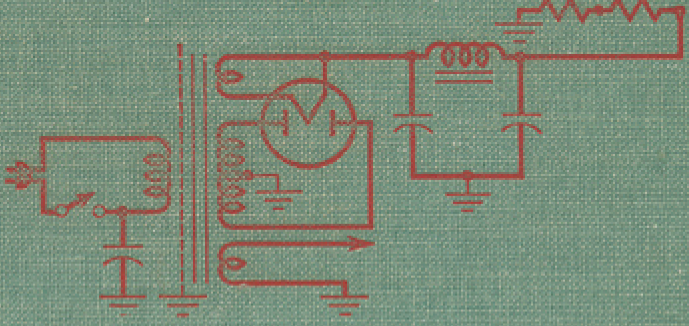
Elements of RADIO SERVICING



ELEMENTS OF RADIO SERVICING

WILLIAM MARCUS

The combination of technical skill, practical experience, teaching ability, and skill in writing has given William Marcus eminence as a teacher and as an author. He taught radio at the Abraham Lincoln High School and at the Melville Radio School. William Marcus is a member of the Standing Committee for Science in the Junior High Schools in the City of New York.

ALEX LEVY

Practical experience as a radio serviceman, as a sound technician, as the owner of a radio-service shop, and as a writer of technical manuals on electrical equipment for the armed forces well qualifies Alex Levy as a writer on radio servicing. He is a teacher of radio mechanics at the Thomas A. Edison Vocational High School, New York City, and in the Veterans Training Program. Alex Levy is the author of the syllabus for Radio and Television Mechanics for the Vocational High Schools in the City of New York.

Elements

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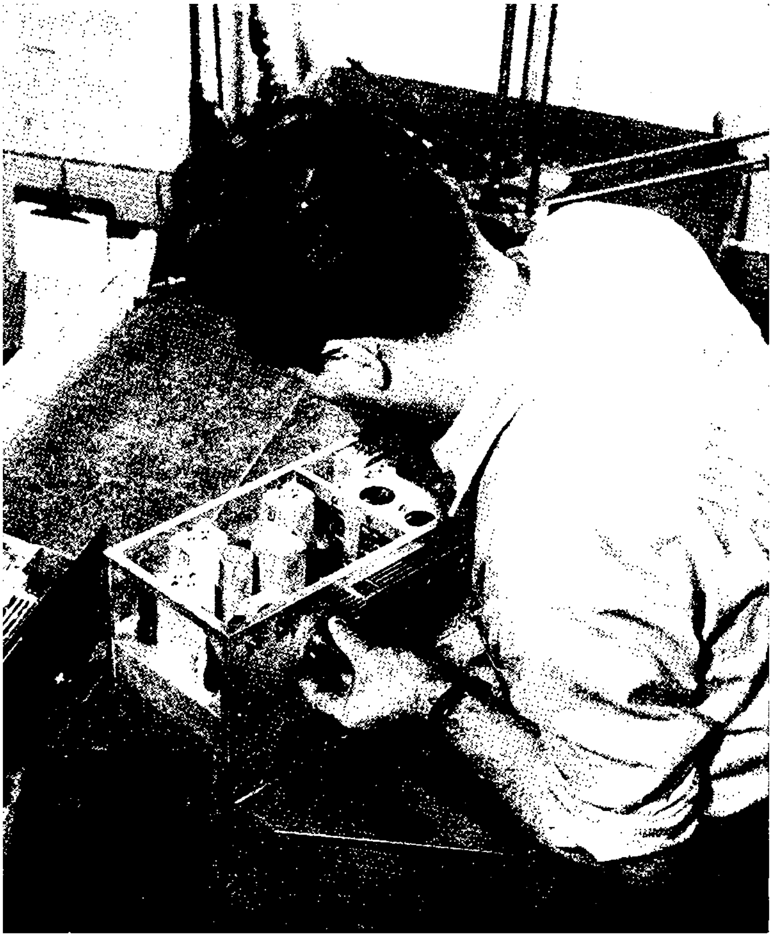

RADIO SERVICING

Second Edition

William Marcus
Alex Levy

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PREFACE

The field of radio servicing is still vigorous. Far from fading out of the picture with the rapid development of television, it still exists in its own rights as well as being a necessary prerequisite for the understanding of television servicing. Indeed, vocational schools recognize this fact and have set up their course accordingly.

As in the case of the first edition of this book, basic and necessary information together with a dynamic serviceman's procedure are presented. The many tributes paid to the first edition have indicated to the authors the sound basis of their pedagogical methods.

It is assumed that the reader has acquired an elementary background of radio theory prior to delving into service work. Nevertheless, elementary theory is presented in this book wherever it serves to make clear a particular procedure.

Design theory has been eliminated, since it is felt that such theory does not fall within the province of the serviceman. It is axiomatic that the serviceman must never redesign a receiver brought in for repair unless so advised by the manufacturer.

Since the publication of the first edition of this book, new practices and circuits have been developed. The authors have been cognizant of new trends and have included them in this second edition. Additional information has been added on the electronic multimeter. Completely new chapters have been added on battery and three-way portable receivers and on frequency-modulation receivers. This latter information is particularly important, since the sound portion of television sets is an FM receiver. New information has been added to the Appendix to make it more useful. Ever mindful of the desire for improvement, sections of the book have been rewritten for greater clarity. The authors feel that this second edition has definitely grown from elements of radio servicing to a more comprehensive level.

A book of this size could not possibly cover all the variations in radio receivers, so the authors have confined their survey to the most widely used practices of the past ten years. It is felt that on this basis the serviceman will be able to comprehend other variations.

The Text-Film Department of the McGraw-Hill Book Company, Inc., have prepared a special series of six filmstrips to correlate with and to illustrate visually specific items in this book. These are three filmstrips on the converter: *Part 1, Oscillator Stage; Part 2, Mixer Stage;* and *Part 3, Identification of Parts;* and two filmstrips on alignment:

Part 1, IF Amplifier, and *Part 2, Front End.* The sixth filmstrip is entitled *How to Use the Signal Generator.* Detailed descriptions of these six filmstrips are given on pages 555 and 556 of the "Correlated List of Visual Aids," at the end of this book.

William Marcus
Alex Levy

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Text-Films for

ELEMENTS OF RADIO SERVICING

The following series of six filmstrips has been prepared by the Text-Film Department of the McGraw-Hill Book Company, Inc., to correlate and to illustrate visually specific items in this book:

Converter. Part 1: *Oscillator Stage*

Converter. Part 2: *Mixer Stage*

Converter. Part 3: *Identification of Parts*

How to Use the Signal Generator

Alignment. Part 1: *IF Amplifier*

Alignment. Part 2: *Front End*

Detailed descriptions of these filmstrips are given in the Correlated List of Visual Aids on pages 555 to 557.

CONTENTS

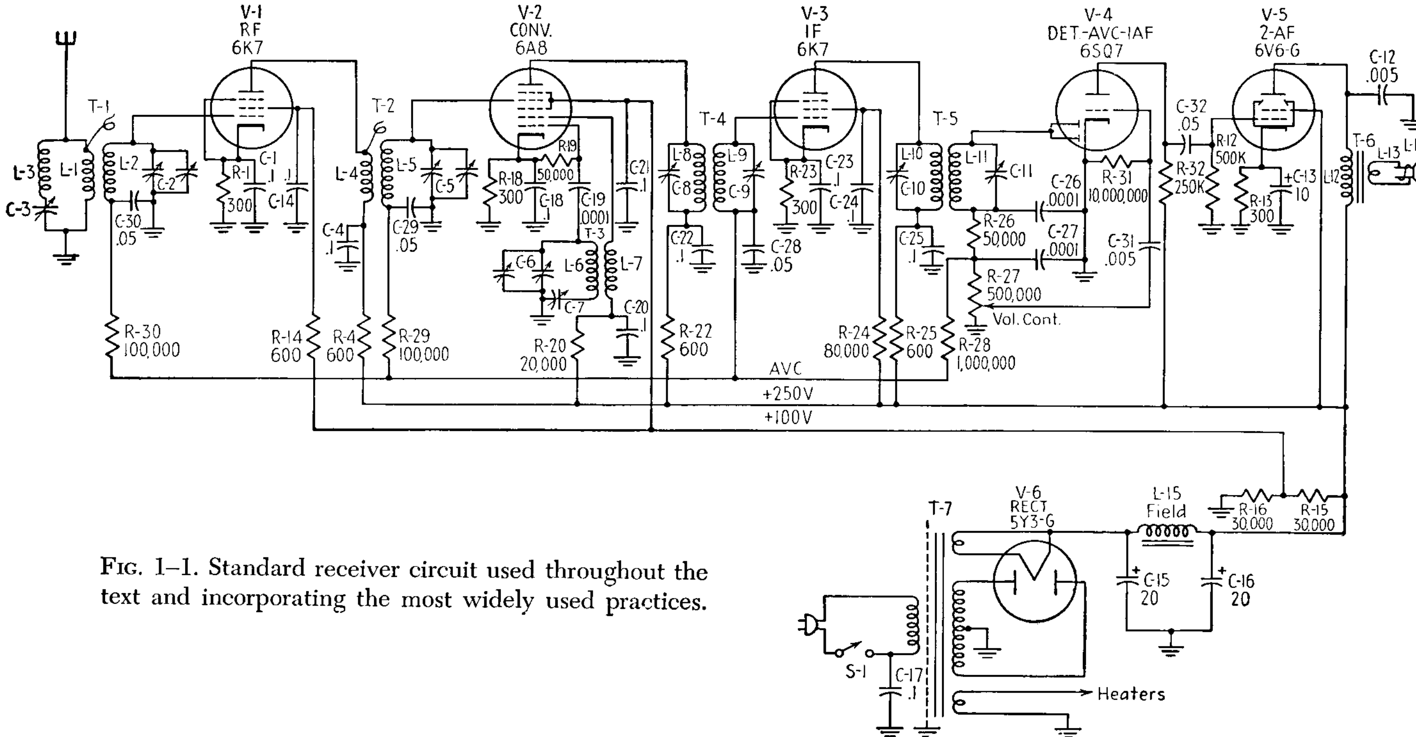


FIG. 1–1. Standard receiver circuit used throughout the text and incorporating the most widely used practices.

1 INTRODUCTION

Functional servicing. Thinking, especially in the solving of problems, involves the application of random bits of information to a particular situation. Two distinct elements are involved in this procedure. The first is that sufficient information to draw from is available. The second is that the information necessary for the solution is applied to the particular problem. The first element is a static one; the information may be compiled in a book for continuous reference. The second element is a dynamic one and cannot be assumed to develop from the first element unless specific exercise is provided.

Too many servicing manuals and books are organized on the premise that servicing skills can be developed if only enough bits of information are presented. In this respect, they fail to develop functional skills. The learner finds his path a slow and uncertain one.

The purpose of this book is to apply the psychology of learning to radio servicing. Basic information is presented at all times. In addition, the information is so organized that it develops whole dynamic procedures for application to specific radio troubles.

Scope of the book. It would be impossible to present in any small book procedures for servicing all types of radio receivers, as well as all the variations of each type. For this reason, the scope is restricted to the most widely used receiver—the superheterodyne.

All the individual variations could not be given. Therefore, a standard circuit, based on the most widely used practices, is presented as the basis for study. This circuit is shown in Fig. 1–1. In all probability, there is no receiver that incorporates all the features indicated; but for study purposes, such a standard circuit will be found invaluable. Throughout this book, the standard circuit is broken down and analyzed by stages, in accordance with the plan described in the following section.

All modern practices could not possibly be indicated in one schematic diagram. Therefore, a section on widely used variations in design is included in each chapter of stage analysis. It is felt that enough information will be obtained from the standard circuit and the variations sections to understand and service any other variation.

Finally, the latter part of the book is concerned with important topics that could not be handled in connection with the standard circuit. These topics are the AC/DC power supply, the auto power supply, the service bench, etc. Each of them is important enough to merit a separate chapter.

Organization of dynamic material. In order to make the material of this book dynamically functional, information is presented in the sequence that it would be used practically in servicing a superheterodyne receiver. Instead of proceeding from stage to stage in the order that a radio signal would pass from the antenna to the speaker, the stages are presented in the order that a serviceman would investigate a defective receiver. Standard radio-servicing procedures are given for each stage. In addition, simple practical tests performed by servicemen on the bench are presented. These tests are based on years of practical servicing experience.

Each stage is analyzed in a similar manner. The outline of analysis is presented below:

1. Quick check for normal functioning of the stage
2. Typical or basic circuit schematic
3. Function of the stage
4. Function and common value for each component part
5. Normal test data for the stage
6. Common troubles encountered in the stage
   a. How they are found
   b. Special problems involved in replacement of components
7. Variations from the typical stage that are frequently used; special trouble-shooting procedures in these variations
8. Summary of tests including outline of procedure to be followed in tracing various symptoms to their cause

The organization of the information, as outlined above, is the method by which the material information will become quickly functional. A little practice in its use will assure a quick practical approach to radio servicing problems.

It should be understood that this book is not intended to be an encyclopedia of radio servicing. Once the method of attack is mastered, reference to service notes distributed by radio-receiver manufacturers will be more useful than before. Where an unusual circuit is encountered, such notes will prove to be of great value.

2 SUPERHETERODYNE RECEIVERS

Block diagram of a superheterodyne receiver. Before the stage analysis of the superheterodyne receiver is presented, it is advisable for the serviceman to have an overview concept of how it works. This picture will be obtained readily from a block diagram. Each block represents a stage that will be shown later in schematic and more detailed form. The accompanying wave forms or pictures of the types of electric currents show how each stage alters the signal entering it. It will be seen later that some of these stages may be omitted or that two stages may be combined into one. The block diagram of the superheterodyne receiver is given in Fig. 2–1.

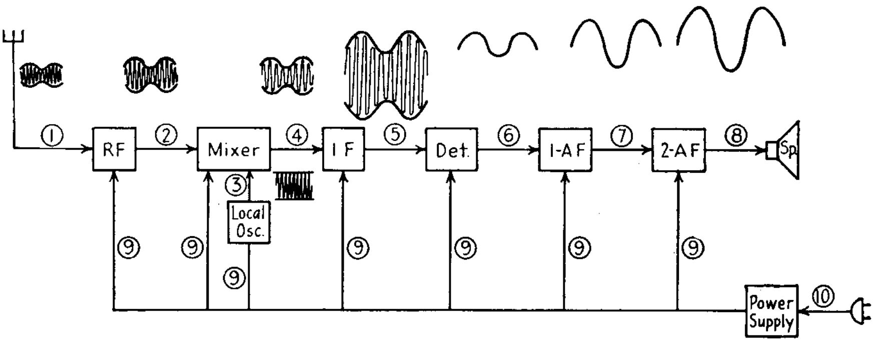
How the superheterodyne receiver works. An analysis of the block diagram shown will clarify this matter. Down the antenna come the modulated RF carrier signals of all stations within the receiving area of the set. In the broadcast band, they vary from 550 to 1,600 kc. Before passing through the RF stage, one station is selected by tuning and its signal is passed on. The modulated RF carrier signal is a high-frequency wave modulated or varied by a lower frequency wave known as the "audio modulation." The audio modulations represent the useful component that will eventually drive the speaker.

The RF stage merely amplifies the station to which we are tuned and passes the amplified signal with its audio modulation on to the mixer. The audio modulation retains the same wave form as the signal received at the antenna.

The mixer and local oscillator work together as a team. Often the two stage functions are performed by one tube, which is called a "converter." The local oscillator is a generator of unmodulated RF waves, automatically adjusted to a frequency of about 455 kc above that of the received station RF frequency. When the output of the local oscillator is mixed with the RF station frequency in the mixer stage, the resulting output of the mixer is at a frequency of 455 kc, with the same audio modulations as that of the original signal that came down the antenna.

The 455-kc signal is then fed into the IF stage, which is fixed-tuned to about 455 kc. Here the signal is amplified and fed into the detector. The audio modulations still retain the original wave form.

The detector stage removes the 455-kc RF component from the audio modulation component and passes the latter into the first audio stage. This detector is frequently referred to as the "second" detector, and the mixer or converter is called the "first" detector.



1. RF (550 to 1,600 kc)—modulated at radio frequencies.
2. Tuned and amplified RF (550 to 1,600 kc)—modulated at audio frequencies.
3. Unmodulated RF (RF one + 455 kc).
4. IF (455 kc)—modulated at audio frequencies.
5. Amplified IF (455 kc)—modulated at audio frequencies.
6. Audio frequencies (50 to 10,000 cycles) for high-fidelity receivers.
7. Amplified audio frequencies (50 to 10,000 cycles) for high-fidelity receivers.
8. Amplified audio frequencies (50 to 10,000 cycles) for high-fidelity receivers.
9. DC *B*—supply.
10. 110-volt, 60-cycle AC supply or 110-volt DC supply.

FIG. 2–1. Block diagram of a superheterodyne receiver with associated wave forms.

The audio component enters the first audio stage, where its voltage is amplified. It still retains the same wave form as that of the original audio modulation on the station carrier.

The second audio stage amplifies the audio signal even more, developing sufficient power to drive the speaker, which is a power-driven device. The audio signal still retains its same wave form at the input to the speaker. The speaker response is a series of sound waves.

Power for the entire receiver is usually obtained from a 110-volt, 60-cycle AC source or a 110-volt DC source. The power supply will rectify the AC supply, where such power is supplied, and will filter the rectified voltage to obtain a fairly smooth direct current, which now becomes our *B* supply. Where 110-volt DC power is furnished, the power supply will merely filter it to obtain the *B* supply. In battery portable sets the *B* supply is obtained directly from batteries.

Using the block diagram. It is important that the block diagram shown in Fig. 2-1 be committed to memory before going on. Where test instruments are used, the input and the output waves of each stage will determine how to make proper settings. This is especially important in signal-substitution methods where a signal generator is used.

3 SERVICING PROCEDURE

Receiver servicing systems. When a radio receiver is brought in for servicing, the demand made of the serviceman is that he put the set back into normal operation. The means is of relatively no importance to the customer. Although this end also becomes the aim of the serviceman, he is confronted with a more immediate goal. What method shall he follow in locating the defect?

The various techniques that he uses can be grouped into a few systems of procedure, which are listed below:

1. Reliance on sight, touch, smell, and past experiences with the same type of receiver
2. Part-substitution method
3. Voltage measurements across components
4. Point-to-point resistance measurements
5. Electrode-current checking
6. Signal substitution
7. Dynamic-signal tracing with a vacuum-tube voltmeter and oscilloscope

The first system is a self-evident one. Wherever a component appears to be broken or burned, or smells as if it has been overheated, or feels too hot, the assumption might reasonably be made that it is defective and should be replaced. Similar difficulties previously experienced with the same type of receiver might guide the serviceman. Unfortunately, too many defects will not result in extremes of breakdown. Also, the defective component is not disclosed as the cause of the receiver failure or the result of some other defect. Finally, experience as the guide can at most be a helpful rather than an infallible aid.

The second system involves the substitution of a part, known to be good, for a similar part that seems to be defective in the receiver. The weakness in this procedure is that it is too time-consuming by itself and may be useless where the trouble involves a number of defective components.

The third system is one in which voltage measurements are taken across various components. When the observed values are compared with normal voltage data, defective components are readily found. There are several weaknesses in this system when used alone. The time required to make all voltage checks in a modern complex receiver makes it extremely inefficient. At the very best, it may be used alone for making routine checks. In addition, many defects will not alter voltage readings to an extent that would indicate where the defects may be found.

The fourth system is similar to the third, except that resistance measurements are taken with an ohmmeter across the various components, rather than voltage measurements with a voltmeter. Used alone, this system has the same weaknesses as the voltage test.

The fifth system is one in which current measurements are made in various portions of the receiver to locate deviations from normal values. It is not often used, because it involves either the opening of circuits to insert ammeters in series, or the use of special adapters.

The sixth system is a popular one. A signal, similar to the one normally encountered in operation, is fed into the input of a stage, and the result at the output is then observed and compared with normal expectations. It is not suitable when used alone, since it primarily locates a defective stage without indicating the defective component.

The last system is one that involves expensive equipment and complex techniques. Commercial instruments are of various types, but most attempt to analyze the stages of the receiver under actual working conditions. Basically, all are combinations of vacuum-tube voltmeters, capable of making measurements without loading the circuits tested, and are excellent for measuring weak signals in the order of microvolts. The signal indicators are of various types: oscilloscopes, electron-ray tubes, loudspeakers, meters, etc. These instruments readily indicate loss of gain of stages, distortion, intermittents, regeneration, oscillation, noise, and other conditions. However, they still require supplementation by the multimeter and the signal generator.

Which servicing procedures shall we use? No one of the servicing systems referred to in the above section can be used with speed and efficiency when taken alone. Experience has shown that it is most efficient first to determine the defective stage by means of a signal check and then carefully to analyze that stage for defective components.

This book assumes that the intelligent and combined use of the first four systems listed, plus the signal-substitution system, will give a highly efficient trouble-shooting procedure. Reference to the stage analysis in later sections will give great facility in the proper combined use of the suggested systems.

What instruments should the serviceman have? To follow the suggestions that are recommended, a voltmeter, an ohmmeter, and a signal generator are required. Two of these are combined in one popular instrument called a "multimeter," which combines a voltmeter, ammeter, and ohmmeter in one unit, with a switching device to obtain the desired function as well as the proper range.

Order of use of instruments. The advantages of the recommended procedures will become evident with use. The general rule to be followed in servicing a receiver is, first, to use the signal generator in order to locate the defective stage or interstage components. The voltmeter and ohmmeter are then applied in order to close in for the kill, that is, the determination of the actual defective components.

The latter part of this book breaks down a typical superheterodyne receiver into its stages and gives procedures for testing the normal operation of each one. For each stage, typical test voltage and resistance measurements are listed for comparison with those actually found in the defective receiver. In addition, where possible, practical methods of testing stages are listed.

Finally, the order of presentation of the stages analyzed is, in general, the order in which a serviceman would be expected to subject the defective receiver to analysis. It is felt that in this way he will use this book with a more functional approach to his problem.

The question might arise at this time as to the place of a tube tester in a service shop, since many receiver defects may be due to faulty tubes alone. A word with regard to this matter will explain the lack of emphasis placed on that instrument.

There are two types of tube testers: the mutual-conductance type of tester and the emission tester. In the first, a small designated change of grid voltage is applied to the tube. The resulting change of plate current determines whether to call the tube good or bad. In the emission tester, the current flow or emission that results when the filaments are heated and a fixed voltage is placed on the plate determines whether to call a tube good or bad. Emission decreases with the age of the tube. In addition, both types of testers have circuits for determinating whether there is leakage or a short between the tube elements.

The tube tester is suitable for testing rectifier tubes. However, for other tubes, it does not measure their operation under the same dynamic conditions that they encounter in actual operation. Tubes that test good in it may be poor in actual receiver operation. A far better check for the serviceman is to hook up the signal generator and an output meter to the receiver and observe the output. Then substitute a good tube for the one believed to be bad and compare the two outputs. Of course, where the customer brings only his tubes for testing, the tube tester is the instrument to use, its limitations being understood.

4 MULTIMETERS

A typical multimeter. The multimeter is one of the radio serviceman's constant companions. It is the instrument that finally localizes troubles in the receiver after the defective stage is found. A typical multimeter is shown in Fig. 4–1. Its purpose is primarily to make voltage, current, and resistance measurements throughout the receiver.

To perform its functions, the multimeter is a milliammeter, voltmeter, and ohmmeter combined in one case. In addition, it is designed to furnish various ranges of current, voltage, and resistance measurements. To select a particular function and a particular range from the instrument, a front-panel selector switch is provided. Each position of the switch is labeled for that purpose.

FIG. 4–1. The Simpson Model 260 multimeter.

In describing the components of the multimeter, it is better to treat the voltmeter and ohmmeter as though they were separate. Nothing will be said about the milliammeter as a current measuring device, since few servicemen will make such measurements without adapters. The only principle to be kept in mind, when currents are measured, is to be sure to be on the correct range. A good policy is to start at the highest range and switch down to lower ones until the correct one is reached.

General principles of the voltmeter. The purpose of a voltmeter is to indicate the potential difference or voltage between two points of a circuit. This is accomplished by connecting the two input terminals of the voltmeter to the two points to be tested in the circuit. The placement of the voltmeter, in parallel with the circuit to be measured, brings up some interesting factors that will be described later.

Essentially, the voltmeter is a D'Arsonval galvanometer in series with a fairly high-ohmage resistor. The latter is commonly called the "multiplier." Figure 4–2 shows a basic voltmeter. The size of the multiplier determines the range of the voltmeter. A brief analysis will make this point clear.

Begin with a galvanometer that gives full-scale deflection at 1 ma (0.001 amp). Such an instrument is usually called a "one-mil milliam-

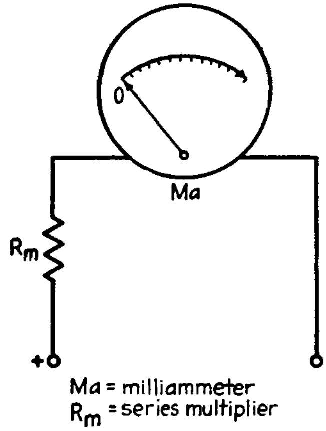


FIG. 4–2. A basic voltmeter.

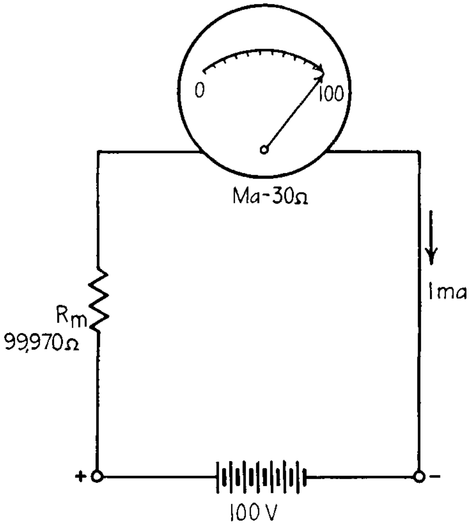


FIG. 4–3. Voltmeter with 0- to 1-volt range at full-scale deflection.

meter." Assume that it has an internal resistance of 30 ohms. What must be the resistance of the multiplier to convert it into a 0 to 1 voltmeter? When so converted, 1 volt placed across the milliammeter and multiplier will drive 1 ma through it to give full-scale deflection, as shown in Fig. 4–3. Using Ohm's law, determine the resistance that will give this condition.

$$R = \frac{E}{I} = \frac{1}{0.001} = 1{,}000 \text{ ohms}$$

Since the milliammeter has a resistance of 30 ohms, the multiplier R_m must have a resistance of 1,000 minus 30, or 970 ohms. An instrument of this sort is called a 1,000-ohms-per-volt voltmeter, because 1 volt is applied across 1,000 ohms: (1,000/1) = 1,000. This designation is an indication of its sensitivity.

Suppose that it was desired to convert the same milliammeter into a voltmeter of 0 to 100 volts. What must be the resistance of the multiplier? By similar reasoning, 100 volts now placed across the milliammeter and multiplier will drive 1 ma through it to give full-scale deflection, as shown in Fig. 4–4. Using Ohm's law for the total resistance,

$$R = \frac{E}{I} = \frac{100}{0.001} = 100{,}000 \text{ ohms}$$

Again subtracting the milliammeter resistance from the total resistance, we find that the multiplier must have a resistance of 100,000 minus $30 = 99{,}970$ ohms. Its sensitivity is still found to be 100,000/100, or 1,000

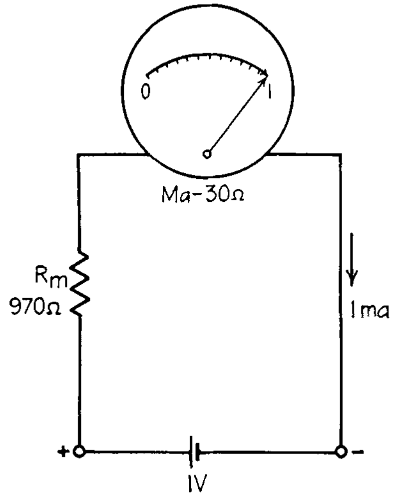


Fig. 4–4. Voltmeter with 0- to 100-volt range at full-scale deflection.

ohms per volt. A switch is usually provided on the multimeter to give a voltmeter of different ranges by cutting in different multipliers. Such a switching device is shown in Fig. 4–5.

In using various voltmeters, the serviceman may be surprised when he measures the voltage across two points of a circuit and obtains two different readings. His first impulse might be to say that one of the instruments is inaccurate. Yet they may both be right, and the serviceman must interpret his results more carefully.

The explanation for this condition lies in the different sensitivities of the voltmeters. The example given above was for a 1,000-ohms-per-volt voltmeter. Commercial voltmeters with different sensitivities have been made. There are voltmeters with sensitivities of 100, 125, 1,000, 2,000, 2,500, 5,000, 10,000, 20,000, and 25,000 ohms per volt. For example, let us assume that a galvanometer requires 50 microamperes (0.00005 amp) for full-scale deflection. What must be the size of the total resistance to give a voltmeter with a range of 0 to 1 volt? From Ohm's law,

$$R = \frac{E}{I} = \frac{1}{0.00005} = 20{,}000 \text{ ohms}$$

The sensitivity of this voltmeter is 20,000/1, or 20,000 ohms per volt. Similarly, with the same basic movement, we could convert it into a voltmeter with a range of 0 to 100 volts. From Ohm's law,

$$R = \frac{E}{I} = \frac{100}{0.00005} = 2{,}000{,}000 \text{ ohms}$$

The sensitivity is still 2,000,000/100, or 20,000 ohms per volt. Now,

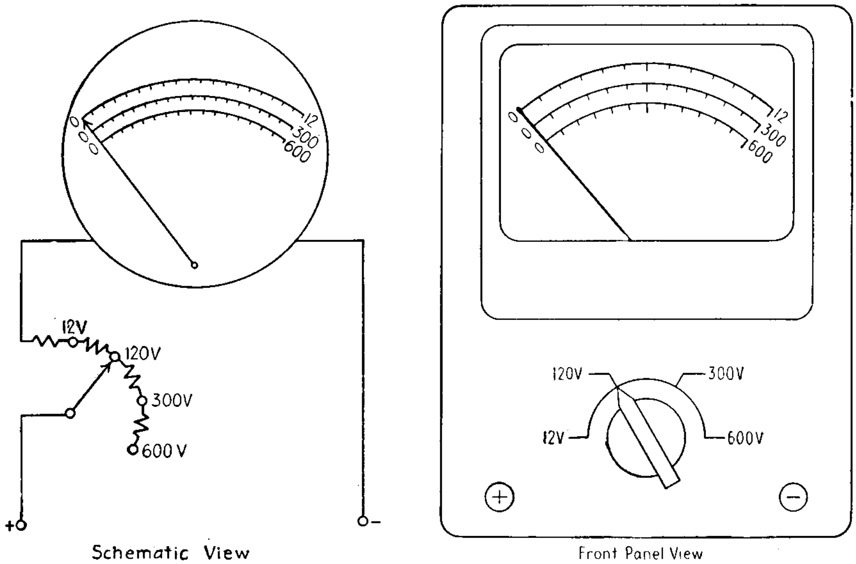


FIG. 4–5. Multirange voltmeter showing range switch.

consider the following circuit in Fig. 4–6, across which 60 volts are dropped. We shall use voltmeters on the 100-volt range.

Since $R_1 = R_2$, the voltage dropped across each is equal and is 30 volts. If the 1,000-ohms-per-volt voltmeter is connected across R_2, we have the condition indicated in Fig. 4–7. The voltmeter and R_2 are equal in resistance and in parallel. The combined resistance of the parallel branch is now 50,000 ohms, and the circuit now appears as in Fig. 4–8. Since the two resistors are now not equal, the voltage divides differently, (100,000/150,000) $\times$ 60, or 40, volts across R_1, and (50,000/150,000) $\times$ 60, or 20, volts is dropped across R_2 and the voltmeter. The voltmeter reads 20 volts. If the 20,000-ohms-per-volt voltmeter is substituted for the 1,000-ohms-per-volt voltmeter, the condition indicated in Fig. 4–9 prevails. The combined resistance of the voltmeter and R_2 is about 95,238 ohms. The circuit now appears as shown in Fig. 4–10. Across R_1, (100,000/195,238) $\times$ 60, or about 30.7 volts are dropped. Across R_2 and

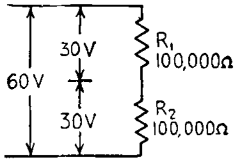


FIG. 4–6. Voltage distribution across two equal resistors.

