HOW IT WORKS

Special Section of Volume IX

RIDER'S MANUAL

by

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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 IX. 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 IX 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.

This Special Section is smaller than was originally intended and advertised, because the dial mechanisms and tuning arrangements selected for inclusion in this section have been inserted in the main volume among the respective manufacturers' products.

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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.

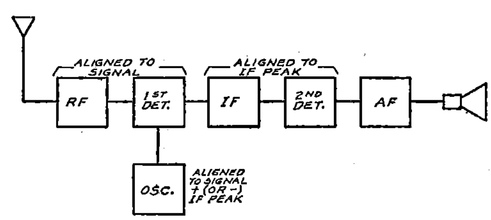
There is a great deal to be said for this policy of condensing alignment data so as to exclude all general information which should be part of the equipment of every well-informed serviceman. For one thing, it releases a considerable amount of space which can be used to better advantage for the inclusion 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,



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

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 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 re-alignment, 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 over-estimated; 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.

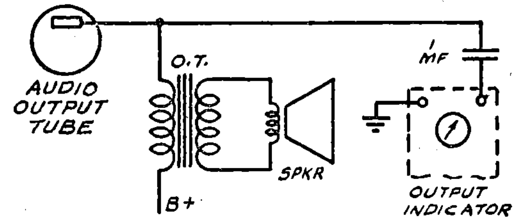
To avoid short circuiting the d-c grid path in the receiver, the output terminal of the signal generator should contain a blocking condenser, the capacity of which is of the order of .01 mf. In many signal generators this condenser is contained internally, but there are a considerable number of signal 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.

The aforementioned discussion relative to the connection of the signal generator refers to conventional alignment methods. The application of the Rider Chanalyst to alignment ordinarily requires but one connection of the signal generator and this is at the antenna, where the signal generator is tuned to a radio frequency such as 600 kc. This connection is the same as normally used for alignment of the radio frequency portion of the receiver. The manner in which the alignment work is carried out is discussed elsewhere in this book, under the various headings of "r-f. alignment," "i-f. alignment," etc.

Output Meter Considerations

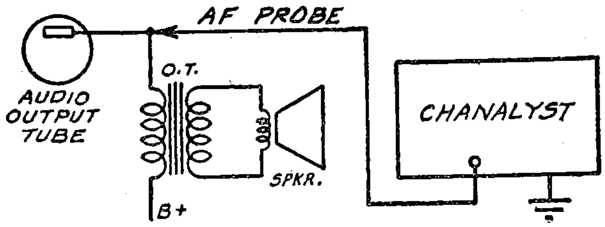
There are many different types of output meters used for alignment work, but as far as the alignment procedure is concerned, they can be divided into two different classes. One group of output indicators, which we shall consider first, measures directly the amount of audio output, while the second group 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.



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

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.

A convenient arrangement for those who own the Rider Chanalyst is to use the AF Channel as an output meter. This channel can be connected any place in the audio system of the receiver. The illustration shows the AF Channel connected across the plate of the output tube. The "ground" of the instrument is connected to the chassis of the receiver and the a-f. probe is joined with the plate of the output tube. It can just as readily be connected to the control grid or plate of any of the a-f. tubes in the system, or to the voice coil.



The AF Channel probe is connected to the output tube plate or to some other point in the audio system.

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.

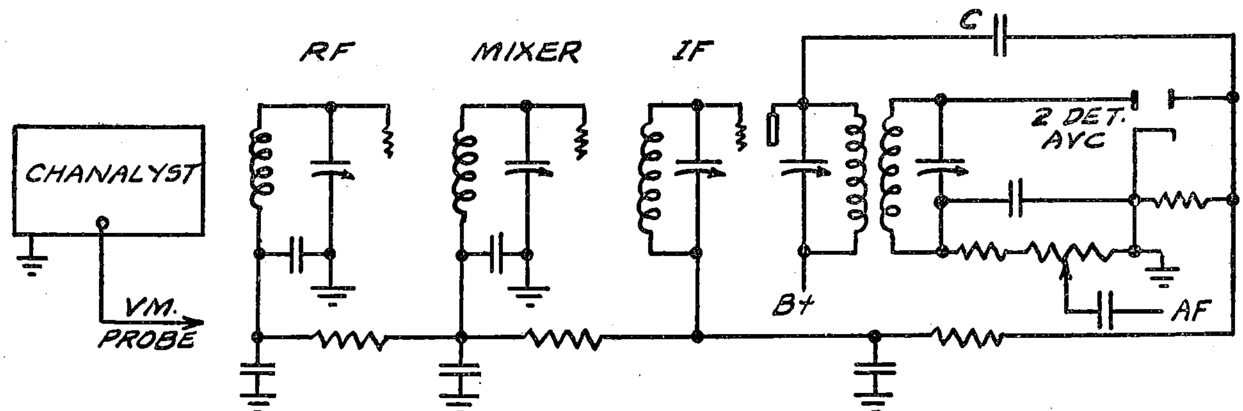
In using this type of output meter, the action of which depends upon the amount of audio output, the output of the signal generator must constantly be reduced so that the lowest possible value of input signal is used. The point here is that the use of a large input signal will tend to keep the audio 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.

In this connection, the Electronic Voltmeter in the Rider Chanalyst serves admirably as an accurate and very easily connected indicator. The voltmeter is adjusted either to the 5 or 25 volt range, which ever is required, and the voltmeter probe is connected any place along the a.v.c. bus or across the second detector load. The instrument ground is connected to the chassis of the receiver as shown in the illustration.

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.



The voltmeter probe is connected to the AVC bus or to the grid of one of the controlled tubes.

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.

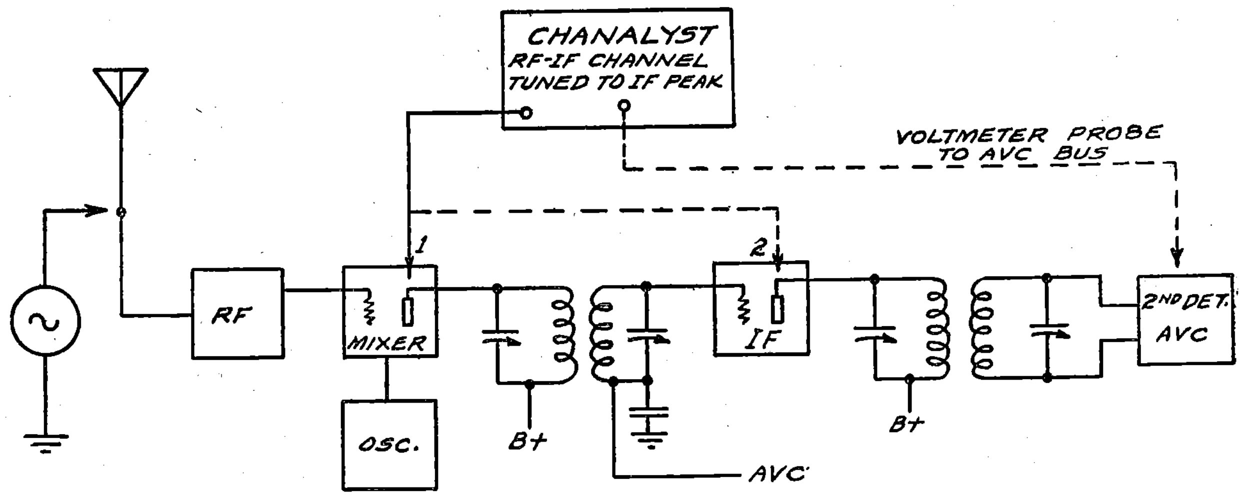
As a general rule, elaborate instructions are provided in the Rider Manuals for the alignment of high-fidelity receivers, and it is recommended that these instructions be followed carefully in order to insure good receiver performance.

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 1/4 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.



The RF-IF probe is used in the mixer and i-f systems and the voltmeter probe is used in the diode circuit.

Supplementary to the method of i-f. alignment outlined in the foregoing paragraphs, a somewhat different method can be used by those men who own the Rider Chanalyst and wish to use the device for i-f. alignment.

When using this device, the i-f. amplifier is aligned after the r-f. and oscillator systems have been properly aligned, as described in the respective sections of this discussion. With the signal generator connected to the antenna, and the r-f. circuits aligned at 600 kc.—the RF-IF Channel of the instrument is tuned to the correct i-f. peak and is connected to the plate of the mixer tube. The oscillator padder then is adjusted for maximum indication upon the RF-IF Channel eye. Then the RF-IF probe of the Chanalyst is moved to the plate of the i-f. tube and the i-f. trimmers on the transformer coupling the mixer tube to the i-f. tube are adjusted for maximum indication.

Then the RF-IF probe is removed from the i-f. tube plate and if the next tube is the second detector, the voltmeter probe is connected to the a.v.c. bus and the trimmers upon the i-f. transformer which couple the i-f. tube to the second detector are adjusted for maximum a.v.c. voltage indication.

In the event that two i-f. stages are used, then the RF-IF probe is moved from the plate of the first i-f. tube to the plate of the second tube and the trimmers adjusted. When trimming the second detector input transformer, the a.v.c. voltage is used as the indicator. During all this time, the signal generator is connected to the antenna of the receiver. Naturally all of these adjustments are made with "maximum selectivity" in the i-f. system.

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 impedence, 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

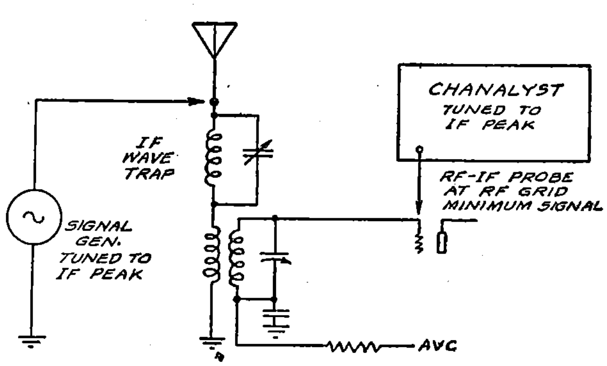
Following the alignment of the i-f amplifier, it is a good general policy to check the position of the dial pointer with respect to the condenser gang setting. The procedure for doing this varies for different dials, and wherever this data is given by the manufacturers, it has been included in the manual 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.

Adjustment of the i-f. wave trap with the Chanalyst is carried out in the following manner. The signal generator is connected to the antenna and



Use of chanalyst to adjust wave-trap.

tuned to the i-f. peak of the receiver. Then the Chanalyst is resonated to this same frequency by placing the RF-IF probe at the antenna and tuning the instrument. The RF-IF probe is moved to the control grid of the first r-f. tube.

With the probe at the grid of the first r-f. tube or mixer tube (if the receiver does not employ an r-f. stage), the wave trap is adjusted for minimum signal indication with the signal generator output advanced to produce a strong signal.

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.

