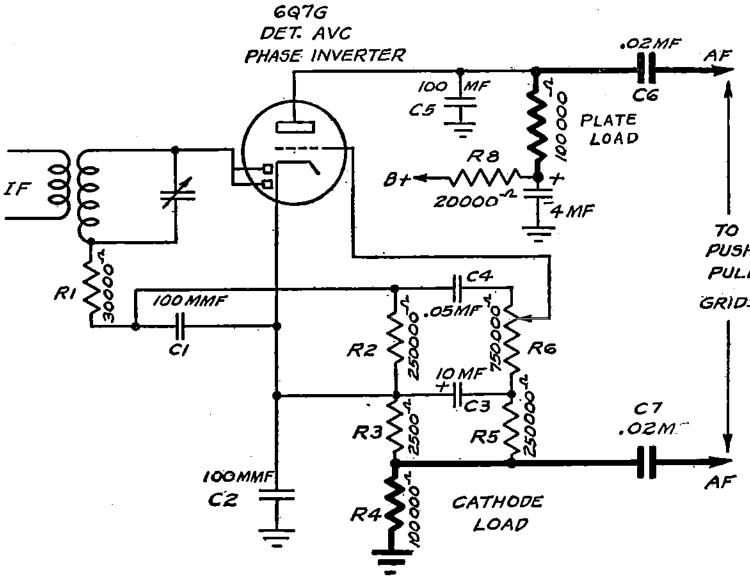


FIG. 24.—The paths of the two out of phase signal voltages are shown by the heavy lines. The audio voltage across R4 is 180 degrees out of phase with the audio voltage across the plate load resistor.

plate to ground through the same value of capacity, C5. In this way, although the gain and phase of the tube are affected at the higher audio frequencies, both the cathode and plate sides are affected to the same extent, so that the push-pull tubes receive the proper excitation voltage. In this connection, it is desirable, where replacement of the electrolytic C3 becomes necessary, to mount this condenser so that it is not close to the metal chassis. This precaution is more important in cases where cathode and plate by-pass condensers similar to C2 and C5 are not used.

The beam power output stage used in this receiver is discussed elsewhere in this section.

Phase Inversion in the Philco 38-4, 38-5

The phase inverter circuit used in the Philco Model 38-4, 38-5 receiver is shown in Fig. 25. The operation of this circuit is different from phase inverter circuits which have hitherto been used, and depends upon the use of the first three elements in one of the pentode output tubes as a triode phase inverter tube.

To clearly illustrate this action, the phase inverter part of the circuit is shown in heavy lines. If we consider the screen of the upper 6F6G as the plate of a triode section (formed by the cathode, control grid, and screen elements), and the 3500-ohm resistor as the triode load, then it is clear that the audio voltage developed across this load resistor is 180 degrees out-of-phase with the voltage applied to the control grid of this tube. The .01-mf condenser couples this audio voltage to the control grid of the lower 6F6G, so that push-pull excitation of the output tubes is obtained.

In the design of this circuit, the value of the screen load resistor is fixed so that the value of audio voltage developed across it is equal to the signal applied to the control grid of the upper tube. In this way the audio signal on the grids of the two tubes is made equal without the necessity for a voltage divider. The outstanding feature of this circuit is its simplicity, there being a minimum of circuit components employed to accomplish the phase inversion of the signal. It is worth noting that this amplifier is designed to operate as a Class A amplifier. Class AB operation with this type of circuit is not feasible because non-linear operation of the output tube (shown in heavy lines) would distort the phase-inverted signal applied to the other output tube, and hence would distort the overall output.

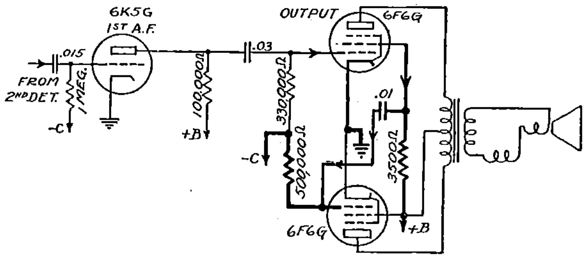


FIG. 25.—Phase inverted voltage is secured from the screen grid of one tube. Philco 38-4, 38-5.

AUTOMATIC VOLUME EXPANSION

Sparton 827X, 827XD, 997X

The Sparton models listed above employ an automatic volume expansion arrangement, shown in Fig. 26, which makes possible an automatic expansion in the volume of audio output in accordance with the average audio level being reproduced. The need for this type of audio compensation can be understood from the following considerations.

During the broadcasting of a program at the studio, the audio output which modulates the transmitter is constantly monitored by the control man so as to insure the greatest efficiency of operation and the widest station coverage. During periods when the average level of the music being broadcast is large, the control man often must reduce the gain of the audio amplifier to prevent overmodulation of the carrier. On the other hand, during periods when the average audio level is low, the control man raises the gain of the audio amplifier so that the level of the music will be greater than the noise and hum level of the carrier. This process is called "riding the gain" and obviously it reduces the volume range of the program as it is transmitted from the broadcast station and received in the home. In a sense, this compression of the volume range during broadcasting is a form of distortion because it tends to make the program as reproduced in the home different from the program as it originates in the studio.

Volume expansion circuits compensate for this reduction of the volume range in the broadcasting studio by automatically raising the volume in accordance with the average audio level. An ideal type of volume expander would of course be one in which the degree of volume expansion is inversely proportional to the amount of compression at the studio, so that the resultant audio output of the receiver is exactly the same as the signal reaching the studio microphone.

The circuit in Fig. 26 is an example of the use of volume expansion in radio receivers. Basically the method of operation will be clear from the insert diagram in this figure which is identified as Fig. 26A. A 120M-ohm resistor in series with the plate resistance of the 6K7G expander tube forms a voltage divider across the input to the power amplifier stage. As a result of this connection, the grid of the output stage receives only the voltage which is developed across the plate resistance of the 6K7G, represented in the figure by a resistor within a circle. The automatic expansion of the volume is achieved in this circuit by automatically varying the value of the plate resistance in accordance with the average audio or modulation level. During periods when the modulation level is high, the bias on this tube is likewise high, and consequently the plate resistance of the 6K7G is high, and the average volume level is increased because of the voltage divider action. On the other hand, during periods when the modulation percentage is small, the bias on the 6K7G is likewise small, its plate resistance is small, and the fraction of the total audio output which reaches the grid of the output stage is likewise small. In this way an automatic expansion of the volume is secured.

Having considered the operation of the circuit from a broad standpoint, let us now examine the function of the several circuit components in somewhat more detail. Referring again to Fig. 26, the audio voltage produced by the full-wave second detector is amplified by the triode section of the 6Q7G, and the output of this stage is fed to the grid of the 6N6G output tube through a resistor-condenser network. In order to automatically bias the 6K7G in accordance with the average output level, the audio voltage present across the output of the 1st a-f stage is fed to the grid of the 6J7G expander-amplifier through a .006-mmf condenser and a 1-meg resistor. Essentially this tube acts as a rectifier-amplifier, or as a detector, and produces a pulsating d-c voltage across the 470M-ohm resistor in its plate circuit. This rectified voltage, from which the audio component is removed by the filter consisting of a 1-meg resistor and a .2-mf condenser (aided by the .3-mf condenser across the plate resistor), is applied to the suppressor grid of the 6K7G.

As the signal level applied to the 6J7G increases, the rectified voltage across the plate resistor of this tube increases, and as a result the d-c bias on the suppressor grid of the 6K7G expander tube increases. Since the plate resistance of the 6K7G increases with increasingly large values of negative bias, it follows that the plate resistance of this tube will increase as the percentage modulation increases, and that because of the voltage divider

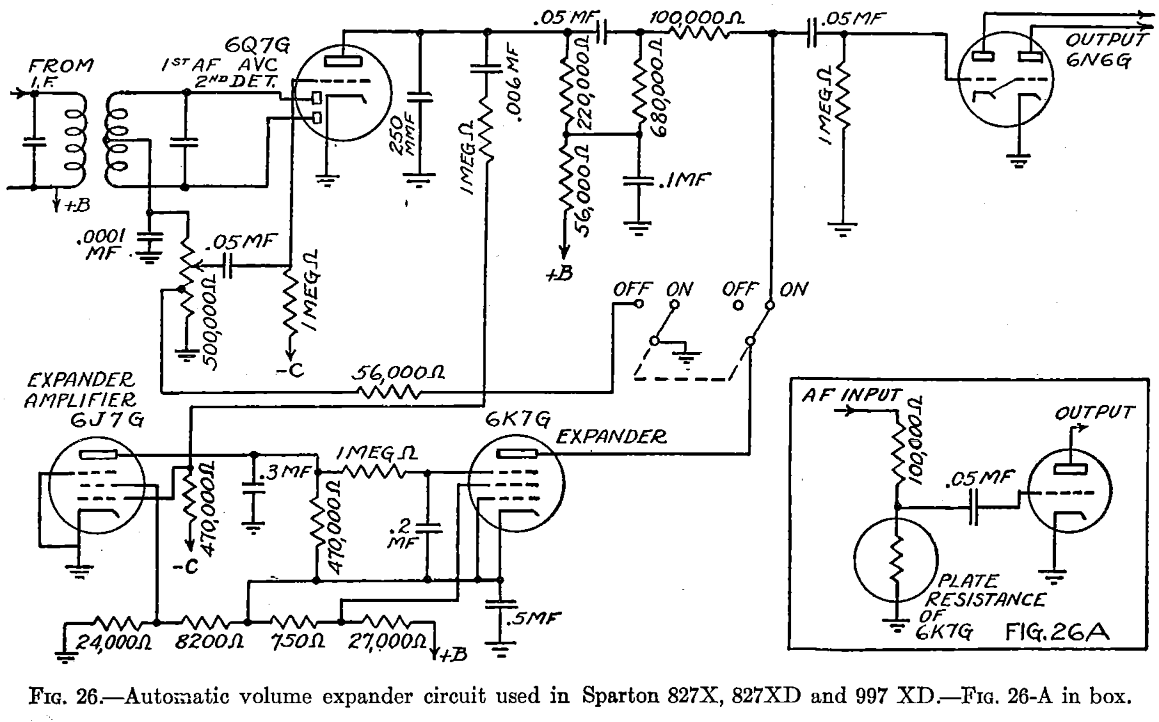


FIG. 26.—Automatic volume expander circuit used in Sparton 827X, 827XD and 997 XD.—FIG. 26-A in box.

action explained by Fig. 26A the final voltage reaching the grid of the output tube will increase beyond the value without the volume expansion action.

A double pole-double throw switch makes operation of the volume expansion circuit optional. When the volume expansion action is switched off, one section of this switch disconnects the plate of the 6K7G from the voltage divider, while the other section shorts a 56M-ohm resistor across the tapped section of the volume control. The function of the latter section is to increase the amount of signal fed to the 1st a-f stage when the volume expansion is on, so as to keep the volume at about the same level with the volume expansion switch on or off. This arrangement is required because of the shunting effect of the 6K7G plate resistance.

The volume expansion circuit used in this receiver is especially valuable in connection with the reproduction of recorded music (some of the models have provision for the connection of a phonograph pick-up). In this connection the automatic volume expansion overcomes the effects of the compression in the recording; this compression of the volume range in phonograph records is required because the volume level at which the recording is made must always be larger than the noise level, and at the same time can never exceed a certain value. If this value is exceeded, the cutter will jump over into the next groove.

AUTOMATIC BASS AMPLIFIER

Philco 37-690

The audio circuit of this receiver provides a special channel which makes possible the additional amplification of the lower audio frequencies. Since it is desirable to provide increased bass response at low volume levels, the gain of this channel is automatically controlled in proportion to the volume level at which the receiver is being operated. In addition, a manual adjustment is provided which enables the listener to vary the amount of bass amplification in accordance with his own preference. The latter adjustment then becomes essentially a bass tone control, although the manner of operation is essentially different from the conventional tone control.

Referring to the basic schematic shown in Fig. 27, the output of the 2nd detector is fed to the grid of the 6J5G 1st a-f stage through a compensated volume control network, which is not shown. At the plate circuit of the 6J5G, the audio signal branches off into two channels, the main amplifier channel and the bass amplifier channel. Following the main amplifier channel, the signal is fed into the grid circuit of the 6R7G 2nd audio stage, which incorporates a fidelity control in the grid circuit. This fidelity control consists of a 500M-ohm potentiometer in conjunction with its shunt 500M-ohm resistor and a 110-mmf condenser shunted from grid to ground. In combination, these elements act as a low-pass filter and limit the high-frequency response of the main amplifier channel. Physically this does not appear as a

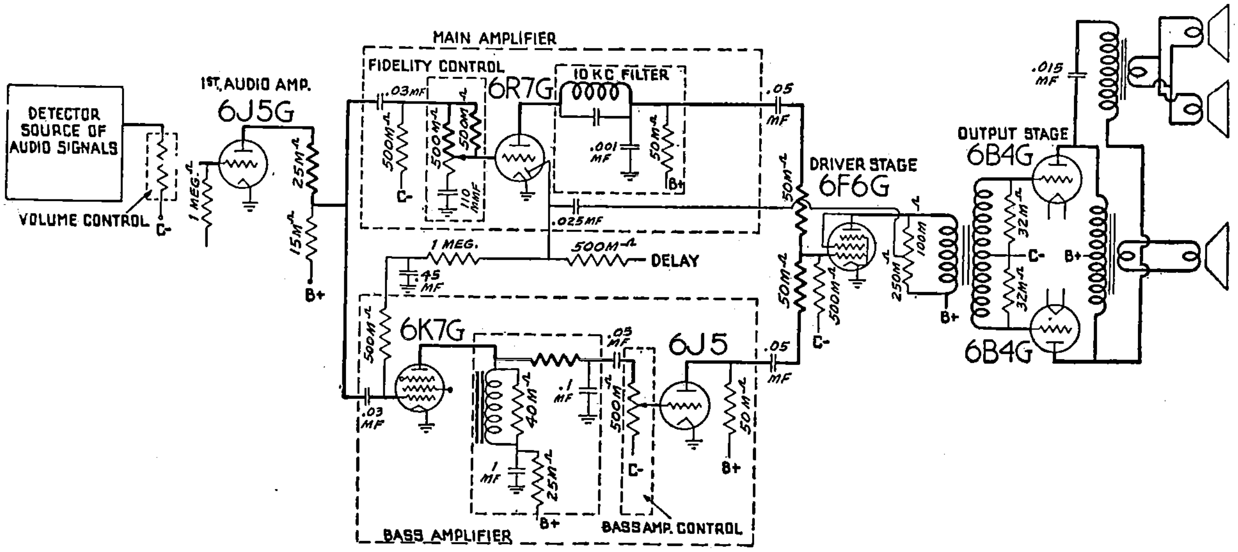


Fig. 27.—Bass amplifier circuit used in Philco 37-690. The bass amplifier and control tubes are the 6K7G and 6J5 respectively.

separate control, but it is ganged with the selectivity control which controls the band width of the i-f amplifier. When the band width control is wide open, the sliding tap on the fidelity control is at the top, so that the higher frequencies admitted by the i-f amplifier are not attenuated. On the other hand, when the selectivity control is adjusted for a narrow band width, the sliding tap on the fidelity control is in its lowest position so that the higher audio frequencies are attenuated. Essentially, then, the fidelity control functions as a high-frequency tone control which is manipulated simultaneously with the band width or expander control.

The plate circuit of the 6R7G feeds into a 10-kc low-pass filter which operates to prevent audio frequencies and whistles higher than 10 kc from getting into the output of the audio amplifier. The audio voltage developed across the 50M-ohm load resistor for this stage is coupled over to the driver grid through a .05-mf condenser and a 50M-ohm resistor.

Going back to the plate circuit of the 6J5G first audio tube, and tracing the bass amplifier channel, rather than the main amplifier channel, the signal voltage is impressed on the grid of the 6K7G bass amplifier tube. The load circuit of this tube is arranged so that the greatest amplification is obtained for the low audio frequencies, and so that the gain of the 6K7G stage falls off for the higher audio frequencies. The audio voltage developed across the output choke is fed over to the grid of the 6J5G tube which functions as a bass amplifier control tube. The manual control which varies the gain of the bass channel is the 500M-ohm control in the input circuit to this stage. The output feeds into the grid circuit of the 6F6G driver stage, at which point the output of the bass channel is combined with the output of the main channel. Note that a symmetrical bridge circuit is used to combine the output of the two channels, in order to prevent interaction and consequent distortion of the output.

The manner in which the automatic bass control action functions is evident from the simplified schematic in Fig. 27. A portion of the output of the 6F6G driver stage is coupled to the diode plates of the 6R7G and this audio signal voltage rectified. The resulting d-c voltage across the 500M-ohm diode load is filtered through the 1.0-meg resistor and .45-mf condenser and fed over to the grid of the 6K7G bass amplifier tube. In this way the d-c bias on the 6K7G is made to vary in accordance with the strength of the signal at the output of the driver stage, in other words, in accordance with the output level of the receiver. When the output level is low, the bias voltage on the 6K7G will likewise be low, and thus the gain of the audio amplifier for the low audio frequencies will be greatest; on the other hand, when the output level is high, the bias will be correspondingly high, the gain of the 6K7G will be reduced, and the amplification of the bass channel is likewise correspondingly reduced. As we previously mentioned, this condition is desirable in order to compensate for the physiological characteristics of the ear, which make it comparatively insensitive to low audio frequencies at low volume levels. A delay action is incorporated in this automatic bass control circuit by putting a negative voltage on the diode load resistor return. For this reason the diode does not begin to rectify, and furnish a voltage to control the gain of the bass channel until the output level of the receiver reaches a certain value.

AUTOMATIC TONE CONTROL

Garod Model 1650

This receiver employs a tone control circuit designed to automatically vary the high-frequency audio response in accordance with the strength of the signal being received. In the case of a strong signal, the action is such that the higher audio frequencies are allowed to get through, while in the case of a comparatively weak signal—where the noise level is high and is composed largely of the higher audio frequencies—the action is such that these frequencies and the noise level are attentuated.