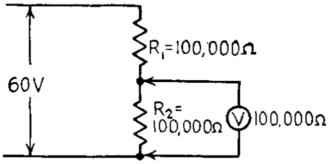


FIG. 4–7. Measuring voltage with a 1,000-ohms-per-volt voltmeter.

the voltmeter are dropped (95,238/195,238) $\times$ 60, or about 29.3 volts. The voltmeter reads 29.3 volts. In both cases above, the effects of change of current when the voltmeters were connected have not been taken into consideration because the relative results would still exist.

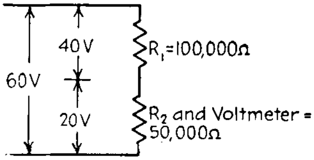


FIG. 4–8. Voltage distribution resulting from loading the circuit with a 1,000-ohms-per-volt meter.

Which voltmeter was correct in its reading? If interpreted properly, both gave correct results. The serviceman may use either of the two voltmeters of different sensitivities, but at all times he must interpret his results. Generally, it is true that, when the voltage across a high-resistance circuit is measured, the voltmeter of the higher ohms-per-

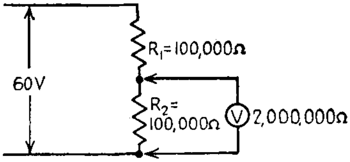


FIG. 4–9. Measuring the voltage with a 20,000-ohms-per-volt meter.

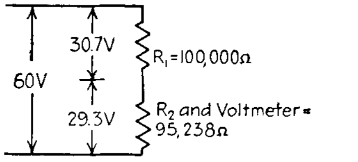


FIG. 4–10. Voltage distribution resulting from loading the circuit with a 20,000-ohms-per-volt meter.

volt sensitivity will give a more accurate reading. However, many radio manufacturers often give voltage tables in their service data, and specify "Readings taken with a 1,000-ohms-per-volt voltmeter"; and some multimeters have switches for changing from 20,000 to 1,000 ohms per volt for the above purpose.

Where the voltage is measured across a low-resistance circuit, the difference in readings between the voltmeters of different sensitivities is not so great. This fact is tabulated in Fig. 4–11.

To summarize, the voltmeter of higher sensitivity gives the more accurate readings, especially when measured across high-resistance circuits. Thus, when cathode voltages across a resistor of several hundred ohms are measured, the 1,000- and 20,000-ohms-per-volt voltmeters will give about equally accurate results. However, when voltages

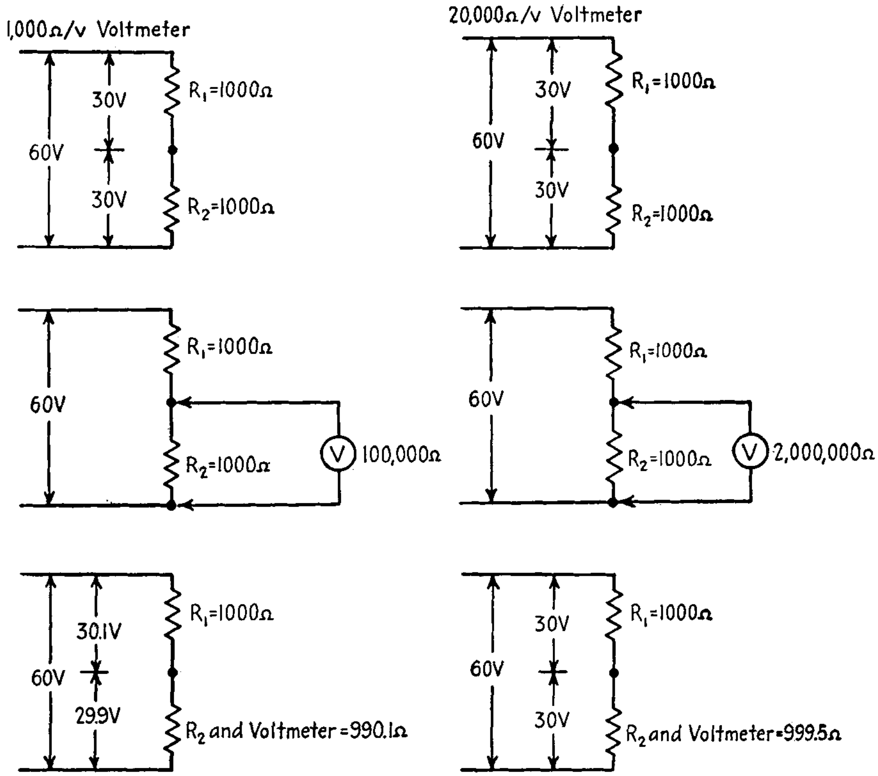


FIG. 4–11. Comparison between a 1,000-ohms-per-volt meter and a 20,000-ohms-per-volt meter in a low-resistance circuit.

in the plate circuits across resistors of hundreds of thousands of ohms are measured, the voltmeter of greater sensitivity will be the more accurate, and the limitations of one of low sensitivity should be kept in mind. The 1,000-ohms-per-volt voltmeter may be used almost everywhere, except in very high-resistance circuits like the AVC bus and the actual cathode to control grid voltage in the audio stage, where the usual grid load is 500,000 ohms. A 20,000-ohms-per-volt voltmeter will give a reading on the AVC bus, but it will load the circuit and throw off its operation. For best measurement in this case, a vacuum-tube voltmeter, with a high internal impedance in the order of 15 megohms, will load the circuit least by drawing only an infinitely small current. Regardless of which meter is used, the results must always be properly interpreted.

The voltmeter section of the multimeter is usually designed for various ranges of AC as well as DC voltage measurements. The voltmeter is converted into an AC meter by placing a rectifier in the circuit, as shown in Fig. 4–12. The rectifier converts the alternating current to direct current, which is then read on the DC meter. Different ranges of AC voltage may be measured by use of the range switch, as was done for the DC voltmeter. The rectifier is switched in and out of the circuit by a separate switch, one position of which is marked AC and the other DC.

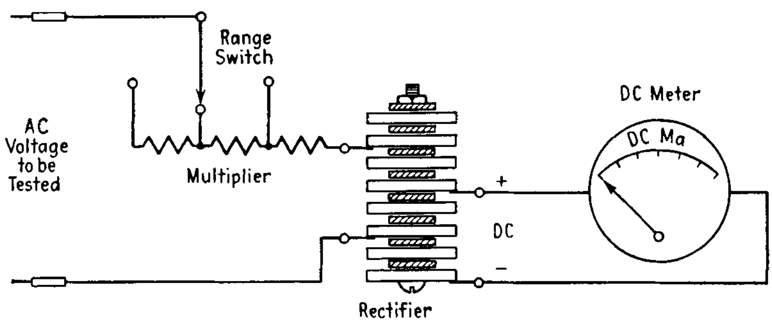


FIG. 4–12. Typical multirange AC voltmeter.

Several considerations must be kept in mind when using the voltmeter. When used as a DC voltmeter, polarity must be observed. There is a positive terminal and a negative terminal. The test leads are color-coded, one red and the other black. The usual convention is to connect the red lead to the positive terminal and the black lead to the negative terminal. It is advisable to clip the black, or negative, lead to the *B* minus of the power supply or the chassis, and to tap the red, or positive, lead to points to be tested in the receiver. This latter step should be done with one hand to avoid severe shocks.

When using the instrument as an AC voltmeter, such polarity need not be observed. Either terminal may be connected to any point. The rectifier takes care of the polarity required by the voltmeter itself.

A final important precaution to remember is that a high voltage, applied across the voltmeter when it is switched to a low-voltage range, will burn out the meter. With an AC voltmeter, a similar error will burn out the rectifier. Good practice is to switch to the highest range and then to decrease the range by steps until the proper one is attained. Of course, voltmeter readings in the receiver are always taken with the power from the mains turned on. Voltage measurements on a receiver are usually taken with the volume control turned full on, and the tuning dial in an off-station position.

General principles of the ohmmeter. The ohmmeter is an instrument indicating the amount of resistance that a component offers to the flow of a direct current. When used to make such measurements in a radio receiver, the power must be shut off if we do not wish to ruin the ohmmeter by placing an external voltage across it.

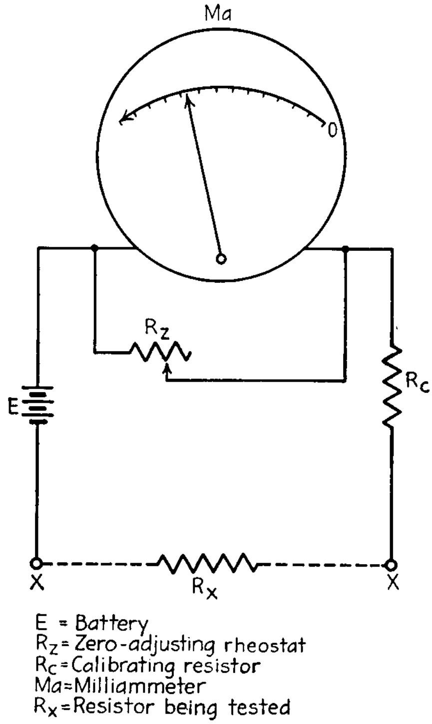


FIG. 4–13. Basic ohmmeter circuit.

Basically, the ohmmeter is a milliammeter that requires current to energize it. Since the power in the receiver is off, another driving source of voltage is required. A battery is included in the instrument itself for this purpose. To compensate for any change in battery voltage as time goes on, a zero-adjusting rheostat is included. A basic circuit for an ohmmeter is shown in Fig. 4–13. The component to be measured is placed across the points marked *x–x* in the figure. If the component has practically no resistance, the milliammeter will be fully deflected. The higher the unknown resistance, the less the amount of current through the milliammeter, and the less the deflection. For this reason, the zero of the ohmmeter scale is at the right and the scale increases toward the left.

Unfortunately, the scale is not linear; that is, the units are not equal. Values of resistance at the upper, or left, end of the scale are very crowded and hard to read. For this reason, a switching device is included to give various ranges. In some ohmmeters, the switch markings and

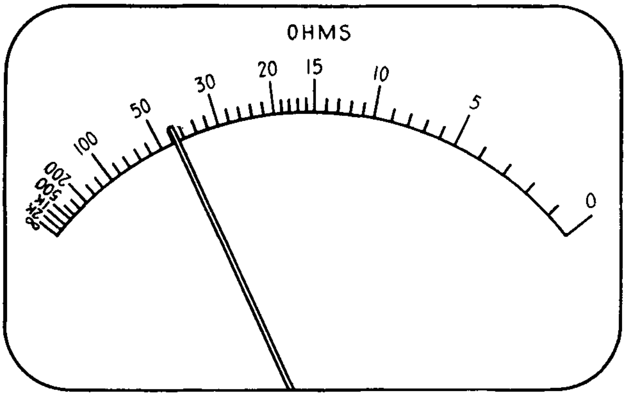


FIG. 4–14. Typical ohmmeter scale.

scales present a problem in reading. For this reason, an example in reading would be of great value. Figure 4–14 shows the ohmmeter scale of a typical multimeter, with the meter needle indicating a particular reading. Note that the left end of the scale shows 2K. The letter K stands for 1,000. Unfortunately, owing to previous practice, the letter M is often used for 1,000. This latter practice leads to confusion. For example, 2M

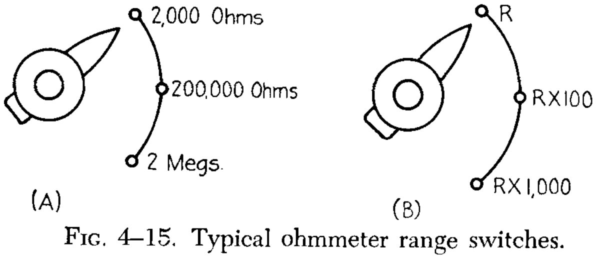


FIG. 4–15. Typical ohmmeter range switches.

ohms equals 2,000 ohms, while 2Mc equals 2,000,000 cycles. It therefore becomes necessary for the serviceman to interpret the meaning of M in schematics. This book will use K for 1,000 and M for 1,000,000.

The ranges of such an ohmmeter are 0 to 2,000 ohms; 0 to 200,000 ohms; and 0 to 2 megohms. The switch ranges are indicated in either of two ways by multimeter manufacturers. These are shown in Fig. 4–15.

The switch designation in Fig. 4–15*B* is more convenient, since it tells directly by what value the scale reading must be multiplied in order to get the true reading for each range. It is suggested that, if the ohmmeter of the serviceman has scale indications as indicated in Fig. 4–15A, he paste over the ranges multipliers similar to those at *B*.

Now what is the reading if the switch of our meter is at *R*? Here the scale is read directly as 43 ohms, approximately. If the switch is at the $R \times 100$ range, the reading is 43×100, or 4,300 ohms. When the switch is at the $R \times 1{,}000$ range, the reading is $43 \times 1{,}000$, or 43,000 ohms.

A good rule to follow is to select the range that gives the resistance reading about the middle of the scale. Of course, since a battery is included in the ohmmeter and is properly polarized, no polarity need be observed when the resistance of components is measured.

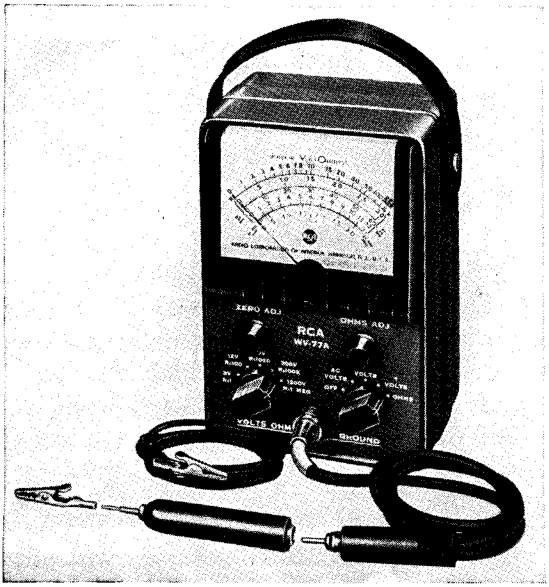


Fig. 4–16. RCA Junior Voltohmyst.

A final word must be said about making resistance measurements in the receiver with an ohmmeter. The serviceman must be sure that there is no parallel branch across the component that he is measuring. Reference to a schematic of the receiver being tested will aid in such determination. When in doubt, disconnect one terminal of the component under test. The serviceman will also encounter difficulty where an electrolytic condenser is in parallel with a tested unit. Normally, condensers are practically infinite in resistance to direct currents. But electrolytic condensers have a fairly low leakage resistance (from 1 to 50 megohms). The rule to follow, where such is the case, is to measure the resistance of the component, then reverse the ohmmeter prods, and measure again. This is done because the polarized electrolytic condenser will show less leakage in one direction than in the other. Use the higher of the two readings obtained as the reading for the unit being tested. If there is any doubt, disconnect one terminal of the component, as for parallel resistors.

Electronic volt-ohmmeters. Reference was made previously to the vacuum-tube voltmeter with its high-input impedance. These instruments have in recent years become relatively inexpensive. Their popularity has also increased, since the function of ohmmeter has been added. They are referred to as "electronic volt-ohmmeters." Figure 4–16 shows such an electronic meter, the RCA Junior Voltohmyst.

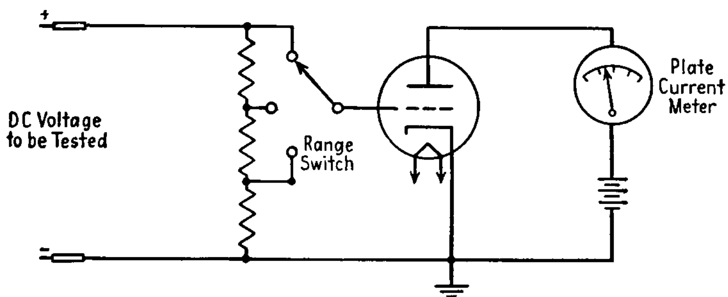


FIG. 4–17. Basic DC electronic voltmeter.

The principle of operation of the vacuum-tube voltmeter is fairly simple. Examine the schematic of a basic DC electronic voltmeter shown in Fig. 4–17. The voltage to be tested is applied across two test prods and is then fed to grid and cathode of a tube. The grid return to cathode is through a high resistance, giving the instrument its high-impedance input. The test voltage applied to the tube grid increases the plate current more or less, depending on the magnitude of the applied voltage.

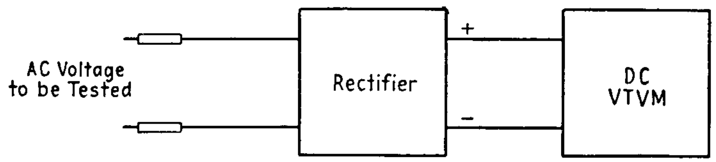


FIG. 4–18. Basic electronic AC voltmeter.

The increase of plate current is then indicated on the DC current meter. The latter is calibrated in volts necessary to produce the amount of plate current increase. The range switch is similar in function to that in galvanometer instruments.

The electronic meter, then, is basically a DC voltmeter. To measure low-frequency alternating voltage, a built-in rectifier is switched ahead of the basic DC instrument, as shown in Fig. 4–18. Usually a diode tube is used for the rectifier. This changes the AC to DC, which is then measured on the DC vacuum-tube voltmeter.

The capacity losses of the test leads make the above type of AC voltmeter unsuitable for testing high-frequency AC voltage. To overcome this difficulty, many instrument manufacturers supply an auxiliary high-frequency test probe. Here the rectifier (usually a germanium crystal) is enclosed in the probe, making for very short, low-loss RF leads. The DC output of the crystal in the probe is then measured by the basic DC vacuum-tube voltmeter. The probe setup is shown in Fig. 4–19. This special probe enables the instrument to measure AC signal voltages at frequencies as high as 250 megacycles.

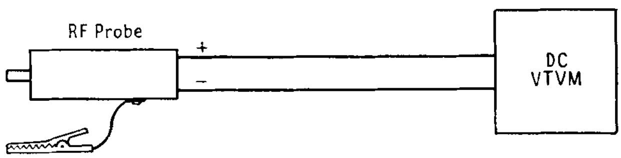


FIG. 4–19. Basic electronic RF voltmeter.

The last function of the electronic instrument is that of an ohmmeter, shown in Fig. 4–20. In this function, the instrument includes a self-contained battery and calibrating resistor R, connected in series with the test prods, as shown in the diagram. The placement of an unknown resistor, R_x, across the prods, produces a closed series circuit, and battery current flows. This develops a voltage across the unknown resistor, of a magnitude dependent on its resistance. This voltage is then measured by the basic vacuum-tube voltmeter.

One of the scales on the instrument is calibrated directly in ohms. Note that the circuit is so arranged that zero ohms is at the left end of

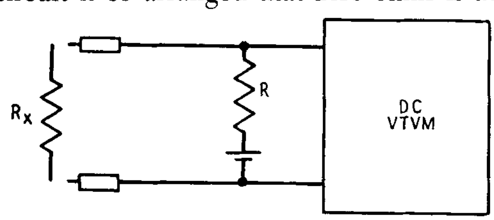


FIG. 4–20. Basic electronic ohmmeter.

the scale, as shown in the top scale of Fig. 4–16. This is opposite to that of a moving-coil ohmmeter.

The general rules previously given for moving-coil meters apply equally to electronic meters. When measuring ohmage, get the reading around the center of the scale by choosing the proper range. Also, be sure that no parallel circuits exist across components being measured. Again, the same precaution exists for both instruments when measuring leakage resistance of electrolytic condensers. Reverse the test prods, and take the higher reading as the leakage resistance. When measuring voltage, begin on a high-voltage range and work down for a good reading.

5 SIGNAL GENERATOR—INTRODUCTORY

Fundamentally, the signal generator is a device for placing into the input of a stage a signal similar to that of the input signal, when the receiver is operating normally. In this way, it can be determined if a stage is operating normally. By placing the signal from the generator at various strategic points, interstage coupling components can also be tested for breakdown. Finally, the signal generator is an invaluable aid in receiver alignment.

Types of currents. A better understanding of the use of the signal generator will be obtained if time out is taken for a review of the various types of currents. The simplest type is the pure direct current. It is a flow of electrons at a steady rate in one direction through a circuit. Such a

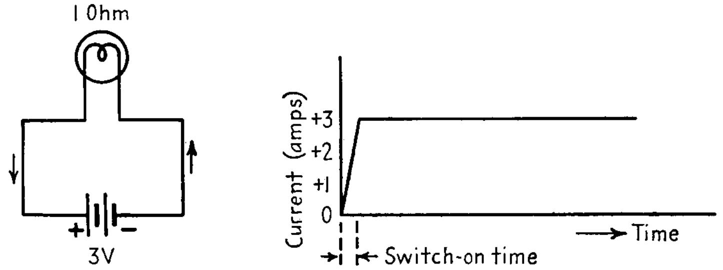


Fig. 5–1. Circuit and wave form for a pure direct current (DC).

current would result from the use of a battery as a power source. The build-up and steady flow of such current could be represented as shown in Fig. 5–1. The fact that the current is steady is shown by the horizontal current line. The fact that the current flows in one direction is shown by the fact that the current line (graph) is always above the zero base line, in the plus direction.

Another type of current is the pulsating or varying direct current. Here, the electrons always flow in one direction but at a *varying* rate. Such a current would result from a varying voltage source or from a varying resistance in the circuit. Figure 5–2 represents the varying direct current resulting in a circuit that includes a flasher button which changes the resistance from that of the lamp alone to an infinite (open) resistance. Notice that the direct current flows only in one direction, as shown by the fact that the graph is always above the base line.

A third important type of current is the pure alternating current. This current continually changes in magnitude and periodically reverses in direction. An AC generator as a power source would produce such a current, often called a "sine-wave current." Figure 5–3 represents a pure alternating current. That the magnitude is constantly changing is shown

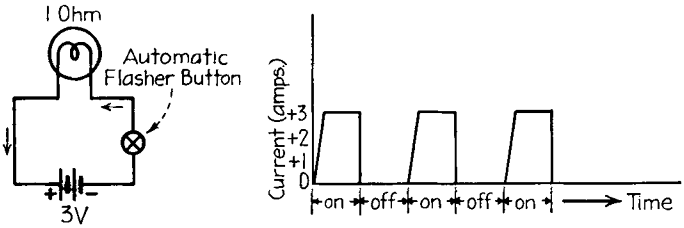


FIG. 5–2. Circuit and wave form for a varying direct current.

by the fact that every point of the current curve is different in value from every point adjacent to it. That the direction of electron flow is regularly changing is shown by the fact that the current curve regularly rises above and dips below the zero base line, first in the plus direction and then in the minus direction.

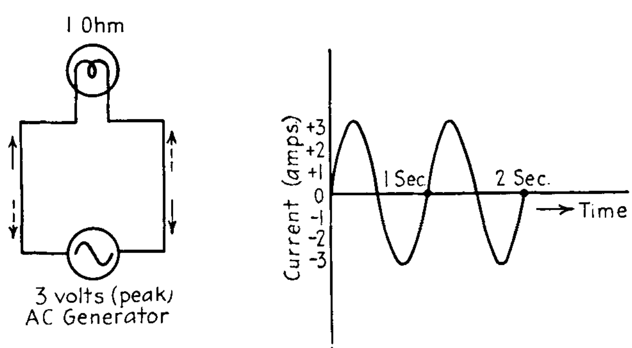


FIG. 5–3. Circuit and wave form for a pure alternating current (AC).

Alternating and direct currents need not be mutually exclusive. They may be mixed and combined in a single circuit. Figures 5–4 and 5–5 show two such combinations. In Fig. 5–4, a pure direct current from a 3-volt battery and an alternating current (1-volt peak) are mixed in a circuit. The result is a varying direct current, whose average is 3 amp, varying 1 amp above and below the average at the same rate as the alternating current. In Fig. 5–5, two alternating currents from two generators of different outputs and different frequencies are mixed. Sometimes their phase relationships are such as to add to each other; at other times, they oppose each other. The result is the regularly recurring AC wave form in the diagram that is like neither of the two pure sine-wave components.

Types of alternating currents. Alternating currents present many interesting aspects that require explanation. Refer again to Fig. 5–3. The complete movement of electrons back and forth through the circuit is

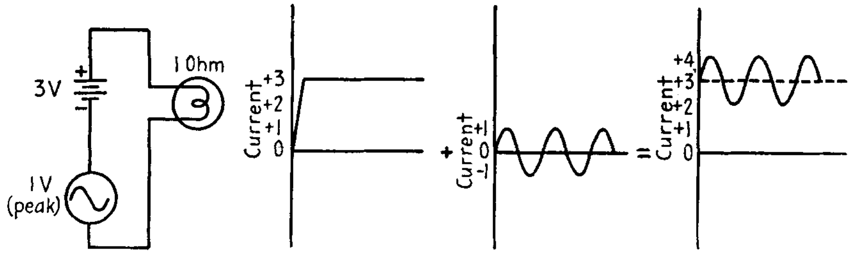


Fig. 5–4. Circuits and wave forms for mixture of DC and AC currents.

called one "cycle." The figure shows one cycle completed in 1 sec. Hence the frequency of the current through the circuit is said to be one cycle per second. It is possible to have currents of any frequency, even up to millions of cycles per second.

On the basis of different frequencies and therefore use, alternating currents are divided into various categories. The first are the power frequencies, which are the alternating currents used to deliver power to lamps, radios, electrical appliances, etc. The most common frequency in

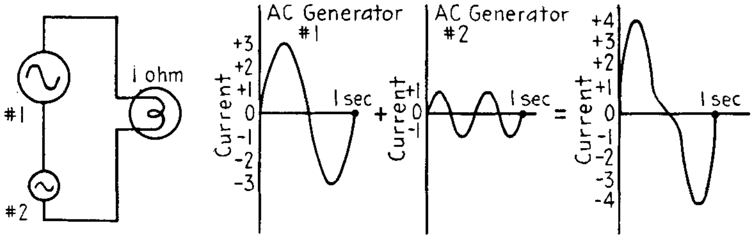


Fig. 5–5. Circuits and wave forms for mixture of two AC currents.

this group is 60 cycles per second. Other power frequencies are 25 and 40 cycles per second.

The second category makes up the audio frequencies (AF). These are alternating currents of frequencies from 20 to 20,000 cycles per second. They are characterized by the fact that, when fed into a reproducer like a pair of earphones or a speaker, they produce an audible sound.

A third category makes up the radio frequencies (RF). These are alternating currents of frequencies above 20,000 cycles per second. Currents of such high frequencies have two important characteristics. If fed into a pair of earphones, they will not produce an audible sound. Also, they tend to radiate energy, in the form of radio waves out into space, from the circuit in which the current is flowing.

Audio frequencies. Sound, as it comes to our ears, consists of nothing more nor less than vibrations of the air particles. However, our ears are limited to a relatively small range of vibration frequencies, about 20 to 20,000 vibrations per second. Anything below or above that range will not be heard; within it, different vibration rates will produce sounds of different pitch.

When a sound falls on our eardrums, it causes them to vibrate at the same frequency as that of the sound itself. Similarly, when it falls on a microphone, it sets up vibrations at the same frequency as the sound. A microphone is designed to produce alternating currents at the same frequency as the mechanical vibration produced by the sound. If these

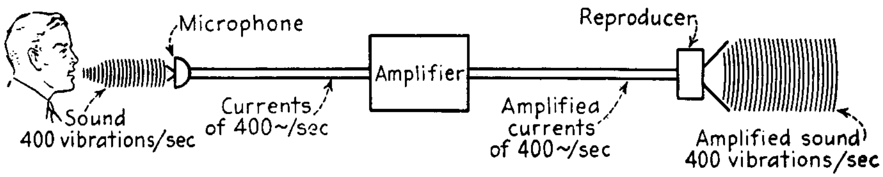


FIG. 5–6. Basic sound system.

alternating currents are amplified and fed into a reproducer, like a loudspeaker, they make it vibrate mechanically at a frequency equal to that of the currents. This mechanical vibration of the speaker makes the air around it vibrate at the same frequency, and the original sound is reproduced. This sequence is illustrated in Fig. 5–6. If the sound is complex instead of one frequency, the electrical currents produced will also be complex as a result of the combination of various alternating currents. The end result will be the same.

Radio frequencies. The problem confronted by a broadcasting station is to radiate into space energy that will eventually result in sound at the reproducer of the radio receiver. Unfortunately, AF currents will not radiate into space to any great extent. When we get up to currents of frequencies above 20,0000 cycles per second, the radio frequencies, radiation of energy into space as radio waves becomes efficient. Unfortunately, the radio frequencies will not produce sound at the receiver reproducer.

To obtain the desired results, the sound-producing audio frequencies must be combined with the radiating radio frequencies. In this combination the radio frequency is called the "carrier" and the audio frequency the "modulating currents." The combined current is called a "modulated carrier." This relationship is shown in Fig. 5–7. The carrier is shown as a pure sine current at 1,000 kc (1,000,000 cycles per second). The audio current is shown as a pure sine current at 400 cycles per second. The modulated carrier is an RF current whose peaks (envelope) vary at the audio rate (400 cycles per second).

This type of modulation of a carrier wave is known as "amplitude modulation" (abbreviated A-M), since the amplitude of the carrier wave is made to increase and decrease at the same rate or frequency as the modulating or audio signal.

Another type of modulation of a carrier wave is known as "frequency modulation" (abbreviated F-M). In this system, the audio signal does

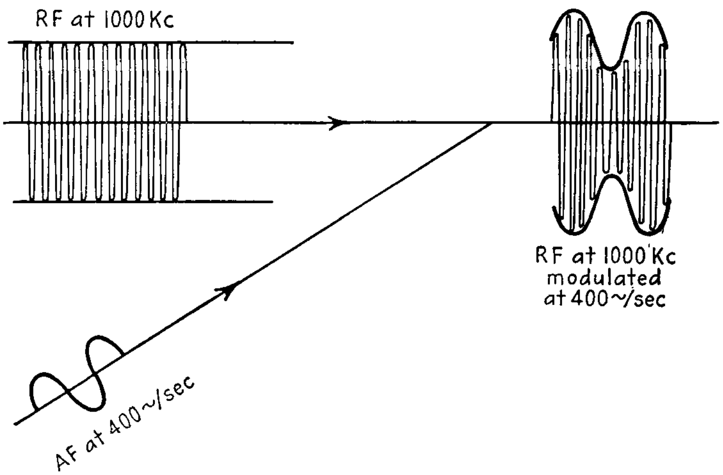


FIG. 5–7. RF carrier (1,000 kc) modulated by 400-cycle audio note.

not alter the amplitude of the carrier but alters the *frequency* instead, at a rate equal to the frequency of the audio signal. For example, if a 400-cycle audio note were modulating an RF carrier whose frequency is 88 megacycles per second, the carrier would be made to shift above and below 88 megacycles 400 times each second. A graph of the F-M system is shown in Fig. 5–8.

The branch of F-M receivers is a system by itself. In this book, we shall first describe the A-M superheterodyne receiver. Later chapters will describe the F-M receiver. The signal generator described at this time produces an A-M signal for A-M receivers.

Nature of an electric current. The question of the nature of an electric current should be cleared up at this point. Too much confusion has arisen from comparing different books. About 1765, Benjamin Franklin evolved a theory of electricity that became widely accepted. He believed that electricity (whatever it was) flowed in an electric circuit.

By convention, he and many others assumed that electricity flowed from the + pole to the — pole. This conventional current flowing from + to — was described in technical literature for many years after, and still leads a virile life.

However, in 1897, J. J. Thomson discovered the electron, and the true nature of an electric current in a circuit became known. An electric current is the flow of negatively charged electrons through a circuit. Hence, the electrons must always flow from — to +, an idea opposite to that of the conventional theory.