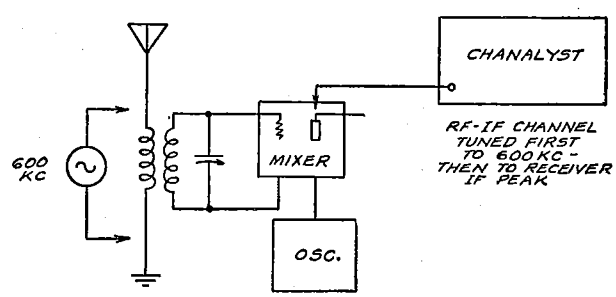
As a general rule, the adjustment of the high-frequency oscillator trimmer follows the alignment of the i-f amplifier. To make this adjustment, the signal generator should be connected to the antenna post of the receiver, and both the signal generator and the dial of the receiver set to the same frequency 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.

As a general rule, no provision is made for alignment of the r-f. stages at the low frequency end of the broadcast band. However, those service organizations who own a Chanalyst can line up the r-f. system with ease and avoid "rocking" when adjusting the oscillator padder.

To line up the r-f. portion of the receiver at say 600 kc., a 600 kc. signal is fed in at the antenna and this signal is checked at the mixer plate. The receiver is tuned for maximum indication at the mixer plate at 600 kc. The receiver oscillator is not in use during this test. The maximum signal indication is obtained at the mixer plate in accordance with the data furnished in the paragraph devoted to "rocking" of the low frequency oscillator padder.

After the correct resonance is established at 600 kc. in the r-f. and mixer circuits, the receiver oscillator is adjusted for the maximum i-f. signal.



The RF-IF probe is used when aligning the r-f system and also when adjusting the oscillator padder.

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.

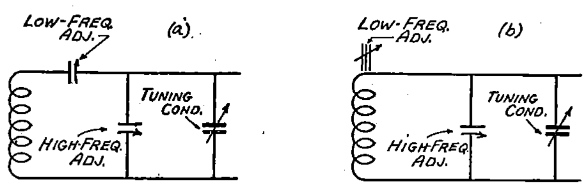
By means of the Rider Chanalyst it is possible to adjust the low-frequency padder without the necessity for rocking. As is the case with conventional alignment procedure, the adjustment of the oscillator padder is made after the adjustment of the trimmers at the high-frequency end of the band, generally 1400 kc.

To adjust the padder, the signal generator is connected to the antenna post and tuned to 600 kc. The RF-IF probe of the Chanalyst is next connected to the plate of the mixer tube and the receiver tuned so that the 600-kc. signal present at the mixer plate is greatest. The r-f. and mixer circuits are now tuned to the 600-kc. signal and the receiver dial should be left in this position in spite of the fact that the dial reading will in general differ by a few kilocycles from 600 kc. Without changing the receiver dial position, the RF-IF probe should be removed and the padder adjusted for maximum output as shown by whatever type of output indicator is being used.

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



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

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.

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 100-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 8470 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 19,060 kc (930 kc below the 20,000-kc signal frequency) 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 20,940 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.

PHILCO MYSTERY CONTROL

Several of the current Philco receivers employ a novel type of remote tuning called Mystery Control. These receivers can be tuned automatically to any one of eight stations, and the volume adjusted to any desired level, from a remote box which is about 6 by 8 by 4 in. This control box is entirely self contained; there are no wires to it from the receiver or from the power lines.

To tune a station (once the receiver is turned on manually, and the band switch set to "remote") it is only necessary to spin a telephone type dial to a stop and then release it. Within 15 seconds the receiver will retune itself to the station dialed. If the volume is too loud or too soft, soft and loud positions are provided on the dial. The set can also be turned off from the remote box.

Control Box

The control box is, essentially, a battery-operated oscillator (Fig. 1). It is designed so that it is normally off and is turned on only during the dialing operations. The molded dial has ten positions; eight station and loud and soft volume positions. This dial is connected to a pulsing mechanism which times the return of the dial so that connection is made to the several dial points at regular intervals.

As soon as the dial is rotated the filament of the type 30 oscillator tube is connected to its supply. As the dial returns the oscillator grid return is connected, intermittently, to the filament. This will set up an oscillation or pulse in the primary inductor (Fig. 1) for each contact on the pulser mechanism. As the dial comes to rest it again disconnects the tube's filament supply. Thus, for any particular position dialed, a given number of pulses are radiated from the primary inductor (Fig. 1).

To increase volume, the position at the extreme right is dialed and the end stop depressed until the volume reaches the desired level. The dial returns to its original position and, as it does so, sets up two pulses in the primary inductor. Depressing the end stop keeps the oscillator functioning and maintains the signal in the primary inductor on the second pulse.

To reduce volume, the second position from the right is dialed and the end stop held depressed until the volume reaches the desired level. This maintains the signal in the primary inductor on the third pulse. If the end stop is held down for a longer period the set will turn itself off.

Control Amplifier

A large coil or loop is located at the bottom of the receiver cabinet (secondary inductor, Fig. 2). This coil is tuned to the frequency of the oscillator in the control box by means of a trimmer located inside a cylindrical cardboard box in one corner of the loop. This loop or secondary inductor acts as the antenna to receive the pulses from the primary inductor in the battery operated control box.

These pulses are amplified first by a type 78 and further by a 6J7G tube (Fig. 2). A 6ZY5G diode is used as avc tube to maintain an even input to the 2A4G thyratron rectifier output stage, throughout a wide range of signal strength. The second diode is used as a limiter to dampen strong peaks, which might cause the thyratron tube to continue firing over too long a period.

The output stage of the control amplifier is an argon-filled thyratron rectifier. This tube is similar to a conventional gas-filled rectifier into which a grid has been placed. A rectifier passes current during the entire portion of the a-c cycle in which the plate is positive with respect to the cathode. A grid inserted between the plate and the cathode would permit current flow only during that portion of the cycle in which the grid has the proper bias. If both grid and plate voltages are taken from the

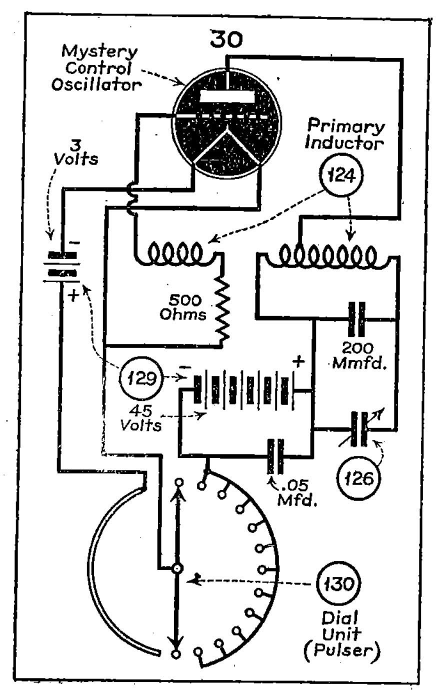


Fig. 1.—Schematic of Mystery Control Box.

same a-c source their phase difference could be arranged so that the grid would permit current flow during the entire half cycle in which the plate is positive with respect to the cathode, so that no plate current would flow, or somewhere between these limits.

A type 2A4G thyratron rectifier is used in the Philco control amplifier. The characteristic curve of this tube is given in Fig. 3. Ratings and other characteristics follow:

Filament voltage	2.5 v
Filament current	2.5 amp
Maximum anode current	
Forward	200 v
Inverse	200 v
Maximum voltage between any 2 electrodes	250 v
Maximum anode current	
Peak	1.25 amp
Average	0.10 amp
Maximum averaging time	45 sec.
Tube voltage drop	15 v
Cold starting time	2 sec.

The grid bias for the 2A4G, used in the control amplifier (Fig. 2), is taken from the secondary of the tube's filament transformer. The plate supply is taken directly from the a-c lines. With the plate and grid voltages thus out of phase, no plate current will flow until the signal from the control amplifiers is sufficient to overcome the bias and supply the proper potential to fire the tube. Once operation has begun it is characteristic of this tube to continue firing throughout the remaining portion of the a-c cycle in which the plate is positive with respect to the cathode, regardless of any change in the grid voltage.

The plate current of the 2A4G flows through and energizes the holding relay and permits operation of the stepping relay as discussed below.

Stepper Assembly

The stepper assembly houses a holding and a stepping relay. When the thyratron lights, the holding relay closes and the stepping relay pushes a ratchet as many times as the pulses sent out by the pulser in the control box.

There is a primary and a secondary ratchet. The stepper relay operates the primary ratchet which is connected to the primary switch. This switch controls the volume control motor and shorts the voice coil to ground in the station selecting positions. A muting switch, which connects the plates of the output tubes together is closed during the station selecting operation. The set, of course, is playing during changes in volume, but is muted as the secondary ratchet returns to its home position, and climbs to the station dialed.

The station selecting switch assembly is located beneath the chassis but is driven by the stepper assembly. There are three groups of contacts operated by the switch. One group switches the oscillator coils, the second group switches the antenna padding condensers and the third group of switches lights the pilot lamps indicating the station dialed.

Volume Control

The volume control and on-off switch are motor driven. The motor has an automatic clutch which releases and drops back as soon as the volume control is released by the stepper primary switch. This prevents over-shooting when changing volume and stops the gear train, which drives the volume control, immediately when the end stop is released on

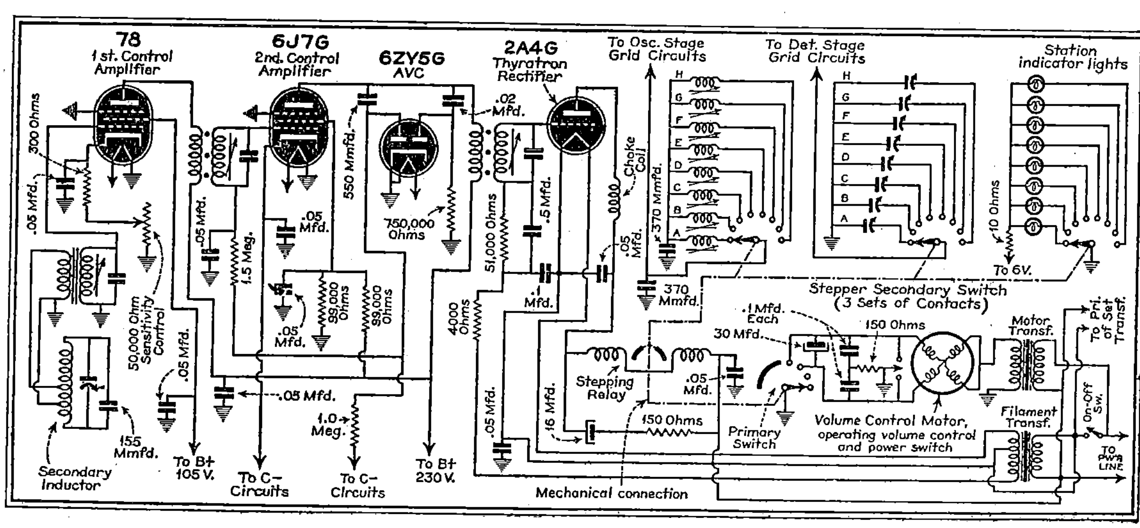


FIG. 2.—The Philco Mystery Control amplifier and station selector located in the receiver.

the control box. There is also a clutch in the volume control itself, so that the mechanism will not jam if the volume control lever is held down after the set is shut off.

The primary switch is a single-pole, double-throw switch which connects the desired winding in the volume control motor to increase or decrease volume. In parallel with this switch there is a single-pole, double-throw switch connected to the manual volume control. This switch is mounted directly below the receiver dial bezel.