As the circuit in Fig. 28 shows, the principle of operation is based on the fact that the capacity between the grid and cathode of a vacuum tube, when arranged as an amplifier, is dependent upon the mutual conductance of the tube. When the gain of the stage is high, the input capacity of the tube is correspondingly high, and similarly, when

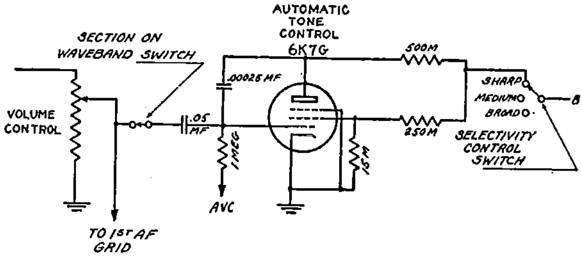


FIG. 28.—The automatic tone control circuit used in the Garod 1650.

the gain of the stage is low, the input capacity is correspondingly low.

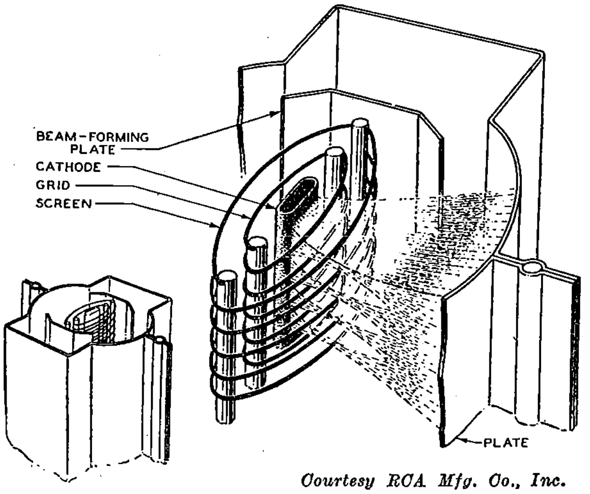
The 6K7G variable-mu tube is arranged in a typical resistance coupled stage of amplification, the 500M-ohm resistor in the plate circuit functioning as the plate load. The control grid of the tube is returned to the AVC line, so that the bias on the tube, and hence the input capacity of the tube, is varied in accordance with the strength of the signal being received. This input capacity is coupled to the audio circuit, and appears as a shunting condenser across the volume control or across the first a-f grid. The function of the .00025-mf condenser between the grid and plate of the 6K7G is to increase the range over which the input capacity varies as the control-grid bias is varied by the AVC action.

Note that since the plate voltage for this stage is fed through the selectivity switch, the automatic tone control action is obtained only when this switch is in the sharp selectivity position. Another switch in the grid circuit is ganged with the waveband switch, so the circuit is operative only on the ultra short-wave range.

THE BEAM POWER TUBE

One of the most important tube developments which appears in a great many of the receivers shown in Volume VIII is the beam power amplifier tube. This tube, of which the 6L6 (and the glass equivalent 6L6G) is perhaps the best known, is essentially a basically new type of tube design in which the undesirable effects of secondary emission are eliminated without the use of the conventional suppressor grid. The characteristics of this tube which have led to its widespread adoption are its unusually high power sensitivity, its high output power, and its high efficiency.

The arrangement of the electrodes in the basic beam power amplifier tube is shown in Fig. 29. As is evident from this figure, the beam power tube is a tetrode, in that it employs a cathode, a control grid, a screen grid and a plate. An essential characteristic of the grid structure in this tube is that the control grid and screen grid elements have the same pitch and are arranged so that the corresponding turns of the control grid and the screen grid lie in the same plane. Because of this alignment of the grids, the control grid focuses the electron stream from the cathode between the turns of the screen wires, so that the electrons emerge from the screen in the form of sheets. This action is clearly indicated in the sketch referred to above.



Courtesy RCA Mfg. Co., Inc.

FIG. 29.—Sketch showing electrode arrangement and formation of the beam sheets in the beam power tube.

The beam tube gets its name from the two beam forming plates which are connected to the cathode, and which confine the electron beam to sheets at right angles to the cathode. Although the figure shows the electron sheets on only one side of the cathode, it is evident from the insert in the figure that the same distribution of current exists on the other side of the cathode.

The object of this special cathode shape, the alignment of the control and screen grids, and the use of the beam-forming end plates, is to secure a certain distribution of electric potential in the tube, such that the harmful effects of secondary emission from the plate are reduced to a minimum. Referring again to the figure, note that the distribution of electrons between the screen and plate is such that the density of electrons in this region is high. Because of this, those electrons which are knocked out of the plate—secondary electrons as they are called—are repelled from the screen and find their way back into the plate. In this way secondary emission is prevented, and it is permissible for the plate voltage to fall below the screen voltage—as it does during part of the audio cycle of operation—without secondary emission causing the plate current to fall off sharply.

It is useful to contrast the method in which secondary emission is avoided in beam tubes with the method which is used in pentode type tubes. In the pentode the secondary emission is reduced by introducing a suppressor grid between the grid and plate. Since this grid is generally connected to the cathode, it tends to repel any secondary electrons which are knocked out of the plate, and thus prevents secondary emission. Since the distribution of electrons in the beam power tube is such that secondary electrons are also driven back to the plate, it is not surprising that the beam power type of tube, although not a pentode tube, shows the characteristics of and behaves much in the same way as the pentode type tube. However, its power sensitivity, power output, and efficiency are considerably greater than comparable pentode tubes using a physical suppressor grid.

The 6L6 Beam Power Tube

The 6L6 type tube was the first beam type tube to be announced and to be used by the receiver manufacturers. In other parts of this section, a number of circuits using 6L6 tubes and taken from receivers appearing in Volume VIII are analyzed and broken down, so that it will not be necessary to go over these here. It should be mentioned that as far as the actual appearance of the circuits in which the 6L6 is used, these are very similar to those which employ conventional pentode tubes. There are, however, a considerable number of points which must be considered in the use of beam power tubes, factors such as the characteristic of the output transformer, the regulation of the power supply, the choice of the proper operating voltages, etc. Since these are of a design nature, they will not be considered here.

Practically without exception, all of the circuits which use degeneration, as discussed in another part of this section, use beam power tubes in the output stage. The reason for this condition is that the 6L6 is admirably adapted for this application since its high power sensitivity tends to offset the reduction in gain which is an unavoidable characteristic of any degenerative audio circuit.

The design of the 6L6 and the other beam type tubes is such that the second harmonic content of the output is made high in order to lower the third harmonic content. Since the use of the push-pull circuit will take out practically all of the even harmonic content introduced by the tube characteristics, the final output is substantially free of the second harmonic and the third harmonic is of very low amplitude. In some designs which do not use the push-pull output stage, the first audio stage or one of the preceding audio stages is arranged so that sufficient out-of-phase even harmonic distortion is introduced to cancel the even harmonic distortion introduced by the beam power output tube.

The 6L6 is used with both fixed-and self-bias and at voltages ranging to a maximum of 375 volts for the plate voltage and up to 250 volts for the screen voltage. In a single tube Class A circuit, the 6L6 is capable of delivering a power output of the order of 6 watts with a total distortion of about 10%; the greater part of this distortion is due to the second harmonic.

Using two 6L6's in push pull, it is possible to obtain a much larger power output since the even harmonic distortion (the limiting factor in single tube operation) is eliminated. As examples indicative of the extremely high power output obtainable with comparatively low plate, screen, and input signal voltages, it is interesting to note that with 250 volts on the plate and screen, a pair of 6L6's in push-pull Class A is capable of delivering about 14 watts with negligible distortion, and requires a peak grid-to-grid signal of only 32 volts. Using Class AB operation, with grid current flowing during part of the cycle, two 6L6's with 400 volts on the plate and 300 volts on the screen are capable of delivering about 60 watts of output power with negligible distortion. While none of the receivers listed in Volume VIII utilizes the maximum power capabilities of the 6L6, many of the receivers do take advantage of the high power output and high power sensitivity of the 6L6 to improve the audio performance of their receivers.

The 6V6 Beam Power Tube

Another member of the beam power tube family, which is widely used in automobile as well as home receivers, is the 6V6 and its glass equivalent, the 6V6G. The design of this tube is similar to that of the 6L6, but the heater and plate current drain of the 6V6 is considerably lower than that of the 6L6.

In smaller home receivers and in automobile receivers, the use of a single 6V6 permits power outputs up to 4 watts with Class A operation and plate and screen voltages at 250 volts. Where two

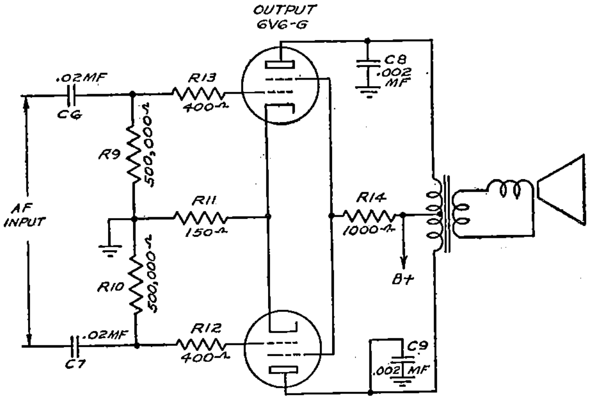
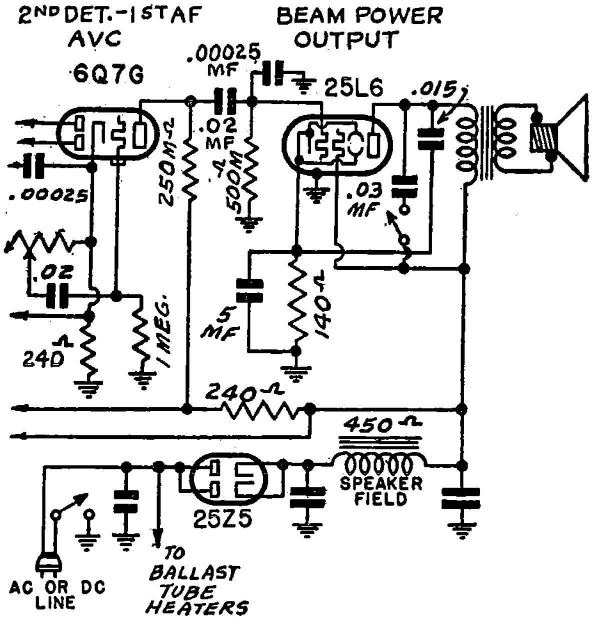


FIG. 30.—The push-pull beam power output stage in the Pilot G-584.

tubes in push-pull are employed, power outputs up to 14 watts can be obtained, without the plate and screen voltage requirement exceeding 300 volts.

A typical home receiver circuit employing a pair of 6V6G tubes in push-pull is shown in Fig. 30. This is the circuit used in the Pilot Model G-584 and G-585 receiver. As the figure shows, the signal is coupled to the two grids through two .02-mf condensers and the grids are returned to ground through two 500M-ohm resistors. A self-bias arrangement is used, and since the operation is push-pull, no by-pass condenser across this 150-ohm resistor is required. The screen voltages are supplied through a 1000-ohm resistor; it is worth noting that the drop in this resistor is unusually small —only 5 volts—because of the characteristically low screen current of beam power tubes.

Because of the high transconductance (mutual conductance) of beam power tubes, oscillation difficulties are sometimes encountered when conventional design is used in the output stage. In this connection, the purpose of the two 400-ohm resistors which are placed near the control grids of the two tubes is to suppress any tendency toward a high-frequency oscillation. The two .002-mf condensers shown in the figure are also useful in preventing oscillation, and to work effectively in this purpose are placed close to the plate. Note that these condensers must have a high voltage rating, since the peak voltage at the plate of the tube rises above 600 volts during parts of the signal cycle.



Courtesy Emerson Radio & Phonograph Corp.

FIG. 31.—The beam power output stage used in the Emerson AH chassis.

The use of the plate by-pass condensers and the grid suppressor resistors is not generally found in receivers using metal tubes rather than the equivalent glass types, since in these cases the grounding of the metal shell through a short heavy wire is generally sufficient to suppress oscillation. In some applications, however, the bias resistor or bias voltage supply is shunted with a small mica condenser of approximately .001-mf capacity to suppress any oscillation tendency.

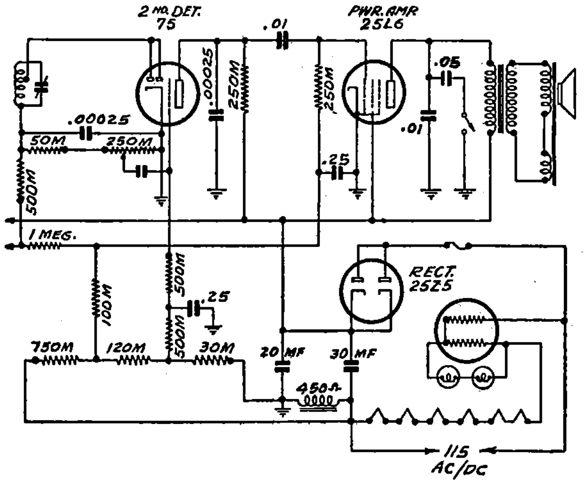
The 25L6 Beam Power Tube

The type 25L6 beam power tube is designed to make possible the advantages of beam power in the output stage for transformerless a.c.-d.c. receivers and for other applications where the available voltage is low. The internal construction of the 25L6 is similar to that of the 6L6 and 6V6, so that the high power output, sensitivity, and efficiency of the former are characteristic of the 25L6 as well. The fact that a single 25L6 can supply about 2 watts of output with reasonable distortion at a plate and screen voltage of only 110 volts is indicative of its usefulness in low voltage applications.

A number of different circuit arrangements are used to obtain the full power output of which the 25L6 is capable. In some circuit designs, the 25L6 is driven by a 6Q7 used as the second detector and first a-f stage, in some a 6J7 is used as a biased detector, and in still others a 6C5 is used as a biased detector. The typical applications shown below illustrate some of the circuits being used.

In Fig. 31 the circuit arrangement used in the **Emerson AH** chassis (as well as a number of other Emerson chassis) is shown. A 6Q7 is used to drive a 25L6 which obtains its bias from the voltage drop across the self-bias resistor R12, the latter being by-passed by a 5-mf electrolytic condenser. In the power supply which is quite conventional, the speaker field is used as a filter choke in the positive leg, and the filaments are connected in series with the ballast tube directly across the line.

In Fig. 32, another circuit arrangement employing the 25L6 in an a.c.-d.c. receiver is shown. In this circuit, which is used in the **Pilot Models G-162, G-163**, a type 75—which is essentially the same as the 6Q7—is used to drive the 25L6. The speaker field is placed in the negative leg of the power supply, a voltage divider is placed across the speaker field, and part of the voltage drop across the field provides bias voltage for the 25L6 (as well as for the other tubes in the receiver). An advantage of placing the field in the negative leg of the power supply, which permits the use of fixed bias on the 25L6, is that it permits a greater effective plate and screen voltage for the 25L6, and thus increases the maximum power output appreciably. Incidentally, the bias arrangement used in this receiver permits grounding the cathodes of all the tubes used in this receiver.



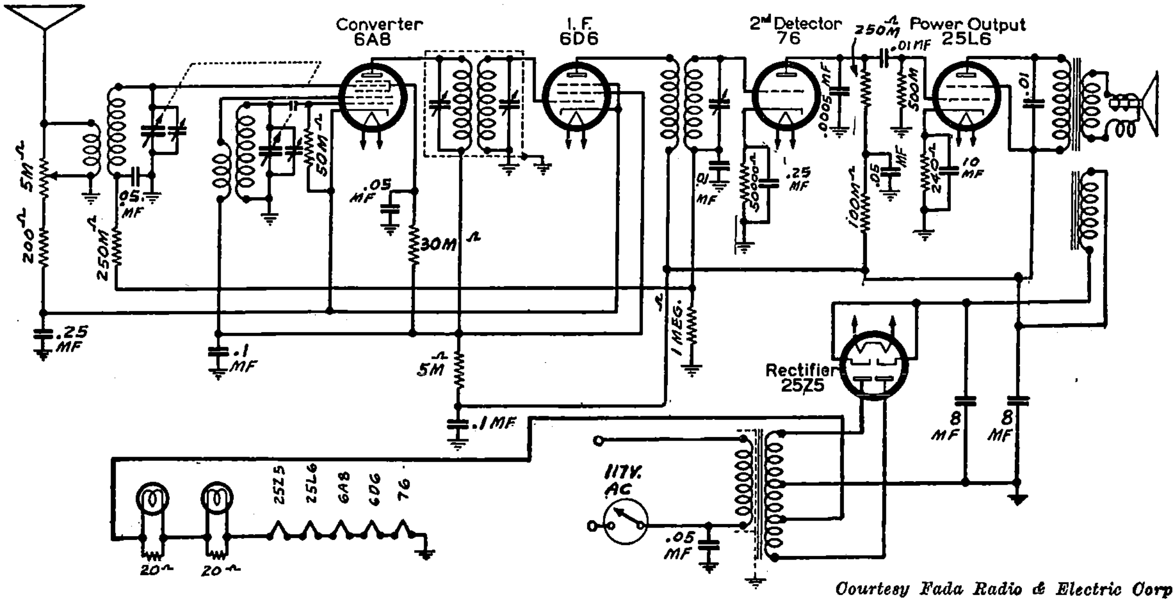
Courtesy Pilot Radio and Tube Corp.

FIG. 32.—The a-f and power supply circuit in the Pilot G-162.

The circuit used in the **Fada Model 254** receiver illustrates the use of a biased triode detector to drive the 25L6 to rated output. As is shown in Fig. 33, a type 76 tube is used as a biased 2nd detector to drive the 25L6 output tube. The bias voltage for the 25L6 is provided by the 240-ohm resistor which is by-passed by a 10-mf condenser.