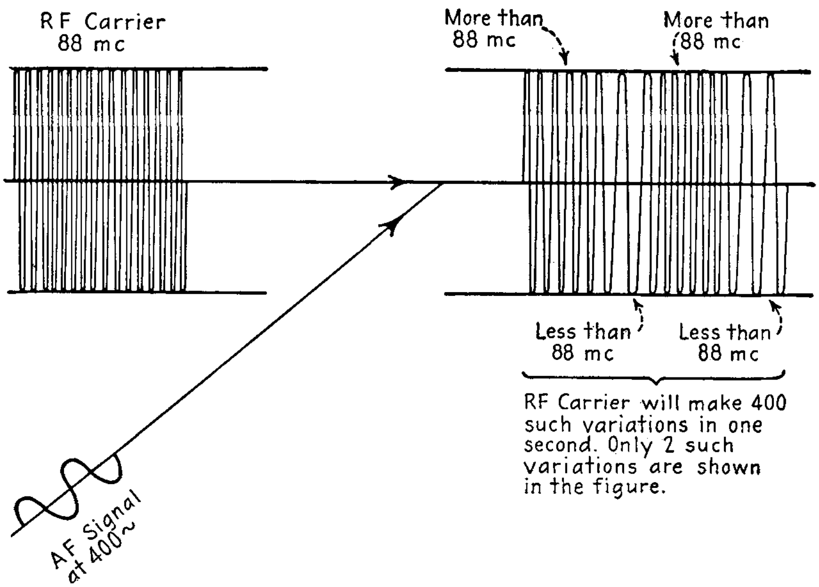


FIG. 5–8. RF carrier (88 megacycles) frequency-modulated by 400-cycle audio note.

The confusion arises because many authors do not define which concept they have in mind when referring to current. As a result, many beginning students confuse the two ideas and erroneously assume that when we say current flows from + to — (Franklin's convention), we mean that electrons flow from + to —. On the contrary, when we say current flows from + to —, we should forget all about electrons. Franklin did not know that they existed when he adopted that convention. When we say current flows from — to +, we are up to date and talking about electrons. Throughout this book, the authors will use the newer concept of the current; a flow of electrons from — to +.

Signal-generator output. The description given above will make the signal output from the signal generator more meaningful. Figure 2–1 shows the block diagram and wave forms of the superheterodyne receiver. Various types of currents are encountered. Modulated radio frequency enters the aerial and produces modulated RF currents up to the mixer. The local oscillator produces pure unmodulated RF currents. From the mixer to the detector stage, modulated RF currents at a lower frequency (called "modulated intermediate frequencies," or IF), are encountered. From the detector to the reproducer, the signal is at audio frequencies.

It is the function of the signal generator to generate all of the above current types to simulate regular receiver signals for testing. Figure 5–9 shows the output voltages and currents obtained from most generators.

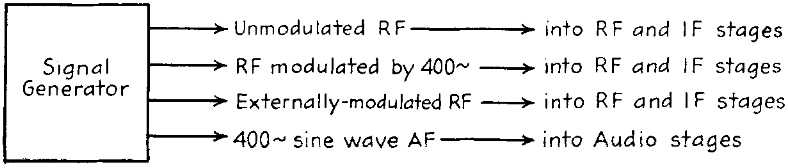


Fig. 5–9. Output voltages and currents from a signal generator.

The unmodulated radio frequency of the signal generator is an alternating current or voltage of a frequency anywhere above about 75,000 cycles per second (usually written 75 kc). Any frequency above that lower limit is selected by means of the various controls. Audio frequencies are alternating currents or voltages ranging from about 20 up to 20,000 cycles per second. Most signal generators have a fixed-frequency audio output of about 400 cycles per second, which is the standard test frequency. Another important output from the signal generator is a mixture of the radio frequency and the 400-cycle audio. This is known as "400-cycle modulated radio frequency." It simulates a modulated RF radio signal. Means are often provided for mixing the RF with an external AF signal. This gives an output on the signal generator known as "externally modulated radio frequency." The RF output signal is amplitude-modulated in either case.

6 SETTING UP THE SIGNAL GENERATOR

Block diagram of the signal generator. There are various differences in detail between one signal generator and another; basically, they are very similar. A block diagram will show to best advantage the elements that make up an average signal generator (Fig. 6–1).

The RF oscillator generates an RF voltage with a range of about 75 kc to 30 megacycles. This range includes the intermediate frequencies of any standard receiver. The output from the oscillator itself is unmodulated.

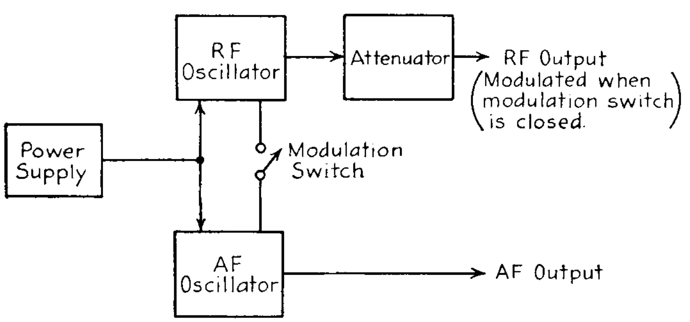


Fig. 6–1. Block diagram of an A-M signal generator.

The AF oscillator, as its name implies, generates a voltage at an audio frequency, which is usually the audio test frequency of 400 cycles per second. On some signal generators, the audio output is variable from approximately 100 to 10,000 cycles per second. The AF oscillator is used to modulate the RF voltage generated by the RF oscillator. In addition, most signal generators provide front-panel terminals where the AF output is independently available. This independent AF output may vary in voltage up to several volts. It is used to check the AF stages in the receiver.

The modulation switch shown in Fig. 6–1 enables the operator to modulate the RF with the AF signal. The usual practice is to have 30 per cent modulation at an audio modulating frequency of 400 cycles. The 30 per cent modulation means that the RF voltage is made to dip and rise 30 per cent below and above its peak value, as shown in Fig. 6–2. Many signal generators make provision for modulating the RF voltage with an external AF signal of any frequency.

The strength of signals at various test points throughout the receiver will vary greatly, beginning at the antenna and ending at the loudspeaker. Since the signal generator must substitute signals comparable to the actual signals, it must have a great range of output. This function of variable output is taken care of by an attenuator that breaks the complete range of output into steps and then gives smooth variation within each step. For the most part, the output readings obtained from the attenuator primarily furnish a value to any setting of the output, rather than give an exact microvolt output for radio-servicing procedures. Later chapters in this book will make this statement more significant, especially in stage-gain measurements.

Up to this point, the description of the signal generator has been generalized to give an overview picture. A more detailed discussion of the actual controls will give greater skill with the instrument. Of course, there is great variation in the control designations. Some common ones will be described and should be sufficient to aid the serviceman in

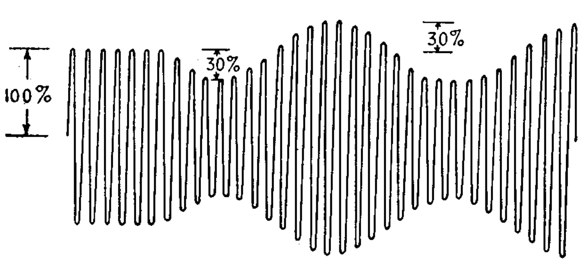


FIG. 6–2. A 30 per cent modulated RF signal.

understanding any other variations. The manufacturer's instructions for all signal generators should serve as the final guide for operation.

A typical signal generator. To get a better understanding of the various signal generators in existence today, it might help to synthesize a typical front panel of such an instrument and study its controls. Of course, there probably is no generator that has this exact make-up. Figure 6–3 shows the signal generator that would be constructed. On the left center is found the POWER switch to energize the signal generator when it is to be used. On the right center is the OUTPUT jack from which the various outputs for application to various test points in the receiver are taken.

To determine the nature of the output, there is an OUTPUT SELECT switch for obtaining pure RF, modulated RF, or audio signals. This instrument is of the usual fixed AF type with an audio output at 400 cycles per second. Therefore, when the OUTPUT SELECT switch is in the MOD. RF position, the output is an RF signal modulated approximately 30 per cent by a 400-cycle audio note.

The entire RF coverage is accomplished by the large tuning dial in the center. This frequency range of RF output is quite large and could not be covered in one sweep of the tuning dial. Therefore, a band selector switch (BAND SW.) is provided to divide the complete coverage

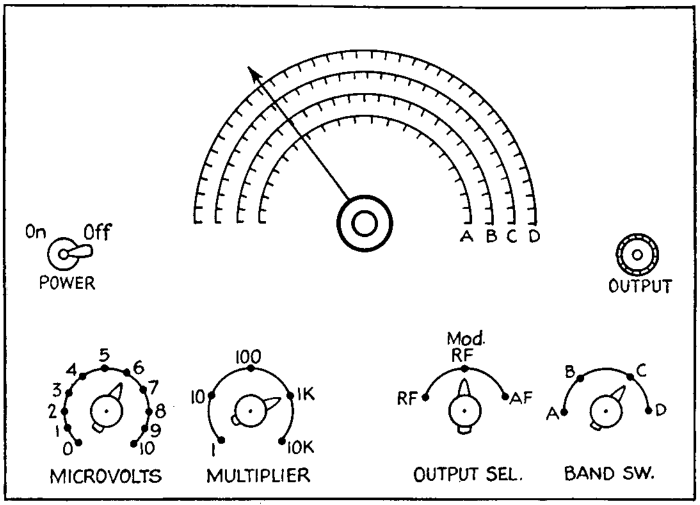


FIG. 6–3. Front panel, showing controls of a typical signal generator.

into bands. The complete swing of the tuning dial will therefore cover only one band. Four distinct bands are shown in our typical signal generator. They are labeled *A*, *B*, *C*, and *D*, each with a different range. Figure 6–3 shows band *C* chosen for coverage.

The output level is controlled by the two dials marked MICROVOLTS and MULTIPLIER. The first of these controls gives the number of microvolts from 0 to 10. It is usually a potentiometer control. The second is a 5-point switch for a step attenuator and determines by what value to multiply the reading from the MICROVOLTS dial to get the output level. The multiples shown are 1, 10, 100, 1K (1,000), and 10K (10,000). For example, the reading shown in Fig. 6–3 would be $6 \times 1K$, or 6,000 microvolts. The caution given in the previous section about the true value of this reading should be kept in mind.

The general information given above is important because the serviceman should see in what ways all signal generators are alike. However, each specific instrument will have its own variations, and the service manual supplied by the manufacturer should serve as the guide. The next few sections will describe three different signal generators, to show

how the controls should be operated to get the various outputs and output levels that are required in service work.

The Precision E-200 signal generator. In the Precision signal generator, the usual tuning dial is found in the upper center part of the front panel (see Fig. 6–4). Frequency coverage from 90 kc to 22 megacycles is performed in six bands, indicated as *A*, *B*, *C*, *D*, *E*, and *F*. The BAND

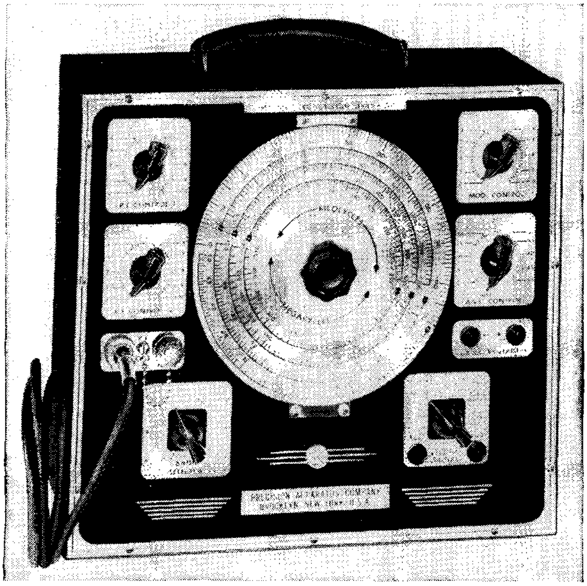


FIG. 6–4. The Precision signal generator, series E-200.

SELECTOR switch is located at the lower left end of the panel. The frequencies covered by each band are as indicated below.

A	90–250 kc
B	215–600 kc
C	550–1,700 kc
D	1.56–5.0 mc
E	3.75–10.0 mc
F	7.4–22 mc

RF output is taken from two jacks above the BAND SELECTOR switch. When large output is desired, the jack labeled HIGH is used; when low output is required, the jack labeled LOW is used. From these two jacks are obtained either unmodulated RF signals or RF signals that are modulated by the audio oscillator signal.

The type of output is determined by the setting of the control at the lower right end of front panel. The settings of this dial are RF UNMOD., MOD. RF, EXT. MOD., and 400~AUDIO, giving unmodulated RF, modulated RF, externally modulated RF, and 400-cycle audio, signal, respectively. The audio signal for the last-named position is obtained from two jacks labeled AUDIO SIGNAL under this control.

The level of the audio output is determined by the setting of a control at the upper right end of the panel. This is labeled MODULATION CONTROL. The setting of this dial also determines the percentage modulation of the RF signal when the output type control is in the MOD. RF position. The AF output is very high—sufficient to operate a high-impedance speaker directly without an intervening amplifier.

Attenuation of the RF output signal is accomplished by two controls at the upper left end of the panel. They are labeled RF CONTROL—1 and RF CONTROL—2. Each of these dials is arbitrarily divided into 10 main units. RF CONTROL—1 delivers increasing outputs at each position as the knob is turned clockwise. The outputs in these various positions are not calibrated but are relative. RF CONTROL—2 is a decimal multiplier. Thus, if the first dial is in position 3 and dial 2 is in position 7, it means that $7/10$ of the total available output for position 3 of dial 1 is available. If dial 2 is turned to position 9, it means that $9/10$ of the maximum available output for position 3 of dial 1 is delivered. If dial 2 is at position 10, then $10/10$, or all, of the available output for position 3 of dial 1 is available. To get more output, return dial 2 to zero and set dial 1 in position 4. The greatest available output is delivered when dial 1 is at position 10 and dial 2 is also at position 10. In other words, dial 1 sets the limit of output and dial 2 tells us how many tenths of that limit are being delivered. Note, again, that the two dials give no actual output reading but merely arbitrary positions for any output obtained.

A final control on this signal generator is one marked AVC CONTROL. It determines the level of steady AVC voltage delivered to two jacks marked AVC VOLTAGE beneath it. This AVC voltage is used for checking AVC operation in receivers, and in aligning receivers with AVC control.

R.C.P. Model 704 signal generator. The Model 704 signal generator produced by the Radio City Products Company (R.C.P.) is shown in Fig. 6–5. The large tuning dial is at the center of the front panel. Frequency coverage from 95 kc to 25 megacycles is performed in five bands, indicated as *A*, *B*, *C*, *D*, and *E*. The band-selector switch is marked FREQUENCY BANDS and is located at the upper left portion of the panel. The frequencies covered by each band are as indicated below:

A	90–290 kc
B	280–900 kc
C	825 kc–2.7 mc
D	2.5–8.3 mc
E	8.2–25 mc

It should be noted that there is a sixth band on the tuning dial, labeled *F*. There is no position on the FREQUENCY BANDS control for this band; it represents a frequency coverage of 16.4 to 50 megacycles and represents the second harmonic output of band *E*. Note that analogous positions of the hairline on bands *E* and *F* always have a 1 to 2 ratio.

RF output is taken from the phone jack marked RF OUTPUT at the right end of the panel. From this jack are obtained either unmodulated RF signals or RF signals that are modulated by the audio oscillator signal.

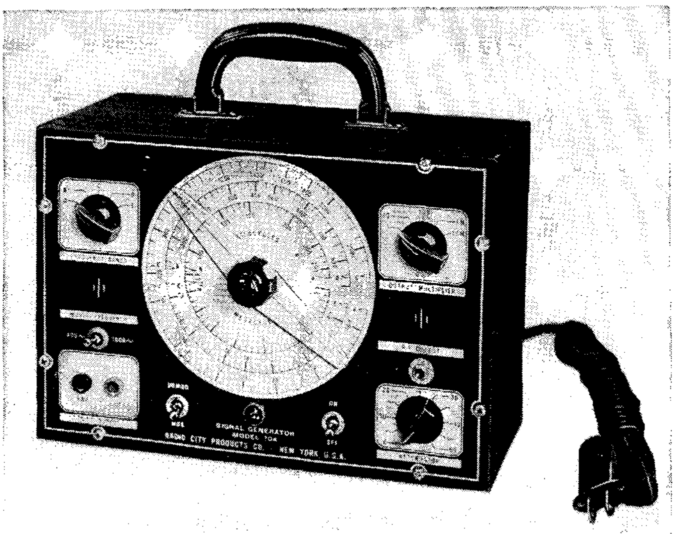


FIG. 6–5. The Radio City Products signal generator, Model 704.

The type of output is determined by the setting of the toggle switch at the lower left of the front panel. In the UNMOD. position, the output is unmodulated radio frequency. In the MOD. position, the output is radio frequency internally modulated by a 400-cycle audio signal.

Two pin jacks at the lower left end of the front panel, labeled AUDIO OUTPUT, furnish an audio signal at a frequency of 400 or 1,000 cycles per second, depending upon the position of the toggle switch above the jacks. Audio output is obtained only when the MOD.–UNMOD. toggle switch is in the MOD. position.

Attenuation of the RF output signal is accomplished by the two controls marked OUTPUT MULTIPLIER and ATTENUATOR. The attenuator is a potentiometer whose coverage is divided into 50 divisions. The OUTPUT MULTIPLIER is a step attenuator with multiples of 1, 10, 100, 1,000 (1M[1]), and 10,000 (10M). Thus, if the first control were at 35 and the second

[1] Note that this manufacturer uses M for 1,000.

control at 1M, the indicated output would be 35 × 1M, or 35,000 microvolts.

A toggle switch at the lower right of the panel, marked ON–OFF, turns the signal generator on or off.

General Electric Model SG-3A signal generator. In the General Electric signal generator, the tuning dial is found in the upper center part of the

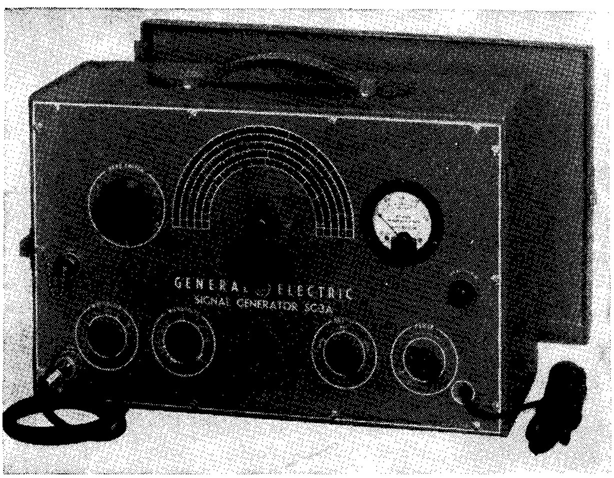


FIG. 6–6. The General Electric signal generator, Model SG-3A.

front panel (Fig. 6–6). Frequency coverage from 100 kc to 33 megacycles is performed in five bands, indicated as *A*, *B*, *C*, *D*, and *E*. The BAND SWITCH is located to the left of the tuning dial. The frequencies covered by each band are as indicated below.

A	33–10 mc
B	10.6–3.2 mc
C	3.2–1.0 mc
D	1.0–0.32 mc
E	0.32–0.10 mc

RF output is taken from two jacks at the lower left end of the front panel. The one labeled HIGH OUTPUT furnishes 1.5 volts of RF output, which is directly metered by a vacuum-tube voltmeter whose meter is at the right of the tuning dial. This high output is obtained at all frequencies except the very highest, where the capacity of the output cable limits the output. A potentiometer knob to the right and below the meter permits adjusting the meter to zero when used. For all test signals up to 100,000 microvolts, connection is made to an attenuator at the jack marked LOW OUTPUT. In the latter case, the vacuum-tube voltmeter measures the RF input to the attenuator.

For outputs up to 100,000 microvolts the LOW OUTPUT jack is used, while maintaining 1.0 volt in the meter by means of the control marked POWER at the lower right of the front panel. The output is then the setting of the MICROVOLT scale (0 to 10) multiplied by the setting of the MULTIPLIER. Both of these latter controls are at the lower left of the panel. The MICROVOLT control operates a potentiometer, and the MULTIPLIER controls a step attenuator with the following multiples: 1, 10, 100, 1,000 (1K), and 10,000 (10K). When higher meter settings are used, the output should be multiplied by the meter reading.

For outputs over 1 volt, the HIGH OUTPUT jack is used. The attenuator controls are then disregarded, and the output is set by the POWER control and read directly on the meter.

The type of output obtained is controlled by the knob at the lower right, marked OUTPUT. In the UNMOD. position, the output is unmodulated radio frequency. In the MOD. position, the output is radio frequency modulated by a 400-cycle audio signal with 30 per cent modulation. In the AUDIO position, a 400-cycle signal up to 1 volt may be obtained from the LOW OUTPUT jack.

Energizing power to the signal generator is controlled by the POWER control. The positions AC OFF and ON are self-explanatory.

Checking signal-generator calibration. It is important that the frequencies of the signal generator should be accurately calibrated and regularly checked. To make such a check, it is necessary to have a standard for comparison that is accurate. The frequencies of the broadcast stations are valuable in this respect, since each station is assigned a fixed carrier frequency from which it deviates to a negligible degree.

It is not necessary to check the frequency calibration of the signal generator all over the dial. In radio service work a few test frequencies are important. These are 455, 600, 1,000 and 1,500 kc. The instrument will be extremely useful if these frequencies are accurately determined on the dial.

Let us see how we could make the check suggested above. Suppose that it is desired to see if 600-kc output from the generator is obtained when the frequency dial is set at 600. The output lead from the instrument should be connected through a 0.00025-mfd/600-volt condenser to the antenna of a broadcast receiver. The generator ground and receiver ground should be commonly connected to a good ground.

If there is a station whose carrier frequency is exactly 600 kc, the check will be quite simple. We first tune our receiver sharply to that station. Then set the output selector switch of the signal generator to unmodulated RF output. As we tune the frequency dial close to 600 kc, a high-pitched whistle is heard. This effect is due to a phenomenon known as "beats." For example, if the signal generator were producing an output at a frequency of 605 kc, it would mix with the station signal of 600 kc and produce a beat note of 5 kc—the difference between the two signals. Since 5 kc is in the audio frequencies, it would be heard in the receiver as a whistle. As the generator output approaches the station frequency, the difference becomes less, producing a lower and lower pitched sound in the speaker, since the beat frequency becomes less. When the two frequencies are identical or very nearly so, the beat note tends to disappear. At that position we have tuned for zero beat. As we tune the frequency dial past zero beat, we again begin to get the beat note. At zero beat, we could safely assume that the signal generator is at the same frequency as the station; namely, 600 kc.

It is not always possible to find a broadcast station with the exact frequencies that we wish to check. Such would be the case in the metropolitan New York area. Suppose the serviceman in that vicinity wanted to check 600 kc on his signal generator. The nearest stations to that frequency are WMCA at 570 kc and WVNJ at 620 kc. To check the signal generator at 600 kc, tune it for zero beat with WMCA, the station to which the receiver is sharply tuned. At that position, the output of the generator is 570 kc. Suppose its tuning dial reads 560 kc. We can then assume that it is 10 kc off and that therefore an output of 600 kc would be obtained when the generator tuning dial is at 590 kc. To verify, tune for zero beat with WVNJ at 620 kc and note whether it too is 10 kc off in the same direction.

Similarly, tuning-dial positions on the generator should be found for 1,000 kc and for 1,500 kc. The stations to use for 1,000 kc might be WAAT at 970 kc and WINS at 1,010 kc. The stations to use for 1,500 kc might be WHOM at 1,480 kc and WQXR at 1,560 kc.

Determining the true setting for 455 kc requires a different analysis, because it is outside the broadcast band. At first, it would seem impossible to check until we realize that, when a signal generator oscillator is set at 455 kc, it is not only producing an output of 455 kc or thereabouts but also whole-number multiples thereof. Therefore, there would be concurrent signals at frequencies of $455 \times 2 = 910$ kc, $455 \times 3 = 1{,}365$ kc, $455 \times 4 = 1{,}820$ kc, etc. These simultaneous multiple signals are known as "harmonics." The fundamental frequency of 455 kc is often known as the "first harmonic," 455×2 as the "second harmonic," 455×3 as the "third harmonic," etc. Now, if we use the second harmonic of 455, or 910 kc, we find that it falls in the broadcast band. Therefore, set the signal generator up as before, but tune on the band including 455 kc. The two stations for comparison near 910 kc are WCBS at 880 kc and WAAT at 970 kc. If we are tuning for zero beat with WCBS, our generator tuning dial should be at 440 kc, since we are using the second harmonic. If we obtain zero beat at 445 kc, the signal generator is off 5 kc. An output of 455 kc will then be obtained at a dial position of 460 kc. Again, this fact should be verified by beating the second harmonic of 485 kc from the signal generator with station WAAT at 970 kc.

A special precaution is required when checking calibration in the IF band. If the check receiver employs an IF amplifier tuned to 455 kc, a confusing double beat may be obtained, since the signal-generator output may beat with the signal in the IF amplifier as well as with the test station. However, if the receiver is equipped with an RF stage and an IF wave trap, there is little likelihood of the signal generator's output beating with the signal in the IF amplifier, and it may be used. Another way of avoiding this effect is to use a receiver whose IF amplifier is tuned to a frequency quite different from the signal being tested. Furthermore, a TRF receiver, if available, could be used for calibration purposes, since it has no IF amplifier.

The proper settings for the important test frequencies should be recorded in some manner by the serviceman for later use. The same technique may be used for regions other than the metropolitan New York area by similarly choosing local stations close to the test frequency points.

7 SIGNAL GENERATOR APPLICATIONS

Uses of the signal generator. Throughout this text, various purposes will be served by means of the signal generator. First, the instrument will be used to determine if a stage and its associated coupling circuits are functioning properly. By placing the "hot" lead at various points in the radio receiver, this fact can easily be determined. This system of servicing is known as the "signal substitution" method and will receive more elaboration throughout the text.

Another use to which the signal generator may be put is that of receiver alignment. For most receivers brought into the serviceman's shop, this will not be a usual procedure. Where alignment is necessary, it is advisable to follow instructions given by the radio manufacturer. However, a generalized procedure will be given for those cases where the manufacturer's notes are not available.

A third use of the signal generator is to determine if each stage is giving proper gain. In this respect, a standard output will be measured by means of an output meter. Then the settings of the output of the generator will be compared with those necessary for each stage on a known good receiver, to obtain the above-mentioned standard output.

How to connect the signal generator to a receiver. The output from the signal generator is fed to the receiver being tested through a coaxial cable or a shielded connector cable. In either case, the external conductor is grounded within the generator and the center, or hot, lead is connected to the receiver test points. The hot lead is usually coded red, and the ground lead is either black or bare braiding.

Both the signal generator and the receiver should be at the same ground potential. This condition may be obtained by connecting the ground lead of the signal generator to the receiver chassis, which in turn should be connected to a good ground. In AC/DC receivers, where the chassis is connected directly to one side of the power line, there is danger of a short circuit in following this direction. This danger may be overcome by connecting a condenser of about 0.1 mfd/400 volts in series with the ground lead.

Where the hot lead is to be connected to an inductance like an antenna coil, it is advisable to use the Institute of Radio Engineers (I.R.E.) standard dummy antenna in series with the lead. This is shown in Fig. 7–1.

Under normal circumstances in using the signal generator for signal substitution service work, it is necessary only to connect a condenser in series with the hot lead. This prevents high DC potential points of the receiver from ruining the test instrument. In each case, the manufacturer's instructions should be followed. Generally, a 0.1-mfd/600-volt condenser should be used where IF and AF signals are delivered to the set. Where RF signals are delivered to the receiver, a 0.00025-mfd/600-volt condenser may be used. When short waves (high-frequency RF signals) are fed to the receiver, a 400-ohm resistor is used.

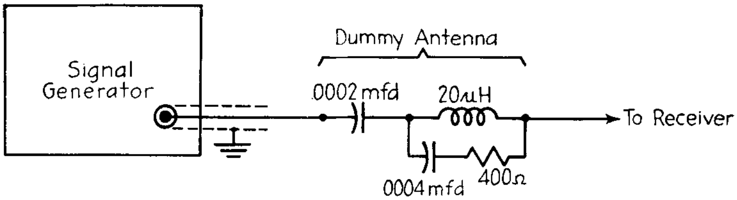


FIG. 7–1. The I.R.E. standard dummy antenna, connected to signal generator and receiver.

Signal substitution method of servicing. The signal generator, as used through the remainder of this book, will primarily concern itself with signal substitution for servicing receivers. At various test points in the receiver it will introduce a signal, similar to the one received in normal broadcast reception, and the results will be observed. Where observed results are not normal or typical, trouble is indicated.

A brief description will serve at this time to set down the outline of testing to check that each stage is operative. Figure 7–2 shows a simplified diagram of a superheterodyne with strategic points indicated by the ballooned numbers. Above each number is indicated the type of signal input for testing the applicable stage. The sequence of the numbers is the order in which to make the test.

Point (1) tests the speaker itself. The test cannot be made unless a signal generator with a high level of AF output is available. Where such is the case, the audio note should be heard in the speaker.

Point (2) checks the operation of the second AF stage, once the speaker has been found to be in good shape. Because of the stage amplification, a lower level AF signal is required at the input. If operation of the stage is normal, the audio signal should be heard clearly.

Point (3) is the test point for operation of the first AF stage, if the preceding tests check perfect. Once again a lower level AF input signal is required. Normal operation would result in a strong, clear audio note in the speaker.

Point ④ is the test point for operation of the detector stage. It should be remembered, as always, that all previous checks have shown proper stage operation. A modulated IF signal introduced at this test point should produce a clear modulation note in the speaker. The intermediate frequency, of course, is that for the particular receiver.

Point ⑤ is the test point for the IF amplifier. A modulated IF signal from the signal generator, at the IF for the particular receiver, should produce a clear modulation note in the speaker. The level of this signal input should be less than that for point ④, because of the gain of the IF amplifier.

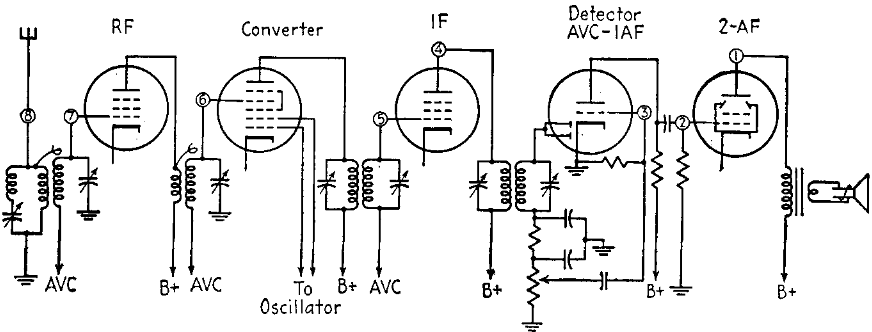


FIG. 7–2. Signal chain of a superheterodyne receiver showing test points.

Point ⑥, the signal grid of the mixer, is the test point for the mixer and oscillator. A modulated RF signal injected at this point should produce the modulation note in the speaker if the oscillator and the mixer are both operative. If no note is heard, then introduce a modulated IF signal at this point. If the note is now heard, then the mixer is functioning and the oscillator may be assumed to be inoperative.

Point ⑦ is the grid of the RF amplifier tube. A modulated RF signal is introduced at this point to check the operation of the RF stage. Again, it should require less input signal at point ⑦ than was needed at point ⑥, the converter grid, because of the gain of the RF tube.

Point ⑧ is the test point for the antenna coil. A modulated RF signal at a lower level than for point ⑦ should produce a clear modulation note in the speaker, if all else is well.