Range

The normal range of the Mystery Control is within a circle of the receiver with a radius of about 25 feet. A sensitivity control is provided in the cathode of the 78 control amplifier, however, to fit a wide range of operating conditions. Normally, sufficient precautions are taken in the amplifier and remote control circuits to greatly reduce the possibility of electrical interference. There is little possibility of interference affecting the receivers if the sensitivity control is kept down to the first half of its total movement.

In some installations, however, owing to the presence of large metal objects around or near the receiver chassis, it will be necessary to increase the sensitivity of the control frequency amplifiers owing to the absorption of the metal surfaces. When this occurs, it will very likely be found that the same metal objects are shielding the receiver from excess static which would normally interfere with the control circuits in high setting of sensitivity control.

Control Frequencies

Mystery Control receivers are designed to operate on a control frequency somewhere between 350 and 400 kc. The purpose of a variety of control frequencies is to assure freedom from interference between the circuits of two sets operated in close proximity to each other. A 20-kc difference is recommended between control frequencies of sets that are operated in the same room.

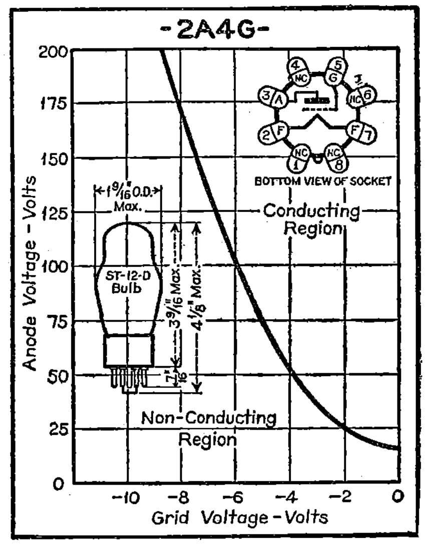


FIG. 3.—Grid voltage-plate voltage characteristic of the 2A4G Thyratron rectifier.

In homes or apartment houses the distance between receivers will determine the difference in frequencies that is necessary. When the control frequencies are 10 kc apart, receivers will not interfere with each other so long as their remote control cabinet is kept a minimum of 10 feet away from the second receiver. By having the control frequencies differ by 20 kc, the second cabinet can be placed anywhere even on top of the first cabinet.

The procedure for setting up stations on the Mystery Control receivers is similar to the procedure followed in setting up Philco electric-automatic tuning models. The eight stations, however, are automatically dialed by the remote unit instead of by push buttons.

—*Service Magazine.*

NEW RADIO SYMBOLS

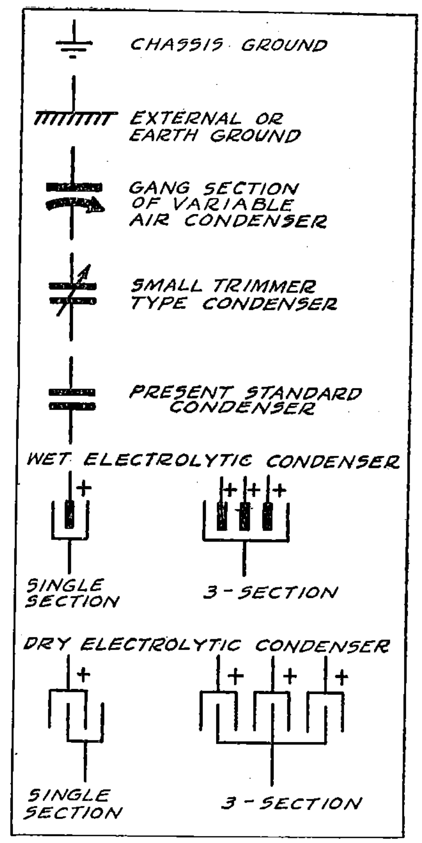
At the June, 1937, meeting of the Service Section of the Radio Manufacturers Association a committee was appointed to draw plans for the standardizing of symbols used in radio schematics. That such a committee should be formed was quite natural because the modern radio receiver utilizes components of various types of a single kind and it would be to the advantage of the entire radio service industry if all schematics illustrated the same type of component in the same manner. Furthermore, it would also be of advantage if the symbol used in the schematic immediately identified the type of component. Such was the reasoning of the various members of the committee.

At the recent meeting of this committee, namely during June, 1938, a number of symbols were proposed and we submit herewith the suggested form of standardization. These have not as yet been officially adopted by the radio industry, but examination of recently issued schematics produced by such manufacturers as Stewart-Warner, Galvin, and Wells-Gardner shows that some of the suggested symbols are already in use. Hence this information should be of value to you, because even if the suggested standardization is not accomplished (and we think that it will be), the individual receiver manufacturers have the right to use whichever symbols they see fit, and they no doubt will continue using the new symbols.

The accompanying illustrations are self-explanatory. However, a few supplementary words will not be amiss. The two types of ground connections are imperative because they appear in AC-DC receivers, wherein the chassis and external ground are not the same. For that matter a similar arrangement may be found in some a-c receivers as well.

The variable air tuning condenser and the adjustable trimmer are distinguished both by size as well as by the fact that the tuning condenser symbol employs a curved line for the rotor, whereas the adjustable trimmer employs a straight line penetrated by the arrow. The lower line is the rotor or grounded plate, when the arrow points upward. Perhaps it is best to say that the tail of the arrow is closest to the rotor or grounded part of the trimmer. In the event that the rotor is not grounded the same illustration is used, except that the location of the arrow then identifies the rotor plate or plates.

The fixed condenser symbol is just the same as it always has been, although certain additions will be seen upon the Motorola diagrams for 1938 receivers appearing in Rider's Manual Volume IX. For that matter if you have seen any of the new Motorola diagrams and have examined the schematics critically you no doubt noted that the variety of fixed condenser was identified by either a solid line or a dash line running through the condenser, midway between the upper and lower lines. Motorola identifies their mica condensers by means of a dash line and their paper condensers by means of a solid line.

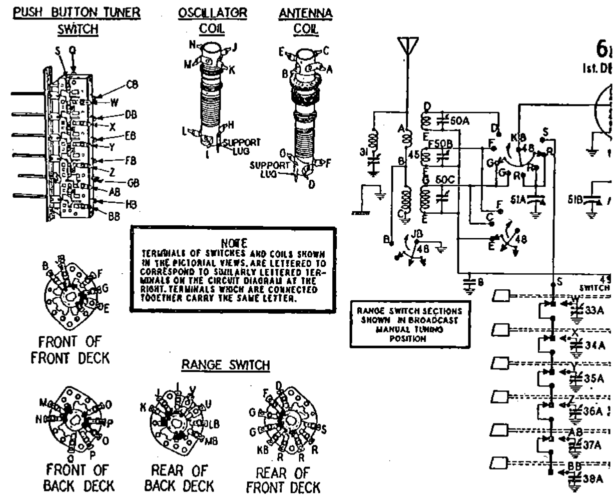


Schematic symbols prepared by the Standardization Committee of the R.M.A. Service Section.

The greatest change takes place in the symbols used for the wet and dry electrolytic condensers. Heretofore, such condensers were identified simply as fixed condensers. It is quite in order to make a change because the different types of electrolytic condensers justify individual identification. The wet condenser cannot replace the dry and it is imperative that the serviceman know the variety of electrolytic being used. For that matter, it is also necessary to mention that the suggestion was made to identify self-regulating electrolytics as against non-regulating by placing the word "regulating" or some abbreviation thereof upon the schematic adjacent to the condenser. These wet and dry electrolytic condenser symbols are already in use by Wells-Gardner and S.-W.

Still another suggestion for standardization is identification of sections of a multi-section condenser or resistor, by the letters a, b and c, or as many as may be desired. In other words, such identification as 21a, 21b and 21c, means that the three condensers or resistors, whichever are being considered, are all parts of a multi-section unit.

Great relief is in store with respect to the comprehension of band switches. While the committee is not making a standardization suggestion for a symbol, a definite method of illustration is being recommended. This recommendation is that the switch be shown schematically on the schematic proper. The coil and other component leads are brought out directly to the proper switch terminal. Each switch terminal or lug is numbered or coded. The individual switch sections can be broken up for convenience in drawing if desired. Adjacent to the switch or nearby on the drawing is an actual pic-



A portion of one of Stewart-Warner's latest schematics, showing the new presentation of band-switch data.

ture or pictorial representation of the switch leaf. The lugs on the leaf have numbers or are coded in a manner corresponding to the schematic of the switch section mentioned above. An idea of what was suggested will be seen in the partial schematic of the Stewart-Warner models 91-68, 98-61 and 910-61 shown herewith.

METER AND SHADOW-TYPE INDICATORS

A number of different factors were responsible for the widespread adoption of tuning indicators of one type or another. Apart from the usefulness of these indicators in reducing distortion and noise background and in simplifying the tuning operation, receiver manufacturers realized that the incorporation of tuning indicators constituted an important item in increasing the attractiveness and salability of their receivers.

Let us investigate some of the early tuning indicators, to examine their construction, the circuit arrangements in which they were used, and their connection with the rest of the receiver circuit.

Relation to A.V.C. System

It was not until automatic volume control had made its appearance that tuning indicators became at all common in commercial receivers. This was no coincidence but occurred because receivers equipped with a.v.c. lent themselves readily to tuning indicator devices with a minimum of added expense. Let us examine the connection between the operation of tuning indicators and the a.v.c system and see the manner in which these are related. In the first place, if we review in a few words the action that takes place in a typical a.v.c. system, then we shall be able to see how an a.v.c.-equipped receiver is adapted for use with a number of different types of tuning indicators. We do not propose to go into any detailed description of a.v.c as this has already been done in "Automatic Volume Control" in the "Hour a Day with Rider" series. For our present purposes we wish merely to present some of the basic ideas as to the factors which change when an a.v.c.-equipped receiver is tuned to a signal.

As you know, a.v.c. operates by feeding a control voltage to one or more of the r-f., mixer, and i-f. tubes and the magnitude of this control voltage depends upon the amount of the signal which reaches the second detector. Generally this automatic control bias is produced by the rectified carrier in the second detector circuit or sometimes by a separate rectifier. All of these different a.v.c. circuits are discussed in the book previously mentioned, but the point which we wish to make here is that the a.v.c. voltage which is produced by the a.v.c. rectifier or by the second detector furnishes a convenient and obvious method of operating a tuning indicator. To understand why this is so, we shall examine the manner in which this a.v.c. control voltage varies as a signal is tuned in.

In Fig. 1 we show in skeleton form a schematic of a receiver incorporating a typical a.v.c. circuit. In accordance with the operation of a.v.c. systems, the rectified voltage across R1 is fed over to the grids of the tubes under control through the first a.v.c. filter resistor R2 and through individual grid filters. Now we want to investigate the changes which take place in this circuit as the receiver is tuned from a point at which no signal voltage is present through a point on the dial where a signal is present. To make the explanation more concrete, we are going to consider what happens when a receiver is tuned to an 800-kc. signal. Suppose that initially the receiver happens to be tuned somewhere in the neighborhood of 600 kc. and that we advance the tuning control to approach 800 kc.