We have shown the complete circuit of this receiver because it illustrates an application of the fact that the high power output of the 25L6 at low plate voltages permits low voltage power supplies to be used in receiver design, with consequent economies of production. As the circuit shows, a 25Z5 is employed as a conventional full-wave rectifier, the speaker field being used as a filter choke in the positive leg of the power supply. The heaters of the tubes are supplied from a tap on the power transformer and since the proper amount of a-c voltage is taken off, no ballast resistor is required. It should be noted that the highest voltage used on any of the tubes in this receiver is approximately 150 volts.

As far as the r-f and i-f portion of the receiver is concerned, a 6A8 tube is used as a converter tube and a 6D6 in the i-f stage. The volume control employs an antenna and C-bias control, which simultaneously varies the signal input, the converter gain, and the i-f gain, so as to provide effective manual control over the volume. An interesting feature of the 2nd detector circuit is the arrangement used in the input circuit: the grid coil of the 2nd detector is returned to ground through a 1-meg resistor, and the grids of both the converter and i-f tubes connected to the ungrounded side of this resistor. Normally, when the receiver is operating with weak or medium values of signal input, there is no voltage developed across this resistor because the bias on the tube prevents the flow of grid current. However, for strong values of input signal, the grid and cathode circuits of the 76 function to provide an automatic volume control voltage in much the same way as



Courtesy Fada Radio & Electric Corp.

FIG. 33.—Schematic of the Fada 254. A type 76 power detector drives the 25L6 to rated output, and an automatic action prevents overloading in the mixer and i-f stages.

the conventional AVC diode rectifier. The action here is much more appropriately called automatic overload control, rather than AVC, since it functions only on strong signals.

AUTOMATIC VOLUME CONTROL CIRCUITS

RCA 9K3

The AVC circuit in the RCA Model 9K3 receiver incorporates a number of interesting features, among which are included the use of a shunt feed circuit for the r-f and 1st detector grids, and the use of a delayed AVC system which makes it possible to ground the cathodes of the controlled tubes and to feed the minimum bias voltage through the AVC bus.

Referring to the breakdown diagram circuit shown in Fig. 34, note that the r-f and first detector grid coils are grounded and that 560-mmf coupling condensers are used to feed the signal voltage to the grids. Not only do the 560M-ohm shunt feed resistors provide a means for feeding AVC voltage to the grids of the two controlled tubes, but at the same time they act as effective decoupling resistors so that no additional filters are required. In this connection you will note that the three controlled tubes; the 6K7 r-f, the 6L7 mixer, and the 6K7 i-f are tied directly to the AVC bus without the use of the customary filter resistors.

One section of the 6H6 second detector and AVC tube is used as a conventional second detector, the 56M-ohm resistor serving as an i-f filter, while the 2.2-meg resistor functions as the diode load. The rectified voltage developed by this diode, the cathode of which is grounded, is fed directly to the AVC bus P through a 2.2-meg resistor.

When no signal is being received, the cathode of the diode D2 in the 6H6 is 3 volts negative with respect to the plate, so that effectively the plate is 3 volts positive with respect to the cathode. Under this condition, the diode is conductive—act as a low resistance—and can be thought of as connecting the 3-volt negative bias directly to the AVC bus. In other words it follows that the voltage developed at point P will be 3 volts negative under the condition of zero input signal to the receiver.

As the input signal to the receiver increases, a rectified d-c voltage is produced across the 2.2-meg diode load, and finally a condition is reached where the value of rectified voltage across the diode load becomes greater than 3 volts. When this occurs, the negative voltage applied to the plate of D2 is greater than 3 volts, so that D2 is blocked to the flow of electrons, and no longer is conductive. As a result, D2 is effectively now out of the circuit, since it no longer can conduct current as a result of its negative plate voltage, and hence D1 functions in the normal manner to supply AVC voltage to the three controlled tubes. It is worthwhile noting that this system functions as a delayed AVC circuit in that the voltage at P is maintained at 3 volts until the signal input is such as to produce at least 3 volts of rectified voltage across the 2.2-meg diode load. A more complete discussion of this and other AVC circuits can be found in the "An Hour a Day with Rider on AVC" by John F. Rider.

AVC Circuit in the Motorola 9

A breakdown diagram of the delayed AVC circuit used in the Motorola 9 receiver is shown in Fig. 35. In addition to having all three r-f and i-f tubes under control, the circuit incorporates a

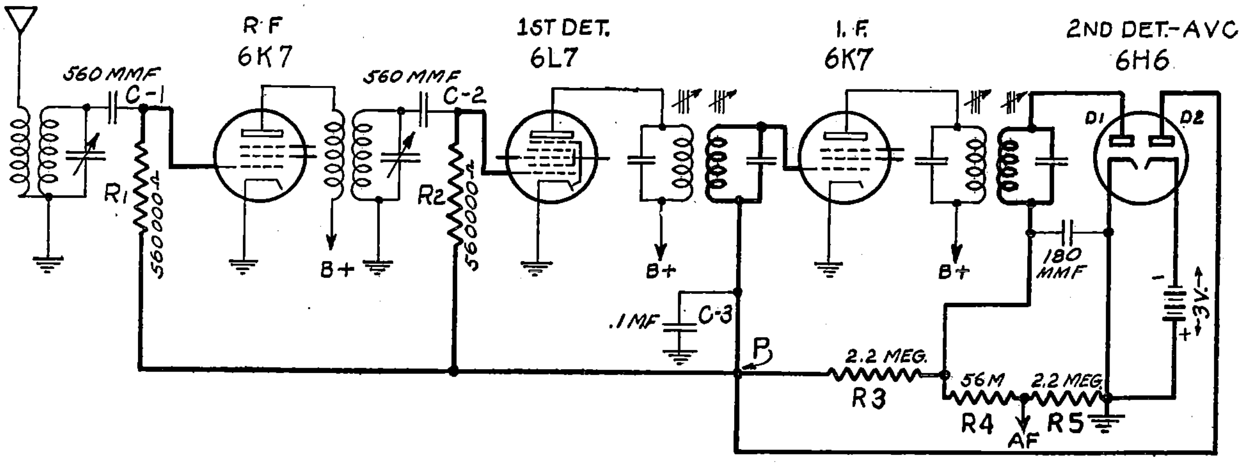


FIG. 34.—Skeleton diagram of the RCA 9K3 showing theAVC circuit and the distribution of the control voltages.

variable delay action in the AVC rectifier circuit and a unique method of biasing the 2nd i-f tube.

As is evident from the breakdown diagram, one section of the 6H6 serves as a conventional diode detector, while the other section functions as the AVC rectifier. This latter diode receives its i-f signal voltage from a tap on the primary winding of the last i-f transformer through a 50-mmf coupling condenser. Note that the cathode of this diode is connected to the cathode of the 2nd i-f tube, and that both cathodes are returned through a 400-ohm resistor to a point on the bias voltage divider which is 2.5 volts negative with respect to ground. In addition, the plate of the AVC diode is returned to this same bias point through the AVC load resistors, the values of which are 330M-ohms and 270M-ohms.

From these connections it is clear that when no signal voltage is being received the bias voltage effective on the grids of the 1st detector and the 1st i-f tube is equal to 2.5 volts, the minimum bias voltage being supplied to these tubes through the AVC line. The grid of the 2nd detector tube also receives the same 2.5-volt bias voltage through the AVC feed line; however, the cathode of the 2nd i-f tube is returned to the same negative point on the voltage divider, while the cathodes of the 1st detector tube and the 1st i-f tube are grounded.

Because of this bias arrangement for the 2nd detector tube, the net bias voltage between the grid and cathode of this tube is equal to the voltage drop across the 400-ohm cathode resistor, so that as far as this tube is concerned, it is just as though the grid were grounded and the cathode connected to ground through a 400-ohm resistor. The only difference in the present circuit arrangement is that both the grid return and the cathode return are made to the same common point which is 2.5 volts below ground instead of at ground potential. While this makes it possible to feed the minimum bias voltage of 2.5 volts to the grids of the other controlled tubes, it does not affect the bias voltage on the 2nd i-f tube because of the common grid and cathode return.

Besides making possible the grounding of the cathodes of the two controlled tubes, the connections explained above make possible an automatic delay action in the AVC circuit. This delay action is obtained because the voltage drop across the 400-ohm bias resistor is inserted directly in the circuit of the AVC rectifier, and acts as a variable delay voltage.

The action taking place here can be explained in the following manner: When the signal input to the receiver is very small, then the voltage drop across R1 is equal to approximately 3 volts, so that the AVC rectifier is blocked or "delayed," the latter term being the technical expression for this action. On the other hand, when the signal input rises to the point where the voltage impressed across the AVC diode rises above this 3-volt bias, then the AVC rectifier begins to function, and to produce an AVC voltage. Approximately one-half of this rectified AVC voltage is applied to the grid of the 2nd i-f tube, so that the grid bias of this tube is increased and the plate current cut down. The reduced value of plate current in this tube causes a smaller voltage drop across R1, so that the amount of delay voltage in the AVC rectifier circuit is cut down. In this way, the AVC rectifier is caused to

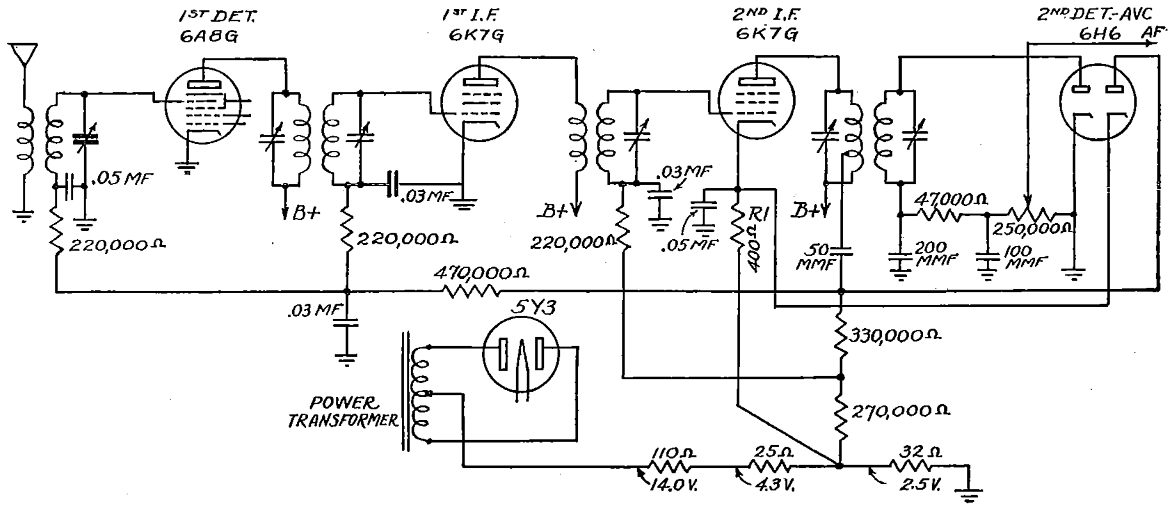


FIG. 35.—Breakdown diagram of the delayed AVC circuit used in the Motorola 9 receiver.

operate at increased efficiency for the higher values of input signal where a greater value of AVC voltage is required to level off the output of the receiver. On the other hand, for small input signals, where the full sensitivity of the receiver is required, it is made available because the delay action prevents the production of an AVC voltage which would cut down the receiver gain.

Aside from the action of the AVC circuit used in this receiver, it should be noted that the circuit is best checked by measuring the various voltages involved in its operation. Unless a high-sensitivity voltmeter or a vacuum-tube voltmeter is used, it is not feasible to measure the value of grid bias directly at the grids of the several controlled tubes. However, a perfectly good method of checking this and other similar circuits is to measure the value of grid bias at the points on the low-resistance voltage divider from which these voltages are taken. In the circuit being discussed, the bias voltage should be measured at the junction of the 32- and 25-ohm resistors on the voltage divider. This measurement, in conjunction with the continuity check of the voltage distribution circuit, provides a perfectly valid check of the AVC grid bias circuit.

6-VOLT BATTERY-OPERATED RECEIVERS

During the past year the number of 6-volt battery receivers employing 2-volt tubes has increased to a marked extent. In outlying sections of the country where no power facilities are available, the use of 2-volt tubes in conjunction with a synchronous vibrator power supply for the B voltage has made possible economical receiver operation from a 6-volt storage battery. The extremely low filament consumption of 2-volt tubes, the increased efficiency of vibrator power supplies, and the more widespread use of wind chargers for keeping the storage battery charged are among the factors which have made for the adoption of this type of receiver design.

Fortunately, most of the problems connected with the complete 6-volt operation of battery receivers have been of a design nature, and the servicing of these receivers is not especially different from the servicing of other receivers. However, there are a number of important differences which should be understood in connection with efficient servicing; the more important of these are the bias arrangements, the methods of measuring bias voltages, and the steps taken to eliminate noise from the vibrator power supply.

Sentinel-Erla 49B

To illustrate these points, let us consider the circuit arrangement used in the Sentinel-Erla Model 49B receiver, shown in Fig. 36. With reference to the B supply, a completely shielded, synchronous vibrator-type power supply is used. In addition to the shielding of this unit, noise is minimized by the use of filter condensers and r-f chokes in all the A and B leads, so that each lead is filtered before it leaves the shielded power unit. A conventional hum filter employing a filter choke and two electrolytic condensers is used to smooth the rectified voltage.

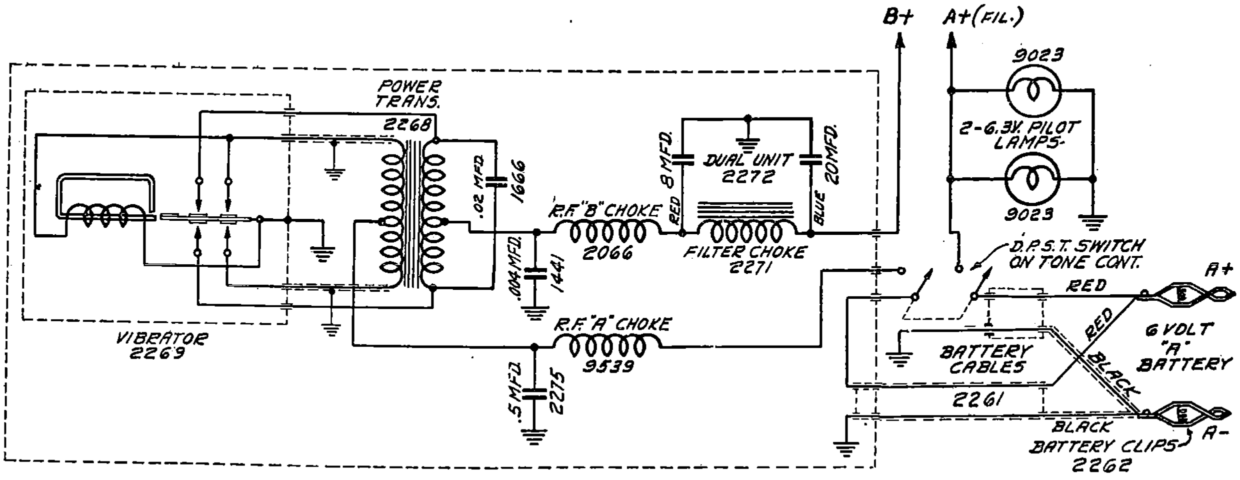


FIG. 36.—Vibrator power supply of the Sentinel-Erla Model 49B.

Courtesy of Sentinel Radio Corp.

Of special significance is the fact that a separate shielded cable is used to supply the A voltage for the vibrator supply, and that another shielded cable is used to supply the filament voltage for the tubes. The use of a double-pole switch makes it possible to further isolate the filament circuit from the vibrator circuit by making possible a direct connection of the filament supply to the battery; in this way, the pulsating current drawn by the vibrator is prevented from flowing through the same wires which feed the tube filaments. If a common A lead were used for both the vibrator and filament supply, then the voltage across this lead would introduce vibrator noise into the filament circuit. By connecting the filament supply directly to the battery, the low internal resistance of the battery short circuits this vibrator noise and delivers pure d.c. to the filaments.

An understanding of the manner in which the filament supply is arranged is essential to making the various voltage tests required in the servicing of these battery-operated receivers. In the receiver being described, a type 1C6 tube is used as the mixer, a type 34 in the i-f, a type 6B7 in the 2nd detector and pentode 1st audio, a type 30 in the driver, and a type 19 in the class B output stage. As the accompanying breakdown diagram Fig. 37 shows, the 60 ma. required by the type 30 driver and the type 34 i-f filament is secured by placing these two tubes in series with a 33.3-ohm resistor directly across the 6-volt storage battery. The type 19 output tube requires 260 ma. and the type 1C6 requires only 120 ma., so that a 240-ma. shunt (14.3 ohms) is placed across the type 1C6; a 7.7-ohm resistor provides the additional 2-volt drop which is required. The type 6B7 tube presents no problem since it is of the heater-cathode type, and so this tube is placed directly across the 6-volt battery supply.

The manner in which these several tubes receive their bias voltage can be followed from Fig. 37. Referring to this diagram, the path through which each tube receives its bias voltage is shown symbolically by including the control grid of each tube, and by indicating the bias path by means of a solid line. The r-f coils, filter resistors and condensers which are present in the grid circuits, but which have no bearing on the static value of the grid bias, are omitted from this circuit for the sake of simplicity.

Considering first the type 34 i-f tube, we note that the control grid of this tube is returned to ground through a 1.25-volt bias cell; this, in conjunction with the 2-volt drop across the 33.3-ohm filament resistor, makes the bias voltage on the grid of this tube 3.25 volts negative with respect to the negative leg of the filament. Note, however, that this is the minimum bias on the tube, and that with a signal this value of bias voltage is increased by the amount of the AVC voltage; this AVC voltage is in series with the 1.25-volt bias cell, the latter being mounted directly in the AVC line.