The check procedure presented briefly here will be elaborated in the stage analyses given later in the book. It should be noted that, where coupling devices are to be checked, introduction of the proper signal at the input and the output of the coupling device should produce modulation notes in the speaker. If the note is heard at the output but

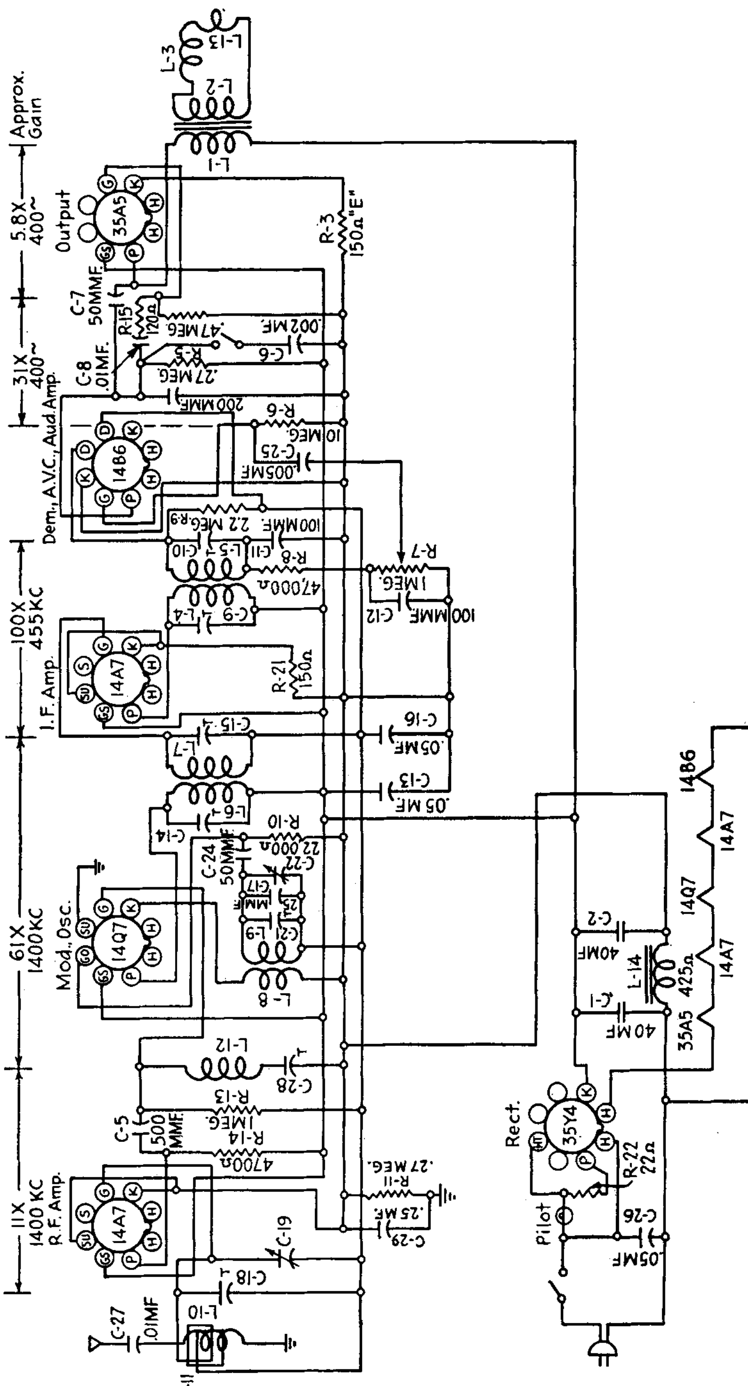


FIG. 7–3. The Stromberg-Carlson No. 1100 AC/DC receiver.

not at the input, then the device or its associated circuit is presumed to be defective.

Using the signal substitution method of servicing. An example of how to use the signal substitution method in localizing a defect will make clear its value. Refer to the receiver whose schematic is shown in Fig. 7–3. We assume a defect and try to localize it. Suppose IF trimmer condenser *C*-14 is shorted. The receiver is brought in with the complaint that it does not work.

Voltage analysis will not disclose the defect, because the DC resistance of parallel coil *L*-6 is quite low, and the DC voltage drop across it is very small. Ohmmeter analysis of the receiver would be too lengthy if used by itself.

Let us proceed by the signal substitution method. An audio signal from the signal generator is delivered to the signal grid of the output tube. It is heard clearly in the speaker. This stage is considered to be all right. The audio signal is then introduced to the grid of the type 14B6 tube. Again the audio note is heard in the speaker and the first audio amplifier is assumed to be good. A modulated IF signal is now introduced on the signal grid of the IF amplifier. The modulation note is heard clearly in the speaker and the detector, and IF stages need no further investigation. Now, when a modulated IF signal is introduced on the signal grid of the type 14Q7 converter, the modulation note is not heard. This indicates that the trouble is between the converter signal grid and the IF amplifier grid. Then a modulated IF signal is introduced on the plate of the converter, and still no modulation note is heard. This localizes the defect between the plate of the converter and the signal grid of the IF amplifier. Thereafter, a simple ohmmeter check across the primary and the secondary (*L*-6 and *L*-7, respectively) of the first IF transformer will show the short across *L*-6.

Receiver alignment. The average superheterodyne receiver has seven or more tuned circuits, each one of which has to be in resonance at its proper frequency for best operation of the receiver. The procedure for bringing these circuits to resonance at their operating frequencies is called "alignment."

The signal generator is an invaluable tool in receiver alignment, since it is used to feed the proper aligning frequency to each circuit. The procedure consists essentially in connecting an output-measuring device across the speaker, which is the output of the receiver; feeding a voltage at the proper frequency to the circuit being aligned; and adjusting the variable component, usually trimmer condensers provided for the purpose, to a maximum deflection of the output meter.

Alignment is necessary when one of the components of any tuned circuit becomes defective and is replaced. Alignment will also perk up a receiver where, owing to natural aging of the components with time and moisture, the tuning-circuit parts change in value.

Stage-gain measurements. In a superheterodyne receiver, each stage, except the diode detector, amplifies the signal before it passes it on to the next stage. When the serviceman has an idea of the approximate amplification or gain that may be expected from each stage and is equipped to measure it while making a signal check of the receiver, he has a powerful service tool for quickly determining the location of many troubles.

For example, assume an open cathode by-pass condenser in a stage of a receiver that is perfect in all other respects. The receiver would produce a weak output. In servicing such a receiver by the old methods, tubes would check good, voltage measurements would be normal, and a routine ohmmeter check would also show nothing. The serviceman would then proceed to substitute parts, more or less at random, until he came to the defective condenser.

With the aid of stage-gain measurements, he would be examining the defective stage in a matter of minutes. Although he would still be confined to the substitution of parts, he would be doing so for the components of only one stage found to be defective.

Accurate stage-gain measurements, as made in engineering laboratories, would require a considerable outlay in the matter of test equipment. However, for servicing purposes, great accuracy is not necessary since the offending stage will usually be far below normal when the receiver is brought in as defective. Adequate stage-gain measurements can be made with the equipment that the serviceman has on hand—a signal generator and an AC voltmeter.

The theory underlying stage-gain measurements is quite simple. The receiver is held at all times during the check at one output, known as "standard" output. A signal from the generator is fed into the input of a stage, and the voltage of that signal, necessary to produce standard output, is noted. Then the signal is fed into the output of the stage. The voltage level of the signal is increased until standard output is again obtained. By dividing the second voltage by the first we obtain the gain of the stage. This sequence is illustrated in Fig. 7–4.

Let us take an example to illustrate the point. If 1 volt of signal at the input of a stage gives standard output, and the signal level must be increased to 10 volts to maintain the standard output when it is connected to the output of the stage being tested, then the gain of the stage is 10/1, or 10.

The standard output used in stage-gain measurements has been set by the I.R.E. at 50 mw of signal power fed into the speaker. The output power may be measured by connecting an AC voltmeter across the speaker voice coil or, more conveniently, across the primary of the output transformer. In stage-gain measurements, the signal input level is adjusted to keep the output meter at the proper fixed value. This value corresponds to approximately 16 volts across the output transformer primary for most receivers. During stage-gain measurements, the AVC system must be inoperative, or it will invalidate results. For this reason, the receiver output is maintained at the low level of 50 mw so that input signals necessary to attain that level will be too weak to activate the AVC system.

The measurement points in the receiver for stage-gain checking are usually taken from one grid to the next. The amount of signal necessary to give standard output from any point in the receiver is often called the "sensitivity" of the receiver from that point on. When a signal of 3,500 microvolts is required at an IF amplifier grid to give standard

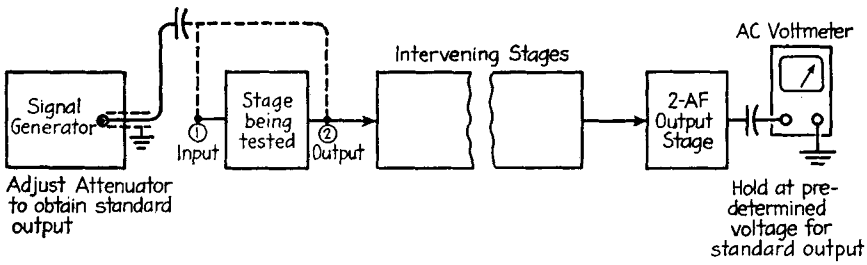


FIG. 7–4. Sequence of measurements to obtain the gain of a stage.

output, the sensitivity of the receiver at the IF amplifier grid is said to be 3,500 microvolts.

For the practical serviceman, exact sensitivity measurements are not necessary. Comparative sensitivity measurements will serve as well. These may be obtained by actually making sensitivity measurements from various points in receivers known to be in perfect operating condition. In each case, the attenuator reading of the signal generator necessary to give standard output should be recorded. When completed, the readings for each point are averaged. As a result, the serviceman will have comparative data for determining proper sensitivity from various points for any receiver brought in. For example, if the attenuator position varies greatly at the grid of the IF amplifier of an unknown receiver from the average setting just obtained, a defect in the IF amplifier stage is indicated, if all later stages check perfect.

On the average, the sensitivity of radio receivers from various points may be summarized in the accompanying table. The diode detector is omitted because its purpose is not amplification but rather demodulation.

Sensitivity, average input	*Generator frequency set at*	*Generator hot lead connected to*	*Output from the receiver*
5–12 microvolts	600 kc	Antenna terminal	Standard
50 microvolts	600 kc	Modulator grid	Standard
3,500 microvolts	455 kc (or other IF)	IF grid	Standard
0.032 volt	400~	First AF grid	Standard
1.6 volts	400~	Second AF grid	Standard

After having obtained the attenuator setting at various points to give standard output, the serviceman may assume that the input values are those given in the table. Thereafter, he may make due allowance if he has service literature from the receiver manufacturer giving sensitivity at various points. For example, if the service data indicate that, for a particular receiver, the sensitivity at the IF grid is 3,000 microvolts to give standard output, he knows that he must turn the attenuator up to give less than his comparative output, which is presumed to be 3,500 microvolts.

Stage-gain measurements are readily obtained from sensitivity measurements. Suppose that the signal generator delivered an output of 50 microvolts to the converter signal grid to develop standard output. The sensitivity of the receiver from that grid would be 50 microvolts. Now, suppose that the generator delivered an output of 3,500 microvolts to the grid of the next IF amplifier to develop standard output. The sensitivity of the receiver from the IF grid would be 3,500 microvolts. The gain of the converter stage would then be found by dividing the latter sensitivity by the former. It is found to be 3,500/50, or 70.

Gain per stage varies in different receivers; therefore a small range of figures rather than a single figure would be desirable for comparative work. The accompanying table lists the various stages of a superheterodyne receiver, gives the test frequencies to the input of each, the ranges of gain for many receivers, and an average gain used in this book. For

Stage	*Test frequency*	*Range of gain*	*Average gain*
Second AF	400~	5– 15	10
First AF (high-mu)	400~	40– 60	50
IF	455 kc	80–120	100
Converter	600 kc	60– 80	70
RF	600 kc	20– 40	25

specific receivers, gain data furnished by the manufacturer in his service notes should be followed, if available.

Examination of the service notes of a typical receiver will now show the value of this stage gain technique. Figure 7–5 shows the schematic for the receiver. Service notes given by the manufacturer give the data shown in the accompanying table. The dummy antenna capacity indicates values to be connected in series with the hot lead of the signal generator. In each case, the input signal is given which results in standard output. From the data given, it is seen that, from antenna to modulator grid (at the same modulated RF frequency), there is a voltage gain of 55/15, or approximately 3.7. From modulator grid to IF grid (at the same modulated IF frequency) there is a voltage gain of 3,700/50, or 74. Any wide variations from these gain measurements would result in an indication of a defective stage.

Average microvolt input	Generator set at	Generator feeder connected to	Dummy antenna capacity
3,700	455 kc	IF grid	0.1 mfd
50	455 kc	Modulator grid	0.1 mfd
55	600 kc	Modulator grid	0.1 mfd
15	600 kc	Antenna terminal	400 ohms

Another method of indicating stage gain is shown in Fig. 7–3. Here, stage gain is indicated between specified points. Beneath the stage-gain value is indicated the frequency to which the signal generator must be set in making the check.

The data may be analyzed as follows. The level of input signal from the signal generator at a modulated 1,400-kc frequency should be 11 times as great at the signal grid of the converter tube as it is at the RF tube signal grid, to give standard output. This means that there is a voltage gain of 11 due to the amplification of the RF tube. The level of input signal at a modulated 1,400-kc frequency should be 61 times as great at the signal grid of the IF amplifier as it is at the signal grid of the converter tube, to give standard output. The level of input signal at a modulated 455-kc frequency at the detector plate should be 100 times as great as it is at the signal grid of the IF amplifier, to give standard output. The level of input signal at 400 cycles per second should be 31 times as great at the signal grid of the output tube as it is at the signal grid of the first audio amplifier, to give standard output. And finally, the level of input signal at 400 cycles per second should be 5.8 times as great at the plate of the output tube as it is at the signal grid of the same tube, to give standard output.

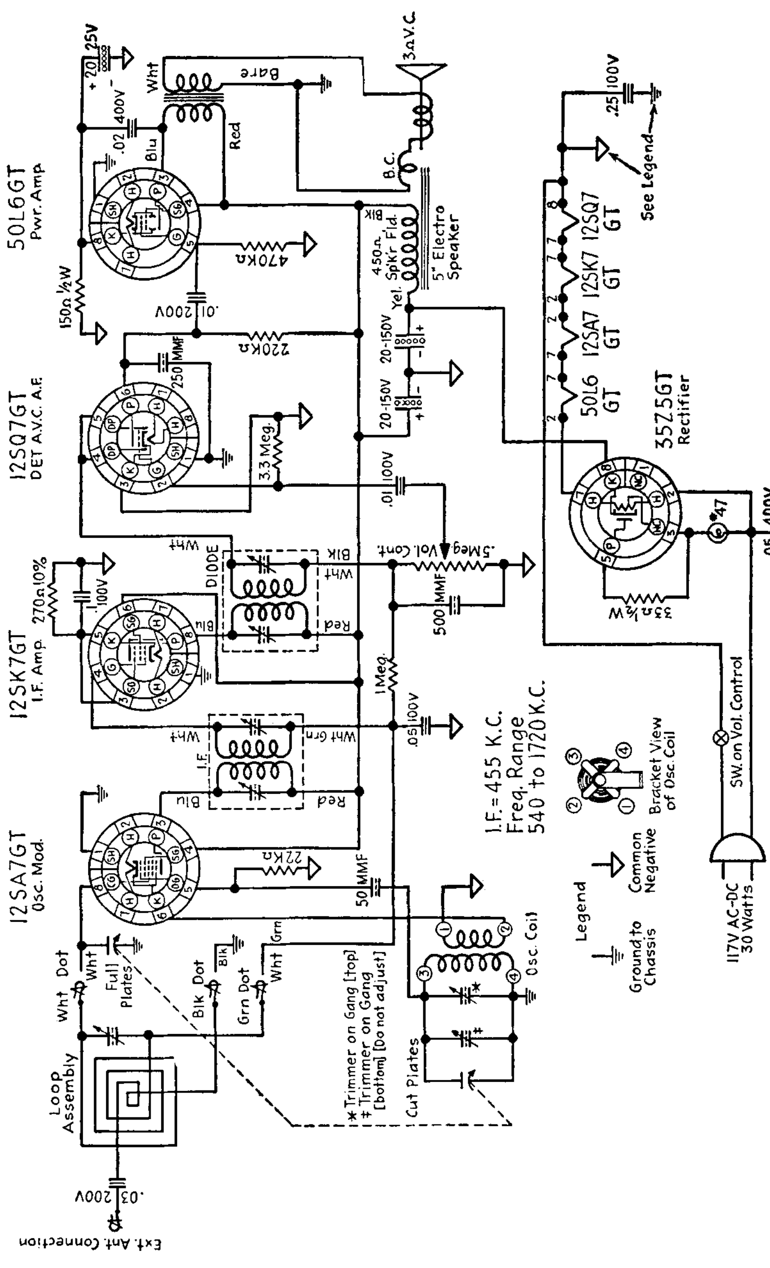


FIG. 7–5. The Motorola Model 56X1 AC/DC receiver.

When service notes do not include sensitivity figures or stage-gain data, the serviceman can still use these ideas for working on receivers with inadequate volume or sensitivity. As was stated previously, he should establish average attenuator settings on his signal generator, based on results with several good receivers. For example, when checking from the IF grid, the average attenuator setting turns out to be 20 $\times$ 100 to give standard output. Then, on a defective set, up to the IF grid, normal attenuator settings produce standard output. But at this point, the attenuator has to be advanced to 80 $\times$ 100 for standard output. He then knows that a defective condition exists in the IF stage.

8 AC POWER SUPPLY

Quick check. If all the tubes in the receiver light, there is no sign of overheating, the hum level is normal, and the *B* plus voltage measures 200 to 300 volts, the power supply is probably functioning properly, and the trouble shooter proceeds to check the next stage.

Function of power-supply stage. The power supply furnishes *A*, *B*, and *C* voltages for the rest of the receiver. The *A* supply lights the filaments of the tubes, the *B* supply furnishes the necessary DC voltage to operate the plate circuit of the tubes, and the *C* supply furnishes DC grid voltage for the tubes.

The power-supply stage can be a set of batteries, as is the case in portable and emergency equipment. Usually, the lighting mains are employed to furnish the power. The power-supply stage, therefore, converts the 110-volt lighting supply into the necessary *A*, *B*, and *C* voltages for the receiver.

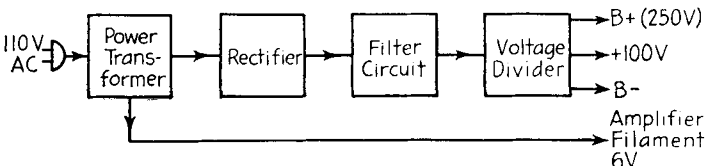


FIG. 8–1. Block diagram of AC power supply.

Two main types of power supplies will be considered: the AC power supply for use on AC mains, and the so-called AC/DC type which permits receivers to be plugged into either AC or DC mains. The AC/DC power-supply stage will be treated in a later chapter.

Theory of operation of AC power supplies. The basic parts of the power supply can be shown by the block diagram of Fig. 8–1.

The power transformer, by stepping voltage up and down, supplies high voltage for the rectifier in the *B* supply, and low voltage for the tube filaments. The low-voltage windings of the power transformer are all that is needed for the *A* supply.

The rectifier allows current to flow in one direction only. Its output, therefore, is pulsating direct current.

The filter circuit smooths the pulsating direct current from the rectifier into unvarying direct current, for use as the *B* supply.

The voltage divider, as its name indicates, subdivides the available *B* voltage into lower values, as needed in various plate and screen circuits. Sometimes additional taps are added, so that *C* voltage is obtained from the same source.

Standard circuit. See Fig. 8–2.

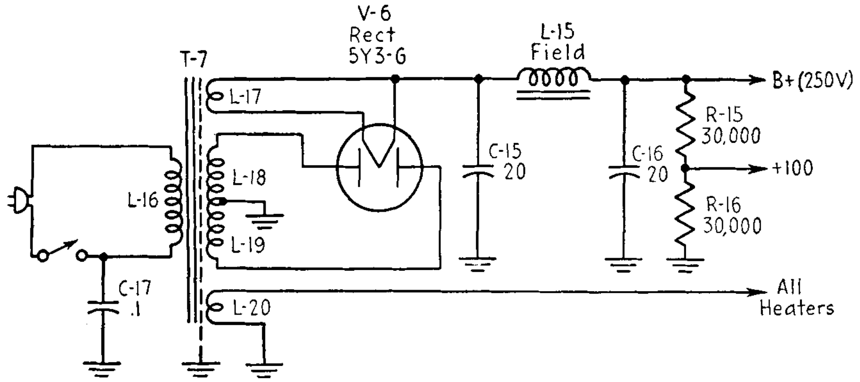


FIG. 8–2. Standard circuit of AC power supply.

Functions and values of component parts. Transformer *T*-7 is the power transformer. It operates on the principle of electromagnetic induction. Current in the primary sets up a magnetic field in the iron core. Since the primary current is alternating, the magnetic field is constantly changing in magnitude and direction: building up, collapsing, building up in the opposite magnetic direction, collapsing, etc., with each change in the alternating current. A changing magnetic field induces voltage in any winding that is exposed to it, and the greater the number of turns, the greater will be the induced voltage. At this point, the inability of transformers to operate on direct current can be easily seen. Direct current sets up a steady magnetic field, and voltage will not be induced in the windings.

Power transformers for radio work are usually designed to operate at 2 to 4 turns per volt. Assume a 2-turns-per-volt transformer. Then the 120-volt primary will be wound with 240 turns. (Although the lighting mains are usually called "a 110-volt line," line voltage will actually measure more nearly 120 volts. Design work assumes a line voltage of 117.) Each 2 turns of secondary winding will have 1 volt induced in it. The 5-volt winding for the rectifier filament will be wound with 10 turns, and the wire will be comparatively heavy to carry the 2 amp that the rectifier filament draws. The high-voltage winding, usually 700 volts, will be wound with 1,400 turns. This will be fine wire, since the radio requires only about 70 ma (0.07 amp) of *B* current.

Caution. 700 volts is dangerous. Care must be exercised in handling and measuring the high-voltage leads.

The filament winding for the other tubes in the receiver will be wound with 12 turns for 6 volts, and the wire will be heavy enough to carry the current drain of several tubes. In the older receivers, this winding is designed for $2\frac{1}{2}$ volts at heavy amperage, to accommodate the $2\frac{1}{2}$-volt tubes used.

The high-voltage winding is always center-tapped for use in the full-wave rectifier circuit. The other windings are sometimes also tapped: the primary at the 220th turn, for use in areas where line voltage is low. The amplifier and rectifier filaments may also be tapped in the center.

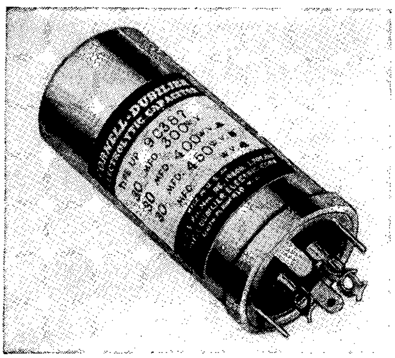
In table-model receivers, the power transformer is usually smaller, the main difference being in the high-voltage winding, which is approximately 500 volts at 50 ma rather than 700 volts at 70 or 90 ma.

The rectifier is a conventional full-wave circuit. Vacuum tube V-6 is an 80, 5Y3-G, or 5Y4-G. In large radio sets where the *B* current drain is heavy, the rectifier may be a 5Z3 or 5U4-G. The full-wave rectifier, operating from a 60-cycles-per-second source, will deliver to the filter 120 pulses per second.

The filter circuit consists of *L*-15, *C*-15, and *C*-16. *L*-15 is usually the speaker field. It consists of a large number of turns of wire, wound on an iron core. Its action in the filter circuit is that of an inductor or choke. An inductor acts to retard any change in current through it in the following way. Any change in current will produce a change in the magnetic field. The changing magnetic field will induce voltage in any winding exposed to it, as it does in the case of the transformer. In the case of the choke, where there is only one winding, the voltage will be induced in that winding. Since the induced voltage is opposite in direction to the original source, it will always tend to oppose any change in current in the coil due to the varying magnetic field. The choke, therefore, has a high opposition to any change in current (alternating current or pulsating direct current), while its opposition to direct current (unchanging magnetic field) is comparatively low. Since the choke is connected in series with the power-supply output circuit, it tends to keep pulsations out of the output.

Condensers *C*-15 and *C*-16 are connected across the power-supply output, one on each side of the choke. The action of a condenser in a circuit containing pulsations is to stabilize the voltage across it. When the voltage across a condenser is exceeded by the momentary peak from the rectifier, the condenser charges and absorbs the peak. During the lull between peaks from the rectifier, when the voltage would drop, the condenser discharges and maintains the voltage. Condensers *C*-15 and *C*-16 are high-capacity, high-voltage electrolytic condensers. Often they are in the same container, which is called a "filter-condenser block." A common size would be labeled "20–20 mfd–450 volts DC–Surge voltage 525." Sometimes the block contains three condensers, such as the one pictured in Fig. 8–3.

R-15 and *R*-16 form the voltage divider. These vary considerably in size and ohmage in different receivers, depending on the voltage required. Where more than one intermediate voltage is required, there will be more than two resistors. In some circuits, intermediate voltages are obtained from series voltage-dropping resistors, as is done for the screen of *V*-3 in the standard circuit (Fig. 1–1), and *R*-15 and *R*-16 may be omitted entirely. Although *R*-15 and *R*-16 may be as low as 5,000 ohms



NOTE: The triangle, square, and half-circle on the label are to identify the individual condensers in the block. They are repeated on the insulating strip near the proper soldering lugs.

FIG. 8–3. A filter-condenser block.

and as high as 50,000 ohms, they do not differ very much from each other. The value of 30,000 ohms each has been chosen for the standard average receiver.

Switch S-1 is the on-off switch for the radio. It is often ganged with the volume control. Switch replacement notes will be found together with volume control replacement notes in Chap. 11 on the first AF stage.

Condenser *C*-17 is the line filter. Its action is to remove various RF line disturbances, such as those caused by sparking brushes on electric motors, from entering the radio. The value of *C*-17 is not critical. Values ranging from 0.002 to 0.5 mfd are found in various radios.

NORMAL TEST DATA FOR THE POWER-SUPPLY STAGE

Check for normal stage operation

All tubes light or heat.
No sign of overheating.
Voltage check—*B* plus to chassis—200 to 300 volts.
Hum level—normal.

Most receivers normally have a slight hum, since it is rather costly to remove the last traces. This is known as "residual" hum, and the serviceman must have some way of determining whether the amount present is normal or excessive. A good check is to place the ear close to the speaker with no station tuned in. If the hum is just discernible, call it normal. This small amount will not be objectionable when the ear is at its usual distance from the speaker and a station is tuned in. If noises from the RF amplifier interfere with the test, the RF end of the receiver can be made inoperative by removing the IF amplifier tube. If the test is being made with the speaker out of its cabinet, as is usual at the bench, the serviceman should remember that the cabinet baffle accentuates low-frequency response and, since 120-cycle hum is low-frequency, he should allow accordingly.

If the quick check indicates trouble in the power supply, disconnect the line plug and, before proceeding to further tests, discharge the filter condensers by shorting them. The filter condensers may retain a charge, with subsequent danger of shock or damage to test equipment.

Normal resistance data. Normal resistance data are given in the accompanying table.

Plug, prong to prong	5–15 ohms
Chassis to rectifier plates	150–200 ohms
Rectifier filament to *B* plus, across speaker field	1,000–2,000 ohms
Chassis to rectifier filament	61,000 ohms

The last reading will vary considerably, depending on the voltage divider design of the particular receiver. Presence of electrolytic condensers *C*-15 and *C*-16 will also affect the reading. In circuits containing electrolytic condensers, always reverse the test prods and take the higher reading.

Normal voltage data. Normal voltage data are given in the accompanying table.

Rectifier filament to filament	5 volts AC
Across other tube heaters	6 volts AC
Chassis to rectifier plate	250–380 volts AC
Chassis to rectifier filament	265–400 volts DC
Chassis to *B* plus	200–300 volts DC
Chassis to screen	90–100 volts DC

Small receivers tend toward the lower *B* voltages. Large receivers tend toward the higher *B* voltages. The measured voltage from chassis to rectifier plate is the RMS or effective value. The rectifier voltage, measured from chassis to rectifier filament, is usually a little higher than the AC input owing to the action of condenser C-15, which maintains the rectified voltage at more nearly the peak value.

COMMON TROUBLES IN THE POWER SUPPLY

All the component parts in the power supply are common sources of trouble. Even the rectifier-tube socket is not immune. In the case of the socket, dirt between the rectifier plate pins causes the high voltage to arc across, burning up the socket material. This is found by inspection, and the cure is obvious: replacement of the socket. The power transformer should be carefully checked, since the heavy drain may have damaged it.

Troubles common to power transformers. The power transformer develops many ills, the chief cause of which is overheating due to overloads

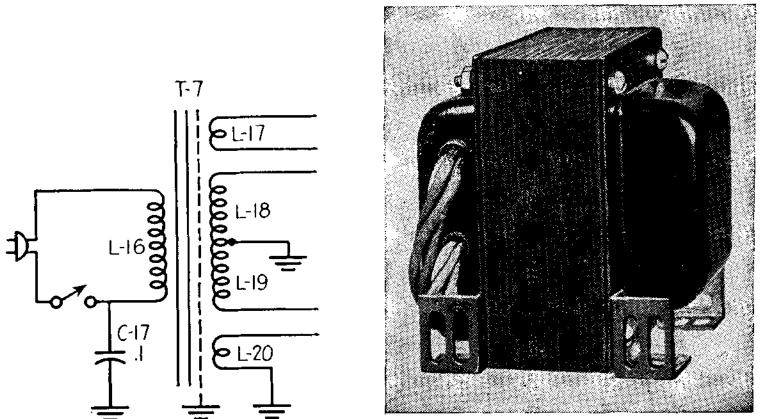


FIG. 8–4. The power transformer.

within the transformer or to external shorts. The ohmmeter check is not entirely reliable. For example, a few shorted turns in the high-voltage winding will not affect the ohmmeter reading to any great extent, while it will cause a heavy drain from the primary and consequent overheating. In a case like the above, even though the voltage would be considerably reduced, the radio would keep on playing, and it might not be brought in for repairs until the overload had caused the primary finally to open or the owner had become concerned about the smell from his radio. Incidentally, the smell from a burned transformer is unmistakable, and the serviceman need only follow his nose to the trouble. When the trouble has been determined, it is wise to check for external shorts before replacing the transformer. As an example of the necessity for this, assume a partial short in the dial-light wiring of a radio. The radio continues to play, and finally the overload causes the transformer primary to open.

The serviceman quickly finds the open transformer; replaces it; checks the radio, which appears to operate satisfactorily; returns it to the customer; and, before long, the new transformer is burned owing to feeding current to the partial short that is still in the dial-light wiring.

How to check the power transformer. The best check for normal operation of the power transformer is a wattmeter, or AC ammeter, connected in the primary circuit. The serviceman's multitester, however, rarely includes scales and ranges that are suitable for this purpose. A good check with inexpensive equipment can be made as follows:

1. Remove all tubes from the radio.
2. Plug the radio into an outlet that contains an ordinary 25- or 40-watt lamp in series with the line, as shown in Fig. 8–5.
3. A good transformer will cause the lamp just to glow.
4. Any short that is present will cause the lamp to glow brightly.

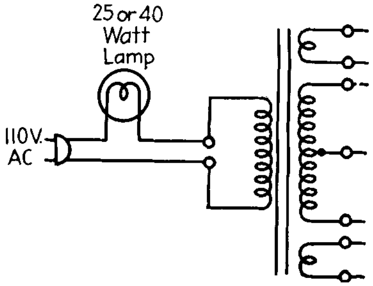


Fig. 8–5. Checking the power transformer.

5. If a short is present, remove the transformer secondary leads from their connection points, one winding at a time, to determine whether the short is internal or external; in the latter case, to determine which circuit contains the short.

To interpret the above checks, it might be well at this point to give some more transformer theory. With all the tubes removed, the secondaries are not drawing current, and consequently, the primary should not be drawing current. This would be true if the transformer were 100 per cent efficient. Since this is not so, the primary will draw a small amount of current to overcome the hysteresis and eddy-current losses in the iron core. With the average radio power transformer, this small amount of current is sufficient to cause the series 25-watt lamp just to glow. This is the test for a good transformer.

Now, assume some shorted turns, or a short in the 6-volt amplifier-filament wiring. The primary must furnish the power that this short consumes. The added primary drain causes more current to flow through the series 25-watt lamp, and the lamp glows more brightly. Now, suppose that we disconnect the 6-volt transformer leads. If the lamp brightness drops to just a glow, we must inspect the receiver filament circuit for a short. If the lamp filament continues to glow brightly, even after all circuits have been opened, the short is within the transformer.