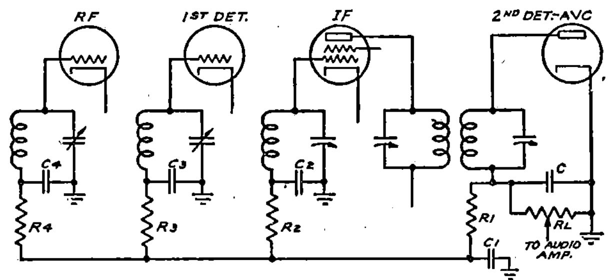


FIG. 1.—Skeleton schematic of a superheterodyne in which is incorporated a typical A.V.C. circuit.

To begin with, the a.v.c. voltage will of course change as the signal is being tuned in. Referring to Fig. 2, you will observe that the amount of control voltage produced is plotted against the frequency to which the receiver is tuned, assuming of course that the signal which is desired is 800 kc. Now when the tuning control reaches 790 kc., the control voltage developed by the a.v.c. rectifier is zero as is shown on the curve. The reason for this is that there is no signal passing through the receiver to develop a control voltage. As the tuning control is further advanced toward the signal frequency the a.v.c. voltage slowly increases from this zero value and at 800 kc. where the signal is tuned in perfectly, the control voltage developed reaches its maximum value. As the correct tuning setting is passed, the control voltage again drops and at 810 kc. the control voltage is substantially zero again.

What conclusions can we draw from the above variation of the control voltage? The most obvious conclusion as far as the problem on hand is concerned is that the variation in automatic control voltage can be utilized to indicate when the receiver is exactly tuned. That this can be done is evident from an inspection of the curve in Fig. 2, since reference to this curve shows us at once that the control voltage is a maximum when the station is tuned in perfectly and hence to insure accurate tuning it is only necessary to tune the receiver so that the control voltage is a maximum.

The connection between the status of the tuning of a receiver and the amount of control voltage developed can be considered as the basic fact which is behind the operation of every tuning indicator

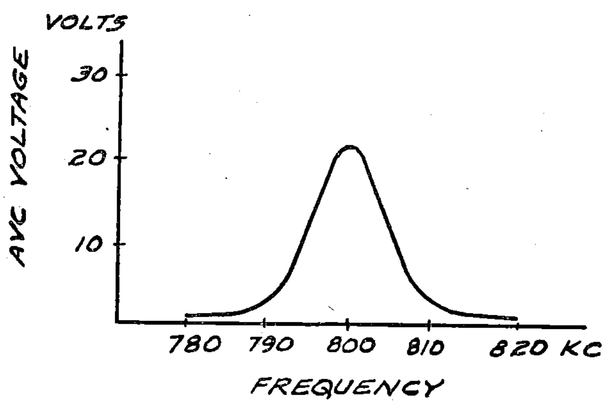


Fig. 2.—The variation of A.V.C. voltage with frequency is illustrated by the above curve.

which we know of at the present time. It makes no difference whether the tuning indicator proper takes the form of a cathode-ray tube, a neon tube, a d-c. meter, the changing intensity of a bulb, or the change in the color of the dial light, or the movement of a shadow—in every case you will find that it is the changing rectified voltage which is the moving force behind the operation.

The Vacuum-Tube Voltmeter Type of Tuning Indicator

One of the most direct and simple types of tuning indicators is that type which uses a simple vacuum-tube voltmeter as the indicating element. The connections for this arrangement are shown in Fig. 3. Note that the grid of the triode is connected to the a.v.c. bus, that is, to the terminal which feeds the a.v.c. voltage to the several tubes under control, and that as the result of this connection the grid voltage of the tube T will vary as the signal is tuned in. This variation takes place in accordance with the curve shown in Fig. 2, and as a result there is a corresponding variation in the plate current. When the signal is tuned in exactly, the negative grid bias on the indicator tube T is a maximum and consequently the plate current of the

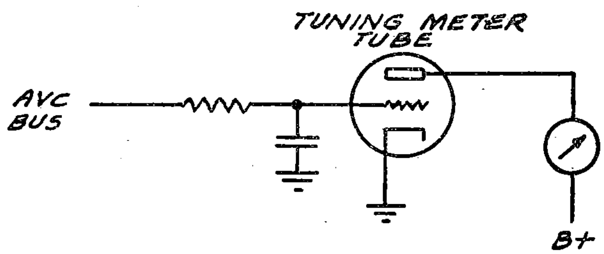


Fig. 3.—Arrangement of vacuum tube voltmeter as the tuning meter tube.

meter is a minimum. In other words, to tune a receiver with a meter of this type, it is only necessary to adjust the tuning control so that the meter deflection is a minimum.

There are numerous variations of this vacuum-tube voltmeter method. In some cases, the meter is inserted in the cathode circuit of the indicator tube rather than in the plate circuit. The operation of this circuit is of course essentially the same as the case in which the meter is in the plate circuit with the exception that, in the circuit of Fig. 4, the meter is at ground potential rather than at a high positive potential and furthermore, the resistance of the meter acts to supply bias for the tube due to the voltage drop across the meter. Other arrangements of this basic circuit include the use of tetrode and pentode tubes to produce a more uniform

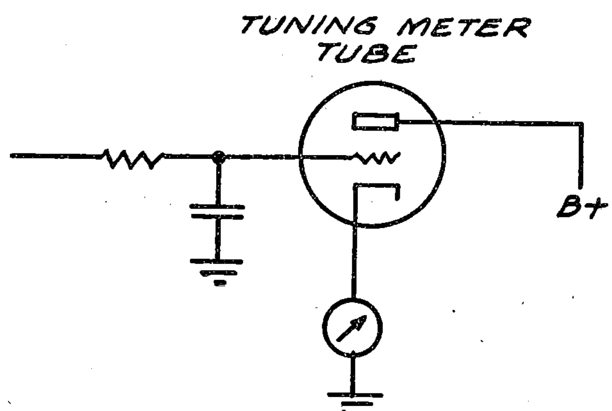


Fig. 4.—Here the tuning meter is at ground potential and the I.R. drop across the meter resistance supplies bias for the tube.

change in the meter reading over a wider range of input signals to the receiver. This facilitates tuning regardless of whether a strong or weak signal is being tuned in.

The R-F. and I-F. Plate Current Meter Indicator

A very widely used tuning indicator circuit is that which is shown in Fig. 5. Essentially this circuit is a further extension and simplification of the method just described, the simplification taking place because of the fact that one or more of the i-f. and r-f. tubes under control is used as the vacuum-tube voltmeter. In this way, the necessity for a separate tube to be used solely in connection with the tuning indicator is done away with. The circuit does not involve any new ideas, since the change in plate current of a tube under a.v.c. control is quite similar to the change in plate current of a tube which acts as a separate vacuum-tube voltmeter.

Referring back to the circuit shown in Fig. 1 you will appreciate that the voltage which is developed across the second detector changes widely as the receiver is tuned through a signal, the changes in grid voltage being of the order of 1 or 2 volts for weak signals, and as high as 20 or 30 volts for strong signals. This varying control voltage is of course that which is responsible for the a.v.c. action in the receiver and at the same time it is also responsible for the change in plate current of the tubes under a.v.c. control occurring when the receiver is tuned through a signal. In other words, it is not necessary to use a separate tube to actuate the meter as we did in the circuit of Fig. 3, but instead the meter can be inserted in the plate circuit of any one of the controlled tubes as is shown in Fig. 5. The deflection of the meter will then be similar to that described in connection with the vacuum tube voltmeter method and consequently tuning is accomplished by adjusting the tuning control so that the deflection of the meter pointer is a minimum.

Inasmuch as the operation of this arrangement is so similar to that of the vacuum-tube voltmeter method previously described, the question arises as to why the other method should be used when an extra tube can be eliminated by placing the meter in the plate circuit of one of the tubes under control. The answer to this question is that the second method *is* used much more widely than the separate tube method; the only advantage which is obtained by the use of a separate tube is that it is possible to arrange the vacuum-tube voltmeter so that a more uniform action is obtained regardless of the strength of the signal being received. However, where the meter is placed in the plate circuit of one of the controlled tubes, then the operation of the tube as a controlled amplifier is of first importance and the characteristic of the tube as a tuning indicator is of secondary importance.

It might be mentioned here that the meter is sometimes placed in the cathode circuit of the tube under control for reasons previously mentioned. In addition the meter may be arranged to carry the plate current of more than one controlled tube.

The Shadowgraph or Shadowmeter Tuning Indicator

Throughout this discussion as we have occasion to go into the various types of tuning indicators which have been and are being used in receivers, you will note that there has been a constant aim in the minds of the set engineers to design and produce tuning indicators which would have eye appeal and increase the salability of their product. If this were not so, there would be no reason for this text on tuning indicators, since basically the meter type of indicator would be quite as satisfactory as any other type available. This factor of sales appeal accounts in large part for the large number of novel arrangements which have made their appearance in radio receivers from year to year.

One of the devices which has been widely used is the so-called shadowgraph or shadowmeter type of indicator. The basic type of circuit in which this indicator is used is similar to that which we described in the case of ordinary current meters; shadowmeters are generally placed in the plate circuit of one or more of the tubes under a.v.c. control or in the plate circuit of a special indicator tube. The latter arrangement corresponds to the vacuum-tube voltmeter type of meter arrangement.

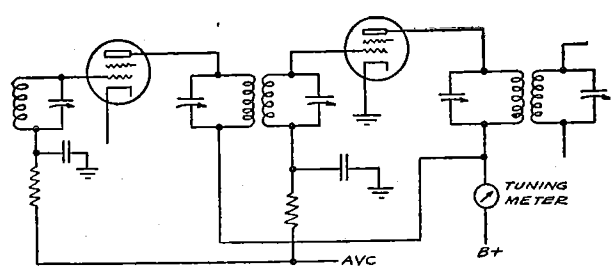


Fig. 5.—By using this arrangement, a separate tuning meter tube is not required.

The actual construction of the shadowgraph indicator is of interest. The indicator mechanism employs a small permanent magnet which is in the form of a circular flat ring having a small air gap. Mounted within this ring so that it pivots on two supports diametrically opposite each other is the moving armature which forms the indicating part of the system. This armature consists of a flat disc of soft iron with a rectangular slit in the center of it. Mounted in the middle of this slit is a thin black opaque vane which is rigidly attached to the iron armature so that any movement of the armature is accompanied by a corresponding rotation of the vane. Surrounding the permanent magnet is a coil of wire placed so that the magnetic field of the coil of wire due to the current flowing through the coil is at right angles to the plane of the permanent magnet.

This description completes the electrical part of the tuning indicator. Let us now examine the manner in which the shadowgraph functions. The first important point is that the magnetic field of the permanent magnet tends to keep the armature in a horizontal plane. This is due to the fact that the magnet does not form a closed ring, so that the leakage flux acts to penetrate the soft iron of the armature and, by a well known property of magnetism, the armature will tend to assume that position which enables the maximum amount of the leakage flux of the permanent magnet to pass through it. In other words, the permanent magnet is essentially a control mechanism and really is an ingenious device which takes the place of the coil spring which is used in meters to return the pointer to zero.

The force which deflects the armature and therefore the vane, is due to the magnetic field created when a current flows through the coil L surrounding the armature. This field is at right angles to the field which tends to keep the armature in a horizontal position and therefore the effect of current flow through the coil L is to turn or rotate the armature and the attached vane. The greater the current which flows through L the greater is the magnetic field created by the current, and consequently the greater the angle through which the armature and vane are rotated.