The bias voltage on the type 30 driver tube is equal to the 2-volt drop across R1 plus the drop across the type 34 filament; this makes the bias voltage on the grid equal to 4 volts, since the grid is returned to ground potential. The type 19 output tube is operated class B so that the grid is

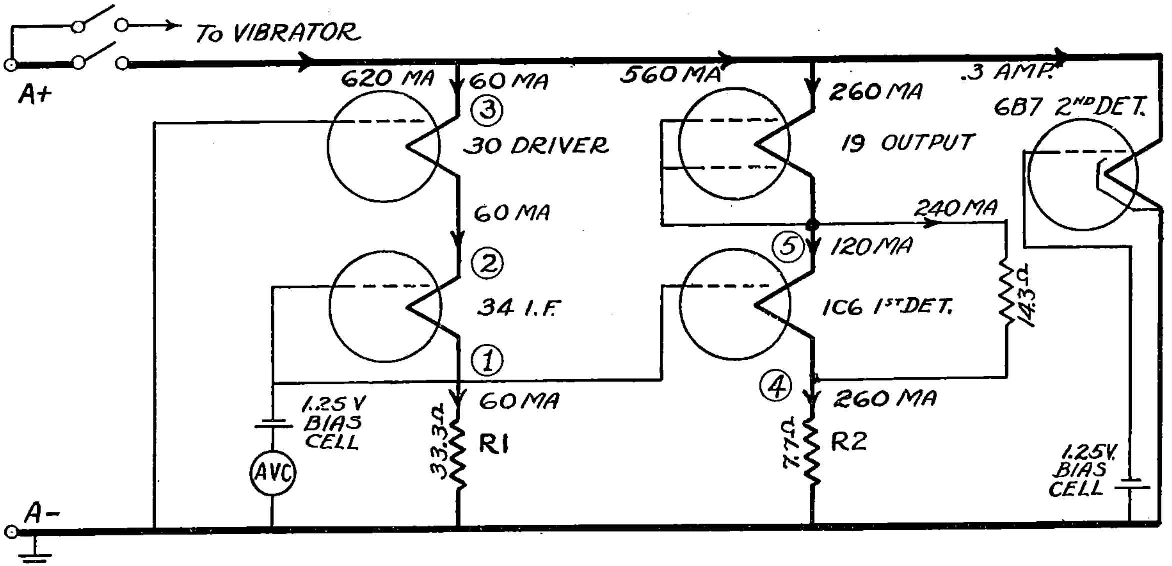


Fig. 37.—Breakdown diagram showing the filament supply arrangement of the Sentinel-Erla Model 49B.

returned directly to the negative leg of the filament, making the grid bias on this tube zero.

The circuit arrangement for biasing the signal grid of the type 1C6 first detector is similar to that used for biasing the type 34 i-f tube. Note that the bias voltage is therefore equal to 3.25 volts, the latter value being increased by the AVC voltage during operation of the receiver.

In order to simplify the arrangement of the AVC circuit, as well as for other design reasons, the cathode of the type 6B7 is connected to ground. A 1.25-volt bias cell is used to supply the grid bias for the first a-f stage, as is indicated on the diagram.

A few words of caution are in order with regard to the actual checking of grid voltages, as a result of the use of grid bias cells in the circuit. These cannot be checked with an ordinary voltmeter, inasmuch as it is inadvisable to draw more than a microampere of current from the cells. The arrangement shown in connection with Fig. 38 is suggested as a rapid means of checking grid bias cells. By means of a conventional analyzer the plate current of the tube (in the grid circuit of which the bias cell is used) is measured by the analyzer meter. The bias cell is then removed, the potentiometer leads clipped to the cell terminals, and the potentiometer across the flashlight cell adjusted for the same value of plate current. The voltage across the output of the potentiometer when the same value of plate current is obtained is then equal to the voltage of the bias cell. Of course the voltage across the potentiometer terminals can be measured directly, or if used often, a small dial may be fixed to the potentiometer so as to indicate the voltage directly.

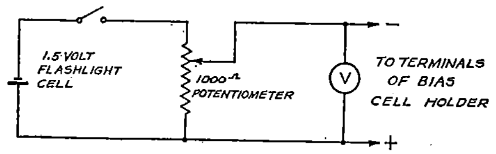


Fig. 38.—With this arrangement the grid bias cells may be checked quickly.

A typical check of the grid circuit of the 34 i-f stage will indicate the manner in which the circuit of stages using grid bias cells is checked. As Fig. 39 shows, if an attempt is made to measure the grid voltage by measuring directly from the grid of the i-f tube to the negative filament terminal, then the circuit includes not only the grid bias cell but includes as well the 1-meg filter resistor in the AVC feed line and the 500M-ohm 2nd detector load resistor. Because of this high value of resistance, the reading will be of no value, and, although the bias cell will not be injured, it is inadvisable to check the grid circuit in this manner.

A better plan is to check the grid bias cell and the continuity of the circuit and to measure the voltage drop across R1. These three tests will provide all the information required for analyzing the grid circuit. In checking the continuity with the ohmmeter, the ohmmeter terminals should not be placed from the grid of the tube to the filament, since this will cause the ohmmeter current to flow through the grid bias cell with consequent damage to the cell. A better plan is to check the resistance of each component in the circuit through which the bias voltage is fed. In the circuit of Fig. 39, this would involve checking the resistance of L1, R4, R3 and R1. The tube should preferably be removed from the socket while this resistance check is made, so that the shunting effect of the other filaments is avoided.

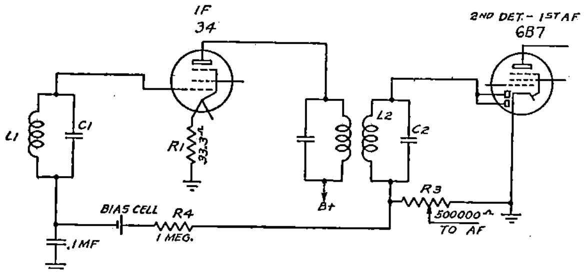


Fig. 39.—The resistances of L1, R1, R3, and R4 should be measured as a check on the grid bias.

The above example is intended to show the general method of checking grid bias circuits. The methods of checking the bias voltage of the other tubes is essentially the same, and in each case where an indication of an abnormal bias condition is found, the bias circuit for that tube should be broken down in accordance with the manner described in the above example.

It should be noted that bias voltages, according to conventional practice, are always measured with respect to the negative terminal of the filament In cases where a d-c vacuum tube voltmeter is available, the measurement of the bias voltage can always be simplified by connecting the vacuum-tube voltmeter between the grid and the negative filament terminal of the tube. The vacuum-tube voltmeter will then indicate the actual bias voltage. Since no current is drawn, this method can be used in all cases, even where the bias circuit includes one or more grid bias cells.

Montgomery-Ward Model 62-327

This receiver is typical of the 6-volt battery design which uses 2.0-volt filament type tubes throughout, and uses a vibrator type power supply to provide the B voltage. The complete schematic is shown on page 8-37 of Rider's Manual and for convenience in analyzing the circuit, breakdown diagrams of both the B-supply, and the filament-bias circuit are shown in the accompanying figures.

Referring to the diagram of the power supply in Fig. 40, it will be noted that a full-wave synchronous vibrator of the split reed type is used in a more or less conventional circuit. One reason for the split reed type of construction is that it makes it possible to isolate the primary and secondary sides of the transformer, so that the pulsating primary voltage is kept out of the final rectified B-supply voltage. Thus the secondary circuit of the transformer is entirely separate from the primary side, in that an independent return is used to complete the rectifier circuit to the A— terminal of the battery. A more important reason for the use of the split reed type of construction is that by making it possible to insert a 150-ohm bias resistor in the negative leg of the voltage supply, it removes the necessity for separate bias batteries. In this way, the flow of rectified current through the 150-ohm resistor creates a 5-volt drop across this resistor, which as we shall see later provides a bias voltage for several of the tubes in the receiver. This type of design is not possible where a single-reed vibrator is used.

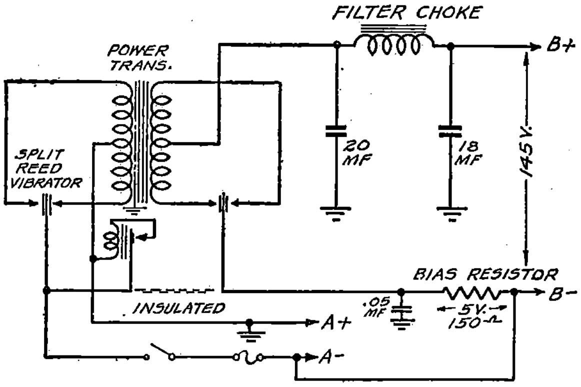


FIG. 40.—The use of a split-reed vibrator enables the pulsating primary voltage to be kept from the B voltage.

Other points of interest in the power-supply section of the receiver are the use of a double-pole switch in the A circuit,—the one section to feed the vibrator and the other section to supply the filament voltage. It was explained above that the purpose of the two sections of the switch is to keep the fluctuating vibrator A current out of the filament circuit. Because of the wide frequency range covered by the receiver, the filtering of the power supply is unusually thorough. Note in this connection that an electrostatic shield is used to isolate the primary and secondary windings of the power transformer, and that each of the leads in the A and B circuits of the power supply is filtered for r-f. All these shielding and filtering details have been removed from the breakdown diagram to simplify the circuit, but these details are evident in the complete schematic.

The arrangement of the filament and bias circuit in this receiver is shown in Fig. 41. Starting from the negative terminal of the battery, the path of the current is through the filament section of the A switch, through the filament of the type 19 output tube, and through the series-parallel network of tubes and resistors shown in the breakdown figure. The 260 ma. required by the filament of the type 19 is divided up among the type 30 2nd detector, the 1C6 1st detector, and the 25-ohm shunt resistor, which combine to produce a 2-volt drop across this part of the network. The current path to ground is completed by the division of the current through the four tubes in parallel, each of which has one

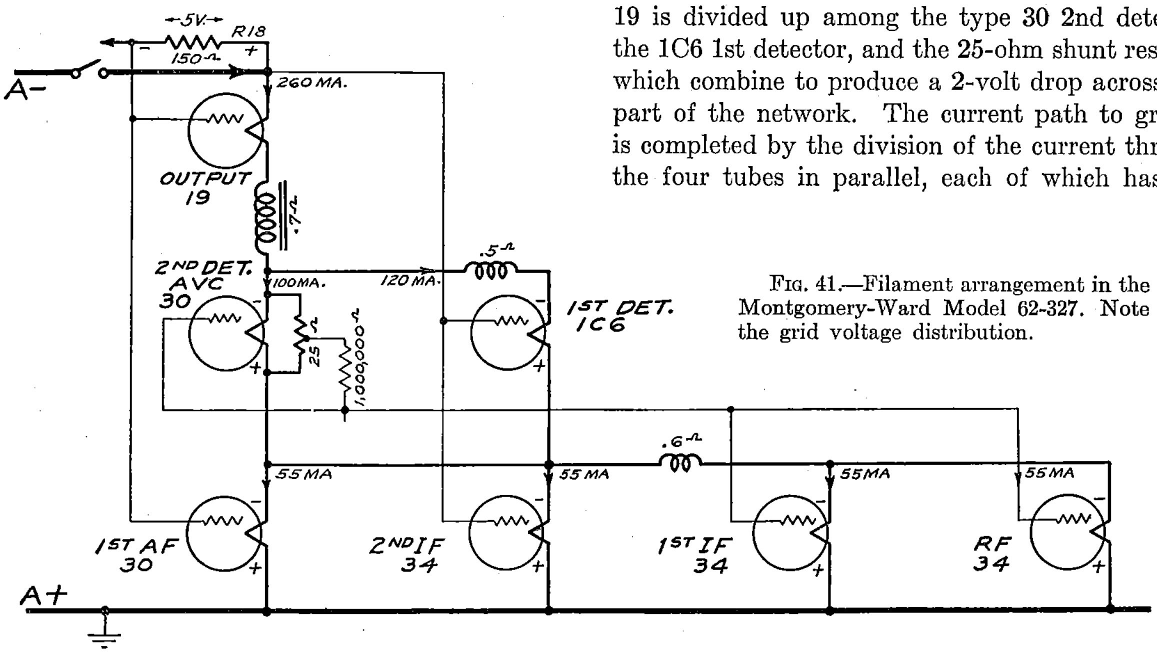


FIG. 41.—Filament arrangement in the Montgomery-Ward Model 62-327. Note the grid voltage distribution.

side of its filament connected to ground; these tubes are respectively the type 30 1st a-f, the type 34 2nd i-f, the type 34 1st i-f, and the type 34 r-f tubes.

Fig. 41 also shows the manner in which each tube obtains its grid voltage. The grid of the type 19 output tube is returned to the negative end of the 150-ohm resistor, which carries the entire 33 milliamperes drawn from the power supply. Since the drop across this resistor is 5.0 volts and the negative end of the filament is connected to the A— terminal of the battery, it follows that the bias voltage effective on the grid of the 19 is equal to 5.0 volts.

Since the grid of the type 30 1st a-f tube is returned to the negative end of the 150-ohm bias resistor, and the negative end of the filament is 4.0 volts above ground potential, it follows that the bias voltage on the grid of the type 30 1st a-f tube is equal to 9.0 volts. Similar reasoning shows that the bias voltage on the grid of the type 34 2nd i-f is equal to 4 volts, since the grid of this tube is returned to A—, and its filament is also 4 volts above ground. Since the grid of the type 1C6 1st detector is returned to A—, while the negative leg of its filament is 2.0 volts above ground, it follows that the bias on this tube is equal to 2.0 volts.

The 1st i-f tube and the r-f tube both receive their grid bias through the AVC circuit. A skeleton diagram of the AVC circuit is shown in Fig. 41, from which it is evident that (with no signal) the AVC feed line is 3.0 volts below ground. On the other hand, the negative filaments of both these AVC-controlled tubes are each 2.0 volts below ground, so that the no-signal bias voltage on these tubes is equal approximately to 1.0 volt. When a signal is being received, this normal bias voltage of 1.0 volt is increased by the value of the AVC voltage developed across the 1-megohm 2nd detector load resistor.

In examining this breakdown diagram, it should be remembered that the coils and resistors have been omitted and that an open circuit or some other defect in these components may affect the voltage distribution. In analyzing the receiver, it is best to first check the voltage between the various filaments and the A+ terminal or ground, to make certain that the filament voltage distribution is correct. This is an easy matter to check, since there are no high resistances involved in the circuit. Assuming that the filament voltage distribution is normal, then the grid bias voltages will be correct provided the continuity of the various circuits is correct. The latter is most easily checked with an ohmmeter against the schematic.

It should be unnecessary to emphasize that no tube should be removed from its socket while the power switch is on, in order to avoid damage to the remaining tubes.

VOLTAGE DISTRIBUTION CIRCUIT

Philco 38-116

One of the most common causes of failure in receiver operation is the failure of condensers and resistors. In the smaller receivers the location of trouble of this kind is not difficult since the circuit is comparatively simple and the testing is further simplified because there are only a few elements which can be responsible for an abnormal voltage or resistance indication. The successive elimination of the suspected parts then makes it a fairly simple matter to locate the defective component.

In the larger receivers, of which the Philco 38-116 is representative, the problem of locating the component responsible for a faulty voltage or resistance indication is relatively a more difficult matter. Whereas in the smaller receivers there will in general be only one high voltage bus, in the larger receivers there may be as many as three or four different, but interconnected, high voltage lines which feed the plate voltages to the several groups of tubes in the receiver. A similar situation exists for the provision of the different cathode, screen, control grid, and suppressor voltages; as the schematic of the Philco 38-116 on page 8-81, 8-82 shows, the overall distribution system presents a relatively complicated appearance.

Actually the voltage distribution system is not as involved and complicated as would appear from an examination of the complete schematic. The complete schematic contains a great deal of other information which tends to obscure the several voltage feed lines, and to make it considerably more difficult to follow the relationships between the various voltage feed circuits. In cases where abnormal voltages are encountered, it will therefore often save time to sketch a skeleton diagram of the parts related to the voltage distribution circuit. A diagram of this type is shown in Fig. 42; all components which are unessential to the distribution of the voltages, including the coils and coupling devices, have been omitted.

To further simplify the breakdown diagram, we have indicated the points at which by-pass condensers are included by showing the schematic number of the by-pass condenser within a small circle; these numbers coincide with the identification numbers used on the complete schematic. The noting of the points at which by-pass condensers appear is of special value in tracking down the cause of an abnormal voltage condition which may be due to a shorted or leaky by-pass condenser.

With the breakdown diagram of Fig. 42 in front of us, it is relatively simple to trace the voltage distribution to the elements of the several tubes. Starting at the power supply, which uses a conventional full-wave rectifier circuit, you will note that a tuned filter choke is used in the positive leg. This choke has the comparatively low resistance of 85 ohms to improve the regulation of the voltage supplied to the 6L6G output tubes. The point **A** feeds both the screens and the plates of the 6L6G's.

Branching off from this most positive point on the power supply line, the voltage is dropped by means of a 1000-ohm resistor in series with a 400-ohm filter choke; the combination of these two units not only drops the voltage but provides additional filtering. From this point **D**, which is bypassed to ground through a 6-mf electrolytic condenser, plate voltage is supplied to the following tubes: the 6K7G r-f, the 6L7G mixer, the 6K7G 1st i-f, the 6K7G 2nd i-f, the 6R7G 1st a-f, and the 6J5G driver.

To drop the voltage to the value required by the screens of the r-f and i-f tubes, a separate feed is obtained by means of the 14M-ohm resistor in parallel with a 70M-ohm resistor. This voltage feed point **C** supplies the screens of the r-f, mixer, 1st i-f, and 2nd i-f tubes, and in addition both the screen and plate voltage for the magnetic tuning amplifier tube are supplied through this bus.