When a power transformer is replaced, an exact duplicate is to be preferred. If this is unobtainable, the serviceman is beset by a number of questions. What size shall I use? Which winding is which? How can I tell the windings apart? What shall I do with the extra leads?

What size of replacement power transformer should be used? Replacement transformers are usually rated in the voltages and currents obtainable from the various secondary windings. These data must be compared with the calculated requirements of the tubes in the receiver being serviced. For example, checking the requirements of our standard receiver with the tube manual, we obtain the information shown in the accompanying table.

Tube complement	*A requirements*		*B requirements*		
	Volts	*Amp*	*Volts*	*Plate current, ma*	*Screen current, ma*
5Y3-G	5	2			
6V6-G	6.3	0.6	250	45	4.5
6SQ7	6.3	0.3	250	0.9	
6K7	6.3	0.3	250	7	1.7
6A8	6.3	0.3	250	3.5 4	2.7
6K7	6.3	0.3	250	7	1.7
Total	5 6.3	2 1.8	250 volts at 78 ma		

Allowing 100 volts for the speaker field, adding this to the plate voltage requirement, and allowing for the voltage divider drain, a replacement transformer with the following rating can be used:

5 volts at 2 amp
700 volts (center-tapped) at 90 ma
6.3 volts at 2 amp

The high-voltage winding is sometimes labeled "350–0–350," which indicates 350 volts on each side of the center tap. This is the way the transformer is used in a full-wave rectifier.

A good rule to follow, as a check of the calculations, is that the replacement transformer should be about the same physical size as the original.

Power transformer color code. Most transformer manufacturers color their leads in accordance with the Radio Manufacturers Association

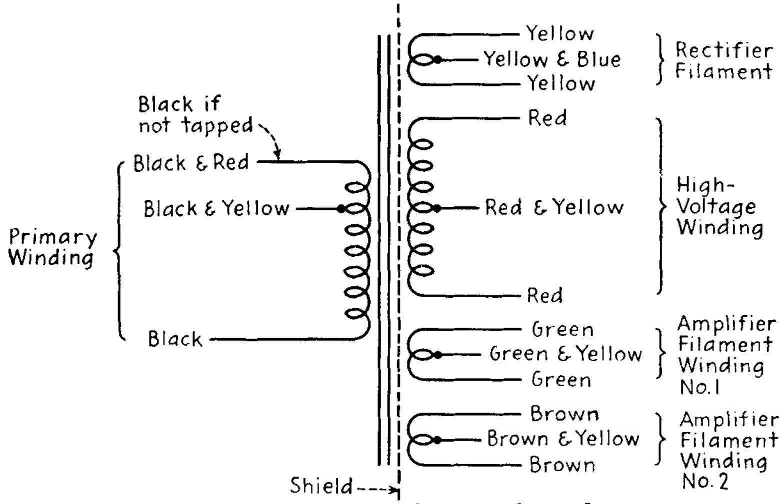


FIG. 8–6. Power-transformer color code.

(R.M.A.) color code. This can be used to advantage for replacement and is given in Fig. 8–6.

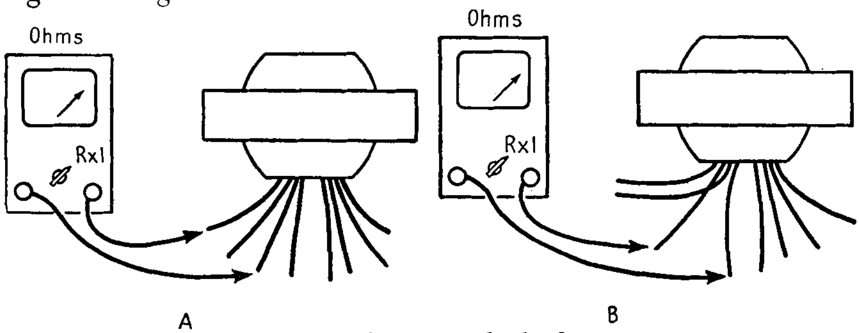


FIG. 8–7. Pairing the leads.

How to identify leads of an uncoded transformer. In case the manufacturer does not follow the code, the leads can be determined with an ohmmeter and voltmeter as follows:

1. Pair up the winding leads by means of an ohmmeter.
   a. First connect the ohmmeter to any lead and check for continuity with all the other leads, as shown in Fig. 8–7A. The lead that shows continuity is the other end of that winding or a tap. In the case of a tapped winding, three leads will show continuity.

b. Separate these two or three leads, as the case may be, and repeat to find the other windings, as shown in Fig. 8–7*B*.

2. Read the resistance of each winding, as shown in Fig. 8–8.
   a. The primary will show a resistance of 5 to 15 ohms (240 turns).
   b. The high-voltage winding will show a resistance of 200 to 400 ohms (1,400 turns) for the entire winding.
   c. The filament windings will show a reading of less than 1 ohm (10 or 12 turns).

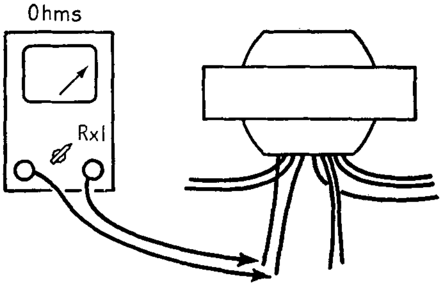


FIG. 8–8. Resistance of each winding.

There will be no mistaking the high-voltage winding. Tape the leads so there will be no danger of shock.

3. Connect the primary to the AC line, and check the voltage of the filament windings to determine which is the amplifier and which the rectifier filament winding (Fig. 8–9).

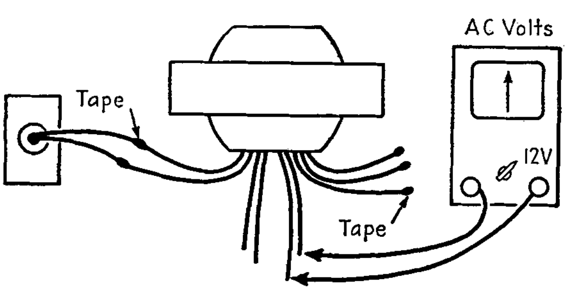


FIG. 8–9. Identifying the amplifier heater winding.

What to do with unused leads. The replacement transformer often has leads that are not used in the original wiring diagram of the receiver. The filament center taps, for example, may not be used. If this is the case, tape the unused leads so that they will not short and dress them neatly in the receiver chassis. If the unused center tap is of the type that has two separate wires in a single piece of spaghetti, solder these two wires together before tapping the end.

Sometimes the replacement transformer has an uncoded lead that does not show continuity to any of the other leads. This lead will be the connection to a noise-reducing Faraday shield, between the primary and the secondary windings. If the transformer has such a lead, connect it to a chassis soldering lug.

General replacement notes. Before concluding this section of replacement notes on power transformers, the authors would like to remind the serviceman that it is a sign of good workmanship always to be careful of wiring and soldering and that this is especially important when replacing the power transformer. A poor connection or resin joint can cause much trouble when it is in the low-voltage high-amperage filament circuit. Poor insulation and sloppy soldering can also cause a messy recall job from flashovers in the high-voltage circuit. Of course, the line cord should be examined for frays, the grommet should be examined for breaks, and the knot should be in place behind the grommet on the inside of the chassis.

Troubles common to the rectifier tube. Rectifier tubes usually have a long life. The 5Y3-G, for example, is rated at 125 ma of output current. This is rarely exceeded or even reached by the typical receiver; when it is, a larger tube, the 5U4-G, is usually employed. As the tube ages, it gradually loses its emission, with a consequent loss in output voltage. Tube checkers are reliable in indicating this condition. Another check is a comparison of output voltage with another rectifier tube that is known to be good. Occasionally, rectifier tubes become gassy and glow with a purplish light. In this case, the receiver will not operate at all, or its speaker might emit only a low tearing growl. Replacement of the tube is the answer. The above applies only to high-vacuum rectifiers like the 80, 5Y3-G, 5Y4-G, 5U4-G, etc. It is normal for a glow to appear in gas rectifiers like the OZ4-G and in mercury-vapor rectifiers like the 82 and 83.

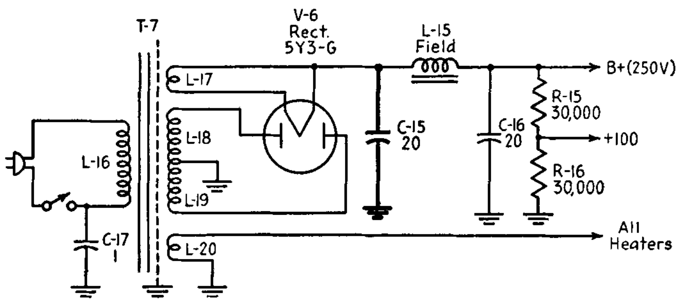
Troubles common to the filter choke (speaker field). The common fault with filter choke *L*-15, the speaker field, is that the winding opens. This will be found on check, by no voltage at *B* plus and abnormally high voltage at rectifier filament. When he finds this condition, before checking to make sure that the field is open, the serviceman should pull the receiver plug and discharge the filter condensers. Input filter condenser *C*-15 remains at full charge, since there is no discharge circuit when the field is open.

When the ohmmeter shows an open field, the serviceman should not rush too soon for a replacement. Especially when the speaker is not mounted directly on the chassis, speaker plug contacts and connecting cables should first be inspected carefully for the open. Sometimes the open is due to corrosion or a break at the soldered connection between the field wire itself and the connection leads that leave the field, and this can often be repaired. The field covering is cut into near the lead to expose the connection. The broken end is then picked up, cleaned with fine sandpaper, and tinned before soldering the new connection.

The lead must be securely taped into position, since mechanical stress will break the fine field wire.

Replacement field coils are not often obtainable, nor are speakers often of a type that can be taken apart for this purpose. A procedure for replacing field coils where feasible is given in Chap. 9, on Loudspeakers. As a general rule, the entire speaker must be replaced. Where the exact duplicate cannot be obtained, the chosen replacement must match the original as nearly as possible in size, mounting details, wattage rating, resistance of the field coil, and impedance of the voice coil. The output transformer can usually be transferred from the old speaker to the replacement.

Troubles common to the input filter condenser. The input filter condenser *C*-15 is the most common cause of trouble in the power-supply stage. It



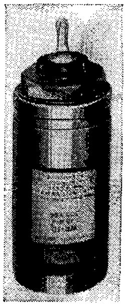


FIG. 8–10. A typical input filter condenser and its position in the power-supply circuit.

is a high-voltage, high-capacity electrolytic condenser of either the wet or the dry type. With time, electrolytic condensers lose capacity and open. When this is the case, the *B* plus voltage will be low and the receiver will hum. The defect is confirmed by bridging the condenser with a good one of similar capacity and noting the improvement.

Condenser *C*-15 also has the highest DC voltage in the receiver across it. In addition, there are large surges in voltage across it. As a result, it is subject to voltage breakdown and shorting. When this happens, the *B* plus voltage is zero, and the rectifier-tube plates become red-hot from the heavy drain of current into the shorted *C*-15.

How to check an electrolytic condenser. The handiest check for an electrolytic condenser is a resistance measurement on the high-resistance range of the ohmmeter. When the condenser is checked, the meter pointer will kick up and then drop. The meter test prods are then reversed. The meter pointer should kick up further and then drop again. The surge of current, indicated by the kick, is caused by the condenser's being charged by the battery in the ohmmeter. When the test prods are reversed, the charged condenser adds its voltage to the battery in the ohmmeter, causing an increased surge of current, as indicated by the increased kick. An open electrolytic condenser will show very little of this charge-and-discharge current.

Electrolytic condensers normally have leakages, which will be different, depending on the polarity of the ohmmeter connections and that of the condenser. Definite values cannot be assigned to the ohmmeter readings of this leakage resistance, owing to differences in condensers as well as in ohmmeters. An approximation for condenser C-15 is 50,000 ohms with the test prods connected one way, and 500,000 ohms on reversal. The difference is due to the fact that the condenser is polarized. Condenser C-15 must be disconnected from the circuit for this test, since other circuits are connected in parallel with it. The above explains the

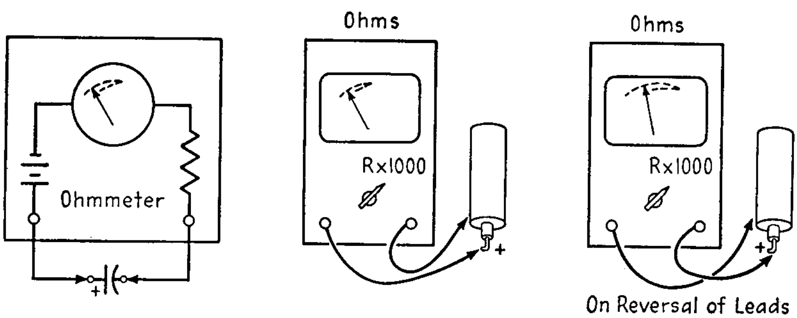


FIG. 8–11. Checking an electrolytic condenser with an ohmmeter.

general rule when making resistance tests in a circuit bridged by an electrolytic condenser: Reverse the test prods and take the higher reading.

Replacement of the input filter condenser. When filter condenser C-15 is replaced, the capacity and voltage rating of the original should be used. A lower capacity may cause hum; a lower voltage rating may soon cause breakdown. Correct polarity must be observed since, if it is reversed, the condenser will overheat and possibly explode.

Sometimes, input-filter replacement condensers continually break down. This is due to high surge voltage and is found in large receivers. The high surge voltage is due to the fact that, when the receiver is turned on, the filament-type rectifier immediately furnishes high voltage, while the cathode-type amplifiers, which constitute the load, have not yet warmed up and are not drawing current. During the period of no load or low load as the amplifier tubes warm up, the voltage output of the power supply is high. Normally, in the average receiver, this is of no consequence, since the surge voltage developed from a 350–0–350 high-voltage winding is approximately 450 volts, well under the 525 surge-voltage rating of an electrolytic condenser. In large receivers, however, where the tube complement includes a 5U4-G and two 6V6-G or 6L6-G tubes, the high-voltage winding may deliver higher voltage, and the voltage across *C*-15 may be 550 volts until the output tubes warm up. Where this is the case, there will be repeated breakdowns of condenser *C*-15.

Surge voltage is easily checked. Simply allow the receiver to cool down, connect the voltmeter across condenser *C*-15, turn the receiver switch on, and watch the voltmeter. If the voltmeter goes up to 425 or 450 volts when the switch is first turned on, and then settles back to about 350 volts as the tubes warm up, there is little likelihood of trouble from surge voltage. If the surge voltage climbs above 525, the safest procedure is to replace condenser *C*-15 with two condensers in series, as shown in Fig. 8–12. Condensers *C*-15*A* and *C*-15*B* should each be twice

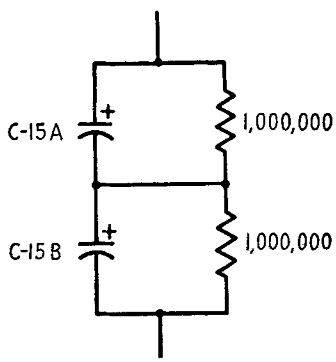


FIG. 8–12. Connecting two condensers to increase voltage rating.

the capacity of condenser *C*-15, since two equal condensers in series have a total capacity of half of one of them. The resistors should be 1 watt, 1 megohm (1,000,000 ohms) apiece. Their purpose is to equalize the voltage across condensers *C*-15*A* and *C*-15*B*. Each condenser, therefore, will have half of the total voltage across it. A circuit of this type, employing condensers of the same voltage rating, will withstand any surge.

When condenser *C*-15 is replaced with a wet electrolytic, it is considered good practice to re-form the condenser plates, which may have deteriorated from shelf life. To do this, connect the replacement condenser (observing polarity) across the output filter condenser *C*-16, where the voltage is smoother and more suited to forming plates. Leave the radio turned on for about half an hour. If the replacement condenser heats, it needed the re-forming process.

When a shorted input filter condenser is replaced, it is advisable to check the rectifier tube to make sure that it was not damaged by the heavy overload.

Troubles common to the output filter condenser. Output filter condenser *C*-16 is usually similar to the input condenser *C*-15 and is subject to the same troubles; it opens and shorts. When it opens, there is no effect on the *B* plus voltage, but there may be excessive hum, squeal, or motorboating, or a combination of all three. Substituting another condenser to see its effect is the fastest check. When it shorts, *B* plus voltage is zero, and the rectifier tube overheats, but not to the point of red plates.

Before condemning condenser *C*-16, the serviceman should look for even a small *B* plus voltage. In parallel with condenser *C*-16 is the plate circuit of every tube in the radio, and the short may very well be elsewhere. Figure 8–13 is a skeleton diagram of the receiver, showing only the plate and *B* plus circuits. If, for example, condenser *C*-12 were shorted, *B* plus voltage would be low, the voltage at the rectifier filament

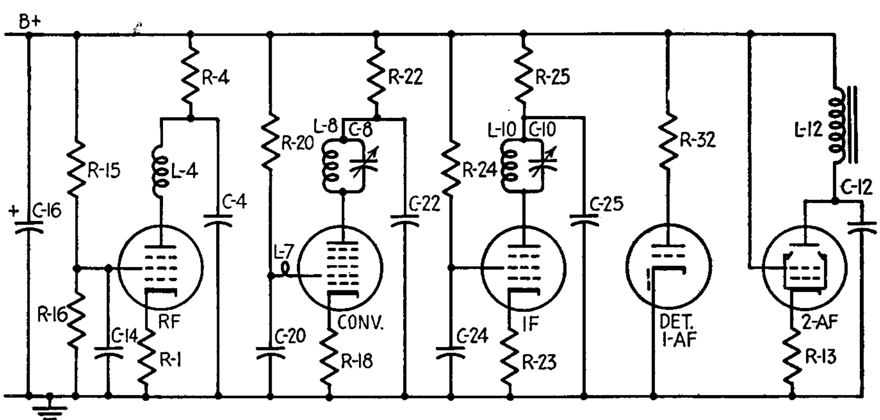


FIG. 8–13. Skeleton diagram of the standard receiver showing the *B* circuit.

would be almost normal, and the plate voltage of the second AF tube, *V*-5, would be zero. It would be a good idea, therefore, to check all plate voltages before going further. Another good indication as to the location of the short would be an overheated resistor. Resistor *R*-4, *R*-22, or *R*-25 would be badly overloaded if condenser *C*-4, *C*-22, or *C*-25 were shorted. If these methods do not locate the short, it would be necessary to open *C*-16 as well as the rest of the *B* plus circuit, one wire at a time, and hunt for the short with an ohmmeter. When the short is located, if it is an item other than condenser *C*-16, replacement notes will be found for it in the chapter dealing with its particular stage.

When replacing condenser *C*-16, the serviceman must be careful to observe polarity. Also, when replacing an open output filter condenser, he should be careful to remove the connection from it when, for one reason or another, the original condenser is left physically on the chassis. Even though the soldering lug might be handy for the replacement condenser, leaving the old one connected in the circuit is a potential source of trouble. Output filter condenser C-16 is not nearly so susceptible to high surge voltage as input filter condenser C-15, and the usual surge voltage rating of 525 volts is adequate.

Finally, condensers C-15 and C-16 are often contained in one filter block. The fact that one condenser has proved defective is no indication that the other cannot still give long, satisfactory service. Whether to replace the single unit or the entire block is up to the individual serviceman. Usually, it is preferable to replace the block.

Troubles common to the voltage-divider resistors. Voltage-divider resistors R-15 and R-16 in modern receivers are usually of the 1- or 2-watt

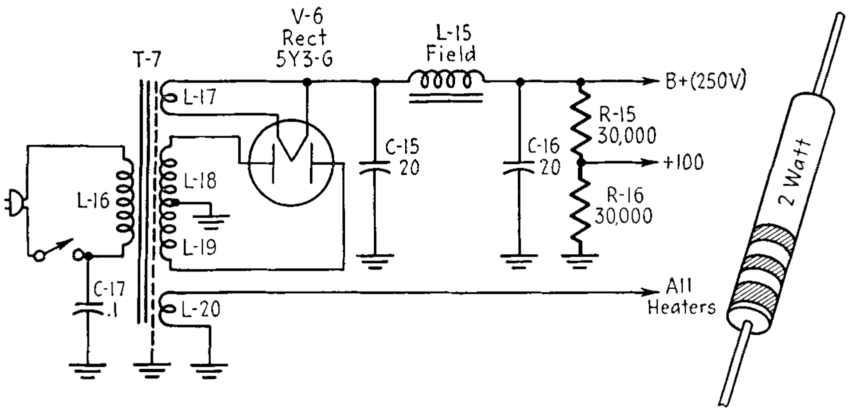


FIG. 8–14. A typical voltage-divider resistor and its position in the AC power supply.

carbon type. The defects common to both are that they open or change in value.

When R-15 is open, the radio will not play and the screen voltage will be zero. The ohmmeter then confirms that R-15 is open. Before going further the serviceman checks resistance from chassis to screen, since a shorted screen by-pass condenser may have been the cause of its failure.

When resistor R-16 is open, screen voltage is high and the radio may oscillate. An ohmmeter check confirms the condition.

If either R-15 or R-16 changes in ohmic value, the screen voltage will be abnormal and the radio may oscillate. Again the ohmmeter is the final check. It must be remembered in making these ohmmeter checks on resistors R-15 and R-16 that electrolytic condenser C-16 is across the pair of them and will affect the readings. In all cases, the ohmmeter test prods must be reversed and the higher ohmic reading taken.

In replacing either R-15 or R-16, it would be well to check the wattage rating against the wattage formula $W = E^2/R$. In the case of R-15, E is the potential difference between B plus and the screen voltage; in the case of R-16, E is the screen voltage. For example, R-15 in the typical circuit is 30,000 ohms, B plus is 250 volts, and screen is 100 volts. Then

$$W = \frac{E^2}{R} = \frac{150 \times 150}{30{,}000} = \frac{15}{20} = \frac{3}{4} = 0.75 \text{ watt}$$

Since a resistor should have at least a 100 per cent safety factor, the required wattage rating for R-15 is 1.5 watts. There is no 1.5-watt size, and the next larger size usually stocked is 2 watts. The replacement for R-15, therefore, should be a 2-watt 30,000-ohm resistor, even though the original may have been a 1-watt size.

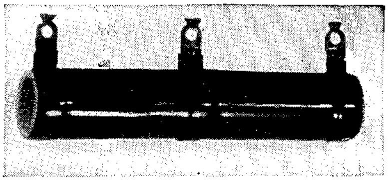


FIG. 8–15. Tapped wire-wound resistor used as a voltage divider.

Voltage-divider resistors R-15 and R-16 are a possible cause of fading in the receiver. As they warm up in operation, they may change in ohmic value. This causes a change in screen voltage, which will cause a change in the amplification of the tubes whose screen voltage is controlled by R-15 and R-16, with a consequent change in volume, known as "fading." This condition can be checked by clipping the voltmeter from screen to chassis, leaving the radio turned on, and noting the reading before and after the fading.

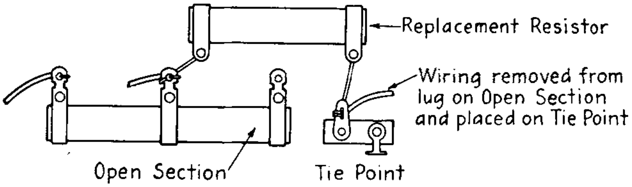


FIG. 8–16. Replacement for an open section of a voltage divider.

Voltage-divider resistors R-15 and R-16 are sometimes tapped wire-wound resistors, as in Fig. 8–15. The defect common to this type is that the resistors open; they rarely change in value. Defects are found by the same procedure as was explained above for the carbon resistor type. When replacing a section, any resistor of the proper ohmic value and wattage rating may be used. However, it is not wise to leave the old unit connected in the circuit. The open may heal intermittently, with consequent noise and fading. A trouble-free replacement for a section is shown in Fig. 8–16.

Troubles common to the line filter condenser. Line filter condenser *C*-17 is a paper tubular condenser, whose usual capacity is 0.1 mfd. With the usual rating of 400 volts, voltage breakdowns are unknown. The condenser may open, and this would theoretically cause greater interference from line disturbances. An open line filter condenser, however, may cause entirely different effects. Owing to its position in the circuit, the receiver chassis is grounded through condenser *C*-17 by the lighting mains, one side of which is grounded. The receiver installation may have no ground at all or an indifferent ground, in which case *C*-17 takes on a

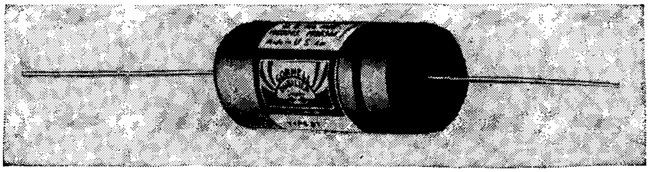


FIG. 8–17. Paper tubular condenser.

new function—that of grounding the receiver. This explains why reception (absence of hum or noise) is often improved by reversing the plug on AC receiver installations. It also explains why a tiny spark or small shock is experienced when connecting a ground to a receiver. When *C*-17 is open, its grounding function is gone. The most annoying manifestation of this is know as "modulation hum"; that is, the receiver does not hum when making a hum check. The hum comes on as a station is tuned in. There will be no hum between stations. Standard procedure for modulation hum is to check the ground and condenser *C*-17. Bridging condenser *C*-17 with another condenser of like value is the check for an open condenser.

VARIATIONS OF THE POWER-SUPPLY STAGE

There are many variations of the power-supply stage having to do with transformer taps, voltage dividers, two-section filters for better elimination of hum, and methods of feeding current to the speaker field. These have all been incorporated in Fig. 8–18, which is fairly representative of many large, high-quality receivers.

Condensers *C*-17 and *C*-117 filter both sides of the line. The electrostatic shield in *T*-7 aids in reducing line disturbances. The primary is tapped so that the receiver can be easily adapted for high- or low-line voltage. The line is also protected by means of a low-amperage fuse, *F*-1. The high- and low-line switch and fuse are usually combined in a simple arrangement, as shown in Fig. 8–19. Clipping fuse *F*-1 into the position marked 110 VOLTS automatically connects the line to the 110-volt primary tap. The connections for the fuse clip terminals are indicated in the schematic diagram of Fig. 8–18 by the circles near fuse *F*-1. For the sake of long life for the filter condensers, the 120-volt position is safest.

The filament windings are shown center-tapped. There may also be a second filament winding of 2.5 volts, for lighting the filaments of 2A3

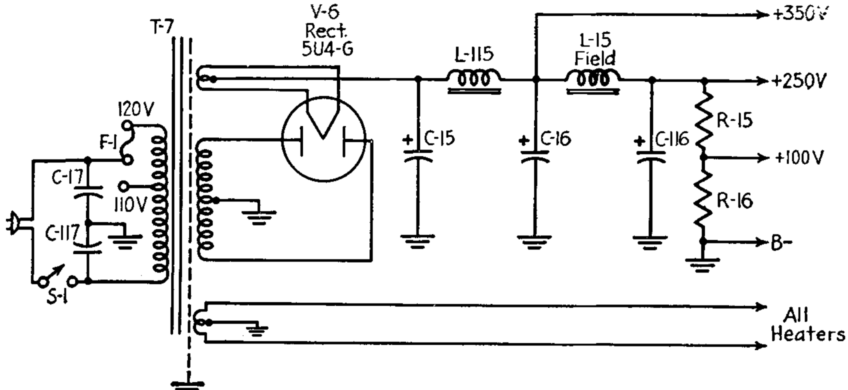


FIG. 8–18. Typical power-supply stage for a large high-quality receiver.

power output tubes. The other tubes are of the usual 6-volt type. A second filament winding is not necessarily for 2.5-volt tubes only. Since these are multitube receivers, the filament drain is quite heavy, and the filament circuit is often split up into two lines fed by individual windings. If there is only one winding, the receiver filament hookup wire is very heavy to take the heavy current load.

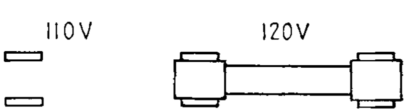


FIG. 8–19. Line-voltage adjustment fuse.

The rectifier used is usually the 5Z3 or 5U4-G. In this type of receiver, the rectified output voltage is considerably higher than is the case in the standard receiver, and surge voltage may cause problems. This was discussed in the section dealing with replacement notes for input filter condenser *C*-15.

Filter choke *L*-115 is a low-resistance, high-current choke coil. It is usually very rugged and rarely gives trouble. If it should open (probably owing to corrosion in a moist climate), the procedure for finding it is identical with that given for speaker field *L*-15. Speaker field *L*-15 and condenser *C*-116 form the second section of the filter circuit and offer no new problems. Voltage divider *R*-15 and *R*-16 is usually a wire-wound tapped resistor of lower ohmic value and higher wattage rating than is found in the standard circuit. The lower resistance drives more magnetizing current through the speaker field and also provides a load known as a "bleeder," which is always connected across the rectifier output, whether the amplifier tubes have warmed up or not, and is therefore instrumental in keeping down the surge voltage. Incidentally, when 2A3 or 6A3 tubes are used in the power output stage, since these are filament-type tubes, they draw current as soon as the filament-type rectifier tube is able to deliver it. In this case, surge voltage can be neglected entirely.

Fixed-bias type power-supply stage. Another common variation in the standard circuit occurs where the filter choke is connected in the negative *B* supply lead. The action of filter choke *L*-15, as an inductance in

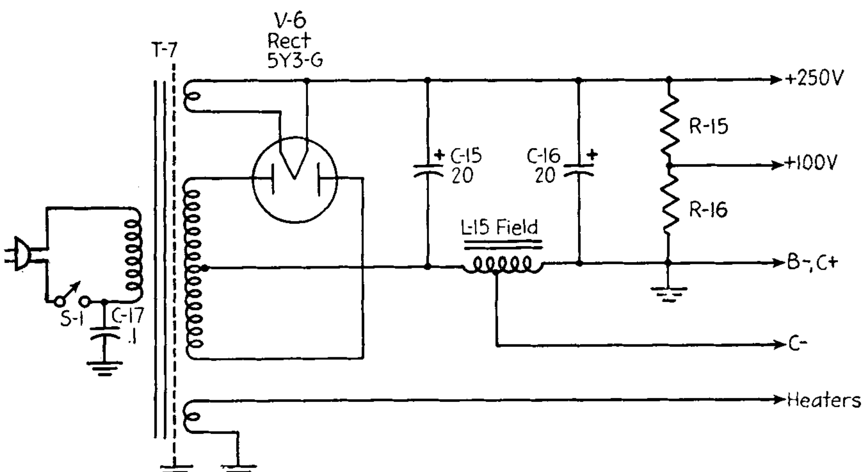


FIG. 8–20. Fixed-bias-type power supply, using a tapped speaker field in the negative *B* lead.

series with the load to offer high opposition to pulsations, is the same whether connected in the positive or negative side of the *B* supply line.

Since the center tap of the high-voltage winding is of necessity the most negative voltage point in the receiver, by placing choke *L*-15 in the negative power-supply lead the transformer end of choke *L*-15 is more negative than the *B* minus or ground end, by the voltage drop across the choke. Control grids in amplifier tubes are kept at a potential that is negative with respect to cathode. This is called the "grid-bias" voltage, or, more simply, *C* voltage. In the above circuit, the amplifier cathodes will be grounded and the grids returned to the point in choke *L*-15 which will develop the proper negative bias voltage. Choke *L*-15 is usually an 1,800-ohm speaker field, tapped at 300 ohms for bias voltage.

Modern variations of this circuit use a resistor in the negative *B* lead to replace the tap on the choke. This resistor is often tapped, as shown in Fig. 8–21, where the resistor is represented by *R*-115 and *R*-116. The purpose of the tap is to give more than one bias voltage. This is done to provide a low value of *C* bias for the RF tubes, and a higher value for the last audio stage. The tapped resistor is called a "*C* voltage divider." In circuits of this type, the speaker field *L*-15 may be found in the positive leg of the *B* power supply, since the bias voltage is developed across *R*-115 and *R*-116. The most common type of *C* voltage divider is a wire-wound tapped resistor.

Either of these systems of obtaining *C* voltage is known as "fixed bias," because the voltage is due to the entire *B* current of the receiver passing through the resistor or speaker field.