As we previously mentioned the circuits in which these shadowmeters are used show a marked similarity to those employing a conventional type of meter indicator. The reason for the similarity of circuits is that the shadowmeter is itself essentially a meter but instead of using an ordinary pointer as an indicator it uses an optical system arranged so that the pointer is represented by the width of the shadow formed on the screen.

A typical circuit arrangement which employs the shadowmeter tuning indicator is that shown in Fig. 6 in which the current flowing through the winding is the plate current of both the r-f. and i-f. stages. You will note that the shadowmeter coil is shunted with a 2000-ohm resistance so that the full plate current of these tubes does not flow through the shadowmeter. In the event of a complete burnout of the shadowmeter coil, the receiver will still be operative, since the plate current has a path through the shunt resistor. In cases where the shadowmeter is not shunted, then the burnout of the shadowmeter coil results in a completely inoperative receiver since there is no plate voltage on one or more of the controlled tubes.

As far as the significance of the shadow width with respect to the tuning condition, this can easily be understood from the following consideration. In the first place, when the station is exactly tuned in, the tubes under control receive the maximum amount of automatic control voltage and consequently the current flowing through the shadowmeter coil is likewise a minimum. Under this condition, the deflection of the vane is a minimum and consequently the shadow cast on the screen has its minimum width when the station is exactly tuned in. Similarly, the plate current of the tubes

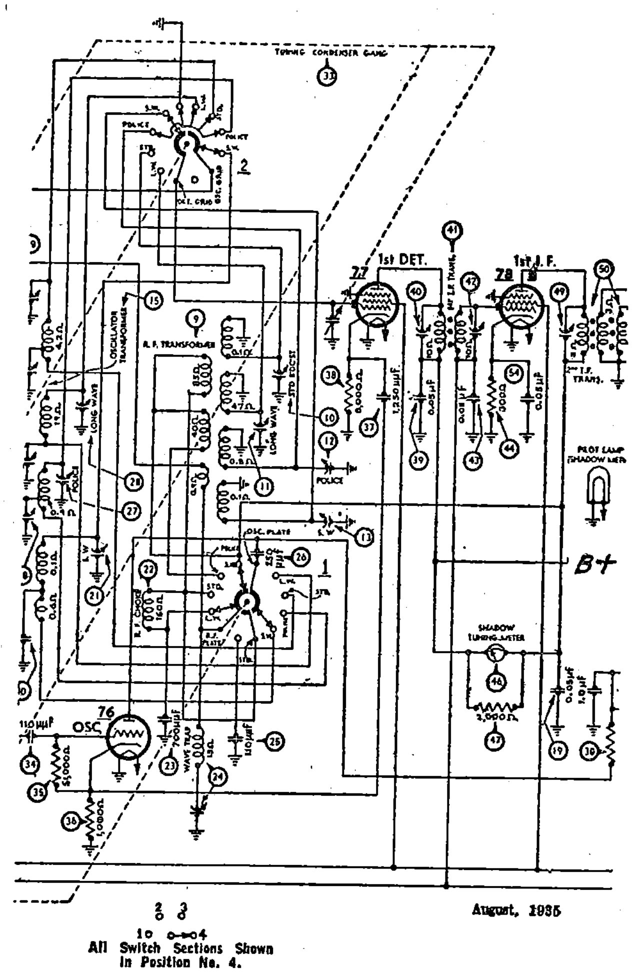


FIG. 6.—The connections of the shadowmeter in Philco receiver, Model 660.

under control is large when a signal is not tuned in and therefore the shadow width is broad.

There are a number of other circuit arrangements employing these shadowtype tuning indicators. Among the arrangements which are quite popular is the type of circuit which uses a separate tube to actuate the shadowmeter. These circuits are similar to those shown in Figs. 3 and 4 with the exception that the plate current flows through the shadowmeter coil rather than through a conventional meter. No further comment is required since the action is the same as that described in connection with meter type indicators.

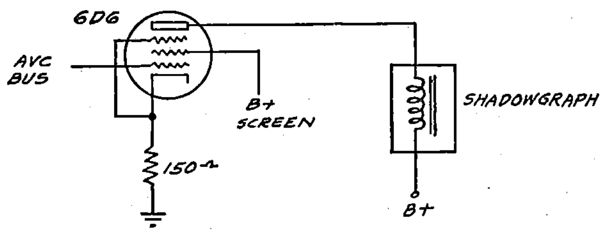


FIG. 7.—In this circuit a remote cutoff, variable mu pentode is used instead of a triode.

The circuit shown in Fig. 7 incorporates the same basic idea as the preceding circuits, with the exception that a long cutoff, variable-mu pentode tube is used rather than a triode tube. In some receiver layouts the use of the pentode tube furnishes a more desirable variation of plate current with tuning, so as to make the tuning meter effective for weak signals as well as for strong signals.

All the circuits which we have shown up to the present time have not had any separate tuned circuits associated with them, apart from the tuned circuits through which the signal passes. However, in some cases, there is an additional tuned circuit for the purpose of sharpening the selectivity of the tuning meter channel. In these cases it is of course important that this circuit be aligned at the same frequency as that at which the i-f. amplifier is peaked. If the tuning meter transformer is aligned at a frequency different from the i-f. peak, then it is quite possible that incorrect tuning will result in spite of the shadowmeter being adjusted for minimum width. These same remarks apply to all types of tuning indicator circuits which employ separate tuned circuits for this circuit.

An example of this type of arrangement is that shown in Fig. 8 which is the circuit used in the Philco Model 201 Receiver. The last i-f. transformer you will observe has three windings which perform the following functions. The primary winding L1 is closely coupled to the secondary winding L2 so as to provide a broad bandpass effect for the signal channel and to prevent the attenuation of the outer sidebands representing the higher audio frequencies. In this connection you may be familiar with the fact that the remaining i-f. transformers in this receiver are also of the three winding type, with a variable resistance in the tertiary tuned circuit to provide variable selectivity. The third winding L3 is loosely coupled to the primary winding so as to provide an increased selectivity for the tuning-meter channel.

The i-f. voltage appearing across L3 is rectified by one of the diode sections of the 75 tube. (The remaining elements of this tube function as the second detector and the first a-f. stage.) The rectifier circuit is somewhat unusual and we might point out that R1 is the diode load across which the rectified voltage is developed. This voltage is filtered by means of the R2-C2 combination so that the voltage actuating the grid of the 37 tube does not contain any a-f components. The shadowmeter is placed in the plate circuit of this tube.

The incorporation of an additional tuned circuit for the tuning-meter channel, as in this receiver, is especially desirable in the case of high fidelity

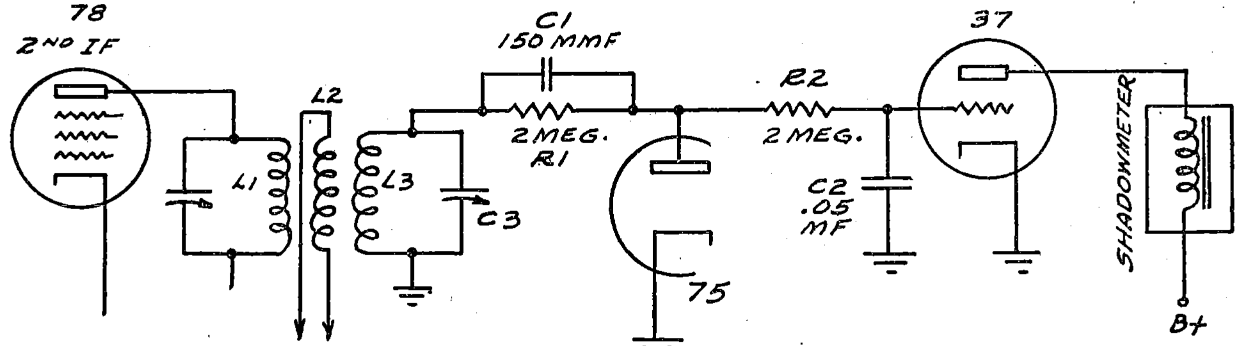


FIG. 8.—Shadowmeter circuit of the Philco model 201.

receivers which have a flat-topped i-f. amplifier. In this case the additional selectivity makes the action of the tuning indicator much sharper and makes it possible to set the tuning condenser so that the signal comes through at exactly the center of the band-pass and not at a point near the edge.

Adjustment of Shadowgraph Indicators

In order to obtain a symmetrical shadow which is properly centered on the translucent screen, it is necessary to properly locate the filament of the bulb. Ordinary bulbs having a U type filament are not satisfactory as double shadows are cast on the screen, therefore a bulb of the type having straight filament is desirable. Use of a bulb having a different or irregularly formed filament will result in a fuzzy and indistinct shadow. It is also important that the bulb itself be mounted in its socket so that the incandescent portion of the filament is in the same plane as the vane. In addition to the proper orientation of the bulb in the socket, it is necessary that the bracket holding the bulb be adjusted so that the filament is centrally located over the hole through which the light casting the shadow is admitted. Failure to have the bulb properly adjusted will result in the shadow being off center on the screen and possibly in a faint and indistinct shadow.

If it becomes necessary to readjust the shadow tuning meter due to any of the above reasons, the initial step should be to remove the rectifier tube and to turn on the power switch. The rectifier tube is removed because it is desirable to make the adjustments while there is no current flowing through the coil of the indicator so that the vane is in a central position. Under this condition, the shadow should be a rather sharply defined line in the center of the screen. If the shadow shows the need of adjustment, then the procedure is to adjust the position of the bulb bracket and the bulb itself as explained above.

Faulty Operation of Shadowmeter

Failure of the shadowmeter to operate may be due to a number of different causes. It is convenient to classify the method of procedure in accordance with whether or not the shadowmeter is shunted by a resistor, is not shunted, or is in the plate circuit of a separate tube.

If the shadowmeter is shunted by a resistor and the receiver is in operating condition, then there are several possibilities for failure of the shadow to change with changes in tuning. Among these are an open circuit in the shadowmeter coil and a jammed or sticky vane. If the receiver is not in an operative condition, then failure of the tuning meter to operate is not generally to be attributed to the tuning meter itself but rather to some defect in the r-f. and i-f. end of the receiver which is preventing the proper change in plate current with changes in tuning. Thus if the shadow broadens in the usual manner after the set has warmed up but does not narrow when a signal is passed, then you can conclude that there is no signal voltage reaching the second detector and consequently the first step is to restore the operation of the receiver rather than to look for trouble in the shadowmeter circuit.

If the shadowmeter is not shunted by a resistor, and the receiver is dead, then one of the first things you should check is the shadowmeter coil. The reason for the importance of this check is that an open circuit in the shadowmeter coil will make the receiver dead and at the same time result in lack of operation of the shadowmeter indicator. If the receiver is operative and the shadow remains fixed, then it is possible that the failure is due to the vane being jammed. Before removing the tuning indicator to examine the condition of the vane, it is desirable to insert a milliameter in series with the shadowmeter to make certain that the current passing through the shadowmeter is changing in accordance with changes in tuning. We might mention here that manufacturers generally do not recommend that shadowmeter indicators be taken apart for repairs because of the difficulties of repair and reassembly. In the case of defective units, the entire assembly should be replaced.