The voltage for the 6A8G oscillator tube is supplied through an entirely separate voltage dropping and filter unit; this consists of a 4M-ohm resistor which is by-passed by means of an 8-mf electrolytic condenser. This junction **B** is used to supply the plate, screen, and oscillator-anode voltages for the oscillator tube. It might be pointed out here that this special filtering and isolation of the oscillator voltage supply is of value in making the oscillator

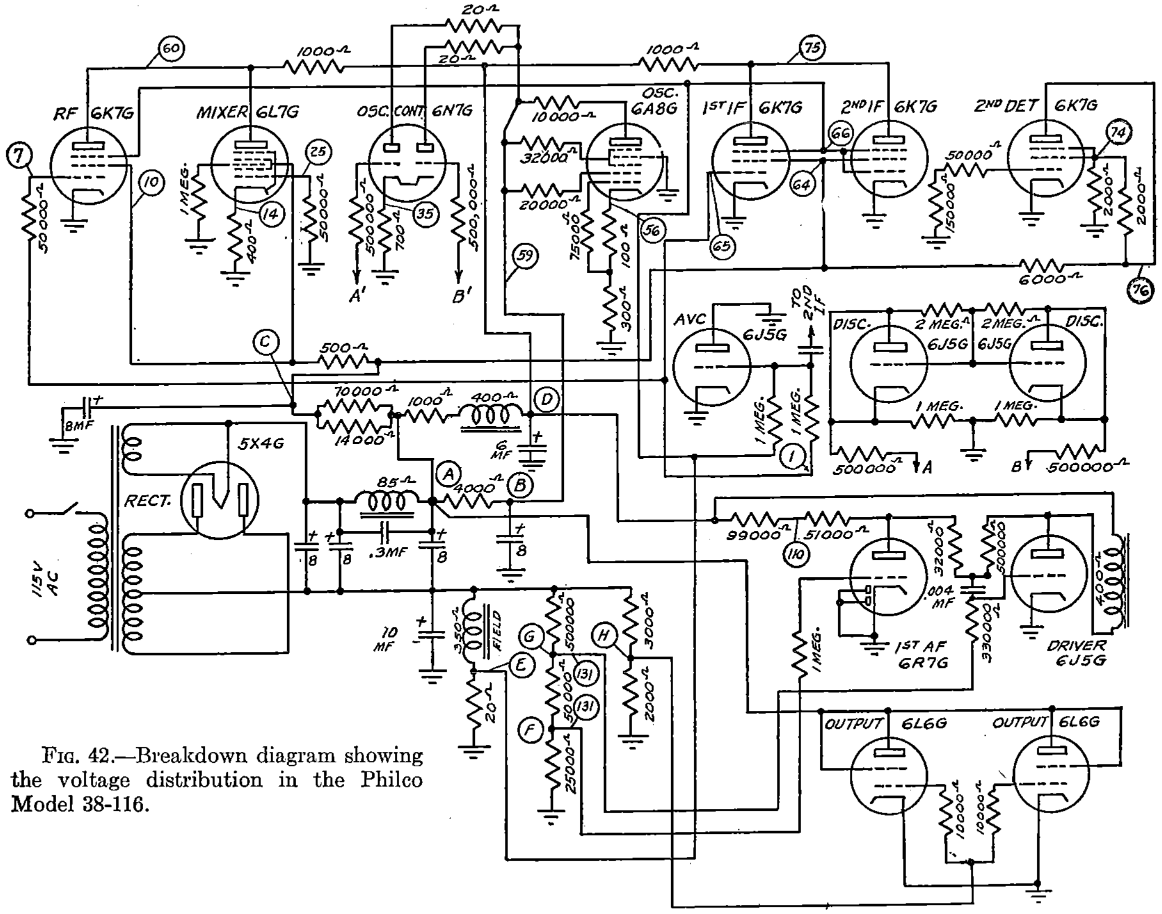


FIG. 42.—Breakdown diagram showing the voltage distribution in the Philco Model 38-116.

frequency independent of fluctuations in the voltage supply; such fluctuations might be caused by the varying amount of current drawn by the other tubes in the receiver, especially the output tubes. The special importance of this consideration in the case of AFC-equipped receivers is discussed in detail in "Automatic Frequency Control Systems" by John F. Rider.

Bias Voltages

The present trend in the design of receivers is to dispense with self-bias resistors and their associated by-pass condensers. Where this procedure is followed, the minimum bias voltage for the tube is generally supplied through the grid circuit.

In the case of the r-f tube in this receiver, the cathode is connected to ground, and the tube receives its initial minimum bias voltage through the AVC feed line. Note that the AVC circuit is so arranged that the diode load resistor returns to the junction of the field choke and a 20-ohm resistor. This point is about 3.5 volts below ground potential and supplies the minimum bias voltage for the control of the r-f tube. When no signal is applied to the receiver, the voltage at the AVC bus **I** is 3.5 volts below ground, and this diode does not begin to rectify until the signal input is sufficiently great so that the peak i-f voltage across the AVC diode is greater than 3.5 volts. For signal inputs above this value, the diode begins to rectify and in this way produces an AVC voltage which increases the bias and so controls the gain of the r-f tube.

A similar situation exists with regard to the 1st i-f tube, the cathode of which is also grounded and the control grid of which is connected to the same AVC bus. In this connection it may be noted that these two tubes are the only ones which receive AVC voltage so that the AVC circuit is comparatively simple to trace.

The bias voltage for the mixer tube is obtained from the voltage drop across the 400-ohm cathode resistor. The signal grid of this stage is returned to ground through a 50M-ohm resistor so that an additional bias which tends to prevent overload of the receiver is provided for exceptionally strong signals.

Self bias is also used for the 6N7G oscillator control tube; the bias voltage here is provided by a 700-ohm cathode resistor. In the oscillator circuit two cathode resistors are used to provide bias for the tube. The oscillator grid is returned to the junction of these two resistors so that the full value of the cathode voltage is not used for the oscillator grid bias. On the other hand the signal grid is connected to ground, so that the bias voltage on the signal grid is the full voltage drop across the two cathode resistors, whereas the bias on the oscillator grid is equal to the drop across the 100-ohm cathode resistor.

The 2nd i-f tube is not automatically controlled by the AVC system, but operates with fixed values of control grid and suppressor grid bias. Note that the suppressor grid is connected to the same voltage line as the control grid so that both operate at 3.5 volts bias.

The Second Detector and Magnetic Tuning Amplifier

The second detector uses a somewhat unusual circuit, in that the first two elements of the 6K7G are used as a diode second detector. The bias voltage for the 6K7G magnetic tuning amplifier is provided by the rectified voltage produced across the 150M-ohm and 50M-ohm resistors in the grid circuit of this stage. When no signal is present, the value of screen and plate voltage used in this stage is sufficiently small so as to prevent excessive plate and screen currents from being drawn.

It may be noted here that the primary function of this stage, insofar as its operation as an i-f amplifier is concerned, is to keep the i-f voltage to the discriminator circuit at a value which is independent of the input signal level at the antenna.

The A-F Circuit

The cathodes of all the audio tubes are grounded and in every case the required value of grid bias is fed to the tube through the grid return resistor. In the case of the first a-f stage, the grid is returned to a point **F** on the negative bias voltage divider through a 1.0-meg resistor. The higher value of bias for the driver stage is similarly obtained by returning the grid through a 330M-ohm resistor to point **G** on the bias voltage divider. To avoid possible interaction with the other audio circuits, a separate voltage divider across the speaker field is used to provide the bias for the 6L6G output tubes; this consists of the 3M- and 2M-ohm resistors which provide the bias junction **H** in the breakdown diagram. In this connection the two 10M-ohm resistors through which this bias voltage is fed are the two resistors across which the negative feedback voltage is developed; this circuit is discussed in another part of this section.

SENSITIVITY DATA IN VOLUME VIII

One of the improvements in service data in this volume is the increased use of sensitivity data for the receivers of a number of manufacturers. We are glad to note that the importance of sensitivity data from a servicing viewpoint is gradually being realized, for we have always been of the opinion that the more efficient sensitivity method of trouble-shooting should be available to the serviceman in the field as well as to the manufacturer on his production lines.

In a certain sense, qualitative sensitivity checking has always been used by radio servicemen since the beginning of radio servicing. Servicemen, for example, almost invariably check the overall sensitivity of a receiver by connecting it to an antenna and noting the performance of the receiver under these conditions. On the basis of previous experience, it is thus possible to form a fair estimate of the sensitivity of the receiver. Nor has this been limited to overall checking of the sensitivity—all of you are undoubtedly familiar with the various grid click tests, and the tube removal tests which indicate whether a certain stage or section of a receiver is operative.

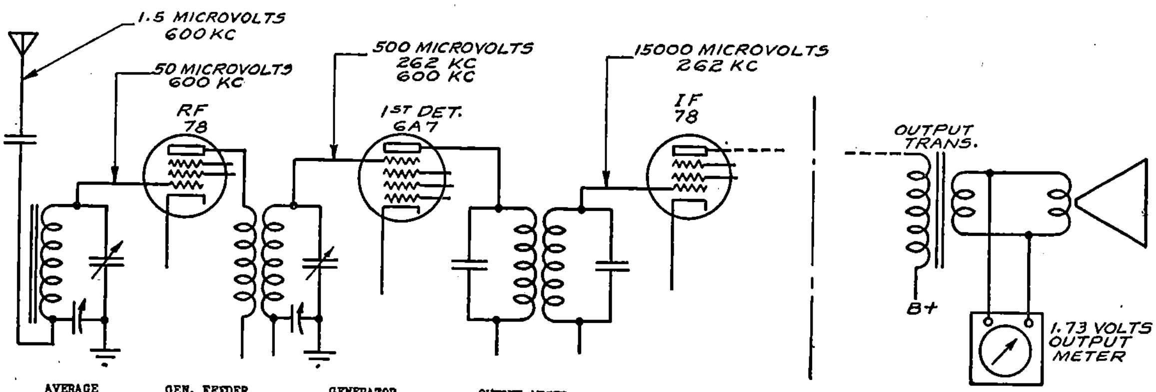
Such tests are admirable as far as they go and are often great time savers in locating trouble, but there is much to be gained from putting these tests on a more systematic and scientific basis. For one thing, the tests mentioned in the preceding paragraph are for the most part qualitative and often give misleading information. Sensitivity data, on the other hand will give conclusive information as to the overall operation of the receiver and, more important, as to the operation of any given section of the receiver. In this way it not only tells you whether the receiver is operating properly, but it also tells you which section of the receiver is responsible for the defective operation in cases where the receiver is inoperative or the performance is below the level indicated by the manufacturer's sensitivity data.

To make the best use of this sensitivity data, a signal generator with a calibrated output is required. At one time, signal generators having an output control calibrated in microvolts, cost considerably more than servicemen could afford to pay, but improvements in design have made possible the production of signal generators with fairly good calibrated attenuators at prices within the reach of servicemen.

Sensitivity Data for the Motorola Model 70

The general method of using sensitivity data will be illustrated in connection with the data provided for the Model 70 Motorola receiver. This data, as well as a skeleton diagram of the receiver, is shown in the accompanying table and Fig. 43 respectively.

Where improper operation of the receiver is encountered, the first step in applying this data is to note whether the trouble in the receiver is due to some defect ahead of or following the grid of the



AVERAGE MICROVOLT INPUT	GEN. FEEDER CONNECTED TO GRID OF –	GENERATOR SET AT	OUTPUT METER ACROSS VOICE COIL
15,000	78	262 K.C.	Voice coil resistance is
500	6A7	262 K.C.	3 ohms—
500	6A7*	600 K.C.	
50	78*	600 K.C.	1.73 Volts equals
1.5	Ant.	600 K.C.	1 Watt output

**Microvolt input may be 10 to 20% more at 600 K.C. than at 262 K.C. This is due to normal conversion loss in the Translator tube. If greater, replace Translator tube.*

FIG. 43.—Skeleton diagram and sensitivity data for the Motorola Model 70.

78 i-f tube. This is done by connecting the signal generator to the grid of the i-f tube, connecting the output meter across the voice coil, and adjusting the attenuator on the signal generator until the output meter reads 1.73 volts. The volume control should be fully advanced for this measurement, and it is important that the signal generator lead be kept as far as possible from the grids of the tubes preceding the i-f tube.

According to the information supplied by the manufacturer, and shown in the figure, the average signal input which should be required at the grid of the first i-f tube to deliver 1 watt output, or 1.73 volts across the voice coil, is 15,000 microvolts. If the signal generator control indicates that approximately 15,000 microvolts are being fed to the receiver to produce the standard output, then it follows that *that part of the receiver included between the 78 i-f control grid and the speaker is operating normally.* If, on the other hand, the signal input required is more than 15,000 microvolts, then it indicates that there is some defect between the grid of the 78 i-f tube and speaker voice coil. It does not follow that the defect is necessarily in the i-f stage, but it may be in the 2nd detector or in some part of the audio system. Further trouble-shooting is thus necessary to determine exactly where the trouble lies.

An explanation is in order here to explain the tolerance which must be applied in connection with all sensitivity data. When, as for example in this case, the manufacturer's sensitivity data calls for a signal of 15,000 microvolts, this must be taken as an average value representative of the average signal strength which has been found necessary to produce the standard output for a number of receivers of this model. This value is necessarily subject to more or less fluctuation, and this must be appreciated. Among the factors which make this value vary from receiver to receiver, are differences in the mutual conductance of the tubes and differences in the characteristics of component parts such as i-f and r-f transformers. As far as the application of this data in service work is concerned, the accuracy of calibration of the signal generator accounts for a considerable permissible deviation from the published value of sensitivity. In this connection, the percentage modulation of the signal is also important (most tables are published for a percentage modulation value of 30%), and if a signal generator having a higher or lower value of percentage modulation is used, then the signal required will be proportionately lower or higher, respectively.

If a reasonably good signal generator is used, and the receiver is in good condition between the test point and the speaker, then the signal required to produce the standard output should not vary by a factor of more than two or three from the published data. Naturally, the judgment of whether a value of input signal different from the published value indicates a defect worth hunting for depends upon the conditions. For example, if a receiver which is entirely dead at the antenna is being serviced, and it is found that 45,000 microvolts is required at the i-f grid, rather than 15,000 microvolts, then this deviation should not be regarded as indicating a defect which would account for the lack of operation of the receiver. In other words, at best, this deviation of 3 to 1 from the average sensitivity (45,000 instead of 15,000 microvolts), would account for the set being only ⅓ as sensitive at the antenna, but would therefore not account for the set being completely inoperative. The conclusion drawn from this measurement would thus be that the lowered sensitivity between the i-f stage and the speaker is not significant, and that there must be some other defect—between the antenna post and the grid of the first i-f stage—which is responsible for the lowered value of sensitivity.

On the other hand, suppose that a receiver were being serviced which is slightly under par and requires about three times the average value of input signal. If, for this receiver, 3 times the average input signal were required at the grid of the first i-f stage, then this would indicate that the condition responsible for the low value of receiver sensitivity lay between the i-f grid and the speaker. It is thus evident that whether or not a deviation from the specified value of the signal input is significant depends entirely upon the particular conditions, and that the serviceman must use his judgment in deciding this question.

To continue the above example, suppose that the signal required at the grid of the i-f stage is 20,000 microvolts, in which case the correct conclusion is that the receiver is normal between the i-f grid and the speaker. The next step in finding why the receiver is not working properly is to connect the signal generator to the grid of the preceding stage, and to measure the signal input required at the grid of the 1st detector. For this check, the signal generator should be set at the intermediate frequency, 262 kc, and the value of input signal again adjusted so that the output meter across the voice coil reads 1.73 volts. As indicated in the table, the specified value of signal input required at this point is 500 microvolts.

The same type of reasoning is again applicable at this point. If the signal required here is normal or sufficiently close to the normal value so that the deviation is not significant, then it follows that the receiver is normal between the grid of the first detector and the voice coil—as far as an i-f signal is concerned. This, however, does not imply that the first detector is functioning properly as a converter, but proves only that the 1st detector is functioning as an *amplifier.*

To test the action of the 1st detector tube as a *frequency converter,* it is convenient to feed a 600-kc signal into the grid of the 1st detector tube. According to the manufacturer's data, it should require approximately 500 microvolts to obtain the same standard value of output across the voice coil —if the 1st detector and oscillator are operating properly. If it requires considerably more than this to produce the required output, then this indicates that there is somehing wrong in the frequency converter part of the 1st detector; since the 1st detector functioned properly as an amplifier, it is probably due to lack of operation of the oscillator portion of the circuit, possibly a defective tube. Inasmuch as the trouble has been narrowed down to a very definite and restricted portion of the receiver, it is a relatively simple matter to locate the actual cause of the trouble.

Assuming on the other hand, that it requires only approximately 500 microvolts at 600 kc at the grid of the 1st detector, then it follows that the receiver is in normal condition between the grid of the first detector and the voice coil, including the oscillator portion of the 1st detector. This means that the trouble lies between the grid of the 1st detector, and the antenna post of the receiver. Proceeding further ahead in the same direction, the signal generator should be connected to the grid of the 78 r-f stage, the signal generator adjusted to 600 kc, the receiver tuned to the signal, and the output of the signal generator adjusted to obtain 1.73 volts across the voice coil.

According to the data in the table, it should take approximately 50 microvolts to produce this standard audio output. If this is about the reading of the signal-generator attenuator, then it can be assumed that the trouble lies between the grid of the 78 r-f tube and the antenna post. On the other hand, if it requires appreciably more than 50 microvolts to produce 1.73 volts across the voice coil, then it follows that there is some defect between the r-f grid and the grid of the 1st detector. In the latter case, that part of the circuit should be examined for defects, and in the former case, the r-f circuit including the antenna coil primary and secondary should be examined to determine why the voltage step-up of approximately 30, which is normally obtained through the use of the iron core antenna coil, is not present.