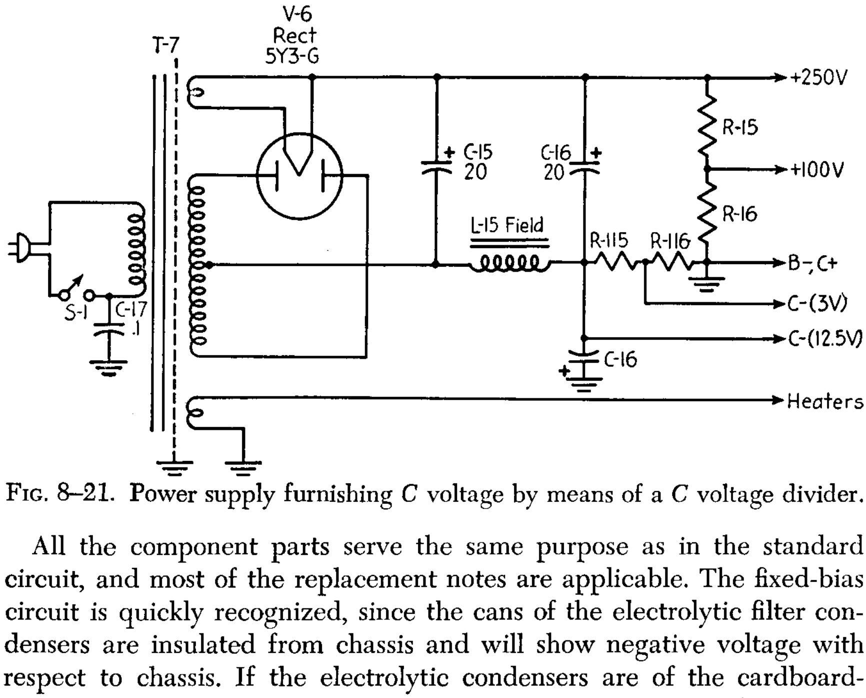


FIG. 8–21. Power supply furnishing *C* voltage by means of a *C* voltage divider.

All the component parts serve the same purpose as in the standard circuit, and most of the replacement notes are applicable. The fixed-bias circuit is quickly recognized, since the cans of the electrolytic filter condensers are insulated from chassis and will show negative voltage with respect to chassis. If the electrolytic condensers are of the cardboard-covered type, the negative leads do not connect to chassis. If *C*-15 and *C*-16 are enclosed in one filter-condenser block, the positive is the common lead.

In the test procedure, readings are not taken from chassis. For example, chassis to rectifier plate would not be checking the high-voltage winding but would include *R*-115 and *R*-116 and the speaker field. It would be best, when servicing a power supply of this type, to keep the receiver wiring diagram constantly at hand for reference to the proper test points for checking each component part. A good reference point for readings would be the center tap of the high-voltage winding.

Power supplies with R-C filters. The power supplies described so far make use of the field of an electro-dynamic speaker as a filter choke. Many receivers, however, are equipped with P-M speakers, where the field is provided by a permanent magnet made of alnico alloy. In this case, the field winding could be replaced by a choke, but most receiver manufacturers prefer to use resistance-capacitance, or R-C filters.

The circuit is shown in Fig. 8–22. It is similar to the two-section circuit of Fig. 8–18, using resistors instead of chokes. Resistor *R*-15, together with condensers *C*-15 and *C*-16, make up the first section of the filter system and provide the high *B* supply for the power amplifier plate circuit. This point is labeled *B*+ (HIGH) in the diagram. The R-C filter is not quite so efficient as an inductance-capacitance or L-C filter, so that there is some hum content at the *B*+ (HIGH) point. Since the power

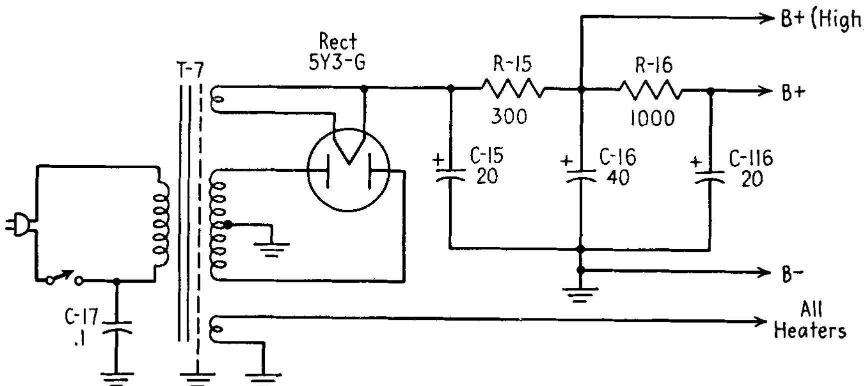


FIG. 8–22. Power supply with R-C filter.

amplifier plate circuit is not followed by further amplification, this hum content is not noticeable. If this voltage were applied to other parts of the receiver, however, the hum content would be amplified and heard in the loudspeaker. Therefore, *B* power for the rest of the receiver is obtained from a second section R-C filter, which further reduces the hum content. The second filter section consists of resistor *R*-16 and condenser *C*-116 and provides lower *B* voltage at the point labeled *B*+ in the diagram. Bleeder resistors are uncommon in circuits of this type, screen voltage being obtained by dropping resistors in the individual screen circuits.

Filter resistors *R*-15 and *R*-16 are usually wire-wound high-wattage types like the one illustrated in Fig. 8–23. The values given in Fig. 8–22 are typical. The two resistors may be combined in a single tapped unit, or they may be separate. The metal shell is attached directly to the chassis, which therefore helps dissipate the heat generated in the resistors.

When working on a set of this type, remember that it is normal to find a higher voltage at the plate of the power-amplifier tube than at the plates of the other tubes. If you do not have service data for the receiver you are working on, you can expect a reading of 250 to 300 volts at the rectifier cathode, about 5 or 10 volts less at *B* plus (HIGH) point and 200

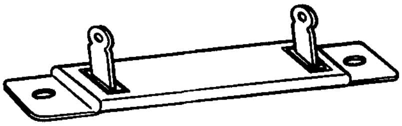


FIG. 8–23. Wire-wound resistors commonly used in R-C filters.

to 225 volts at the *B* plus point. Resistance readings from any *B* positive point to chassis will show a condenser charge reading, since there is no bleeder resistor. Failure of a filter resistor would be found by the same servicing procedure that discloses a defective choke or speaker field. Similarly, a complaint of hum is usually found to be caused by the failure of one or more of the filter condensers. When replacing a filter condenser, check the size of the original. Capacitances of 40 mfd are not unusual in R-C filter circuits.

Power supplies in small AC receivers. In small lower-priced AC receivers, manufacturers incorporate certain economies, such as a smaller speaker, fewer components, and a smaller power transformer delivering

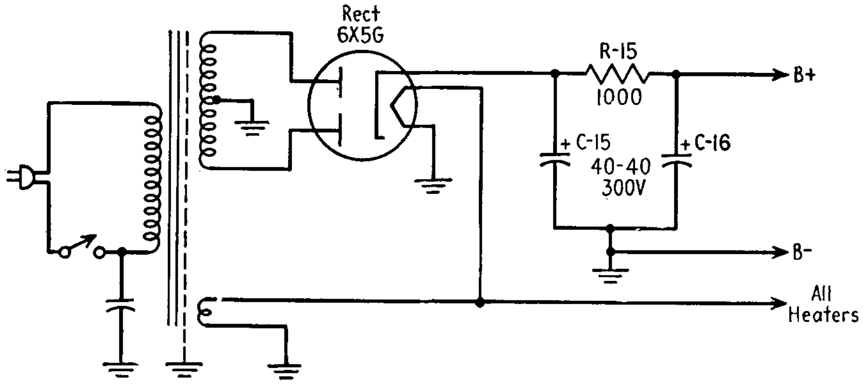


FIG. 8–24. Power supply in small AC receivers.

a lower voltage. The volume capabilities of such a set are, of course, lower than in the larger receivers.

A typical power supply for this type of set is shown in Fig. 8–24. The *B* voltage is usually low, 150 to 200 volts. This allows for a much smaller power transformer. An additional economy in the transformer is obtained by the use of a 6X5-G type of rectifier, which saves the extra 5-volt filament winding. The 6X5-G is a cathode-heater tube with a 6.3-volt heater, fed from the same winding that lights the other tubes. The filter circuit is usually a single-section R-C filter. The single filter section is satisfactory, since the small speakers used in these sets do not respond too well to the hum frequency. Note the large size of the filter condensers. A filter block of 40-40 mfd/300 volts is usual. The filter resistor is a wire-wound type similar to the one pictured in Fig. 8–23.

Servicing this type of power supply is very similar to work on the standard circuit. The following exceptions should be kept in mind. Voltage measurements will be low—200 to 250 volts AC at the rectifier plates, 200 to 250 volts DC at the rectifier cathode, and 150 to 200 volts DC at *B* plus. Resistance measurements will show condenser charge readings at any *B* plus point, since there is no bleeder resistance.

If the transformer should prove defective and require replacement, try to get a duplicate part from the receiver manufacturer. When this is not possible, a standard replacement must be used. Choose one with a low rating for the high-voltage winding. One rated 250-0-250 at 40 or 50 ma should be satisfactory. Carefully insulate the 5-volt winding by taping the ends, since it will not be used. The use of a transformer delivering higher voltage may harm the rectifier tube or filter condensers.

SUMMARY

Quick check for normal operation of stage

All tubes light.

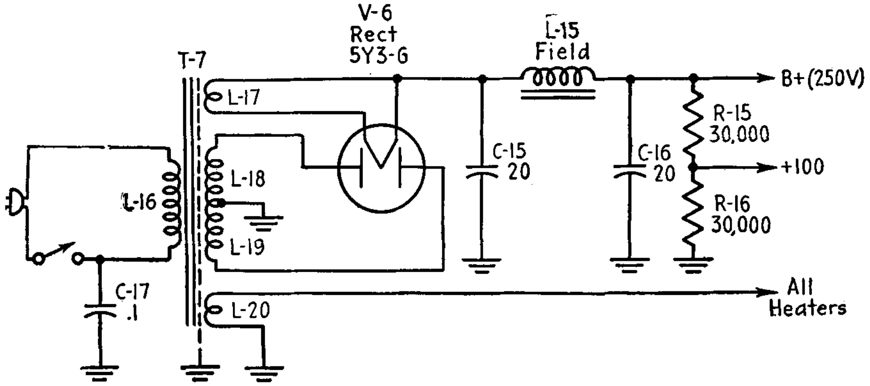
No signs of overheating.

Hum level is normal.

B plus voltage measures 200 to 300 volts.

Typical AC power supply

Typical AC power supply is shown diagrammatically in the accompanying figure.



Normal resistance data

Plug, prong to prong	5–15 ohms
Chassis to rectifier plates	150–200 ohms
Rectifier filament to *B* plus, across speaker field	1,000–2,000 ohms
Chassis to rectifier filament	61,000 ohms

Normal voltage data

Rectifier filament to filament	5 volts AC
Across other tube heaters	6 volts AC
Chassis to rectifier plate	250–380 volts AC
Chassis to rectifier filament	265–400 volts DC
Chassis to *B* plus	200–300 volts DC
Chassis to screen	90–100 volts DC

SERVICE DATA CHART

Symptom	*Abnormal reading*	*Look for*
Tubes do not light	Plug, prong to prong checks open with ohmmeter	Defective line cord and plug. Open fuse. Defective line switch *S*-1. Open power transformer *T*-7 (primary)
Rectifier-tube plates show red	Chassis-to-rectifier filament checks short circuit with ohmmeter	Shorted input filter condenser C-15. Check surge voltage on replacement
Rectifier tube overheats	*B* plus voltage checks zero. Chassis to *B* plus checks short circuit with ohmmeter	Shorted output filter condenser C-16. Short circuit in *B* plus wiring
Rectifier tube overheats	*B* plus voltage low	Zero plate voltage on amplifier tubes. Short-circuited plate filter condenser
Hum	*B* plus voltage low	Open input filter C-15
Hum	*B* plus voltage normal	Open output filter C-16. Open grid
Oscillation or motorboating	*B* plus voltage normal, or fluctuating with motorboat beats. Screen voltage normal	Open output filter C-16 (or C-116)
Rectifier tube shows purplish glow		Gassy high-vacuum type of rectifier tube
Weak reception. No sign of overheating	*B* plus voltage checks low	Weak rectifier tube
No signal from speaker. No sign of overheating	*B* plus voltage checks zero (discharge filter condenser)	Dead rectifier tube. Open filter choke *L*-15
No reception. No hum. *B* plus voltage normal	Screen voltage zero	Open voltage-divider resistor *R*-15, short-circuited screen by-pass condenser, or both
Modulation hum		Poor ground, open line filter condenser C-17, or both
Fading		Screen voltage changing, owing to defective voltage-divider resistors *R*-15 and *R*-16
Oscillation	Screen voltage high	Open voltage-divider resistor *R*-16

QUESTIONS

1. The tubes of an AC radio receiver do not light. List the various possible sources of trouble in the order in which you would check them.

2. An AC receiver does not play, and the rectifier plates get red-hot. What is the most likely cause of the trouble?

3. An AC receiver is brought in for hum. How would you check to see if the hum originates in the power-supply stage?

4. An AC receiver does not play. A check of the receiver shows that the tubes light and that there is no sign of overheating or hum, but there is no *B* voltage. List the possible causes of the trouble, and explain how you would check for each one.

5. After a shorted input filter condenser has been replaced, what two checks should be made before checking the receiver for normal operation?

6. The power transformer of an AC receiver overheats. The radio plays, the hum level is somewhat high, and *B* voltage is low. A voltage check of the power supply shows 280 volts AC on one rectifier plate and 80 volts AC on the other. What is wrong?

7. Describe the series lamp check for a short in a power transformer or its associated circuits.

8. When using the series lamp check on a receiver with an overheating power transformer, the lamp glows brightly until the amplifier filament wires are removed. Where would you look for trouble?

9. When a 5Y3-G rectifier tube glows with a purplish light, what is likely to be wrong?

10. Thordarson lists the following general replacement power transformers:

	T-13R11	*T-13R12*	*T-13R13*
HV winding	580 volts CT at 50 ma	700 volts CT at 70 ma	700 volts CT at 90 ma
Rectifier filament	5 volts at 3 amp	5 volts at 3 amp	5 volts at 3 amp
Filament No. 1	6.3 volts CT at 2 amp	6.3 volts CT at 2½ amp	6.3 volts at 3½ amp

Which one would you choose as a replacement for the receiver of Fig. 10–14?

11. Which of the power transformers listed in question 10 would you use as a replacement for the receiver of Fig. 10–17?

12. The receiver of Fig. 11–24 does not play. In checking the power supply, *B* voltage measures 260 volts, screen voltage measures zero. What should the next check be?

13. The receiver of Fig. 10–14 motorboats. What component in the power supply is likely to cause this condition?

14. The receiver of Fig. 10–17 does not play. A voltage check shows *B* plus to ground voltage equals zero, and *B* plus to the center tap of the high-voltage winding measures low—about 100 volts. The *C* voltage divider, resistors (46) and (47), overheats. A resistance check shows *B* plus to ground checks short, and *B* plus to high-voltage center tap is 350 ohms. What is likely to be wrong?

15. The hum level in a receiver is normal, but the receiver hums badly when certain stations are tuned in. What component in the power supply can cause this condition?

16. Resistor *R*-3 of Fig. 11–24 is found to be open. The *B* plus voltage measures 260 volts, and the IF screen voltage measures 85 volts. What should be the wattage of the replacement resistor?

9 LOUDSPEAKERS

Quick check. To determine whether a loudspeaker is functioning, momentarily unseat the second AF tube. A loud click should be heard. Where the output stage is of the push-pull type, removing either tube will produce the same result.

Function of the loudspeaker. The loudspeaker is a device that takes electrical energy or power at audio frequencies from the second AF output stage and converts it into sound energy. Its fidelity of reproduction depends on its ability to convert into sound all the component frequencies at the second AF output.

Types of loudspeakers. Many varieties of loudspeaker have paraded across the stage throughout the period of radio evolution. All of them, however, can be grouped into three main types: the magnetic loudspeaker, the crystal loudspeaker, and the moving-coil dynamic loudspeaker. Much could be said about each of these, but the trend in recent years has been toward the dynamic type. Therefore, the balance of the description will concern itself with that type.

Theory of operation of the dynamic loudspeaker. The theory of operation of a dynamic speaker is quite simple. In these speakers, the AF signal from the second AF stage is impressed across a small, free-floating coil of wire (called the "voice" coil), which is suspended in a strong stationary magnetic field. The AF current causes a varying magnetic field around this coil. This varying field reacts with the stationary field and causes motion of the voice coil. The latter is cemented to a paper cone which vibrates with the voice coil and produces the audible sound waves.

Two main varieties of moving-coil dynamic loudspeakers have been developed. The difference between the two lies in the manner in which the stationary magnetic field is produced. The two types are the electromagnetic dynamic speakers and the permanent-magnet (P-M) dynamic speakers.

In the electromagnetic type of dynamic speaker, a powerful stationary magnetic field is created by passing a direct current through a field coil, wound on an iron core which is part of an electromagnet. The pole pieces of the electromagnet are brought very close together. The voice coil, suspended freely by means of its paper cone, rides between the field poles. AF currents are fed to the voice coil from the output transformer coupled to the second AF stage. (The output transformer may be mounted on the speaker unit itself.) The result is a vibratory motion of the voice coil and its attached cone. The outer edge of the paper cone is attached by means of soft leather or plastic, or even directly to

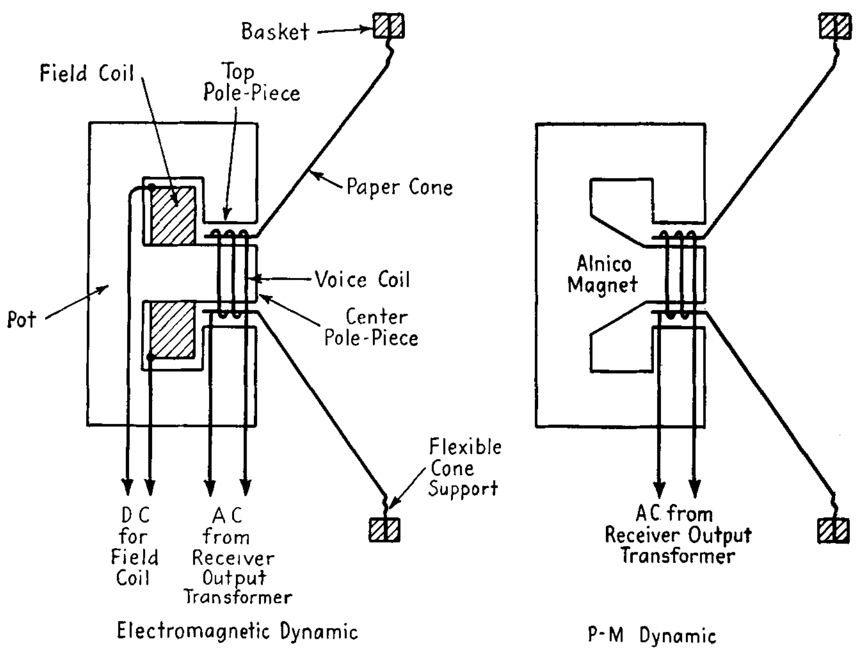


FIG. 9–1. Typical moving-coil dynamic speakers.

its basket, so that the voice coil may float freely. A typical electromagnetic dynamic speaker is shown in Fig. 9–1. A flexible membrane, called a "spider," is usually attached to the voice-coil form and guides its motion within the space between the center pole piece and the pot. A dust cap, usually made of felt, is cemented at the front end of the voice-coil form to prevent dust or other grit from getting in between the voice-coil form and the adjacent poles.

The other type of dynamic speaker is the P-M dynamic speaker. This type is exactly like the electromagnetic dynamic speaker except that the field is created by a permanent magnet, made of such material as alnico, rather than by an electromagnet. In all other respects, the construction and operation of the two speakers are identical. Both speakers are illustrated in Fig. 9–1. Note that the electromagnetic type requires four leads, whereas the P-M dynamic speaker uses two.

Energizing the electromagnetic dynamic-speaker field. The field of the electromagnetic dynamic speaker must be energized by means of a direct current. This DC supply is usually obtained from the power supply itself.

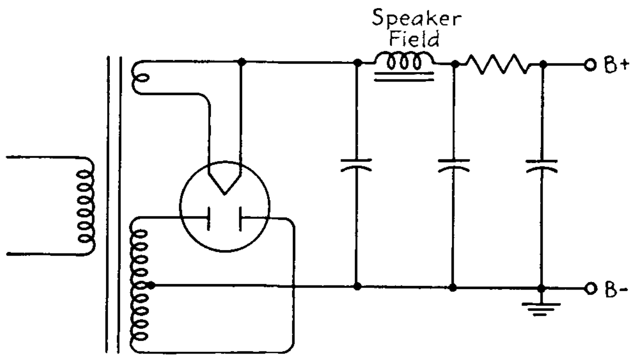


FIG. 9–2. Energizing the field coil—field coil used as filter choke.

In most cases, the speaker field serves as a filter choke and therefore passes through it direct current with a small ripple component. Such a circuit is shown in Fig. 9–2.

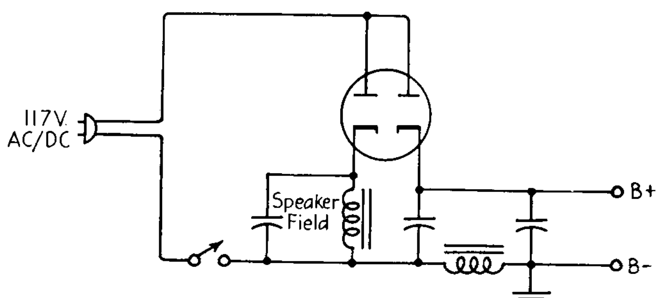


FIG. 9–3. Energizing the field coil—field coil across the rectifier.

In other circuits, the field coil receives its DC supply by being placed across the rectifier output. Such a circuit is shown in Fig. 9–3.

In other circuits, the field coil receives its DC supply by acting as a voltage divider across the filter circuit in the power supply. This circuit is shown in Fig. 9–4.

The hum-bucking coil. The electrodynamic speaker is very likely to have a high hum component. This condition occurs because the DC supply for the field is not pure direct current but has a ripple component that affects the voice coil. Several devices have been employed to reduce this hum in the speaker so that it is not objectionable. The most widely used device is the hum-bucking coil, which consists of a few turns of wire, wound on the center core and fixed stationary to the field coil.

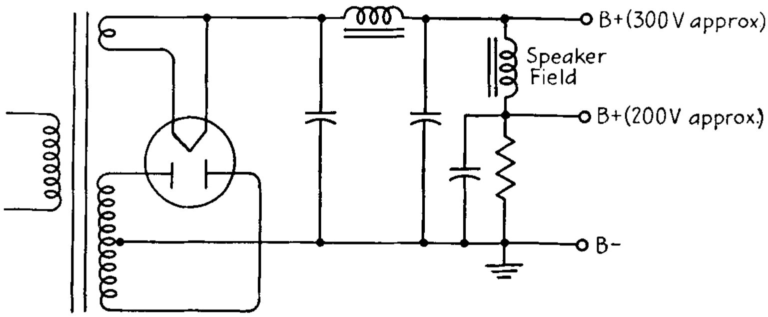


FIG. 9–4. Energizing the field coil—field coil used as a voltage divider.

This hum-bucking coil, however, is connected in series with the voice coil. The two coils are connected in such manner that any voltage induced in them will be in opposite phase and cancel out. Thus, the hum component from the field coil will be canceled out in the voice coil. Figure 9–5 shows an electrodynamic speaker with a hum-bucking coil.

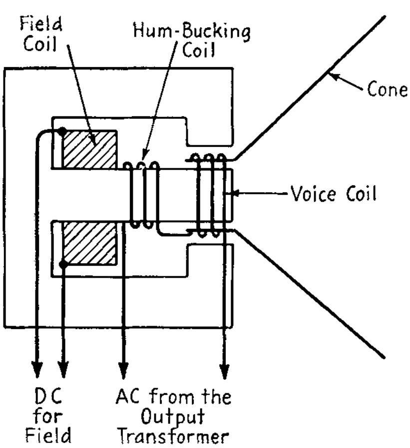


FIG. 9–5. Electrodynamic speaker with a hum-bucking coil.

Another device used to reduce hum from the field is the shading ring. Here, a thick copper ring, fixed between the field and the voice coil, acts as a single-turn coil in which eddy currents are produced and tends to shield the voice coil from the ripple component in the field coil.

The hum-bucking coil is used in speakers in which the field coil is the filter choke. Speakers in which the field is connected across the rectifier output use a hum-bucking coil or a shading ring. Speakers in which the field coil acts as a voltage divider do not require any hum-bucking device, since they are being fed direct current from which the hum ripple has been removed.

CHECKS FOR LOUDSPEAKER OPERATION

When the quick check indicates trouble in the speaker or if the servicing complaint is rattles or poor tone quality, the speaker should be carefully tested. The following section describes the quick check in detail and discusses other tests that may be applied to the loudspeaker.

Quick check for speaker operation. In the quick check, the second AF tube is unseated. When this is done, a click should be heard in the speaker. Unseating of the tube causes the *B* plus voltage to the plate pin of the tube to rise to maximum, with a consequent surge through the primary of the output transformer. This surge, induced in the secondary of the transformer, momentarily energizes the voice coil and produces the click.

This quick check does not tell us how well the speaker is functioning, merely that the voice coil is not open.

To determine if the field coil of an electromagnetic dynamic speaker is open, a blunt piece of iron, like a socket wrench, should be held near the center pole piece. A perfect field coil will cause the tool to be attracted strongly. An open field coil will give either no attraction or a slight attraction due to residual magnetism. Unfortunately, the dust cover may in some cases make this test somewhat unreliable. Of course, this latter test is not necessary for a P-M dynamic speaker.

Signal-substitution check for speaker operation. In the signal-substitution test, an audio signal is fed into the speaker, and its response observed. The test may be made with a signal generator whose level of audio output is sufficiently high to drive the speaker directly.

The "hot" lead from the signal generator is connected, in such case, to the primary of the output transformer, and output from the generator is turned on full. The receiver is turned on to energize the speaker field, if the speaker is of the electrodynamic type. The receiver should be tuned to an off-station position, and its volume control set to minimum position to remove any station signal from interfering with the test. When the signal generator is turned on, the audio note should be heard clearly and loudly, if the speaker is operative. If no note is heard, the voice coil is probably open. If the note is weak, the field coil is open or not receiving sufficient current.

If the signal generator is of the type delivering a variable-frequency output, other checks may be made. After the test just described indicates that the speaker is operative, its frequency response may be checked by swinging the signal generator output from low audio frequency through high audio frequency. In addition, this last check will indicate rattles from the speaker or a vibrating component in the receiver. Sympathetic vibrations of objects in the receiver, at any one audio frequency, will also be found.

The tests just described may be made with a beat-frequency oscillator (BFO), if that instrument is available on the service bench. It furnishes high-level, variable-frequency audio output. The output from the BFO is a pure audio wave form, with good frequency and output stability.

In using the BFO to check speakers, the speaker and the BFO are hooked up as shown in Fig. 9–6. Its proper impedance output is connected across the voice coil. It is not necessary to disconnect the voice coil from the secondary of the output transformer. If the speaker is of the P-M dynamic type, the test may now be made. If it is of the electrodynamic type, the receiver must be turned on to energize the speaker field. Then tune the receiver to an off-station position and reduce its volume control to minimum position. Adjust the BFO at a low output level for a 400-cycle note, which should be heard in the speaker. As with the signal generator, no note indicates open voice coil; a weak

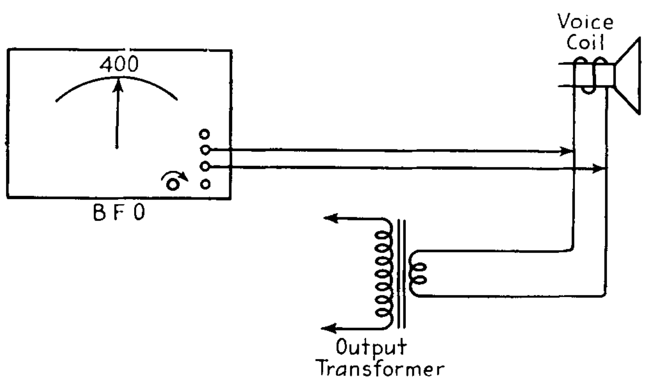


FIG. 9–6. Checking a speaker with a beat-frequency oscillator.

note indicates that the field coil is open or not receiving sufficient current.

If a normal response is heard, the BFO frequency control is rotated from low to high frequency. The sound will indicate the frequency response of the speaker. In addition, rattles and sympathetic vibrations will be found.

Substitution of a test speaker. When the serviceman is not sure that the speaker is the cause of weak operation or distorted output, substitution of a test speaker will resolve this doubt. If the distortion also appears in the test speaker, the cause is in the receiver, etc. A description of a bench test speaker is given in Chap. 28, The Service Bench.

Resistance check for the loudspeaker. In the final analysis, the speaker is checked with an ohmmeter. To test that the voice coil is neither open nor shorted, disconnect it from the secondary of the output transformer and measure its ohmic resistance with the ohmmeter. It should have the resistance indicated by the receiver manufacturer on his schematic. If this information is not indicated, voice-coil resistance measurements are found to vary from 2 to 15 ohms, the higher values being found in larger speakers.

The resistance of the field coil may be measured without disconnecting. There will be considerable variation from receiver to receiver, and it is best that its value be determined by actual reference to the schematic diagram. However, average values will be given where schematics are not available.

Where a field coil acts as a filter choke in the power supply, as shown in Fig. 9–2, its value may be found on the average to be as follows:

For AC receivers	800–2,000 ohms
For AC/DC receivers	450 ohms

Where a field coil is connected across the rectifier output, as shown in Fig. 9–3, its value may be found on the average to be as follows:

For AC receivers	6,000–10,000 ohms
For AC/DC receivers	3,000 ohms

Where the field coil is part of the voltage-divider system, as shown in Fig. 9–4, no average value can be given, and the serviceman should refer to the schematic diagram and service notes for the receiver being checked.

TROUBLES COMMON TO THE LOUDSPEAKER

From the servicing point of view, the loudspeaker may be responsible for many receiver defects. The receiver may be dead because the voice coil is defective, or because the field coil, acting as a filter choke in the power supply, is open. The receiver may produce a weak output because the speaker field, used across the rectifier output, is open. Weak output caused by a weakened magnet in a P-M speaker is unusual. Strange rattles may develop because of loose parts, torn cone, off-center voice coil, dirt between the voice-coil form and the field poles, or sympathetic vibrations of parts within the receiver. Each defect will be described from the point of view of its source.

Troubles common to the voice coil. Many receivers are brought in for servicing because of troubles attributed to the voice coil and its associated paper cone. Such conditions may be an open voice coil, an off-center voice coil, dirt and grit between the voice coil and the field pole pieces, loose voice-coil wires, broken cement between the voice coil and the paper cone or spider, and a broken lead from the voice coil to the voice-coil connection strip.

If a receiver is brought in as dead and unseating of the second AF tube does not produce a click, the voice coil may be presumed to be open. The signal-substitution and resistance check for continuity may then be used to confirm the condition. If an open is found, the leads to the voice coil should be inspected to see if one has not broken loose. The lead may be resoldered. If the open is in the voice coil, it is not advisable to try to rewind it. Rather, it and its associated paper cone must be replaced with an exact duplicate.

Replacement of a voice coil and cone involves several steps, executed with extreme care. First, an exact duplicate is necessary. If such is not obtainable, a new speaker unit must be obtained. Second, the voice coil must be properly centered around the center pole piece.