In the case of receivers of the type shown in Fig. 8, failure of the tuning meter to function properly or at all may be due to lack of alignment of or a defect in the tuned circuit associated with the tuning-meter channel. Thus in Fig. 8, an incorrect setting of the trimmer C3 would result in insufficient change of shadow width and if the circuit were badly out of alignment there would be no noticeable change in the shadow width with changes in tuning. The proper method for adjusting this trimmer is to feed a signal into the grid of the first detector at a frequency equal to the i-f. peak and to adjust the trimmer so that the shadow width is a minimum. This indicates that the shadowmeter tuned circuit is peaked at the intermediate frequency. Under this condition the signal passes through the i-f. amplifier at the i-f. peak when the tuning control is adjusted for minimum shadow width.

In this connection lack of sharp variation in the shadow width is very often a sign that the receiver needs realignment. This remark applies with equal force regardless of the type of indicator and the circuit in which it is used.

SATURABLE CORE TUNING INDICATORS

Let us now consider those tuning indicators which depend for their operation upon the variable impedance of an iron core inductance which carries a d-c. magnetizing current. At first glance, this may seem rather complicated, but actually it involves the application of a principle with which you have previously come in contact.

Referring to the familiar power supply circuit shown in Fig. 9, you will note that the filter choke L carries both alternating current as well as direct current. In this connection you will recall that filter chokes are commonly rated in accordance with the value of direct current which they can safely carry. This value of direct current does not bear any relation to the safe value of current as regards the heating effect, but rather is the value of current which must not be exceeded if the inductance of the filter choke is to be maintained. In other words, the inductance of L, or the opposition which it offers to the flow of alternating current, depends in a very marked manner upon the value of direct current which flows through the coil. When the direct current through an iron core choke is excessive, then the iron core is said to be "saturated" and its inductance falls to a very low value.

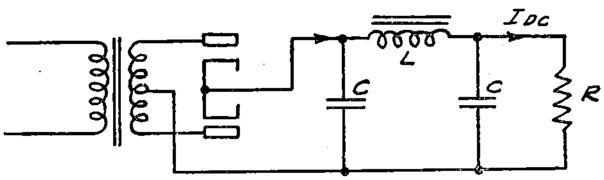


FIG. 9.—Note that the choke coil L carries both alternating and direct current in this typical power supply circuit.

This fact is illustrated graphically in Fig. 10. Note that the inductance or opposition to the flow of alternating current is greatest when there is no direct current to saturate the core. As the direct current flow increases, however, the inductance falls rapidly. Without going into too much detail, the decrease in inductance with large values of direct current is due to the fact that the direct current sets up a condition in the iron core wherein the molecular magnets all become aligned or drawn up in the same direction. As a result the core is said to be saturated and the superimposed alternating current is incapable of causing any appreciable change in the magnetic flux existing in the core. Since the opposition which a coil can offer to the flow of alternating current is dependent upon the ability of the flux to change, it is evident why this opposition (inductance or impedance) falls to a very low value for large values of direct current. Expressed in a slightly different manner, large values of direct current saturate the core and make it impossible for the flux to change in accordance with applied alternating voltages.

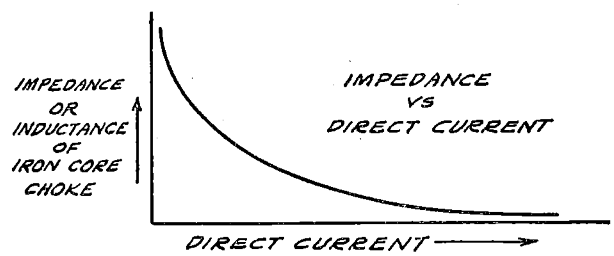


FIG. 10.—Note that the inductance is greatest when the core is not saturated.

Saturable Core Transformer

In order to use the principle which we have just described in connection with tuning indicator circuits, it is generally found necessary to isolate the winding section which carries the direct current used to saturate the core from that which carries the alternating current used to operate the tuning indicator. This is accomplished by using a transformer with two windings, as is shown in Fig. 11. The primary winding is used to carry the direct

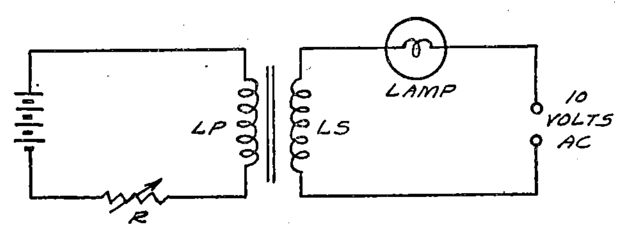


FIG. 11.—When R is increased the secondary winding offers a high impedance to the flow of A.C.

current while the secondary winding is in series with the tuning indicator bulb and a source of 60-cycle voltage. Generally this a-c. voltage is obtained from a low-voltage winding on power transformer but this point is not of special importance at the moment.

Suppose that the current in the primary winding is varied by means of the rheostat R. How will the brightness of the lamp in the secondary circuit be affected? When the current in the primary circuit is made very small by increasing the resistance R, there will be no tendency toward saturation and as a result secondary winding will offer a high impedance or opposition to the flow of the alternating current. It follows that the bulb will be only very dimly lit because of the small amount of alternating current which flows in the secondary circuit.

As the direct current in the primary circuit is increased, the magnetic flux produced by the current tends to saturate the core. As a result the impedance of the secondary winding falls. With this decrease in impedance of the secondary, a corresponding increase in the alternating current through the bulb takes place. The greater the direct current in the primary circuit, the greater is the briliancy of the bulb because of the lowered impedance of the secondary.

To summarize this action, we see that the bulb will light only dimly when there is no current through the primary winding and will light very brilliantly when the core is saturated as the result of a large direct current in the primary.

Divided Core Saturable Transformer

The simple type of transformer shown in the preceding section is not widely used because the alternating current in the secondary circuit induces an alternating voltage in the primary circuit. This transformer action is of course not desired in this instance but is nevertheless present as it is in all ordinary transformers. The factor which makes it undesirable to have alternating voltages present in the primary winding is due to the fact that this primary winding is generally connected to the plate circuit of several of the r-f. and i-f. tubes and any a-c. voltage which is present in this circuit tends to cause hum in the output of the receiver.

A simple arrangement of the windings on a three-leg transformer core is used to get around this difficulty. As Fig. 12 shows, the primary winding L1 is wound on the center leg of the core, while the secondary winding is in two sections, L2 and L3, which are wound on the two outer legs of the core. These two secondary sections are joined in such a way that the a-c. currents flowing in each of the secondary sections induce equal and opposite voltages in the primary winding so that no net a-c. voltage appears in this winding. The arrows shown on Fig. 12 show the direction of the flux due to the two sections of the secondary and it is quite evident that the flux in the center leg which is due to the current in L2 is cancelled by the flux due to L3 so that there is no net voltage induced in the primary winding.

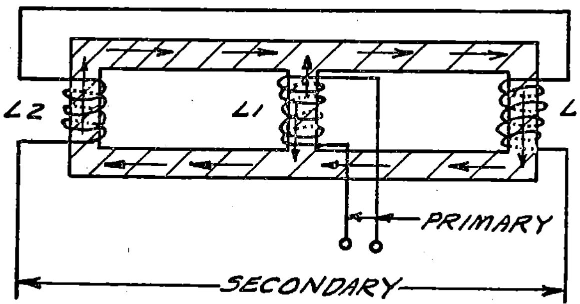


Fig. 12.—Arrows show the direction of the flux due to the two sections of the secondary and the flux in the middle leg is cancelled.

Majestic Reactance Dimmer Indicator

One of the most widely used applications of this type of transformer is found in a number of Majestic models. The circuit shown in Fig. 13 is a simplified schematic of the tuning indicator circuit used in the Majestic 300 series. The circuit is so arranged that the plate current of the r-f., the first detector, and the i-f. tubes flows through the primary winding of the saturable core transformer. The secondary winding consists of two sections which are connected together and in series with indicator bulb and the low voltage winding on the power transformer. From the manner in which the power supply circuit is arranged it should be clear that all the plate current drawn by the three aforementioned tubes—which are controlled by the a.v.c. system—must flow through the primary winding.

As in the case with the other tuning indicator system considered previously in this discussion, the action which takes place in this circuit is tied in with the a.v.c. system. First let us consider the action affairs when there is no signal tuned in. Under this condition, the a.v.c. voltage on the grids of the three controlled tubes is at its smallest value with the result that the plate current flowing through the primary circuit is quite high. As a result of this high value of direct current, the core of the transformer becomes saturated so that the secondary windings offer little opposition to the flow of alternating current. The bulb therefore lights up brilliantly when no signal is being received or when the receiver is detuned considerably.

What changes take place when a signal is tuned in? Under this condition, the grid bias of the controlled tubes will be high and the plate current of the tubes will be correspondingly low. This means a low value of direct current through the primary winding and consequently means that the core will be in an unsaturated condition. Having previously seen that the effect of a low current in the primary circuit and of the corresponding unsaturated condition of the core is to make the secondary offer a high opposition to the flow of current, it follows that the lamp will be dimmed appreciably as the signal is tuned in.

We see then that this tuning indicator functions by the dimming of the bulb which takes place as the station is tuned in. When the station is exactly tuned in the light will be at its dimmest and it will increase in brilliance in accordance with the extent to which the receiver is detuned from the signal.

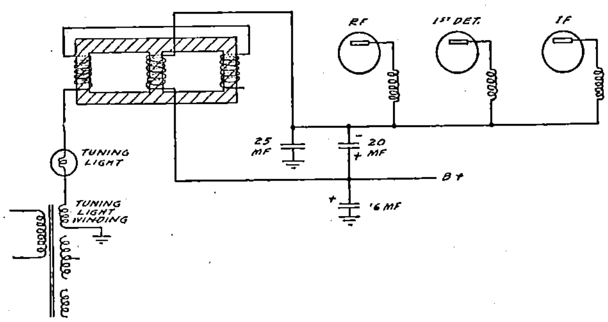


FIG. 13.—Simplified schematic of the tuning indicator circuit of the Majestic 300 series.

There are several points about this circuit which are of interest from the point of view of the tuning indicator. We have already commented on the fact that the secondary winding is arranged in two sections so as to prevent hum voltages from appearing in the plate circuit of the controlled tubes. Theoretically, there should be no hum voltage at all present in the center leg, but actually because of small unbalances which may occur in the production of the transformer, small hum voltages will appear across the center leg. These are prevented from introducing hum by means of the 20 mfd. electrolytic condenser which is shunted across the winding. This in conjunction with the 16 mfd. filter condenser is effective in preventing hum from being introduced into the receiver output.

When trouble is experienced with receivers using this type of tuning indicator and the evidence points to the tuning indicator as being a probable cause of the trouble, the best method of procedure is to disconnect the high voltage wires connected to the primary winding. The plate return lead should then be connected directly to the high voltage end of the power supply. This procedure eliminates possible short circuits to ground in the transformer or an open circuit in the primary winding as possible cause of defective receiver operation.