Signal Generator Connection

In feeding the signal to the grids of the successive tubes, in order to compare the signal strength required to produce the standard output with that required according to the sensitivity data, it is important that the signal generator connection be made so that the action of the AVC circuit is undisturbed. A good general method of connection is shown in Fig. 44. In addition to preventing the short circuiting of the AVC voltage, this method of connection is of special value in cases where a signal generator having a high output impedance is used. In the latter case, the insertion of the 10,000-ohm resistor serves as a load for the signal generator, and prevents the tuned circuit in the grid from dropping the voltage output of the signal generator. This method of connection is in general desirable even where signal generators of the low-impedance type are used, although in the latter case it is not so important that the 10,000-ohm resistor be used, but the signal generator lead may be connected directly to the grid without removing the grid cap. In testing all-wave receivers, the resonant frequency of the tuned circuit in the input to the 1st detector may be sufficiently different from that of the intermediate frequency so that it is difficult to drive a signal through the i-f amplifier and so that the calibration of the signal generator is impaired; making the connection through the 10,000-ohm resistor as indicated in the figure avoids error from this cause.

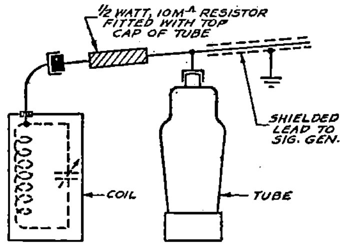


FIG. 44.—By connecting the output of the signal generator to the grid of the tube as shown on the right, the AVC voltage is not short-circuited.

Powerful Method of Troubleshooting

The above explanation of how this type of sensitivity data can be used to the best advantage, although far from complete, indicates how powerful a tool this method can be in quickly localizing trouble to a restricted portion of the receiver.

It is to be hoped in the near future, that co-operation on the part of more manufacturers in supplying this type of data, on the part of the equipment manufacturers in supplying calibrated signal generators, and on the part of servicemen in learning how to use this information to the best advantage, will go far towards putting troubleshooting on a more scientific plane.

In this connection, this method of troubleshooting is not limited to the i-f and r-f portions of the receiver, as might seem at first glance to be the case in view of the typical data just discussed. If an audio signal generator is available, then the same method of troubleshooting can be used to determine whether the audio amplifier is functioning properly, and if not, which stage of the receiver is defective.

While we have chosen the Motorola 70 data to illustrate the manner in which this general sensitivity method of testing is carried out, it should be pointed out that a number of other manufacturers, among which are Wells Gardner, Noblitt Sparks, and Sears-Roebuck, have published the same general type of data for their receivers. In the case of all-wave receivers, this same data is sometimes published for the different bands, and here the information is valuable in checking the performance of the receiver on the short-wave bands. In applying this data, the serviceman should be cautioned as to the necessity of perfect shielding of the signal generator. In general, sensitivity data for the short-wave bands at the present time is not so valuable as is the sensitivity data for the broadcast, i-f, and a-f channel, because of the difficulty of making quantitative measurements at the higher frequencies. We predict that sensitivity information will be in the near future an important part of the service data on all receivers, and that servicemen will use this data as a powerful method of quickly locating trouble in receivers, and restoring them to their original peak performance.

AUTOMATIC FREQUENCY CONTROL

Beyond any question, the perfection and extended used of automatic frequency control is the outstanding development in this year's receivers. This development is important because modern selective receiver circuits demand accurate tuning for high-fidelity reception, and in compensating for errors in manual tuning AFC not only simplifies the tuning of receivers, but reduces distortion arising from faulty tuning, minimizes the effects of fading on the short-wave bands, and make practical various types of automatic and remote control tuning systems of which the pushbutton and telephone-dial types are the more familiar.

It is not our intention in this section to go into the basic principles behind the operation of AFC circuits, since we have already covered this subject in detail in "Automatic Frequency Control Systems." But rather it is our purpose to describe how these principles are applied in the circuits which are used in many of the receivers contained in Volume VIII, and it will be taken for granted that those of you who are not familiar with basic AFC principles will consult the aforementioned book.

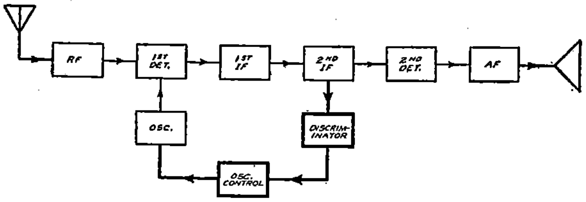


Fig. 45.—How the oscillator control and discriminator are tied into a superheterodyne circuit.

How AFC Works

Receivers which are equipped with AFC use two new elements in the receiver circuit, and these elements are tied in with the rest of the circuit in the manner indicated in Fig. 45. The first new element is called the "discriminator," and as its name implies, it is the job of the discriminator to tell when the receiver is properly tuned and when it is not properly tuned. Basically the operation of all discriminator circuits depends upon the fact that when a superheterodyne receiver is incorrectly tuned, the i-f signal frequency is different from the i-f peak; and when the receiver is accurately tuned, the i-f signal frequency is exactly equal to the i-f peak. Depending upon the condition of tuning of the receiver, the discriminator supplies a control voltage which varies both in polarity and magnitude in accordance with the frequency of the i-f signal.

The control voltage produced by the discriminator, as the block diagram of Fig. 45 shows, is fed to the so-called "oscillator control" circuit. By this means the oscillator frequency is automatically changed by the oscillator control circuit, so that the i-f signal produced in the 1st detector stage will be exactly at the i-f peak. Thus any error in the oscillator frequency is automatically compensated for by the action of the discriminator acting through the oscillator control circuit. Note especially that AFC is essentially a system for automatically correcting errors in the frequency of the oscillator; it does not correct for errors in the tuning of the r-f and detector circuits.

The Discriminator Circuit

Although the purpose of this section is to analyze AFC circuits used in the receivers shown in Volume VIII, it is worthwhile here to consider a general basic discriminator circuit, some variation of which is used in practically every AFC-equipped receiver. It is the job of this circuit, shown in Fig. 46, to produce a control voltage which depends upon the frequency of the signal passing through it, and the question before us is concerned with how this is accomplished.

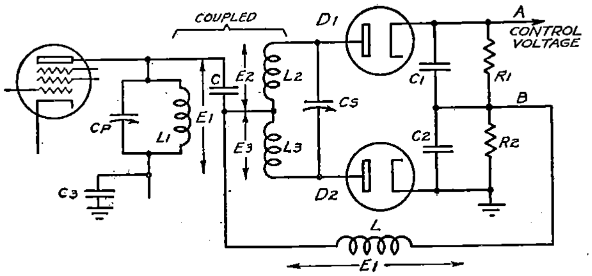


FIG. 46.—A basic discriminator circuit. The AFC transformer consists of L1, L2, and L3.

The heart of this discriminator circuit is an i-f transformer containing a center-tapped secondary with both primary and secondary windings tuned to the i-f peak; this is generally termed the AFC transformer. The secondary winding of this transformer feeds into two diodes—generally a 6H6 is used for this application—and the voltage which is developed across the two diodes load resistors R1 and R2 is the voltage which is applied to the control tube circuit and which is therefore called the control voltage or the AFC voltage.

In brief the operation of the discriminator circuit depends upon the fact that the voltage which causes current to flow through each of the diode load resistors is made up of two parts in series. One of these parts is the primary voltage E1 which is coupled into the discriminator circuit by means of the small condenser C and which appears across the i-f choke L. The other part of this voltage is the voltage which appears across each half of the secondary winding because of the fact that the primary and secondary windings are coupled inductively to each other; these voltages are indicated by the symbols E2 and E3. It so happens, as is explained in "Automatic Frequency Control Systems," that the phase of these voltages depends upon how much the frequency of the signal differs from the i-f peak, and it is for this reason that the discriminator is able to distinguish or discriminate between signals of different frequencies.

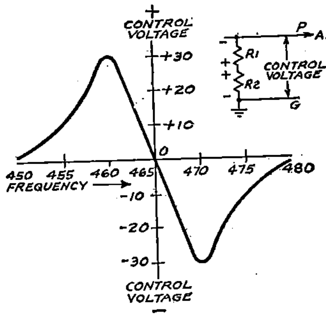


FIG. 47.—The discriminator output voltage varies in accordance with the frequency of the input signal as shown on the right.

Fig. 47 shows how the output voltage of the discriminator varies in accordance with the frequency of the input signal. It shows that when the oscillator frequency is such that the signal comes through the i-f amplifier exactly at the i-f peak, then the control voltage produced is zero. Similarly it shows that when the signal comes through above or below the i-f peak, then a positive or negative control voltage is produced, the magnitude of which depends upon the extent of the mistuning, and the polarity of which depends upon whether the mistuning is below or above the i-f peak.

We have taken the space to show this basic discriminator circuit and the voltage output which it produces because, without exception, every AFC-equipped receiver of American manufacture employs a discriminator which is basically similar to the one described and which produces a similar type of voltage output characteristic.

The Oscillator Control Circuit

Oscillator control circuits, as a general rule, show more variation among the different receivers than do discriminator circuits; but nevertheless most of the oscillator control circuits which are to be described follow the general operation of the typical

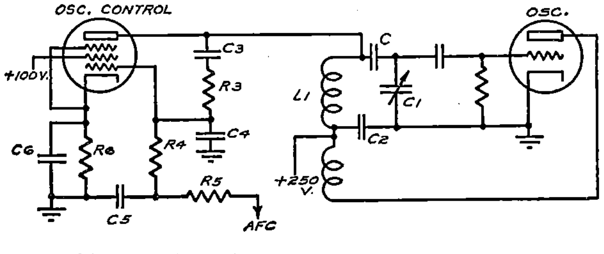


FIG. 48.—A typical oscillator control circuit.

control circuit shown in Fig. 48. Basically this control circuit functions by reflecting a variable amount of inductance across the tuned circuit of the oscillator (L1, C, C1, C2), because of the connection of the plate of the control tube to the high side of the oscillator tuned circuit.

Briefly the reason why the oscillator control tube appears to the tuned circuit as an inductance is this: By means of the phase shifting network composed of R3 and C4, the phase of the oscillator voltage is split, so that a lagging voltage is developed across the small condenser C4, which is generally about 20 mmf. This lagging voltage is applied to the grid of the control tube, which is generally a 6J7 tube, and as a result the 6J7 control tube draws a lagging current. Since this lagging plate current flows through the oscillator tuned circuit,—as far as the oscillator circuit is concerned, it sees the control tube as an inductance, because it is characteristic of inductances that when they are connected to a source of voltage they draw a lagging current from the source. In this case the tube appears as an inductance to the oscillator circuit because it is made to draw a lagging current by the expedient of splitting the phase of the voltage across the tuned circuit, and applying this voltage to the control tube grid.

In practice, the amount of inductance which is reflected across the oscillator tuned circuit is varied by varying the d-c bias on the grid of the control tube. When the bias on the grid is high the mutual conductance of the control tube is small, so that the lagging current is small and hence the inductance reflected by the control tube is *high*. Under this condition the oscillator frequency is raised only slightly, since shunting a high value of inductance across a tuned circuit is similar to shunting an r-f choke across the circuit and, as you know, this has only a slight effect on the oscillator frequency. As the bias on the oscillator tube is decreased, however, the mutual conductance of the oscillator tube is increased, the tuned circuit draws a greater lagging current from the tube, and as a result the tube appears to the tuned circuit as a smaller value of inductance. By way of summary, it can be stated that the oscillator frequency is controlled by varying the grid bias of the control tube, and that the smaller this value of control grid bias is made, the higher does the frequency of the oscillator become.

It is now clear how the basic circuit shown in Fig. 45 functions. First of all the i-f signal is fed to the discriminator circuit, and the discriminator circuit produces a control voltage which, as Fig. 47 shows, depends upon the condition of tuning of the receiver. If the oscillator frequency is too high or too low, the control voltage produced by the discriminator will be of such value and polarity as to cause the proper amount of inductance to be reflected across the oscillator tuned circuit, and in this way to bring the oscillator frequency to the proper value. It should be noted that if the receiver happens to be tuned accurately to begin with, then the discriminator produces a zero control voltage and therefore the oscillator frequency remains unchanged.

Having briefly discussed the general operation of discriminator and oscillator control circuits, we are ready for an examination of some of the commercial receivers which incorporate modifications of these circuits. You will find that for the most part everything which has been said before is applicable to these circuits but that each of the individual circuits embodies its own more or less distinct developments.

AFC in G.E. E-155

The AFC system used in this General Electric receiver, as shown in Fig. 49, is a commercial application of the principles discussed in connection with the basic discriminator and oscillator control system. An examination of the discriminator arrangement shows it to be essentially the same as that described in connection with Fig. 47. Of course the complete diode load circuit differs from the arrangement shown in the figure mentioned, but this is to be expected because Fig. 49 also shows the AVC and audio circuits.

One modification of the discriminator network appears in this circuit. This is the use of the resistance-capacity filter R-C1-C2 in the common lead which joins the input and output circuits of the rectifier. The purpose of this filter is to keep i-f voltages and currents out of the diode load resistor circuit. You will note that the audio voltage is secured from the junction of the load resistors R1 and R2, making it necessary to include a filter ahead of this point. In the basic discriminator circuits previously discussed it was unnecessary to use an i-f filter, because the circuit arrangement was such as to permit the use of a large bypass condenser at the junction of R1 and R2, thus effectively keeping the i-f out of the a-f amplifier.

In addition to supplying the AFC and a-f voltages, this discriminator is used to furnish AVC voltage. You will observe from the figure that four resistors are used to make up the diode load. The load resistor for the diode D1 consists of R1, while the load for the second diode D2 consists of three separate resistors R2, R3, and R4. Three resistors are used for the load of the second diode so as to permit different degrees of AVC voltage to be fed to the i-f and r-f tubes and to supply a control voltage for the *Colorama* tube. Essentially, however, this does not affect the AFC action—the circuit is still balanced.

The lower part of the discriminator load circuit appears to deviate from the circuit described previously. Normally, the lower end of the discriminator load circuit is returned to ground. However, you will note that in this receiver, this point P is by-passed to ground through a 10-mf condenser and returned to a point on the voltage divider which is 3 volts negative with respect to ground. This connection is made through a 100,000-ohm filter resistor, which, in conjunction with the 10-mf electrolytic, acts to prevent any hum or audio voltages from being fed into the discriminator circuit. As a result of this connection, the entire discriminator circuit is placed at a potential of 3 volts below ground. In this way an initial bias is fed to the grids of the tubes which are controlled through the AVC bus, so that it is unnecessary to use individual cathode resistors and by-passes for each controlled tube. Instead, the cathodes of the controlled tubes are connected directly to ground.

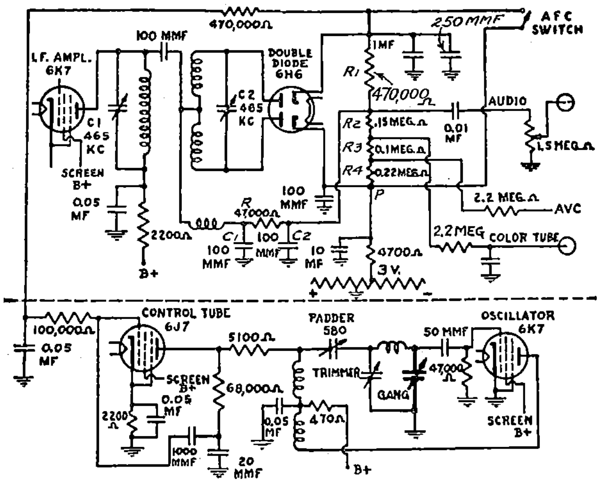
The high side of R1, you will see by reference to Fig. 49, is by-passed to ground through a 1-mf condenser. This condenser serves a two-fold purpose: it prevents hum and audio voltages from being fed to the oscillator control tube, and in addition increases the time constant of the AFC circuit so that it is greater than that of the AVC circuit.

Two additional condensers of 100-mmf and 250-mmf capacity are used to by-pass the diode cathodes. The purpose of these condensors is to provide more effective by-passing for the intermediate frequency and its harmonics. During visual alignment of the circuit, when it is necessary to disconnect the 1-mf condenser temporarily, the 250-mmf condenser offers a low-impedance path to the i-f and its harmonics, and so prevents feedback and its attendant instability.

The Control Tube

The control circuit used in this receiver is essentially similar to that shown in Fig. 48. Note especially that the phase shifting network consists of a 68,000-ohm resistor and a 20-mmf condenser. The .001-mf condenser does not play any part in shifting the phase because of its large value and serves only to prevent the d-c plate voltage from reaching the grid of the oscillator control tube.

A 5100-ohm resistor is included between the plate of the oscillator control tube and the tuned circuit of the oscillator. This resistor is used primarily as a control on the variation of the AFC range at the various frequencies throughout the band.



Courtesy of General Electric Co.

FIG. 49.—The AFC system employed in the G.E. Model E-155.

A switch for shorting out the AFC action is incorporated in the circuit. When this switch is closed, the cathodes of the two diodes are joined together so that essentially the discriminator circuit becomes a conventional full-wave rectifier circuit. Note that under this condition the two diode loads are in parallel with each other and that therefore no AFC voltage is generated. However, the audio and AVC voltages are still produced just as they would be in the case of a conventional full-wave rectifier circuit.

This circuit uses a separate 6K7 tube as an oscillator and while the arangement of the oscillator circuit itself is slightly different, the manner of connection to the 6J7 oscillator control tube is the same as before. Here again, you will note that the plate voltage for the control tube is obtained through the oscillator coil, and that for this reason the oscillator grid coil is some 200 volts above ground potential. The .05-mf by-pass condenser at the junction of the oscillator grid coil and tickler is, of course, part of the oscillator tuned circuit.

In this receiver the AFC action functions only on the broadcast band. However, the discriminator circuit is not disturbed on the short-wave bands, but the AFC action is rendered inoperative because there is no connection between the control tube and the oscillator.

AFC in Crosley 1516

The schematic of the AFC circuit used in the Crosley Model 1516 and in a number of other receivers of the same manufacture is shown in Fig. 50. The plate of the 6A8 first detector, you will note from Fig. 50, feeds directly into the first i-f transformer which is of the triple-tuned type. This type of transformer is used for the purpose of obtaining a more desirable overall i-f response, having an essentially flat top and steep sides approaching the ideal selectivity curve. Following along the regular i-f channel, you will observe that one i-f stage is used and that this feeds directly into a diode detector through another transformer of the same type.