Centering of the voice coil is dependent upon the variety of speaker used. Usually, the outer edge of the paper cone is fastened to the outer housing or basket of the speaker by means of a ring and several bolts and nuts or cement. The voice coil itself is kept centered and freely

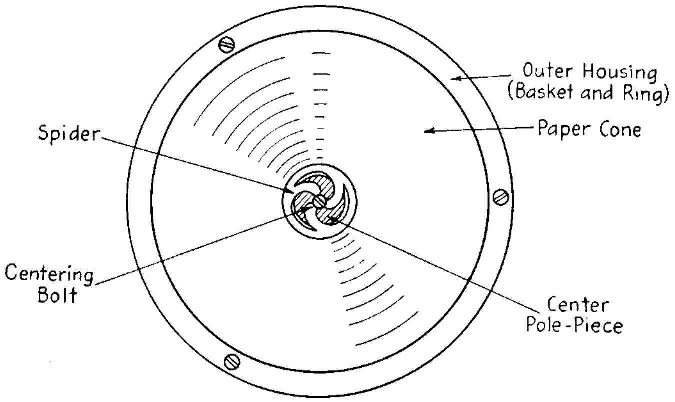


FIG. 9–7. Front view of a speaker showing the spider.

floating by means of a membrane, called a "spider," which is cemented to the voice coil. The spider permits movement of the voice coil parallel with the length of the center pole piece but restrains it from making sidewise movements.

Several types of spiders are used. One, shown in Fig. 9–7, is attached to the paper cone near the voice coil. A bolt through the center attaches it to the center pole piece. When a replacement is made, the new voice coil and cone should be placed over the center pole piece. By means of cone-centering shims, which are flat steel or fiber strips made for the purpose, the voice coil should be centered around the center pole piece. The shims are inserted through the spaces in the spider between the center pole piece and the voice-coil form, as shown in Fig. 9–8. Use three or four shims evenly spaced, depending on the spider structure. Then tighten the centering screw. This retains the voice coil in a centered position. Then fasten the outer rim of the cone, by means of cement or nuts and bolts, to the basket of the speaker. Finally, remove the shims. A check is then made to see that the voice coil floats freely. Move it gently in and out manually, and watch for rubbing against its surroundings. The dust cap of the speaker, if one is used, should be cemented over the end of the voice-coil form.

As a final step in replacing the voice coil of an electrodynamic speaker, the hum-bucking coil, if present, must be reconnected to the new voice coil and be in such phase that it reduces hum. If, after connection, hum is excessively loud, reverse the connections of the hum-bucking coil to the voice coil.

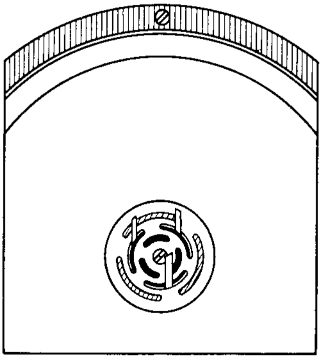


FIG. 9–8. Centering a voice coil with three shims.

Another type of spider consists of a membrane, attached to the voice-coil form at its center and connected to the housing either by cement or by machine screws. This type is shown in Fig. 9–9. Here again, in replacement, the voice-coil form is centered around the center pole piece by means of shims. The spider is cemented or bolted to its support to keep the voice coil in position, and the outer rim of the cone fastened to its basket. Then the centering shims are removed. Move the voice coil gently in and out, and observe that it floats freely. Finally, cement the dust cap over the voice coil and reconnect the hum-bucking coil, if present.

Another condition that may develop from the voice coil is rattle. If the spider in some way becomes loose, it will permit the voice coil to go off center and rub against adjacent parts. The result is rattle and loss of power in the speaker, as well as distortion. The condition may be checked by moving the voice coil in and out manually, and observing if rubbing occurs; or a substitute test speaker will show improvement in power, tone, and elimination of rattle. Where such is the condition, repair is fairly simple. The voice coil is recentered in the manner just described, and the spider screws are retightened.

Sometimes, the same condition of a rubbing voice coil may be caused by grit and dirt collecting between the voice-coil form and the center pole piece or pot. Here, the cone and voice coil are removed, the dirt is cleaned out with a pipe cleaner, and the coil and cone unit are replaced and recentered.

A rubbing voice coil may result from a voice coil whose shape has become warped. This condition may be presumed when repeated recentering of the voice coil does not remedy the condition. It is not advisable to try to reshape the coil. Replacement of the voice coil and cone is suggested.

Sometimes, the cement binding the voice coil itself breaks, and the turns come loose. This condition, too, will cause mysterious buzzes. The voice coil and cone should be removed, and new coil cement carefully applied. Then replace and recenter, as described.

Again, rattles may occur if the voice coil loosens its cement connection to the cone or spider. Recementing is the cure. Then replace and recenter as before.

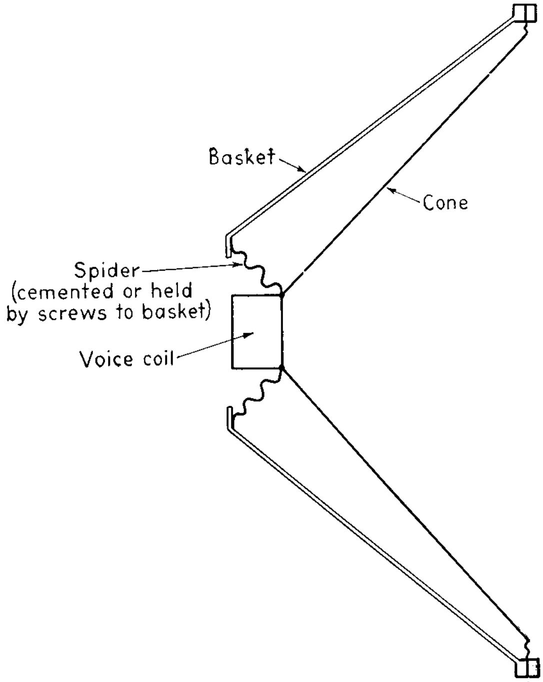


FIG. 9–9. Inside spider connected to speaker basket.

Infrequently, the pot and center pole piece may loosen or warp, giving the effect of an off-center voice coil. This condition will become obvious when repeated centering of the voice coil does not remedy the condition. The voice coil is removed under the impression that it may be warped; inspection shows that it is round but the field gap is not uniform. In some cases, the field gap is adjustable, and a procedure for resetting the top pole piece is given in the section describing the replacement of field coils. When the gap cannot be adjusted, the entire speaker must be replaced.

Troubles common to electrodynamic speaker field coils. The speaker field of an electrodynamic loudspeaker may be the source of many receiver defects. The manner in which it will make itself manifest depends on the way in which it receives its excitation. Where a defective field coil is indicated, replacement depends upon the construction of the speaker and the availability of a similar coil. If replacement is not possible, the entire speaker must be replaced.

Where the speaker field coil is used as a filter choke, the defect will be located in a power supply check. It will be noticed from Fig. 9–2 that an open coil will cut off the *B* plus supply, so that all stages will be inoperative. The receiver will be brought in dead. A check of the power supply will show no *B* voltage. Disconnect the power plug and dis-

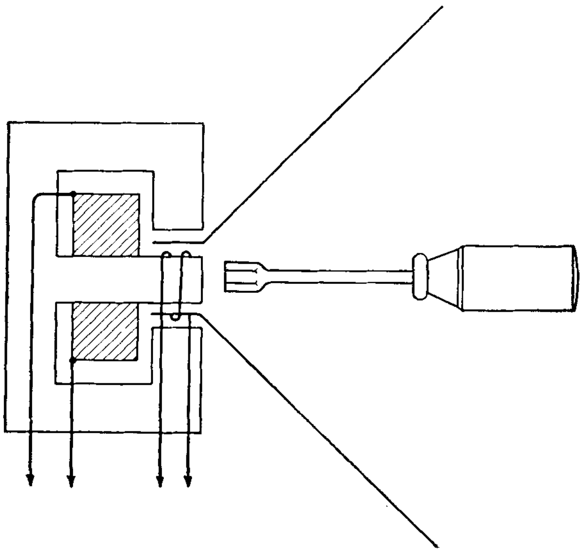


FIG. 9–10. Checking the magnetic pull of a speaker with a socket wrench.

charge the filter condensers. An ohmmeter check for continuity will confirm the open field. The open may be due to a break in the field leads or in the connection between the field wire itself and the lead. These should be inspected and, if found at fault, repaired.

The effects of a defective speaker field coil across the rectifier output, as shown in Fig. 9–3, will be different from that given above. The receiver will be brought in for weak operation if the coil is open. This is because the set is operating with no field, but only the residual magnetism in the pole piece. The *B* voltage will not be disturbed. The quick check for speakers will show a weak click, focusing attention on the field. Confirmation will be obtained by trying the receiver with the test speaker or by checking the magnetic pull of the speaker field, as shown in Fig. 9–10. A blunt piece of iron like a socket wrench is brought near the center pole piece. Make this check with care, lest the tool tear the paper cone or dust cover.

When the field excitation circuit includes a separate rectifier and filter, as is the case in the circuit of Fig. 9–3, the lack of field strength may be due to defects in the rectifier or filter, while the field coil itself is perfect. These associated components should be checked.

Final confirmation of the field condition may be made with an ohmmeter. The serviceman is again cautioned to discharge any associated filter condensers before making ohmmeter checks on a speaker field.

Where the speaker field is used as a voltage divider, as in Fig. 9–4, defects would show up differently. If the field coil opened, the defect would be found in a routine check of plate voltages. The set would be

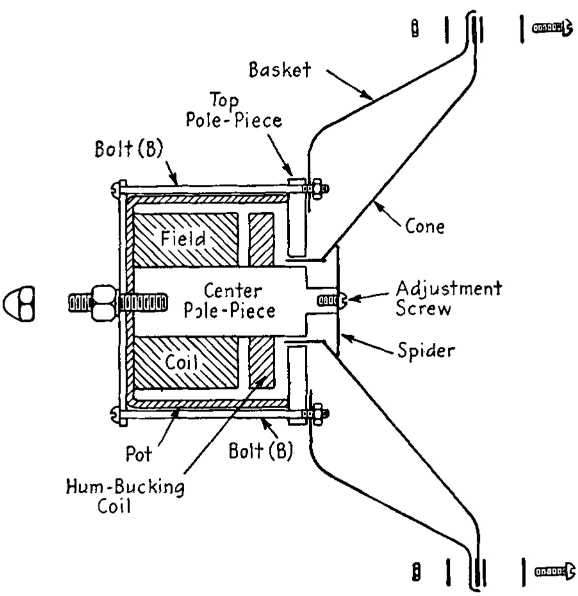


FIG. 9–11. A typical electrodynamic speaker with a replaceable field coil.

dead. There would be no *B* plus voltage on the RF and IF tubes. High *B* plus would, however, be present in the other stages. The socket-wrench test would show no field strength. Substitution of a test bench speaker for both field and voice circuits would restore normal operation. The ohmmeter check for continuity would finally confirm the defect.

Another field-coil defect, common to all three excitation circuits, is that of shorts between the field winding and the center pole piece or the outside pot. If the speaker is mounted on the chassis, the short will cause partial or complete loss of *B* voltage and possible damage to the power supply. This condition will be found in a check of the power supply. The power-supply check would seem to indicate a shorted filter condenser. The actual defect would be found when removal of the suspected filter condenser does not remove the short from the circuit. If the speaker is not on the chassis, the speaker case will become "hot" with high voltage, but the receiver operation may not be affected.

Replacing a speaker field coil. The construction of the speaker pot does not always lend itself to the replacement of the field coil. Nor are field coils obtainable for all speakers. When the field coil cannot be replaced, the entire speaker must be replaced.

A typical electrodynamic speaker, which has a replaceable field coil, is shown in Fig. 9–11. Here, the entire pot can be taken apart.

The procedure for removing the field coil is outlined in the following steps:

1. Remove the voice coil and cone in the manner described under Troubles Common to the Voice Coil.
2. Remove the nuts from the bolts that hold the basket and the top pole piece to the pot.
3. Remove the field coil (and hum-bucking coil, if used) by sliding it forward over the center pole piece. This may involve first unsoldering the field-coil terminals from a terminal strip.
4. Slip a replacement field coil over the center pole piece and, where necessary, solder its leads to the terminal strip. The replacement coil should be as nearly like the original as is possible. Replace the hum-bucking coil (if used).
5. Replace the basket and the top pole piece. Replace the bolts *B*, and loosely engage them with their nuts.
6. The next step centers the center pole piece, so that the field space in which the voice coil floats is uniform. Place three or four pieces of drill rod of the proper size to fit exactly in the field space, as shown in Fig. 9–12.

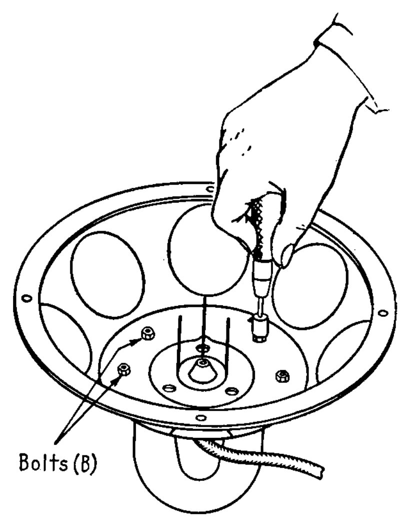


FIG. 9–12. Centering the center pole piece with drill rod.

7. The nuts for bolts *B* are then tightened. It is wise not to tighten any one nut completely while the others are loose. The recommended procedure is to tighten one nut loosely, then the next, and the next, etc. Continue around several times until each nut is securely tightened.

A socket wrench is used in this step. The serviceman is cautioned to use care, so as not to strip the nuts or bolts.
8. Remove the drill rods.
9. Replace and recenter the voice coil and cone, as described in the section on Troubles Common to the Voice Coil.

Since the above operation may have reversed the phase of the hum-bucking coil, should a hum now develop, the serviceman should try reversing the voice coil or hum-bucking coil connections, as well as checking the power-supply filter circuit.

Where a pot and center pole piece may loosen or warp, giving the effect of an off-center voice coil, the procedure listed above must be followed, except for replacing the field coil.

R.M.A. color code for loudspeakers. The various terminal wires of a loudspeaker may often be identified for servicing by means of the R.M.A. color code, tabulated below:

Voice coil	
1. Green	Finish
2. Black	Start
Field coil (if any)	
1. Black and red	Start
2. Yellow and red	Finish
3. Slate and red	Tap (if any)

Troubles common to the paper cone. The troubles common to the paper cone are those usually associated with the voice coil. The cement binding the cone to the voice-coil form may dry and crack, with resulting rattles from the speaker. This condition may be remedied by using a standard voice-coil cement for reconnection. This latter procedure should be done with care.

On occasion, the paper cone may tear or crack and produce rattles. As a rule, it is not advisable to try to patch it, because the cement usually contracts when it dries and distorts the cone shape. A distorted cone produces distortions from the speaker. The entire cone and voice coil should be replaced. Where such a replacement is not available, the patch job should be done with a standard speaker-cone cement.

In many receivers, there is a felt or cardboard ring that is fastened around the rim of the basket. Its purpose is to prevent acoustic continuity between the speaker and the baffle to which it is attached. After replacing a voice coil and cone or a speaker field coil, the ring should be either bolted or cemented back into position.

Troubles common to speaker assembly and mounting. After continuous operation, various parts within the receiver may have a tendency to become loose. Various screws in the speaker or associated with its mounting may also loosen, because of continuous operation. Where such is the case, rattles and buzzes may mar the speaker reproduction. The serviceman may verify this condition by connecting in a substitute test speaker from his test bench and observing if improvement results. If the rattles and buzzes disappear, a careful hunt must be made for any loose part prone to vibrate. This is done by holding various parts with the fingers while the receiver is operating, and observing if the vibrations are damped. No part should be beyond suspicion. Even the cabinet must be inspected for loose or cracked parts.

Replacing a complete loudspeaker. Many speaker defects require the complete replacement of the entire loudspeaker assembly. Where such is the requirement, an exact replacement is most desirable. This may not always be possible, and a speaker that resembles the original as closely as possible must be used.

Several factors must be kept in mind by the serviceman. Is there sufficient space within the cabinet? Can the new speaker be mounted with sufficient ease? Is the resistance of the field coil, if an electrodynamic speaker is used, similar to that of the original? Is the current-carrying capability of the field coil of the replacement speaker sufficient for the receiver? Is the impedance of the new voice coil the same as that of the old speaker? And finally, is the power-handling capability (wattage) of the voice coil of the new speaker sufficient for the receiver?

Replacement speakers are usually listed according to the following factors:

1. Diameter of the basket in inches
2. Voice-coil impedance in ohms
3. Voice-coil wattage
4. Field-coil resistance in ohms

Although the current-carrying capability of the field coil is not listed, it is an important factor that must not be overlooked. In this consideration, the size of the pot is an indication of the current-carrying capability of the field coil. The pot of the replacement speaker should be no smaller in size than that of the old speaker.

If the wattage output of the receiver is not indicated in the manufacturer's schematic, the proper wattage for the voice coil may be determined in another manner. The tube or tubes used in the second AF or output stage are determined by inspection. Then reference to a tube manual will give the undistorted power output for that tube. This wattage may be considered as the voice-coil wattage.

Often in making a speaker replacement, the old output transformer, mounted on the old speaker, may be removed and used with the new replacement speaker. The transformer primary will thus match the second AF stage. Care must then be taken that the transformer secondary impedance matches that of the voice coil of the new replacement speaker.

If the chosen replacement speaker has a voice-coil impedance differing considerably from the original, this will necessitate changing the output transformer for proper impedance match. Replacement notes on output transformers are found in Chap. 10.

Replacing an electrodynamic with a P-M speaker. Sometimes an electrodynamic speaker has to be replaced, and a similar speaker is unobtainable. In such a case, a P-M dynamic speaker of proper voice coil, wattage, and size may be used with some provision to replace the field coil in the circuit of the receiver.

When the speaker field acts as part of the voltage divider, it must be replaced by an equivalent circuit, composed of a choke that is an equivalent inductance, and a series resistor to give the unit an equal resistance. The latter consideration is necessary to maintain proper operating potentials for the tubes in the receiver. The choke must have proper current-carrying capabilities. The series resistor plus the ohmic resistance of the choke should equal the resistance of the original field coil. The current in the field can be determined by Ohm's law, and the wattage of the resistor can be determined by substituting in the wattage formula $W = E^2/R$. Figure 9–13 shows a replacement of this type.

When the field excitation is obtained by connecting the field across the rectifier output, no provision for its replacement need be made. When the field coil is acting as the filter choke for the receiver, it should be replaced by a choke coil of equivalent inductance and current-carrying capability. The choke will probably have a lower ohmic resistance than the field. An 800-ohm/10-watt resistor, connected in series with the choke, will compensate for this condition.

Dual speaker systems. Some receivers are built with two speakers within the same cabinet. Where a condition develops in such a receiver that one of these speakers must be replaced or requires a voice coil and cone replacement, the procedure is similar to that described for single-speaker replacements.

However, a new consideration develops. If one voice coil moves in while the other moves out, interference effects develop and reduce the volume of total output. This condition is undesirable and may be remedied by reversing the voice-coil or field-coil leads to one of the speakers. The voice coils will then move in and out together, and the speakers are said to be in phase.

To determine if the speakers are properly phased after replacement, turn on the receiver and tune to a nonstation position. Place your hands on the cones of the two speakers. Then apply the voltage of a dry cell across the output transformer secondary. The movement of the cones will be felt and seen, and proper phase may be found.

Adding a speaker to a receiver. In some cases, a customer may desire a second speaker connected to his receiver and installed in another

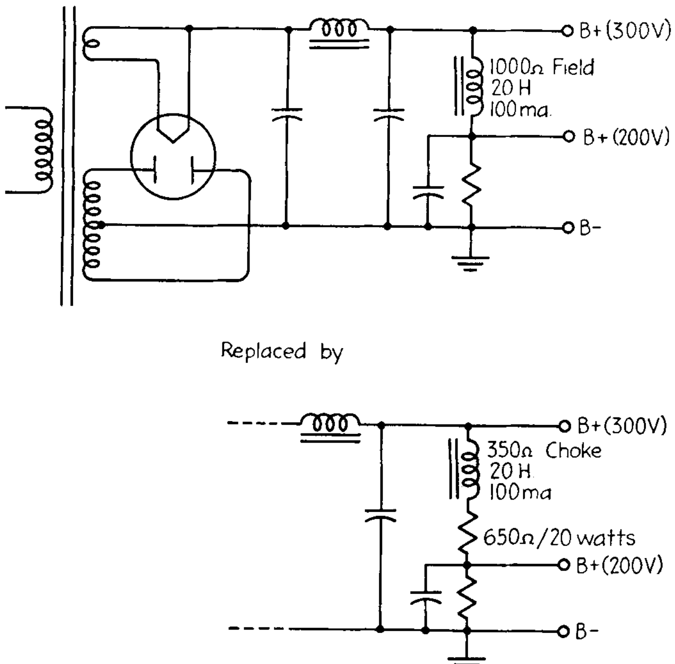


FIG. 9–13. Replacing an electromagnetic with a P-M dynamic speaker—field-circuit adjustments.

room. Since the speakers are remote from each other, phasing is not important.

A simple procedure in this requirement is to obtain a P-M dynamic speaker and connect its voice coil in parallel with the voice coil of the receiver speaker. Of course, this will cause mismatch with the output transformer secondary, but the effect will not be too poor. Besides, the larger the impedance of the voice coil of the P-M dynamic speaker, the less will be the total mismatch, although less power will be fed to the auxiliary speaker. This may be of advantage, since it is generally desirable to operate the auxiliary speaker at a reduced volume. The combination is shown in Fig. 9–14.

In the setup described above, both speakers will operate simultaneously. If it is desired to shut off the receiver speaker while the auxiliary speaker functions, it is necessary to use a single-pole double-throw switch to cut out the first voice coil. In addition, a resistor, of comparable impedance to that of the voice coil just cut out, should be

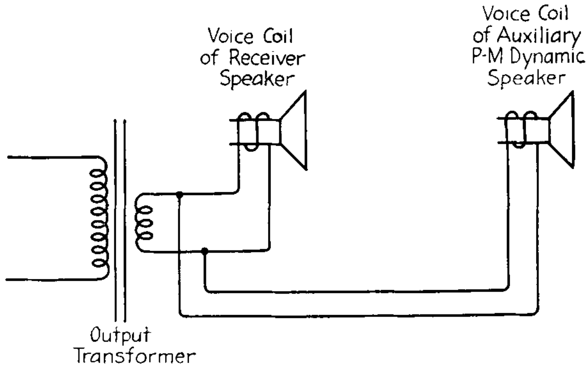


FIG. 9–14. Adding an auxiliary P-M dynamic speaker to a receiver.

connected across the secondary of the output transformer. A second switch is connected at the auxiliary speaker to cut it out when not in use. This setup is shown in Fig. 9–15.

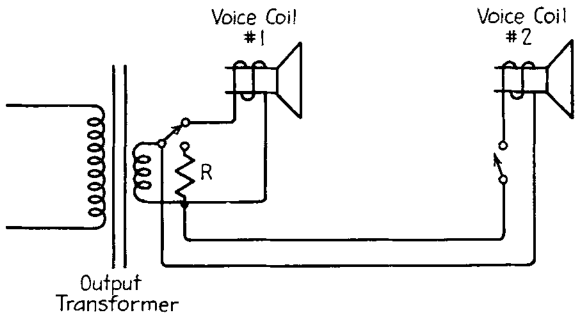


FIG. 9–15. Switching the receiver speaker and the auxiliary speaker—individual control.

It is now possible to control the volume of the receiver and auxiliary speakers only by means of the receiver volume control. If it is desired to vary the volume of the auxiliary speaker at the speaker itself, a standard *L* pad control may be inserted across the voice coil of the auxiliary speaker. The ohmic rating of the pad should match the impedance of the auxiliary voice coil. The complete setup is now shown in Fig. 9–16. No switch is required at the second auxiliary speaker, since the *L* pad can replace its function. The minimum position of the *L* pad will cut out the auxiliary speaker.

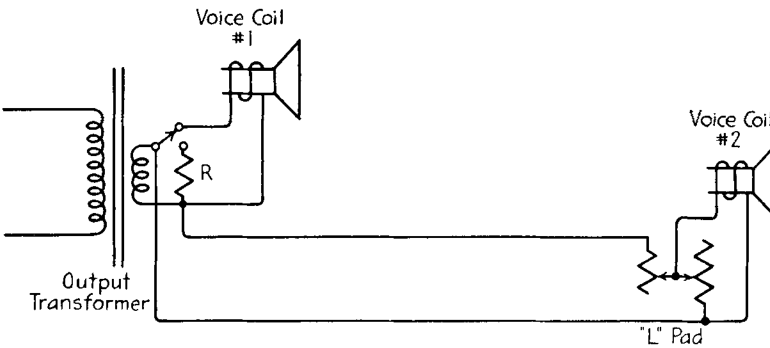


FIG. 9–16. Volume control for an auxiliary speaker.

Adding headphones to a receiver. A customer may request that headphones be installed on his receiver, so that he may turn off the loudspeaker and still listen to the radio late at night. The simplest procedure is to connect the phones across the voice coil. The high impedance of

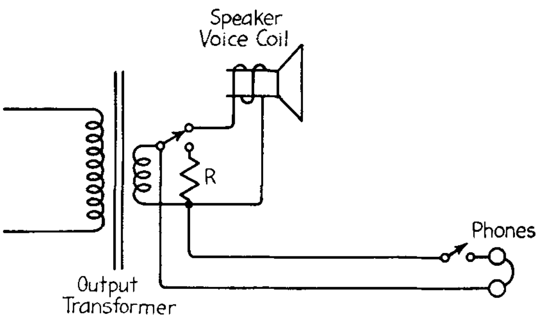


FIG. 9–17. Circuit for connecting headphones to a receiver.

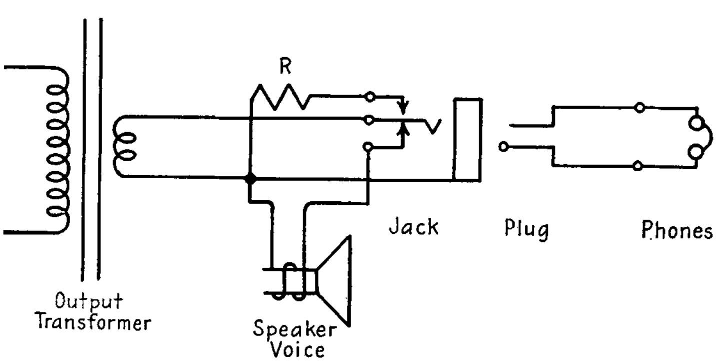


FIG. 9–18. Circuit for adding headphones to a receiver—using jack and plug.

the phones will cause great mismatch and keep power fed to the phones low, giving low volume. A switch may be installed to cut out the speaker voice coil and to cut in an equivalent impedance resistor. A second switch may be used to cut out the phones. The setup is shown in Fig. 9–17.

The same effect may be achieved by the installation of a circuit-switching phone jack, as shown in Fig. 9–18. Pushing the phone plug only part way in will allow simultaneous operation of the phones and speaker. Pushing the phone plug all the way in will cut out the speaker voice coil and allow operation of the phones alone.

SERVICE DATA SHEET

Symptom	*Abnormal reading*	*Look for*
No reception	No *B* plus voltage	Open field. See Chap. 8
	No click on quick check	Open voice coil. Open voice-coil leads
Weak reception	Weak click on quick check	Deenergized field (open field or low excitation voltage). Jammed voice coil
Distortion		Rubbing voice coil. Low field excitation voltage. Warped cone. Factors within the receiver (eliminate the speaker by substitution test)
Rattles		Rubbing voice coil. Loose voice coil. Torn paper cone. Cone loose from basket rim. Loose spider. Grit and dirt in field gap. Loose dust cap. Loose screws on speaker. Loose parts in radio

QUESTIONS

1. A receiver is brought in as dead. No plate voltage appears to be present. If you suspect that the speaker is defective, what part would you suspect? How would you test for it?

2. A new voice coil and cone are installed in a receiver. When the set is turned on, it hums excessively. What is probably wrong? What remedial measures would you take?

3. A receiver requires a new speaker. An exact replacement is not obtainable. What considerations must be made in replacing a new speaker?

4. A rattling, rasping speaker is reported by a customer. Examination shows an off-center voice coil. What remedial measures would you make?

5. A receiver has a dual speaker system. One speaker requires replacement of a voice coil and cone. List the steps in order by which you would make this replacement.

6. A customer has a receiver in his living room. He wants to add an auxiliary speaker to operate in the cellar. He wants to be able to operate either or both speakers and also to control the volume of the cellar speaker in the cellar. Design a circuit for these requirements.

7. A customer wants to use headphones with his receiver at night, so that he can cut off the loudspeaker. Design a circuit for him.

8. A receiver with a power supply like the one of Fig. 9–3 gives very weak reception. A signal check produces a very weak click in the speaker. What factors can cause this condition? How would you check for each?

10 SECOND OR POWER AUDIO-AMPLIFIER STAGE

The second AF amplifier stage is also called the "power-amplifier" stage or "output" stage.

Quick check. If a plugged-in soldering-iron tip or finger is placed on the control grid of the second AF amplifier tube and causes a low growl to be heard in the speaker, the second AF stage is probably functioning properly, and the trouble shooter moves on to the first AF stage.

Standard circuit. Figure 10–1 represents our standard second AF stage.

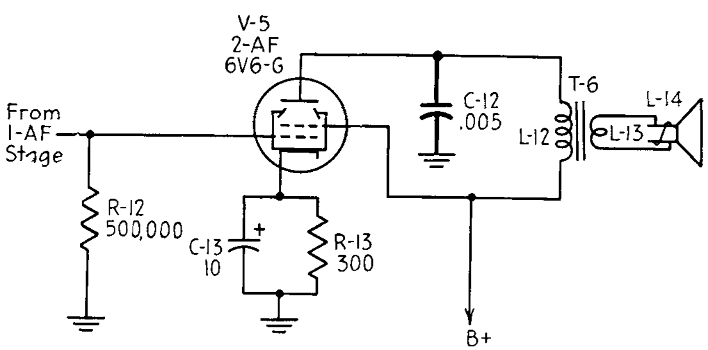


FIG. 10–1. Standard circuit for a typical second AF stage.

Function of second AF stage. The control-grid circuit is the signal input of the stage; the plate circuit is the signal output. The signal fed into the stage is an AF voltage, the magnitude of which would be about sufficient to operate headphones. It is the function of the second AF stage to amplify this signal to an amount sufficient to operate a loudspeaker. To get an idea of the magnitude of the signal voltages handled by the second AF stage, a 6V6-G tube (most commonly used) gives an output of 4.25 watts with an input grid signal voltage of 12.5 volts peak. A smaller signal-input voltage would give a smaller output power; 12.5

volts is the maximum the tube will handle without undesirable distortion. The input signal is fed from the preceding first AF stage. The plate or output circuit of the stage feeds the amplified signal to the speaker.

Regardless of whether the receiver is AC, AC/DC, or battery-operated, the function and operation of the second AF stage is the same. Indeed, this is true for all stages but the power-supply stage.

FUNCTIONS AND VALUES OF COMPONENT PARTS

Grid-load resistor R-12. Resistor *R*-12 is the grid-load resistor, and the input signal is impressed across it. Its value usually is 500,000 ohms. When a different ohmage is used, a lower value would result in lower gain and better frequency response, while a higher value would give slightly higher gain at a sacrifice of tone quality.

Self-bias. Since grid-bias voltage affects tone quality and amplification and is a valuable indication of trouble to the serviceman, the theory underlying self-bias circuits should be thoroughly understood.

Let us first remember that, in order to maintain a grid-bias voltage, the grid must be made negative with respect to its cathode. Assume no signal input voltage, and examine the amplifier circuit redrawn as in Fig. 10–2, with components unnecessary to the self-bias circuit eliminated. Observe that resistor *R*-13 and the tube *V*-5 are in series across the *B* power supply. Tracing the screen circuit, current flows from *B* minus through *R*-13, through the tube to the screen and *B* plus. Tracing the plate circuit, current flows from *B* minus through *R*-13, through the tube to the plate, and finally through *L*-12, the output-transformer primary, to *B* plus. It is seen that both screen and plate currents flow through *R*-13 and, as a result, a voltage drop is developed across it. Note also that the cathode is made positive with respect to *B* minus by this voltage drop. Then, when the grid is returned to *B* minus through *R*-12, the grid is negative with respect to the cathode. A negative grid will not attract electrons and, as a result, there is no current in the grid circuit through *R*-12 and no voltage drop across it. The full voltage developed across *R*-13, therefore, is applied to the grid as the bias voltage.