Failure of the tuning indicator itself to function—where the receiver operation is otherwise normal—can generally be traced to a burned out dimmer bulb, or a defective transformer. A shorted 20 mfd. bypass condenser across the primary winding of the transformer will not interfere in any way with the operation of the receiver but will prevent the tuning indicator from functioning. In the same way, a partial short in this condenser will have no effect on the receiver operation, but will prevent an appreciable brightening of the dimmer lamp from taking place as the receiver is detuned from the signal.

General Electric Colorama Tuning Indicator

Some General Electric receivers incorporate an interesting tuning indicator system in which the color of the dial scale illumination changes in accordance with whether or not the receiver is correctly tuned. When the receiver is detuned, the entire dial scale is illuminated with a red light. As a signal is tuned in, this red illumination changes to a brilliant green. Among the advantages claimed for this system is the fact that it does not require that the set operator shift his attention from the dial scale to the tuning indicator to tune in a signal correctly.

As far as the mechanical arrangement is concerned, the dial scale lighting is accomplished by means of four red bulbs and three green bulbs which are spaced in alternate positions behind the linear dial scale. When no signal is tuned in, the red bulbs are lit brilliantly and the green bulbs are very dim so that the net result is a red glow over the entire dial scale. When a signal is tuned in accurately, the red bulbs are dim and the green bulbs brilliant so that the final effect is a green glow over the entire dial scale. For intermediate positions, that is, for the condition that the signal is partially tuned in, the illumination is a combination of green and red light which combines to produce a whitish light. The sequence of changes as a signal is tuned in, is thus from red to white to green, the latter condition indicating the correct setting of the tuning control.

The electrical system employed to accomplish the action described in the previous paragraphs is shown in Fig. 14. Basically the circuit consists of a saturable core transformer of the type which we discussed previously in connection with the Majestic Reactance Dimmer Indicator. Unlike the latter system, the plate current of a separate tube is used to vary the saturation in the iron core. This tube is a 6K7 and is controlled by the a.v.c. system. The lamp network consisting of the seven bulbs is connected to the secondary winding of the saturable core transformer, while a-c. voltage required for the bulbs is obtained from a separate winding on the power transformer.

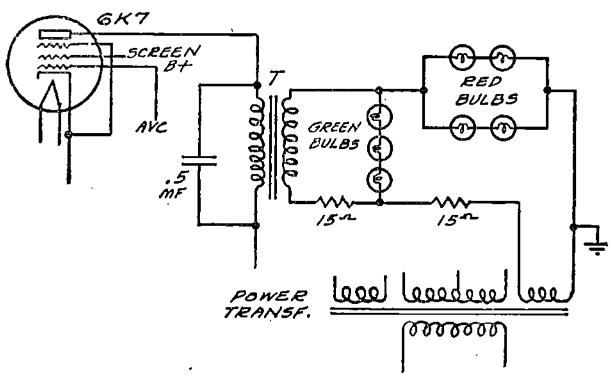


Fig. 14.—Schematic of the General Electric "Colorama" tuning indicator.

We can best analyze the action of this system, by considering the properties which the saturable core transformer shows for different values of plate current through the primary winding. This is very clearly shown by the graph in Fig. 15. For zero value of plate current through the primary, it is evident that the impedance of the secondary winding is close to 700 ohms. As the primary plate current (the saturating current) is increased, the impedance of the secondary winding drops steadily. When the plate current of the 6K7 has dropped to a value of 10 milliamperes, the secondary impedance has fallen to about 25 ohms. We bring up this point here because it is important for you to realize that effectively there is shunted across the bulb network in Fig. 14 an impedance which varies from a value as low as 25 ohms to as high as 700 ohms, depending only upon the plate current through the primary winding.

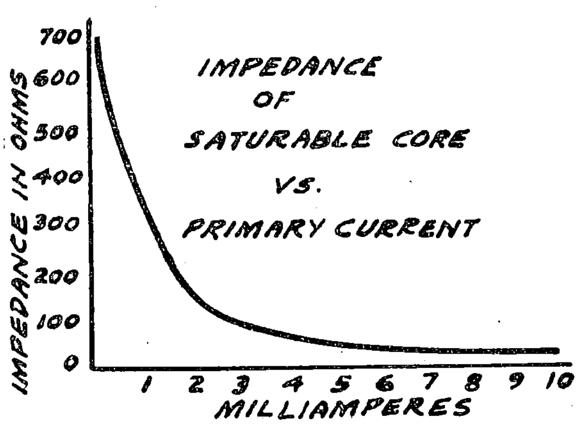


Fig. 15.—Variation of core saturation with primary current.

For our present purposes, we can simplify the circuit by replacing the transformer and tube with a variable impedance shunted across the input to the network of bulbs. This modified circuit is shown in Fig. 16. Obviously the amount of current through the red and green bulbs is going to depend upon the particular value of the variable impedance and this in turn is determined by whether or not the receiver is correctly tuned to the signal.

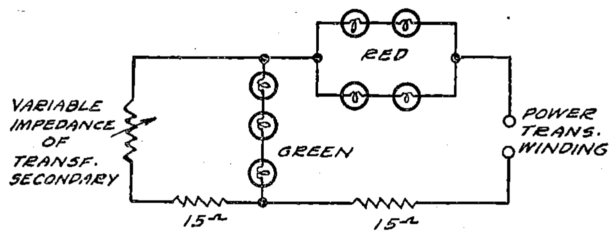


Fig. 16.—Equivalent circuit of Fig. 14.

Suppose that we consider first the case where the receiver is not tuned to a signal. In the first place the a.v.c. bias on the 6K7 tube will be low and consequently the plate current through the primary winding of the transformer will be large. From our previous discussion of the characteristics of the variable impedance transformer, we know that the value of the shunt impedance in Fig. 16 will be about 25 ohms. This is quite small in comparison with the resistance of the bank of three green lamps and therefore in analyzing the action of the circuit we can consider that the green bulbs are short circuited. The circuit, further simplified in accordance with this explanation, is shown in Fig. 17.

Clearly enough the current flowing through the red bulbs will be quite large and in fact the circuit is so designed that the red bulbs will be brilliantly illuminated under the conditions of Fig. 17. The green bulbs, however, are shorted by the transformer secondary so that practically all of the current passing through the red bulbs goes through the transformer secondary instead of passing through the green bulbs. To summarize the action where the receiver is detuned from the signal, we see that the green bulbs are short circuited by the transformer secondary so that the dial scale illumination is due solely to the red bulbs.

When the receiver is tuned to a signal, we have an entirely different set of conditions. For one thing, the a.v.c. bias is increased so that the current through the primary of the transformer is at a very low value. This means that the transformer is in an unsaturated condition so that the impedance of the secondary winding is quite high. Quantitatively, the graph in Fig. 15 shows us that the impedance of the winding is of the order of 600 ohms, which is large enough so that it can be neglected in comparison with the resistance of the lamp network.

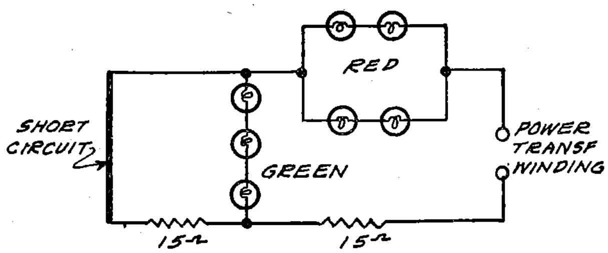


FIG. 17.—Here the red bulbs will glow brightly due to the virtual short across the green bulbs.

Fig. 18 shows the same circuit redrawn in accordance with the conditions existing when a signal is being received. The circuit is simplified by omitting the transformer, because of the high impedance which it presents under these conditions. As you can see the circuit reduces to a simple series circuit. The total current drawn in this case is less than that in the case of no signal input because the shunting effect of the transformer secondary is removed. Not only is the total current less than in the preceding case, but the current through each of the red bulbs is approximately half of the current through the green bulbs. Because of the decreased current, and the division of the currents between the two branches of the red bulbs, these are lit only dimly when a signal is received.

How about the intensity of the green bulbs under these same conditions? Clearly enough, according to the simplified circuit of Fig. 18, the total current drawn from the low voltage winding on the power transformer passes through each of the green bulbs so that the full value of the current is effective in lighting these bulbs. Furthermore the shunting effect of the transformer, which caused the green bulbs to dim and the red bulbs to light brilliantly in the case of the no signal condition, is now removed. As a result, the three green bulbs throw a brilliant green light over the dial scale which indicates that the receiver is correctly tuned to the signal.

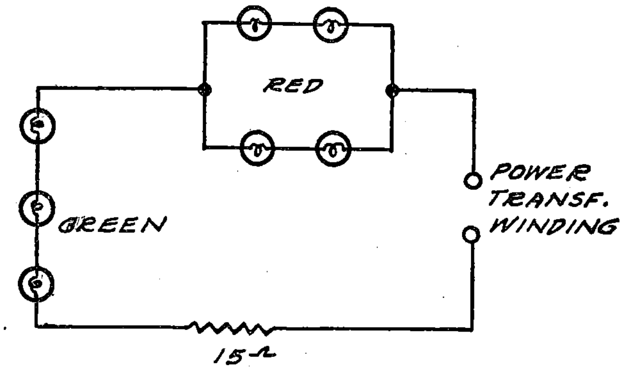


FIG. 18.—Here the green bulbs have about twice the current going through the others.

The saturable core transformer used in this circuit is of the type shown in Fig. 12, employing the special core construction described in connection with the Majestic Reactance Dimmer circuit. As in the previous circuit, a condenser is placed across the primary winding of the transformer to short out any a-c. voltages which would be induced in the primary winding because of unbalances in the two sections of the secondary winding. In addition, this condenser also short circuits a harmonic component of the power frequency which would be induced in the primary because of the saturated condition of the core. The second harmonic, 120-cycles is by far the strongest of these harmonic voltages.

We are indebted to H. R. Shaw of The Field Service Division of the General Electric Company for the technical data presented in this description of colorama tuning.

THE ELECTRONIC PIANO

Automatic Envelope Control for the Electronic Piano

The basic principles of the Electronic Piano were covered in the "How it Works" section of Volume VIII of Rider's Manual.

The pick-ups were shown to be nothing more than condenser microphones with the vibrating strings of the piano replacing the vibrating diaphragm of the microphone, while the back plate is replaced by the pick-up screws. It was also shown that the envelope of a piano tone was of a decaying type, with the strength of the sound very loud immediately after the hammer strikes, reducing in intensity at first rapidly, and later more slowly. An organ tone begins softly, quickly rises to its full intensity, and then remains steady. The application of a volume control to cut down the sudden peak of the piano tone and increase the gain as the tone dies away would give a tone from the electronic piano very closely approaching that of an organ. It was also mentioned that automatic means of actuating this volume control could be devised. The following paragraphs will describe such means.