Separate I-F Channel for AFC

An interesting feature of this circuit is that the regular i-f channel does not feed the AFC circuit. Instead, a broader channel is obtained by feeding the grid of another 6K7, arranged as an i-f amplifier stage, from the secondary winding on the first i-f transformer. The output of this stage feeds directly into a conventional discriminator transformer. As a result of this arrangement, the selectivity of the AFC channel is made considerably broader than usual—without sacrificing the selectivity of the regular signal channel.

The Discriminator

The discriminator used in this receiver is of the conventional type, the i-f choke in the secondary center-tap circuit being omitted and the center-tap returned directly to the midpoint of the load connected between the two cathodes. The high side of the discriminator load is by-passed to ground with a comparatively small condenser—.1 mf. However, the AFC voltage is fed to the oscillator control tube through a 3-megohm resistor which is by-passed to ground through a .02-mf condenser. This filter, of course, has the effect of further increasing the time constant so that it is greater than that of the AVC circuit.

The Voltage-Limiting Diode

Inspection of the schematic in Fig. 50 will show you that the AFC bus is connected to one of the diode plates in the 6R7 second detector and first audio tube. Since the cathode of this tube is 2.0 volts above ground, this diode will start to draw current whenever the positive AFC voltage produced by the discriminator exceeds 2.0 volts. This current will flow through the 3-megohm filter resistor, and the voltage drop across this resistor will prevent the voltage at the grid of the 6J7 control tube from rising appreciably above 2.0 volts.

There is, of course, no connection between the audio circuit and the AFC system. The fact that the AFC bus is connected to a diode in the first audio tube is purely a matter of convenience. The results and operation would be exactly the same if a separate diode with its cathode 2.0 volts positive with respect to ground were connected across the AFC bus.

This voltage-limiting diode is used to prevent a high positive value of AFC voltage from reaching the grid of the 6J7 control tube. This action is desirable since positive values of AFC voltage cause the control tube to reflect low values of resist-

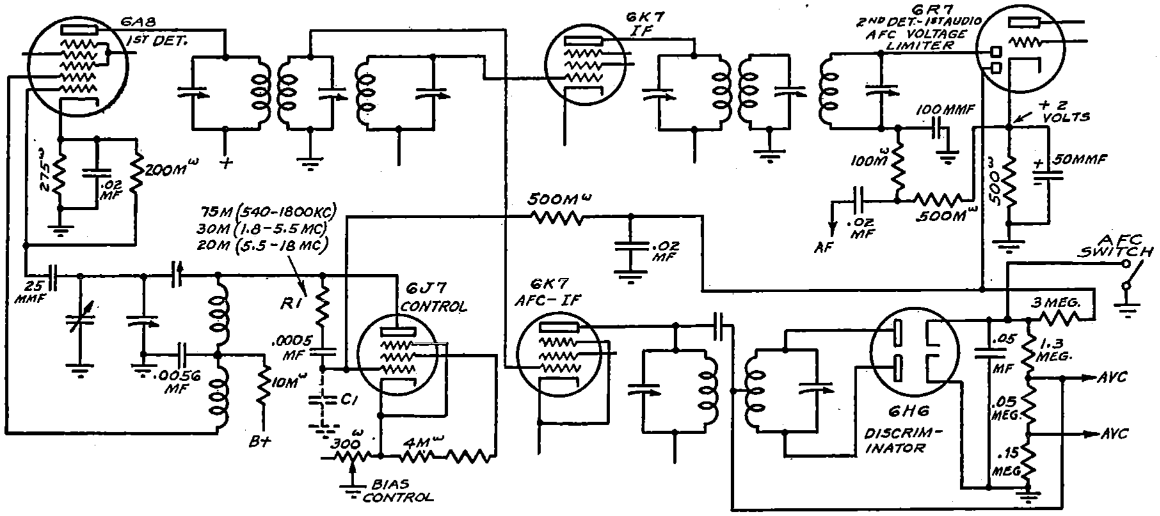


Fig. 50.—The AFC system employed in a number of Crosley receivers.

ance across the oscillator tuned circuit, and in extreme cases, cause blocking of the oscillator. The use of the voltage limiting diode removes this possibility since the grid of the control tube can never go positive enough to cause the oscillator to stop functioning.

As far as the oscillator is concerned, this much of the circuit is conventional; essentially, the same basic system described in Fig. 48 is used. The r-f voltage appearing across the tank circuit of the oscillator is fed to the plate of the 6J7 control tube in the conventional manner, so that the control tube obtains its plate voltage through the oscillator grid coil. Note that a different value of resistance is used in the phase shifting network for each of the three wave bands. These are respectively 75M, 30M and 20M ohms for the broadcast, police and amateur, and the short wave bands. While no condenser is used between the grid of the control tube and ground, actually there is sufficient capacity between the grid and ground due to the tube capacity and associated wiring (as indicated by C1) to provide the required capacity for shifting the phase.

The reason for the use of smaller values of resistance in the phase shifting network for the higher frequency bands becomes apparent when we consider that R1 must be large with respect to the reactance of C1 in Fig. 50, and at the same time must maintain a more or less fixed relation with respect to the reactance of C1 at the particular frequency of operation. Since the reactance of C1 is considerably less on the short-wave bands, it follows that the best performance is secured by using a progressively lower value of R1 on the higher-frequency bands. This problem was not encountered in the case of the other receivers discussed because these circuits are operative only in the broadcast band.

An interesting point about the oscillator control tube is that the bias for this tube is adjustable by means of a rheostat in the voltage divider circuit. This control is ordinarily not adjusted, except when the control tube is replaced or the receiver is being aligned. The most desirable control action is obtained when the control is set so that the bias voltage on the 6J7 is 4.8 volts. Because of the infrequent need for adjustment of this control, the receiver must be removed from the cabinet before the control is accessible.

AFC in Double Superheterodynes

The double superheterodyne principle is quite old, and, as you may recall, was used in receivers quite a few years back. Its revival at this time in a number of current receivers is due to the fact that in connection with AFC it offers certain advantages. This will be brought out in the course of the following discussion. However, before we go into the application of AFC to the double superheterodyne, let us review briefly the manner in which the circuit functions.

As the name implies, a double superheterodyne is one in which the superheterodyne principle is applied twice in succession. In Fig. 51 we show the block diagram of a modern double superheteodyne, the Westinghouse Model WR-315 which is equipped with AFC. For the moment we shall disregard the components which are indicated in heavy black squares and consider the path of a signal through the receiver, without regard to any AFC action.

For the sake of clarity, we shall assume that the input signal to the receiver has a frequency of 5000 kc. As the figure shows, this signal is amplified in the first r-f stage, which uses a 6K7 tube, and is passed on to the first detector-oscillator stage, which employs a 6A8. Here the 5000-kc signal is mixed with the 5465-kc frequency produced by the first oscillator, so that an intermediate frequency of 465 kc (5465-5000) is produced in the plate circuit of the first detector. Up to this point you will note that the action is identical with that which takes place in any ordinary superhetorodyne.

The 465-kc frequency, you will observe from the block diagram, is not amplified in the ordinary manner, but instead undergoes a further frequency change in a second detector; this tube should not be confused with the conventional second detector. Here the 465-kc signal mixes with the 365-kc voltage generated in the oscillator section of the second 6A8 and, as a result, a second intermediate frequency equal to 100 kc is produced.

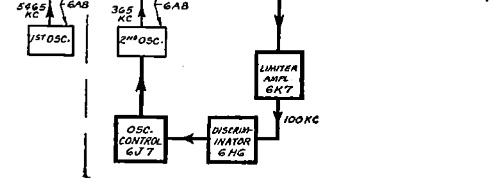


FIG. 51.—Block diagram of a double superheterodyne such as is used in the Westinghouse Model WR-315.

To appreciate why this double superheterodyne circuit is used in connection with AFC, it is necessary to understand which circuits remain tuned to the same frequency regardless of the signal frequency being received, and which circuits must be tuned to correspond with the signal frequency being received. This is clearly shown in figure 51 and you will observe that all the circuits to the right of the vertical line are fixed tuned. On the other hand, the r-f, first detector, and first oscillator circuits are, of course, tuned in the conventional manner by means of a three-gang variable condenser. A further study of the block diagram will show you that most of the selectivity in a receiver of this type resides in the final i-f system (100 kc), since four tuned circuits are associated with this frequency, while only two are associated with the 465-kc intermediate frequency, and these are purposely made broader than normal.

Because of the predominance of the receiver selectivity in the 100-kc i-f amplifier, whether the receiver is tuned correctly as a whole will depend upon whether the signal passes through the 100-kc i-f amplifier at 100 kc or at a frequency different from this—say 95 kc or 105 kc. Naturally an error in the tuning of the gang condenser in the variable-tuned section will upset the frequency of the signal passing through the i-f amplifier, since it will cause the first detector output to differ from 465 kc. This is the normal manner in which errors in tuning are introduced.

The important thing to note, however, is that a change in the frequency of the second oscillator, which normally operates at 365 kc, will also change the frequency of the signal passing through the 100-kc amplifier. That is, if the frequency of the oscillator is changed from say 365 kc to 369 kc, then the frequency of the second i-f signal will be changed from 100 kc to 96 kc. In other words, whatever change is made in the frequency of the second oscillator—which normally operates at a fixed frequency—is reflected as an equal change in the final intermediate frequency.

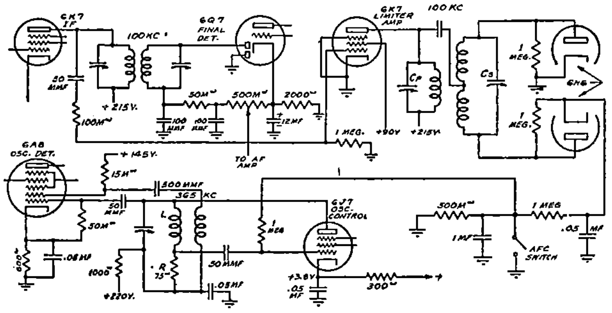


Fig. 52.—Schematic showing connections of the limiter amplifier tube. Note the circuit of the 6H6 discriminator.

The significant thing about this is that AFC is made possible by controlling the frequency of an oscillator *which operates about a fixed frequency.* In the conventional superheterodyne, we saw that the AFC system in some of these receivers was operative only on the broadcast band, and that in others the constants of the oscillator control circuit had to be changed on the different bands so as to secure the desired degree of control over the entire frequency range covered by the receiver. This of course is due to the fact that the operation of AFC in these receivers is dependent upon controlling the frequency of an oscillator which tunes over an extremely wide range.

Essentially, then, the use of the double superheterodyne principle makes it possible to obtain a *uniform AFC action on all bands* by controlling the frequency of the second oscillator—the fixed-frequency oscillator. Any error which may occur in the variable-tuned section, so that the signal going into the second detector is not exactly 465 kc, will be corrected by a change in the frequency of the fixed-frequency (365 kc) oscillator—with the result that the final output from the second detector will be the required 100-kc signal.

The Limiter Amplifier Stage

The block diagram in figure 51 shows the elements belonging to the AFC system in heavy black outline. The output of the last i-f stage is coupled to the grid of a so-called limiter amplifier stage which feeds the discriminator circuit. The control voltage produced by the discriminator is in turn fed to a 6J7 oscillator control tube which controls the frequency of the oscillator having a nominal frequency of 365 kc.

There are a number of points of interest in this system and for this reason we have drawn the circuit in some detail in Fig. 52. Beginning at the output of the last i-f (100-kc) stage, you will note that a 50-mmf condenser attached to the primary winding of the last i-f transformer is used to feed the 100-kc signal into the grid of the tube called the *limiter amplifier*. You will observe that the limiter amplifier is essentially another i-f stage which amplifies the signal before it is fed into the discriminator circuit. Although this stage does not receive any AVC voltage, it operates to provide an essentially constant output at the discriminator. On weak signals the full gain of the stage is available to bring up the signal fed to the discriminator, while on strong signals, the flow of grid current through the one-megohm grid leak acts to limit the gain so that the output of the tube cannot exceed a certain value. In this way, a more uniform AFC action is obtained on weak as well as strong signals.

A slightly different circuit arrangement from those previously described is used in the discriminator circuit of this receiver. Essentially the action of this circuit also depends upon the phase difference in the directly coupled voltage and the inductively coupled voltages in the secondary winding of the discriminator transformer, but the arrangement of the diodes and their load resistors is different from that employed in the previous circuits. The final control voltage output of the discriminator circuit is that which is developed across the 500M-ohm load resistor, across which is shunted the AFC switch. The manner of operation of this type of discriminator is fully described in "Automatic Frequency Control Systems."

The oscillator control circuit also incorporates a slightly different method for obtaining the 90° out-of-phase voltage which is required for the grid of the control tube. As you will observe from the figure, a 75-ohm resistor is placed in series with the inductive leg of the tuned circuit. Since this resistance is small in comparison with the inductive reactance of the coil L, it follows that the current through L and R, as well as the resulting voltage drop across R, will lag the voltage across the tuned circuit by approximately 90°.

This 90° laggage voltage is fed over to the grid of the control tube through a 50-mmf condenser and the grid of the control tube is returned to the AFC bus through a 1-megohm filter resistor. As a result of the lagging grid voltage, the control tube draws a plate current which lags the plate voltage by 90° and therefore the control tube appears to the tuned circuit as an inductance. As before, the value of the inductance, which is reflected across the oscillator tuned circuit, varies in accordance with the mutual conductance of the control tube and this is in turn controlled by the magnitude and polarity of the AFC voltage.

You will observe that the only difference between the oscillator control circuit described here and that shown in Fig. 48, is the method by means of which the phase shift for the control-tube grid voltage is obtained. The former circuit employs a phase shifting network in parallel with the tuned circuit, while the present circuit obtains the required phase shift by the incorporation of a resistance in the oscillator tuned circuit itself.

This same general type of double superheterodyne circuit which is used in the Westinghouse WR-315 is also used in the Arvin Models 1237, 1247, 1247A described on Arvin p. 8-22. The general theory of operation as explained above in connection with the Westinghouse receiver is directly applicable to the Arvin models.

AFC in G.E. FA-80

An example of the application of AFC in automobile radio receivers is illustrated in the G.E. FA-80 circuit shown in Fig. 53. Turning our attention to the discriminator circuit used in this receiver, we note a number of interesting variations. A 100M-ohm resistor is used to replace the i-f choke which is used at this point in the G.E. home receivers, while an i-f filter consisting of a 47M-ohm resistor and two 250-mmf condensers prevents the i. f. from reaching the junction of the two 510M-ohm discriminator load resistors. The audio voltage is taken from this point and it is consequently necessary to filter out the i-f signal voltage so as to prevent this from getting into the a-f amplifier.

Permanence of the discriminator tuning adjustment presents a considerable problem in AFC design for auto radio receivers, since a slight change in the alignment of the discriminator circuit will result in extremely poor operation of the receiver and an especially low signal-to-noise ratio. These problems have been successfully solved in the G.E. FA-80-receiver by using an iron-core discriminator transformer and a special type of fixed trimmer condenser. The inductance of the primary and secondary windings is tuned by movement of the iron cores and the transformer assembly is designed so that even extreme vibration will have no effect upon the inductance value. The primary winding is self-tuned, there being no trimmer condenser—

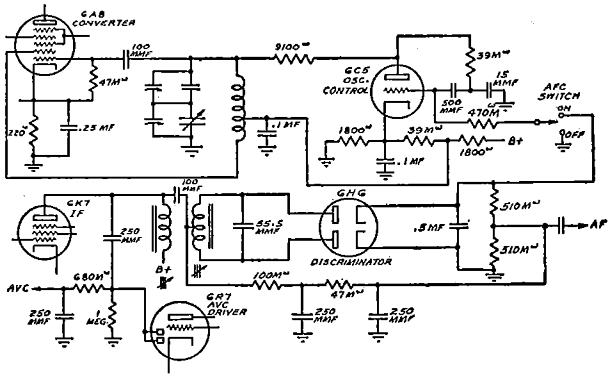


FIG. 53.—AFC system used in the G.E. Model FA-80 auto receiver.

while the secondary winding is tuned by a special 55.5-mmf trimmer condenser. This trimmer condenser consists of a single strip of mica which is silver plated on both sides, the plating forming the two electrodes of the condenser. Capacity variations due to temperature, humidity, and aging are reduced to a minimum through this form of construction so that permanence of the discriminator alignment is assured.

It is worth mentioning that the discriminator does not supply the AVC voltage. The latter is secured from a diode, but a separate AVC diode, which receives its voltage from the primary winding of the discriminator transformer, is used. The 250-mmf coupling condenser feeds the signal into the diode section of the 6R7 driver, while a 1-megohm resistor serves as the diode load. This arrangement makes it possible to obtain reduced selectivity in the AVC circuit.

The oscillator is conventional and requires no special comment. As to the oscillator control stage, several interesting features are evident. To start with, a triode is used in place of the conventional screen grid tube. In accordance with usual practice, the plate of the oscillator control tube is connected to the oscillator tuned circuit through a limiting resistance of 9100 ohms, which has the further purpose in this receiver of preventing the control tube from seriously damping the oscillator tuned circuit for high positive values of AFC voltage. The phase shifting circuit consists of a 39M-ohm resistor in series with a 15-mmf condenser across the grid-to-cathode capacity of the control tube. As a result of the lagging r-f voltage which is thus applied to the grid of the control tube, the triode plate circuit appears to the tuned circuit of the oscillator as a variable inductance the magnitude of which changes in accordance with the AFC voltage applied to the grid of the control tube. The remainder of the circuit is quite conventional.