The translation or response of a condenser microphone is proportional to the value of the polarizing voltage, and varying the polarizing voltage becomes a legitimate means of "volume control" to accomplish the desired result. A modified form of the input circuits is used (Fig. 1) which works in pre-

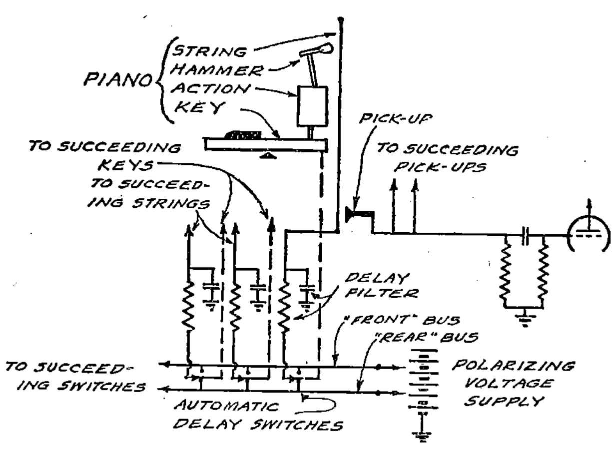


Fig. 1.—Relation of piano action, pick-ups and automatic delay switches.

cisely the same manner as the older circuits. The polarizing voltage is varied by the Automatic Delay Switch which works in conjunction with the piano key, changing the voltage at the instant that the key is struck. The switch moves from the rear to the front bus, as indicated in the sketch. This in itself would not accomplish the desired result, but by interposing a delay filter in the line to each piano string, the change in voltage does not occur instantaneously. The voltage builds up slowly, and, by the proper choice of the resistances and capacities, the build-up can be made of the proper length of time to suit and nullify the initial rapid decay of the piano tone.

Just as removing the "thump" will make a piano sound like a wind instrument, so will accentuating the "thump" make it sound like a plucked instrument, such as a banjo. The same delay mechanism will serve this effect also by reversing the application of the voltages, first applying a high voltage, and then permitting this to drop to some lower value. In this way, when the tone is loudest, the "volume control" gives the greatest translation, and, as the tone dies away naturally, the pick-up is reduced, giving a tone the loudness of which is exaggerated at its beginning.

Practical switching methods are shown in Rider's Volume IX on Krakauer page No. 9-1, 2 in the sketch headed "Details of Delay Switches." It is readily seen that these are nothing more nor less than a series of S.P.S.T. switches, with each switch arm connected to its corresponding string, and each of the two contacts being effectively connected to the corresponding contacts of all the other switches. The only unique thing about these switches is the form of the contact, which is metal to graphited felt. The graphited felt acts as a compression rheostat, having high resistance when the switch arm is pressing lightly against it and low resistance under heavier pressure. This is necessary to avoid an instantaneous change of voltage which would produce a click, due to the high amplification used. Obviously, as the switch arm starts to make contact, the pressure is low and increases as the contact is accomplished.

In order to change the voltages on the delay switch busses so as to give the three combinations at will, namely: from zero voltage to high voltage for organ; from high voltage to low voltage for banjo; or for maintaining the same voltage for piano, a polarizing switch is employed. Again referring to the Krakauer page 9-1, 2 in the manual, a circuit will be found entitled "Polarizing Switch Circuits." The two ½-megohm resistors and the two .1-mf condensers serve as a filter to remove switching clicks. The .2-mf condenser is part of the general hum filters. The other units have to do with varying the polarizing voltages.

When the switch is on position 1, the two 50,000-ohm resistors, which are now in series between B plus and ground, constitute a voltage divider so that the voltage at the two ¼-megohm resistors is one-half the supply voltage. Inasmuch as no current flows through the pick-up system, there is no voltage drop in either these ¼-megohm resistors or in the click filters, and hence the voltages applied to the delay switch busses are equal to each other and are one-half of the supply voltage. This is the piano position.

With the switch on contact 2, the back bus is grounded through its click filter and consequently is at zero voltage. The ¼-megohm resistor to the front bus is now tapped on a voltage divider, consisting of the 50,000-ohm series resistor and the other ¼-megohm resistor. Hence, the voltage on the front bus is 5/6 of the supply voltage, and the polarizing voltage will now vary from zero to 5/6 of the supply voltage, giving the organ effect.

Position 3 operates similiarly, but reversed. The voltage on the back bus, due to the voltage dividing action, is 6/7 of the supply voltage, and the voltage to the front bus, which is connected to ground, not directly, but through a 50,000-ohm resistor, is one-half of this value, or 3/7 of the supply voltage. This gives a voltage change from high to low for the "accentuated percussion" effects.

Wide Range Tone Control and the Triple Pick-up for the Electronic Piano

Pipe organs have thousands of tonal combinations available for the player. While the common radio type of tone control is valuable in the electronic piano, it will give the player no such range of control as the organ has. In order to approximate the flexibility of the organ, it is necessary to devise some means of changing the harmonic content of the original tone. This is most easily accomplished by means of the multiple pick-up and phasing controls now used on many modern electronic pianos. The following paragraphs will describe a simple type using two pick-ups, although practice has indicated that three is the best number to give a reasonable number of variations without too much complexity.

Fig. 2 indicates a string with both a fundamental wave standing on it as well as the second harmonic. Two pick-ups are arranged in the positions indicated at A and B, and each feeds through a preamplifier to a phasing transformer, which is nothing more nor less than a push-pull input transformer. As is well known, the voltages at each end of such a transformer are in opposite phase to each other.

It will be noticed that pick-ups "A" and "B" both pick up the same phase of the fundamental but opposite phases of the second harmonic. With the phasing switches both on contact "1," the voltages at the output are mixed in the same phase as they appear at the pick-up. Hence, the fundamentals, being of the same phase on both pick-ups, boost each other while the second harmonics, being of opposite phase, cancel out. With one switch on "1" and the other on "2," the phases, as picked up, are reversed in respect to each other and now the fundamental cancels out, while the harmonic remains with augmented strength.

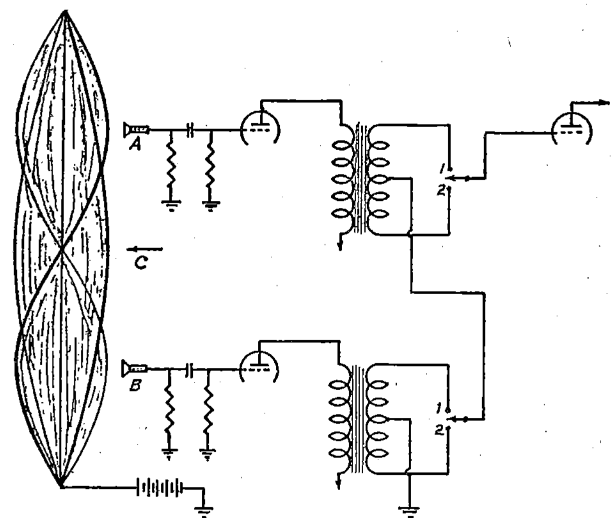


FIG. 2.—Positions of pick-ups in relation to the vibrating string and their output circuits.

If, instead of using switches, potentiometers are used, the control is still further refined so that, in the case illustrated, the balance between the fundamental and the second harmonic can be varied in any degree between the limits of the switch system. Of course, other harmonics vary at the same time, and while it is difficult to formulate rules, simple methods are used in the piano to arrive at the desired tone.

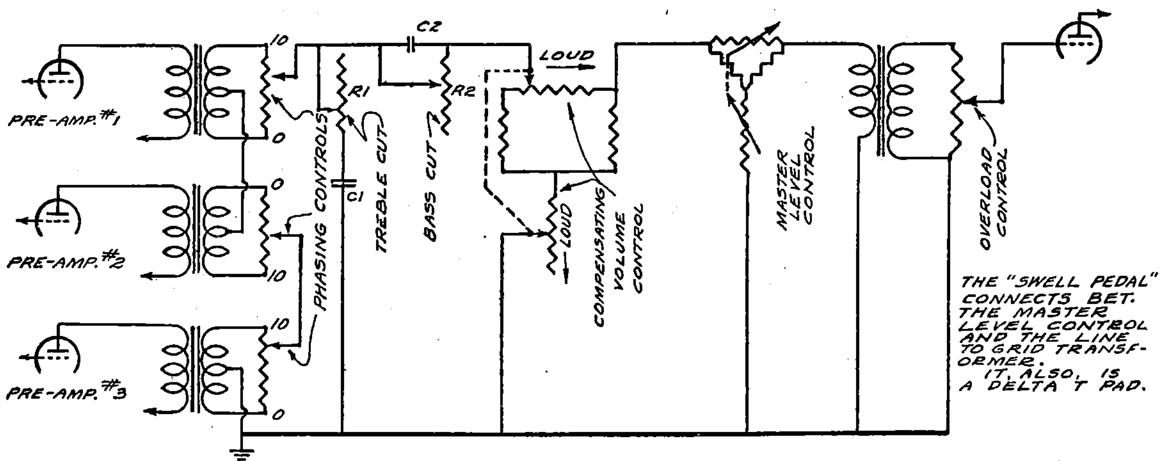
It will be noticed that a pick-up at position "C" would not be affected by the second harmonic vibration as this is of zero amplitude at this point along the string. It will, however, be affected by the fundamental, which is vibratory here. With proper positioning, a pick-up may be placed so that the harmonics picked up by it vary with its position on the string. Three pick-ups are actually used in the instrument, and they are so placed that the components on each of the three are such that the widest tonal range is achieved as they boost each other or buck each other out. The theory of the mixing and positioning of three pick-ups is very complicated, but it is just an extension of the simple case illustrated above.

Fig. 3 illustrates the control system used in the Krakauer piano, although the finished instrument utilizes push-button switches and tapped resistors instead of potentiometers. The peculiar non-symmetrical connection of the three phasing transformers and potentiometers is used to save a switch contact on the push-button switch system. All tone control circuits are at 500 ohms to minimize extraneous pick-up. Condenser C_1 and resistance R_1 comprise a "treble cut" tone control, while condenser, C_2 and resistance R_2 comprise a "bass cut" tone control. The addition of these controls, while not affecting the phasing controls, has been found advantageous. Table 1 gives the extreme settings of each of the phasing controls with the general type of tone produced. Intermediate settings give variations of these basic types of tones. Decreasing R_1 gives a thicker tone as does decreasing R_2. It can readily be seen that when many of the stronger components cancel out, the volume will be lower than if these same stronger components are boosting. In order to compensate for this effect, so that the average volume level is the same for all settings of the push-button controls, some sort of a pre-set volume control is incorporated in the push-button switching. This, as other level controls in the 500-ohm circuits, is of constant impedance type.

While the elementary pick-up system described in Fig. 2 locates the pick-ups opposite the loops of the second harmonic and also only the fundamental and second harmonic are illustrated, it will be understood that this is not the case in practice, but is merely an illustrative example. The piano string is capable of generating definite harmonics up to the fifteenth or twentieth in the richest ranges, and the three pick-ups actually used are placed to give the best control over the most important groups of these harmonics.

TABLE OF BASIC SETTINGS OF PHASING CONTROLS

Control on Pre-amp. 1	*Control on Pre-amp. 2*	*Control on Pre-amp. 3*	*Basic type of tone*
0	Center	Center	Best piano tone
10	Center	Center	Medium thin
Center	0	0	Medium thick
Center	10	10	
Center	Center	0	
Center	Center	10	
Center	0	Center	
Center	10	Center	
0	0	0	Very thick (all boosting)
10	10	10	
0	0	10	Very thin (#2 and #3 bucking)
0	10	0	
10	0	10	
10	10	0	



Schematic showing control system of electronic piano.