Grunow Models 12B, 12W

The essential portions of the AFC circuit used in this receiver are shown in Fig. 54. Starting at the plate circuit of the second i-f tube, you will note that this is coupled to the two diodes of the discriminator through a conventional split-secondary discriminator transformer. Since an i-f choke is not used in the discriminator, the junction of the two diode loads is not by-passed. The load resistance of the lower diode is in two sections, consisting of a 330M-ohm resistor and a 150M-resistor. The function of these two resistors is to supply the proper amount of AVC voltage as well as the audio voltage. Since we are not especially interested in the a-f system at the moment, the tone compensating network, including the volume control, is omitted in this abridged schematic. In accordance with usual practice, the cathode of the the upper AFC diode is by-passed to ground with a rather large condenser, in this case .4 mf. The AFC voltage developed at this point is fed over to the grid of the 6J7 control tube through a 4-meg resistor which is by-passed to ground at the control grid end by a .2-mf condenser.

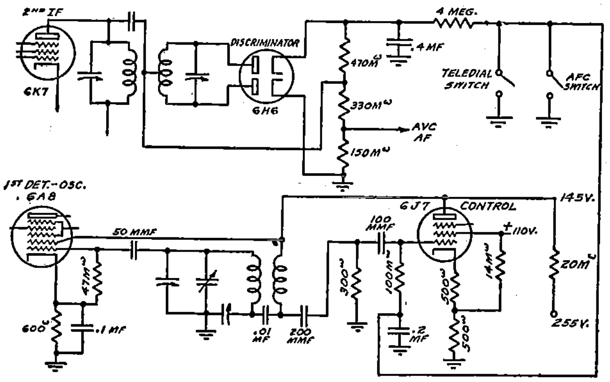


Fig. 54.—Schematic of the AFC circuit of the Grunow Models 12B and 12W.

Two switches are provided across the AFC bus, one of which is designated as the AFC switch, while the other is called the *Teledial* switch. The purpose of the AFC switch is to short the AFC bus so that the AFC action can be eliminated when it is desired to have manual operation of the receiver. The *Teledial* switch, on the other hand, is mounted directly on the dialing mechanism, and functions to short the AFC voltage momentarily when the index pin associated with the particular station being tuned strikes the stop pin. In this way the AFC system is made to take control of the signal on the desired channel and is prevented from holding a considerably stronger signal on an adjacent channel in preference to the desired signal.

The control tube circuit has several unusual features which merit mention. With reference to the arrangement of the 6J7 circuit, you will note that a combination of fixed- and self-bias is used. The self-biasing action is secured by returning the cathode of the 6J7 to ground through two 500-ohm resistors, while the fixed bias effect is obtained by connecting a 14M-ohm resistor from the 110-volt tap on the voltage divider (screen of the 6J7) to the junction of the 500-ohm resistors. Since self-biasing of the control tube makes for stability and independence of tube and voltage characteristics, while fixed bias increases the sensitivity of the control tube action (because degeneration due to the voltage drop across the cathode resistor is reduced), the combination of these two bias arrangements makes it possible to obtain a stable control tube action without undue sacrifice of control tube sensitivity.

Turning our attention to the oscillator circuit, we note that a 6A8 tube is used. The coupling to the control tube is different from the circuits which we have previously discussed, in that the plate of the 6J7 control tube is connected across the feedback circuit of the oscillator rather than across the grid winding. For this reason it follows that the reflected reactance of the control tube is shunted across the feedback circuit rather than across the tuned circuit. The excitation to the control grid of the control tube is obtained by coupling the control grid to the r-f voltage present across the series oscillator paddler through a network consisting of a 200-mmf condenser and a 300-ohm resistor. The final voltage applied to the control grid is the voltage across the 300-ohm resistor. The phase relations existing across the various portions of this circuit through the band are rather complicated, but this much can be said: that the object of the unusual circuit arrangement is to secure as uniform a control action as possible over the broadcast band.

Although this receiver has three bands, we have omitted the band switching arrangement and have shown only one hand. Since the AFC system functions only on the broadcast band, this procedure is entirely justified.

Grunow Model 15W

The discriminator circuit employed in this receiver is essentially the same as that used in the Model 12B, so that to avoid duplication of material we have shown in Fig. 55 only the oscillator and oscillator control circuits which use a somewhat different circuit.

Turning our attention to the grid circuit of the control tube, we note that the tube receives its r-f excitation directly from the r-f voltage present across the oscillator grid coil. Note, by the way, that the oscillator coil is tapped and connected to the cathode, so that feedback is provided through the cathode circuit and the need for a separate tickler winding is eliminated. The phase shifting network in the grid circuit consists of a 75M-ohm resistor in series with a 10-mmf condenser, the capacity of the latter being increased by the normal grid-to-cathode capacity of the tube and associated wiring.

In contrast to the other control tube circuits which we have presented, the plate of the control tube is shunt fed through an r-f choke, the inductance of which is fairly high in comparison with the inductance of the oscillator grid coil. The variable inductance, which is built up across the plate circuit of the control tube because of the lagging grid excitation, is coupled to the tuned circuit of the oscillator through a .001-mfd condenser, as shown in Fig. 55.

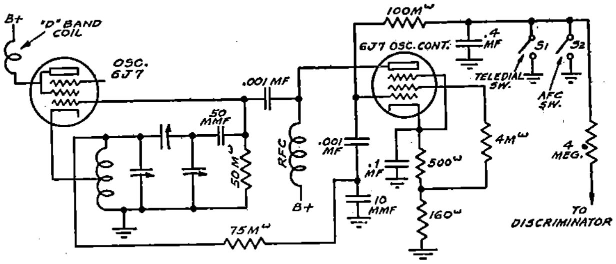


FIG. 55.—The oscillator and control circuit of the Grunow Model 15W. Compare with FIG. 54.

Note that with this arrangement it is unnecessary to maintain the grid coil of the oscillator above ground by the amount of plate voltage needed for the control tube. The operation of the Teledial and AFC switches is in accordance with the facts given in connection with the Model 12B receiver.

RCA Model 812K

This receiver is interesting because it combines the features of AFC with those of the automatic tuning systems which were used on a number of receivers several years ago. The latter arangement makes it possible to tune in a desired station automatically, merely by pressing the appropriate push button. As we explained briefly in the opening chapter, although the AFC circuit functions independently of the motor drive, it is of great assistance in insuring correct tuning. Thus, after the motor drive tunes in the desired station automatically, within several kilocycles, the AFC circuit takes hold and corrects the tuning to within a small fraction of a kilocycle.

Fig. 56 is a partial schematic of the receiver, showing the essential details of the discriminator and oscillator control circuits. Tracing the path of the signal as it leaves the plate circuit of the second i-f stage, we note that the signal feeds into the primary winding L20 of an iron-core transformer, tuned inductively so as to resonate at 460 kc, the i-f peak. The secondary winding, L21, of this transformer is likewise tuned inductively by movement of its iron core, but you will note that this tuned circuit is completed through an additional winding L24, which is inductively coupled to a second i-f transformer. The small pickup winding L24 is symmetrically located between the split primary winding L22 so as to form a balanced input to the discriminator.

At first glance it might appear that the tuning of the discriminator secondary could be accomplished by the movement of the iron core of L22. Actually, however, it is the functions of this iron core to balance the two windings, so that each diode section of the discriminator transformer receives the same amount of inductively coupled i-f voltage. The adjustment of L22 is therefore permanently set at the factory and ordinarily is not to be changed. The auxiliary winding L23, which is in shunt with L22, makes it possible to vary the total inductance in the final tuned circuit of the discriminator transformer and hence to peak this circuit correctly. Note that the movement of the core of L23, which is necessary to obtain the proper tuning adjustment, does not influence the balancing of the circuit, since the latter remains fixed by the position of the iron core in L22.

Of interest is the use of fixed trimmer condensers throughout the i-f amplifier and discriminator, the tuning of the several circuits being in every case accomplished by movement of the iron cores associated with each of the i-f coils.

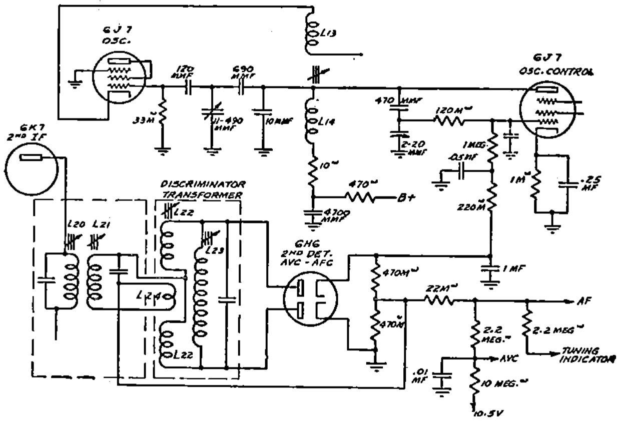


Fig. 56.—AFC system used in RCA Model 812K.

Turning our attention to the oscillator and oscillator control circuits, we note that a 6J7 with the screen and plate tied together is used as the oscillator tube. Both for reasons of simplicity and because the AFC circuit is inoperative on all bands except the broadcast band, the wave-band switch connections have been omitted, and the circuit for the broadcast band shown. Feedback for the oscillator is accomplished through the coil L13 in the cathode circuit, while the iron-core coil L-14 serves as the oscillator grid coil. The r-f voltage appearing across the oscillator coil is fed over to the grid of the 6J7 oscillator control tube through a 470-mmf condenser and a 120M-ohm resistor. This latter resistor, in combination with the grid-to-cathode capacity of the control tube, forms the phase shifting network to supply the lagging grid voltage. It may be noted that the 2-20-mmf condenser shown in the diagram functions to trim the oscillator at the high-frequency end. The adjustment of the oscillator tracking at the low-frequency end of the broadcast band is accomplished by varying the inductance of L14, by moving its iron core.

In addition to supplying AFC voltage, the discriminator supplies voltages for the tuning indicator, the AVC system, and the audio amplifier. The tuning indicator voltage and the AVC voltage are taken from the junction of the two discriminator load resistors and passed on to the appropriate points through suitable resistor-condenser filters, so as to prevent interaction between the circuits and to provide the proper time constants.

An interesting feature of the circuit arrangement is that the minimum bias voltage for the controlled tubes is supplied through the AVC feed line. This is secured by returning the AVC feed line to a point on the voltage divider which is 10.5 volts negative with respect to ground, and provides a minimum bias of approximately 3 volts to the several controlled tubes. The circuit arrangements is such that the discriminator functions in a normal manner and is not interfered with as a result of this negative bias voltage.

The electric tuning circuit used in this receiver which provides automatic push button tuning is described in rather complete detail in the service notes shown on pages 8-164 and 8-165 and will therefore not receive any further description here.

THE ELECTRONIC PIANO

The difference in tone quality which enables us to distinguish between different instruments is due to two properties of the sound wave:—harmonic content and envelope shape. For the piano and violin wave-forms shown in Figs. 1 and 2 respectively, the envelope is indicated by the dotted lines and the difference in shape between the individual waves is due to the difference in their harmonic content. Although both these tones have the same fundamental frequency, it should be observed that their wave-form and envelope shape differ, and it is this difference which accounts for the variation in the quality of the two tones.

It is possible for a stretched string to vibrate in more than one manner and two very common modes of vibration for a string of the type used in a piano are shown in Figs. 3 and 4. In Fig. 3, the string is vibrating in its fundamental mode, and this is the type of vibration which would in general be produced if the string were plucked or tapped at a point half way between the two stops. On the other hand, if the string were struck ⅙ of a wave from one stop, then the type of vibration produced would be similar to that shown in Fig. 4. As in the other figures, the dotted lines indicate the intermediate positions occupied by the string as it vibrates between the two extremes of its motion, the latter being indicated by the heavy envelope lines. It is possible, and in fact it is generally true, that a stretched string, as for example, a piano string, vibrates simultaneously at frequencies which are in harmonic relationship. Thus the typical piano wave-form shown in Fig. 1 is caused by the string vibrating simultaneously in the manner indicated in Figs. 3 and 4, so that it is producing the fundamental tone and its third harmonic; the presence of the latter is clearly evident in Fig. 1.

Basically, the electronic piano operates by changing sound impulses created by the vibrating piano strings into corresponding electrical impulses. In the Electone, a schematic of which is shown on Krakauer page 8-1 in Volume VIII, a small pick-up screw is used and in conjunction with the vibrating string forms what is essentially a condenser microphone. This set-up is illustrated schematically in Fig. 5, from which it will be noted that the metal piano string forms the grounded side of the condenser microphone while the pick-up screw forms the high side of the microphone. When a string is struck by the hammer, the distance between the string and the pick-up screw varies so that the potential at the pick-up screw, and therefore the potential on the grid of the pre-amplifier tube, changes in accordance with the wave-form of the vibration. In this way the mechanical vibration of the string is translated into corresponding electrical impulses which are reproduced by the speaker of the piano. This, in brief, is the basic method of operation of the Electone piano.

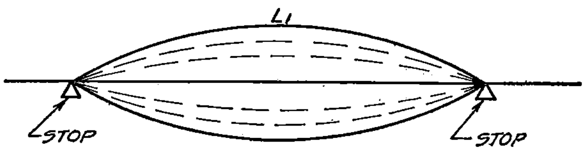


FIG. 3

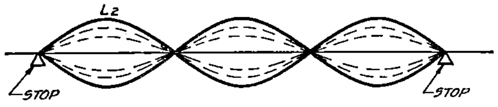


FIG. 4

FIG. 3 shows a string vibrating at its fundamental frequency and FIG. 4 shows one vibrating at the third harmonic.

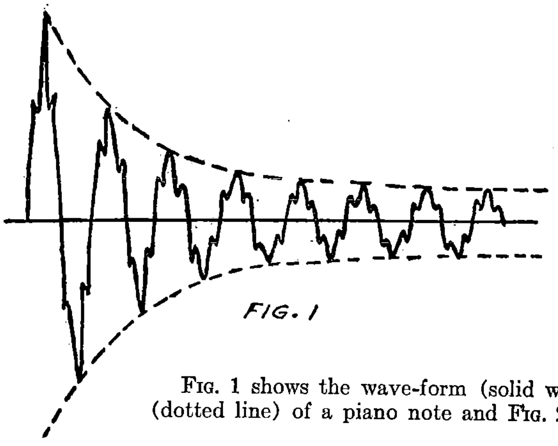


FIG. 1

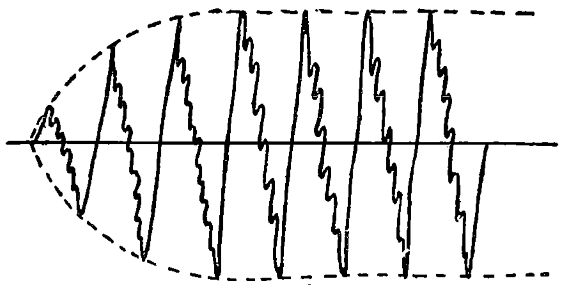


FIG. 2

FIG. 1 shows the wave-form (solid wave) and envelope (dotted line) of a piano note and FIG. 2 those of a violin.

It should be pointed out that the placement of the pick-up screw is of extreme importance in determining the quality of the sound which is reproduced. For example, if we consider that the note shown in Fig. 1 is struck, then the string vibrates at its fundamental frequency and its third harmonic at the same time; that is, both the vibrations of Figs. 3 and 4 are superimposed on each other. If we further assume for the moment that the pick-up screw is one-third of the distance away from the stop, then the fundamental will be reproduced with considerable strength since the amplitude of vibration of the string is comparatively strong at this point. On the other hand, as far as the third harmonic component of the vibration is concerned, Fig. 4 shows that the third harmonic motion is stationary at this point. Therefore the third harmonic would not be picked up, and only the fundamental tone would be reproduced by the speaker. This example is cited to show how the apparent quality of a vibrating string depends upon the placement of the pick-up screw. In the Electone piano, the vibration from each string is picked up by a carefully positioned pick-up and the output of all the pick-ups fed to the grid of the pre-amplifier tube.

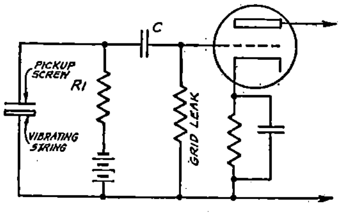


FIG. 5

Simplified schematic of the pick-up and input of the Electone piano.

It is claimed that the output of the electronic piano has a better tone quality in a smaller size instrument than the corresponding acoustic piano. A short string in an acoustic piano, in order to play loud enough, must be comparatively stiff and this stiffness lowers its tonal quality. Since a great amount of power is not required with the electronic method, it is possible to use a tonally correct short string and to compensate for the lack of power by means of additional amplification. This basically is the advantage of the electronic over the acoustic piano.

Other advantages are that wobblators may be used to give tremolo effects; that electronic tone controls can be used to modify the tone, and that a swell-pedal or foot-operated volume control can be used to give complete control over the volume of the note even after the key is struck. It is also possible to use two or more separate pick-ups placed at various points along the string and to produce varying tone qualities by suitably mixing the outputs of these pick-ups.

Organ-like tones may be obtained on the electronic piano through a suitable manipulation of volume controls which may be either manually or automatically actuated. This is accomplished by modifying the wave-form envelope and hence altering the tone quality. In this connection, the organ has virtually the same envelope as that shown in Fig. 2; by knocking off the initial hump in Fig. 1 by means of a volume control, and bringing up the volume control from zero immediately after the note is struck, a wave-form envelope similar to that in Fig. 6 would be produced. This tone is substantially organ-like in character and can be obtained by means of the simultaneous manipulation of the keys and swell pedal. There are a number of different methods for automatically accomplishing this without using the swell pedal.

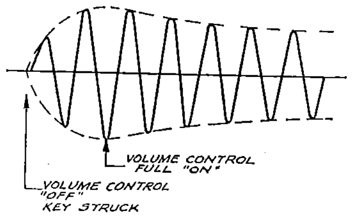


FIG. 6.—By manipulating the volume control the wave envelope can be changed so that the note will have an organ-like quality.

While the instrument described uses a condenser pick-up, it is also possible to use other pick-ups such as those of the magnetic or crystal types.

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