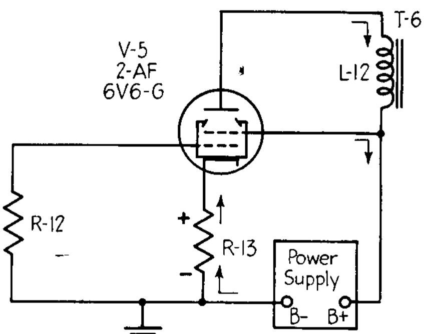


FIG. 10–2. Circuit depicting self-bias.

This system of obtaining grid-bias voltage is known as "self-bias," since the tube's own screen and plate currents cause the voltage drop, which is used for biasing the grid. The self-bias circuit can be used with a triode type of tube also, in which case the voltage drop is caused by the plate current alone.

The ohmic value of *R*-13 will depend on the tube used and its operating potentials. Several common values follow:

6V6-G	300 ohms
25L6-G	150 ohms
6K6-G	410 ohms
6F6-G	410 ohms
6L6-G	170 ohms
25A6	600 ohms

Self-bias by-pass condenser C-13. The input circuit of the tube is between grid and cathode. This involves grid-load resistor *R*-12 and self-bias resistor *R*-13. The input-signal voltage divides itself between them, most of the signal being across the larger grid-load resistor *R*-12. The output circuit of the tube is between plate and cathode. This includes the output transformer primary *L*-12, the *B* power supply, and self-bias resistor *R*-13. The output signal divides itself among these three, most of it being across *L*-12, which has the highest impedance to the output signal. Resistor *R*-13 is common to both the input and the output circuits, and some of the input signal and some of the output signal will mix in *R*-13. This is coupling. Since a tube's output signal is 180 deg out of phase with its input signal, cancellation takes place where the two signals are coupled, as across *R*-13. This effect of coupling, where cancellation takes place, is known as "degeneration" and results in a decrease in the gain of the tube.

The degenerative action can be minimized by bridging *R*-13 with a condenser. The current through *R*-13 has components made up of the DC screen and plate currents of the tube, the AC input signal, and the AC output signal. When *R*-13 is bridged by a condenser, the impedance of the parallel combination to the signal current is reduced, while its opposition to direct current remains the ohmic value of *R*-13. The voltages across the parallel combination therefore are reduced as regards signal voltage, while the DC bias voltage remains the same. The reduced input- and output-signal voltages across the parallel combination decrease the degenerative effect.

The action of the parallel condenser has been called "by-pass," since, from one point of view, the signal current is taken out of resistor *R*-13 and passed around it through the condenser. The by-pass action depends on the impedance of the condenser to the signal frequencies. To be effective, it should be lower than the ohmic value of the resistor being by-passed.

Since the signal in the second AF stage is at audio frequency, a high-capacity condenser will be necessary for adequate by-pass action. Condenser *C*-13 is usually a low-voltage electrolytic type. Capacities from 5 to 25 mfd will be found in various receivers. The higher capacities will provide better by-pass action, with a consequent improvement of the response, especially at the low audio frequencies.

Self-bias circuits similar to *R*-13 and *C*-13 are used to obtain bias voltages for the RF and IF tubes. The action in these tubes is similar, except that the cathode by-pass condensers need be only 0.1 mfd for adequate signal by-pass, owing to the higher signal frequencies at radio frequency and intermediate frequency.

Output condenser C-12. Condenser *C*-12 across the signal-output circuit by-passes high audio frequencies to ground. The pentode and beam-power tubes introduce a considerable amount of harmonics, which will be most noticeable in the high AF range. Placing *C*-12 across the signal output circuit by-passes some of the signal away from the output transformer. This effect will be greatest at the high audio frequencies, since the impedance of a condenser decreases as the frequency increases. Therefore, the harmonic content will be reduced by the action of this condenser.

An average value for condenser *C*-12 is 0.005 mfd. In individual receivers, this value may vary from 0.001 to 0.02 mfd. Receivers using the higher capacity values have been designed to favor the bass register, since the higher capacity by-passes more of the high frequencies out of the output transformer and speaker, making the response deeper by comparison.

Output transformer T-6. Transformer *T*-6, called the "output" transformer, is often mounted on the speaker. Its function is to couple the output circuit of the tube to the speaker. The average beam-power tube requires a load of 5,000 ohms, and the average speaker voice coil has an impedance of 8 ohms at audio frequencies. The coupling transformer is designed, therefore, to have a primary impedance of 5,000 ohms and a secondary of 8 ohms. Obviously, if the output transformer should become defective, the original manufacturer's part should be obtained for best results. However, where this is not possible, a universal-type transformer may be used satisfactorily. The replacement notes on output transformers explain this procedure more fully.

Vacuum tube V-5. Vacuum tube *V*-5 is called the "power" tube, sometimes the "output" tube, as well as the second audio tube. The tube most commonly found in this stage is the 6V6-G beam-power amplifier. Smaller receivers, where the *B* supply voltage and the power output are lower, use the 6K6-G power-amplifier pentode. Receivers equipped with locking-base type tubes use the 7C5-LT.

Older receivers use power-amplifier pentodes, like the 6F6-G, 42, or 47. Receivers of the AC/DC type use the 25L6 or 50L6 beam power amplifiers. Older AC/DC receivers use a type 43 or 38 tube.

All these tubes are characterized by high power sensitivity; that is, a low signal-input voltage causes a high power output. For example, in the case of a 6V6-G, an input signal of 12.5 volts gives an output power of 4.25 watts. By way of comparison, the very much older 45 power-amplifier triode requires an input signal of 50 volts to give an output power of 1.6 watts.

NORMAL TEST DATA FOR THE SECOND AF STAGE

Check for normal stage operation. The signal check for the second AF stage is shown in Fig. 10–3. The signal generator is adjusted to give an AF signal, and the attenuator is set for maximum output. The signal

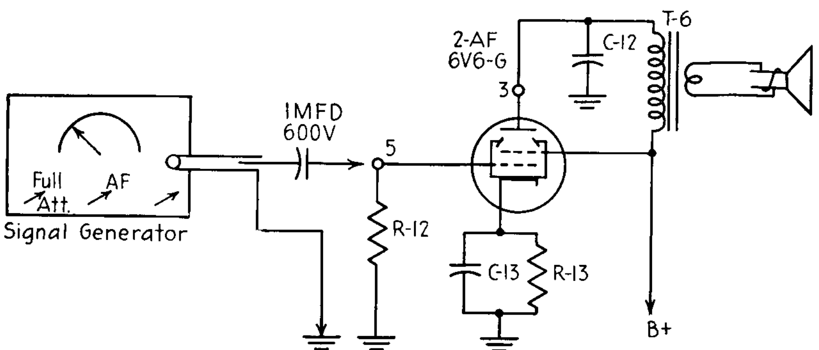


Fig. 10–3. Signal check of the second AF stage.

generator ground lead is connected to the receiver chassis, and the "hot" lead is connected through a 0.1-mfd/600-volt condenser to the plate terminal of the second AF tube (pin No. 3 for a 6V6-G tube). The purpose of the condenser is to prevent the DC voltage, present at the plate of the second AF tube, from affecting the signal generator circuits. Normally, the full AF output of the signal generator is just sufficient to cause an audible note in the speaker. The hot lead of the signal generator is then shifted to the grid terminal (pin No. 5 for a 6V6-G tube) of the second AF tube. The signal-generator note should be heard in the speaker at a much greater volume. The gain in volume is an indication of the gain of the tube.

Experienced servicemen rarely go to the trouble to use this method. A much faster check, given as the quick check at the beginning of this chapter, is to touch the grid terminal with a finger or the tip of a plugged-in soldering iron. In either case, a low growl will be heard from the speaker, indicating that the stage is functioning.

Normal second AF voltage data. Voltages are measured from chassis or common negative to tube terminal indicated. In some AC/DC receivers, where the circuit insulates *B* minus from the chassis, the negative terminal of the voltmeter is connected to the common negative. This is most easily found at the line switch. See Chap. 18 on AC/DC Power Supply.

Tube terminal	*25L6 and 6V6-G pin No.*	*AC receivers, volts*	*AC/DC receivers, volts*
Plate	3	235	85
Screen	4	250	90
Grid	5	0	0
Cathode	8	12.5	6

Voltages may vary somewhat from those given in the accompanying table. A significant point for the observant serviceman to note, however, is that the screen voltage is slightly higher than the plate voltage. This is due to the plate current of the tube, which causes a voltage drop across the output transformer primary. Variations in this voltage relationship are indicative of trouble. For example, if the plate and screen voltages are exactly the same, there is no voltage drop across the output transformer primary. This fact indicates no plate current, a condition resulting from either an open self-bias resistor, or no emission in the tube.

A positive voltage reading at the grid is indicative of breakdown of the coupling condenser *C*-32 in the preceding stage. Service notes on this fault will be found in the chapter describing the first AF stage.

Normal second AF stage resistance data. These data are given in the following table:

Chassis to cathode	300 ohms
Chassis to control grid	500,000 ohms
Plate to *B* plus	200–600 ohms

The 300 ohms of resistance from chassis to cathode is the ohmic value of self-bias resistor *R*-13. When a tube other than the 6V6-G tube is used, a different value will be found. Refer to the diagram of the receiver being tested, or to the table on page 100. The plate to *B* plus reading measures the resistance of *L*-12, the primary of the output transformer.

COMMON TROUBLES IN THE SECOND AF STAGE

Troubles common to the grid-load resistor. Resistor *R*-12 rarely causes trouble. Occasionally it may open, thereby opening the grid circuit and causing lack of grid-bias voltage. This will result in bad distortion. At other times, signal voltage at the grid may build up and discharge periodically through dirt at the socket terminals, acting as a resistance parallel to *R*-12 and allowing a surge of current with each discharge. These surges may be heard in the speaker as a put-put known as "motor-boating." If the surges come more rapidly, they will take the form of a low-pitched growl. The latter is sometimes mistaken for hum, which is also a low-pitched growl. Standard procedure in trouble shooting for hum is first to check the filter condensers in the power supply and then to look for an open grid-load resistor in this or any other stage.

Open *R*-12 would be found in a voltage check of the stage, since an open grid causes a much heavier plate current. This condition makes for

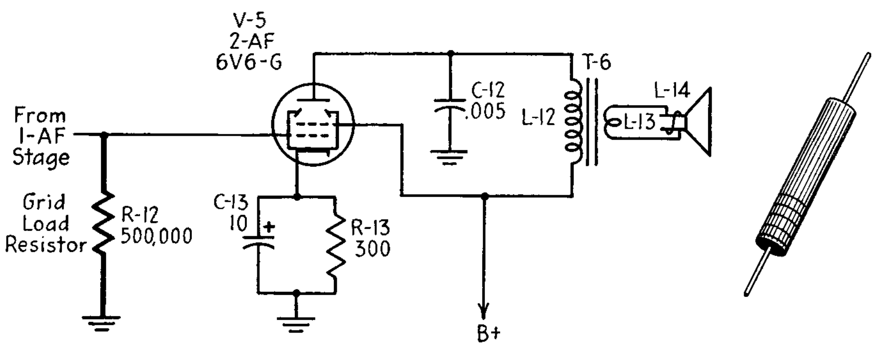


Fig. 10–4. A typical grid-load resistor and its position in the second AF circuit.

a greater than normal voltage drop across *L*-12 and, as a result, the plate voltage is lower. Since the screen voltage remains near its normal value, there will be a greater than normal difference between plate and screen voltages. Since conditions other than an open grid-load resistor will cause heavy plate current, confirmation must be obtained. This can be done with an ohmmeter.

In replacing resistor *R*-12, nothing in particular need be stressed. An exact duplicate of the original is desirable although not necessary. An ohmic value differing by as much as 20 per cent either way will cause no noticeable difference, and the wattage rating is unimportant. However, the soldering must be carefully done, and the socket must be cleaned of dirt and excess rosin.

Troubles common to the cathode by-pass condenser. The cathode by-pass condenser *C*-13 often causes trouble. Like all electrolytic condensers, it is likely to dry out and lose capacity. As *C*-13 loses capacity, approaching an open condenser, the stage would give low gain and poor low-frequency response. This condition would be found in checking for low gain or for poor tone by bridging the condenser with one of 5 mfd or greater that is known to be good.

Less frequently, *C*-13 shorts or leaks badly, acting as a partial or complete short across *R*-13. This will result in poor tone quality due to lowered bias and would be found by a voltage check. Since plate current increases at lowered bias, a greater than normal voltage drop across the output transformer primary would be produced. This results in a lowered plate voltage and a large difference between screen and plate voltages. A shorted *C*-13 may have been caused by an open cathode resistor *R*-13. Check this condition before replacing.

In replacing condenser *C*-13, the serviceman watches for proper polarity, the positive side being connected to the cathode. The defective condenser should be removed. A capacity larger than the original may be used since, if anything, this will improve the low-frequency response. However, a condenser of capacity lower than the original will adversely

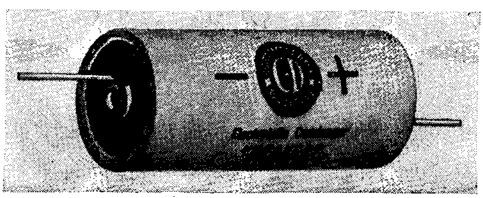


FIG. 10–5. Typical audio cathode by-pass condenser.

affect the low-frequency response. Low-voltage electrolytic condensers are usually rated at 25 or 50 volts. Either will do for *C*-13, since the voltage across the condenser is approximately 12.5 volts for AC receivers and 6 volts for AC/DC receivers. This is the voltage developed across *R*-13 for self-bias.

It is important to emphasize again that a shorted *C*-13 may have been caused by an open bias resistor *R*-13. Therefore, when replacing a shorted *C*-13, the bias resistor should be checked immediately after the shorted condenser has been removed.

Troubles common to the self-bias resistor. Self-bias resistor *R*-13 is a likely source of trouble. It carries considerable current and is subject to heating. Sometimes it changes in ohmic value, and sometimes it opens. A change in ohmic value affects the bias voltage and, therefore, the tone quality. When *R*-13 is open, the cathode circuit is completed by the leakage resistance of parallel condenser *C*-13. Since this leakage resistance is comparatively high, the voltage drop across it will be high, making for abnormally high bias voltage. The condition would be found in a voltage check. The screen and plate voltages would be nearly equal, since at the high bias voltage, plate current would be low, the voltage drop across the output transformer primary would be low, and plate voltage would be high. The open would result in a high cathode bias voltage which might damage parallel condenser C-13.

Any change in ohmic value of R-13 is found in a voltage check of the stage. If it becomes low in ohmage, cathode voltage will be low, resulting in high plate current and a large voltage drop across the output transformer, increasing the voltage difference between screen and plate.

When replacing R-13, it would be wise to use at least a 1-watt resistor, regardless of the size of the original. Manufacturers often cut corners on this item by using the less expensive ½-watt size.

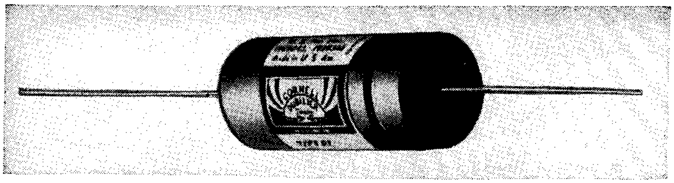
Troubles common to the AF by-pass condenser. Condenser C-12, the high AF by-pass, often comes up as the cause of a dead radio. Its position in the receiver is not only at a high DC potential but also where the AC signal potential (audio variation) is at its highest. This high voltage causes frequent breakdown of insulation, resulting in a shorted condenser, which shorts out the audio signal from the primary of T-6 and also the power supply at this point. This condition is quickly found in a voltage check. Plate voltage equals zero, and screen or B plus voltage is low, since the power-supply voltage drops with the heavy load.

Condenser C-12 may also open. However, a radio will rarely come in for this defect alone, since an open C-12 will merely increase the high-frequency response, and the customer may overlook this. In some radios, an open C-12 may cause a high-frequency oscillation. If this is the case, bridging C-12 with a similar condenser or with a higher capacity condenser is the standard check procedure.

When condenser C-12 is replaced, a good quality of condenser should be used. Regardless of the original value, the voltage rating of the replacement condenser should be at least 600 volts. The outside foil lead or ground lead should be connected to the chassis. Condenser C-12 sometimes is connected from plate to B plus. In that case, the outside foil lead is connected to B plus. The replacement condenser should have the same capacity as the original. If the capacity of the replacement condenser is changed for any reason, it should be borne in mind that a higher capacity will cut more highs out of the signal delivered to the speaker, while a lower capacity will increase the high-frequency response.

Troubles common to the output transformer. Output transformer T-6 is also a common source of trouble. In addition to carrying the audio signal, the primary winding also carries the normal DC plate current of the tube. An open primary often results. When the plate circuit opens, the positive screen attracts the total cathode emission. It was not intended to carry so heavy a current, and the screen mesh becomes red-hot. This can be seen in the case of a glass pentode and is one of the things the experienced serviceman looks for when making a visual inspection of the receiver. In the case of a metal tube, the condition cannot be seen and will be found by voltage analysis, since the open plate circuit will cause zero plate voltage.

As explained before, the output transformer should be replaced with an exact duplicate where obtainable. When this is not possible, a universal output transformer may be substituted. These usually come with an instruction sheet, but servicemen sometimes find it confusing and connect the transformers improperly. This results in poor tone quality. A bit of theory might help to clear up this matter.



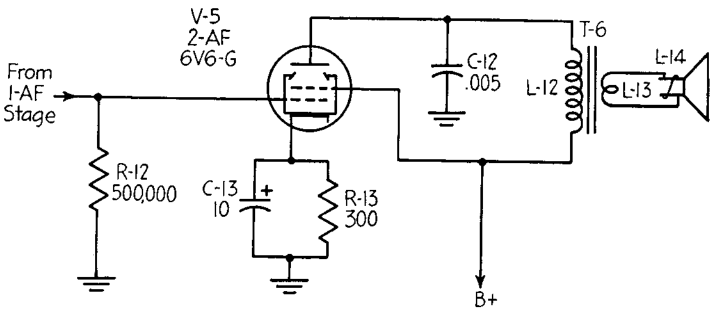


FIG. 10–6. The AF by-pass condenser and its position in the second AF circuit.

The output transformer, as an impedance matching device, works on the principle of reflected load, a term the average serviceman shies away from. Let us first try to explain it.

Assume a power transformer that is being used to light lamps. For simple arithmetical figures, let us also assume a 100-volt line, rather than the usual 110 or 120 volts, and lamps requiring 10 volts at 1 amp each. For further simplification, assume 100 per cent efficiency in the transformer; that is, watts input equals watts output. The transformer has a 10 to 1 step-down ratio to furnish the 10 volts needed for the lamps. Each lamp has a resistance of 10 ohms ($R = E/I = 10/1 = 10$ ohms).

When one lamp is connected, as in Fig. 10–7, 1 amp flows through the lamp. Wattage dissipated is 10 watts ($W = E \times I = 10 \times 1 = 10$ watts). To satisfy watts input equals watts output, the primary current will be 0.1 amp ($I = W/E = 10/100 = 0.1$ amp). To the 100-volt line, the transformer primary looks like a 1,000-ohm impedance or resistance load, since it will drive only 0.1 amp into it ($Z = E/I = 100/0.1 = 1{,}000$ ohms). Now let us light two lamps from the same transformer, as in Fig. 10–8. Two 10-ohm lamps in parallel have a combined resistance of 5 ohms and will draw 2 amp ($I = E/R = 10/5 = 2$ amp) from the secondary, which remains at 10 volts. The actual impedance therefore is 5 ohms. Watts consumed is 20 watts ($W = E \times I = 10 \times 2 = 20$ watts). Once again to make watts input equal watts output, the primary current must now increase to 0.2 amp ($I = W/E = 20/100 = 0.2$ amp). The 100-volt line now looks at the transformer primary as though it were a 500-ohm impedance, since it must furnish 0.2 amp to it ($Z = E/I = 100/0.2 = 500$ ohms). This is called "reflected load." Under the above

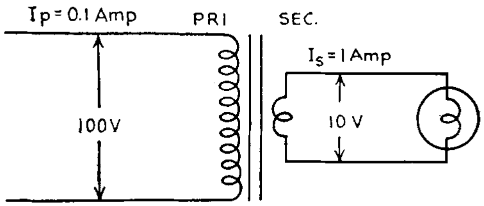


FIG. 10–7. Transformer lighting one lamp.

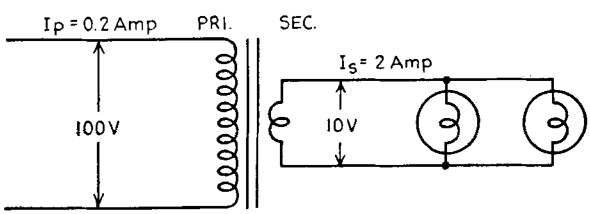


FIG. 10–8. Transformer lighting two lamps.

conditions, a 10-ohm actual load reflects back to the primary a 1,000-ohm load, while a 5-ohm actual load gives a 500-ohm reflected load in the primary. Note also the ratio of reflected to actual load, 100 to 1, which is the square of the turns ratio 10 to 1; that is, a transformer with a 10 to 1 turns ratio would make the reflected load in the primary 100 times (10^2) as great as the actual load in the secondary.

Now let us apply this bit of transformer theory to the output transformer. Assume a 10-ohm voice coil connected to the same 10 to 1 transformer that was used before to light lamps. The connections are shown in Fig. 10–9. The primary would look like 1,000 ohms to any line feeding it. Obviously, this transformer would not do to couple the 10-ohm voice coil to a 6V6-G tube, which requires a 5,000-ohm load resistance for optimum results. A turns ratio of 20 to 1 would make a much better match, since the reflected load in the primary of a 10-ohm voice coil in the secondary would be $(20)^2$, or 400 times as great (4,000 ohms). A turns ratio of 22.4 to 1 would be exactly right.

A universal output transformer is one supplying many possible combinations of turns ratio, so that almost any voice coil may be matched to almost any tube or combination of tubes. A typical universal output transformer is shown in Fig. 10–10. The primary is center-tapped for use in push-pull circuits. In second AF stages using a single tube, the center tap should be taped up and disregarded. Then, either end of the primary winding is connected to the plate, and the other to *B* plus. The

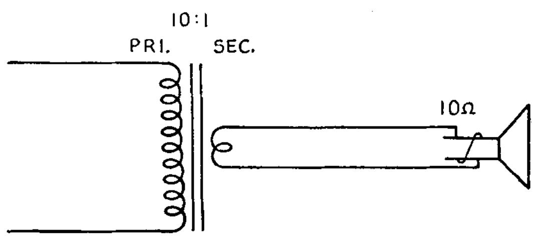


FIG. 10–9. Transformer feeding a 10-ohm voice coil.

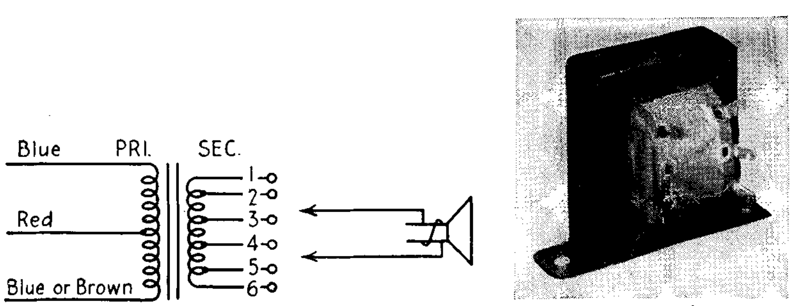


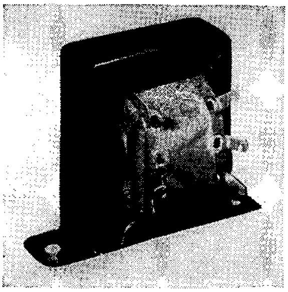
FIG. 10–10. A typical universal replacement output transformer.

secondary usually has six taps, numbered 1 to 6, and a great number of turns ratio combinations is possible.

In using a universal output transformer as a replacement, the first requisite is to use the proper size. They are rated by wattage. Physical size of the transformer is a rough indication of the wattage. Make sure that the replacement is as large as the original. Confirmation may be obtained by comparing the wattage size used with the tube-manual rating for the output tube or tubes in the receiver. The tube manual will also give the recommended load impedance.

The next step is to determine the voice-coil impedance. To do this,

Type No. 2774	4-watt size
Type No. 2776	6-watt size
Type No. 2780	10-watt size
Type No. 2782	12-watt size
Type No. 2788	18-watt size



SIMPLIFIED CHART SHOWING PROPER USE OF SECONDARY TAPS

Primary load impedance	18,000	14,000	10,000	8,000	7,000	4,000	2,000
Single	1F4-1F5G	10-38-950-12A7-1J5G	41-49-6G6G	89 pentode-1G5G-6K6G-6A4/LA	12A-20-31-33-42-47-59 pentode-89-triode-2A5-6AC5G-6B5-6F6-6N6G-GA-PZ-PZH	43-45-50-71A-2B6-6L6-6V6-12A5-25A6-25A7G-59 triode	48-2A3-6A3-6A5G-6B4G-6Y6G-25B5-25B6G-25L6-25N6G-35L6GT
Push-pull	1J5G	41-47-1G5G-6A4/LA-6E6-6K6G-31-33-20-GA-PZ-PZH	42-2A5-6AC5G-6B5-6F6-6N6G	43-50-71A-2B6-6V6-12A5	45-6L6 Class AB_1	48-2A3-6A3-6A5G-6B4G-6L6-25L6	
Class *B*		79 250V 6Y7G 250V	19-49-52-89-6A6-6AC5G-6Z7G-1J6G	30-53-6N7	46-59-79-180V 6Y7G 180V	10	
Parallel					10	12A-31-33-41-42-49-2A5-GA-PZ-PZH	45-50-71A-59 triode
Secondary tap	Voice-coil impedance						
2–3	0.97	0.75	0.54	0.43	0.38	0.22	0.11
3–4	1.2	0.90	0.04	0.51	0.45	0.26	0.13
4–5	1.8	1.4	1.0	0.80	0.70	0.40	0.20
1–2	3.2	2.5	1.8	1.4	1.2	0.71	0.36
2–4	4.2	3.3	2.4	1.9	1.6	0.94	0.47
5–6	4.8	3.7	2.7	2.1	1.9	1.1	0.53
3–5	5.9	4.6	3.3	2.6	2.3	1.3	0.65
1–3	7.7	6.0	4.3	3.4	3.0	1.7	0.85
2–5	11.6	9.0	6.4	5.1	4.5	2.6	1.3
4–6	12.5	9.7	6.9	5.6	4.9	2.8	1.4
1–4	14.8	11.5	8.2	6.6	5.8	3.3	1.6
3–6	21.3	16.5	11.8	9.5	8.3	4.7	2.4
1–5	27.0	21.0	15.0	12.0	10.5	6.0	3.0
2–6	31.5	24.3	17.4	14.0	12.2	7.0	3.5
1–6	54.5	42.4	30.2	24.2	21.2	12.1	6.1
Primary load impedance	18,000	14,000	10,000	8,000	7,000	4,000	2,000

FIG. 10–11. Universal output transformer—instruction sheet.

determine its resistance on the low-ohm scale of your ohmmeter. Then multiply the reading by 1.25. (This rule of thumb is close enough for general service work). Then check with the instruction sheet, which comes with the universal output transformer for the proper taps to use. Figure 10–11 is a sample instruction sheet. As an example of how the sheet is to be used, let us find the proper taps for the standard receiver. The voice coil is measured on the low-range ohmmeter and found to be 5 ohms. Multiplying by 1.25, its approximate impedance is found to be about 6 ohms. The single 6V6-G output tube requires a load impedance of about 4,000 ohms. The output transformer must therefore match about 4,000 ohms to 6 ohms. Look for the single 6V6-G, which is found in the column headed by 4,000 as the primary load impedance. Run down this column into the voice-coil impedances looking for 6 ohms. Then, read across horizonally to find secondary taps 1 and 5, which are to be used.

There is sometimes an inverse feedback lead connected from the secondary of the output transformer back to a previous point in the audio amplifier circuit. In this case, when the output transformer is replaced, the voltage fed back may be in the wrong phase and cause an audio oscillation or squeal, which will be present with or without any signal being fed into the amplifier. When this happens, reversal of either the primary or the secondary leads will clear up the difficulty. More will be said regarding this matter in the section on circuit variations dealing with inverse feedback.

Troubles common to the second AF tube. The tube itself may be the cause of poor operation of the stage. Low emission will cause low gain and poor power-handling capacity. A tube checker usually shows this condition, or it will show up on voltage analysis. Low emission results in low plate current, consequently low self-bias voltage, and a too small difference between plate and screen voltages. The tube also might be noisy (possible loose elements) or cause hum (cathode-to-filament leakage). The best check for these conditions is to substitute a similar type of tube, known to be good.

A fairly common trouble, particularly in the case of 43, 25L6, and 25A6 tubes, is known as "grid emission." The complaint here is that the radio starts playing normally, but after 5 min or so begins to distort badly. A voltmeter connected from chassis to grid will begin to show positive at the grid as the distortion begins.

CIRCUIT VARIATIONS OF THE SECOND AF STAGE

Tone control in the second AF stage. There are many tone-control circuits, the most common of which is shown in Fig. 10–12. Condenser *C*-112 and variable resistor *R*-112 are in parallel with condenser *C*-12.

Like condenser C-12, condenser C-112 by-passes high audio frequencies out of the speaker circuit. Condenser C-112 has a comparatively high capacity, 0.05 mfd being usual. By itself, it would remove most of the high audio frequencies from the signal and make the low notes seem more prevalent by comparison. Variable resistor R-112, which by its setting allows more or less of the by-passing of high frequencies through C-112 to take place, constitutes a tone control. The usual value of R-112 is 50,000 ohms.

All tests for the standard second AF stage are equally applicable to this variation, and all notes applying to condenser C-12 may also be used for tone condenser C-112. If this condenser should short, however, the path for the high B plus voltage to ground would be through the tone-control variable resistor R-112. This would give a variable shunt path depending on the tone-control setting. At the maximum bass position, there would be a very low resistance from plate to ground through

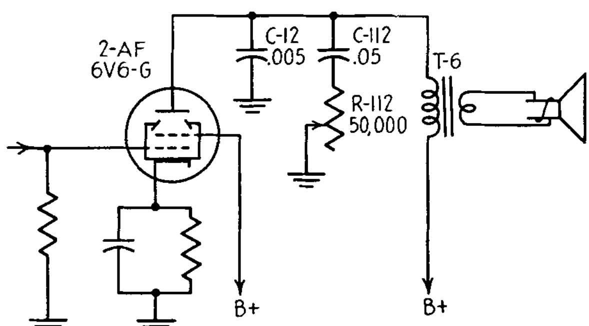


FIG. 10–12. Tone-control circuit in the second AF stage.

the shorted condenser, the B voltage would be low, and the receiver would not operate. At the minimum bass position there would simply be a 50,000-ohm shunt path for the B supply, and the receiver would operate. The erratic action of the tone control would, of course, focus the serviceman's attention to this circuit, and the defect would be found by ohmmeter check. When a shorted tone condenser is replaced, the heavy current through R-112 may have damaged the tone control. It would therefore be wise to replace the tone control also. Replacement notes on volume controls given in Chap. 11 may be applied to the tone control.

A modern trend in the use of tone controls is to replace the variable resistor R-112 with a switch, thereby making a 2-point tone control. An example of this is shown in Fig. 10–13. Note the tone condenser C-23 and its associated switch in the plate circuit of the 50L6 tube. When the switch is open, there is no shunting action, and this is the treble position.

In the bass position, where the switch is closed, C-23, which is 0.04 mfd, shunts some of the high audio frequencies out of the speaker.

Figure 10–14 shows a similar 2-point tone control. In this case, the shunting action of C-21 and its associated switch is in the input circuit of the second AF tube.

Inverse feedback in the second AF stage. Inverse feedback is a form of desirable degeneration often used in the audio amplifiers of radio receivers. There are many types of inverse feedback circuits in common use. In all of them, part of the output signal is fed back in an out-of-phase relationship (hence the name "degeneration") to some point in the input signal circuit, to provide improved over-all audio fidelity by

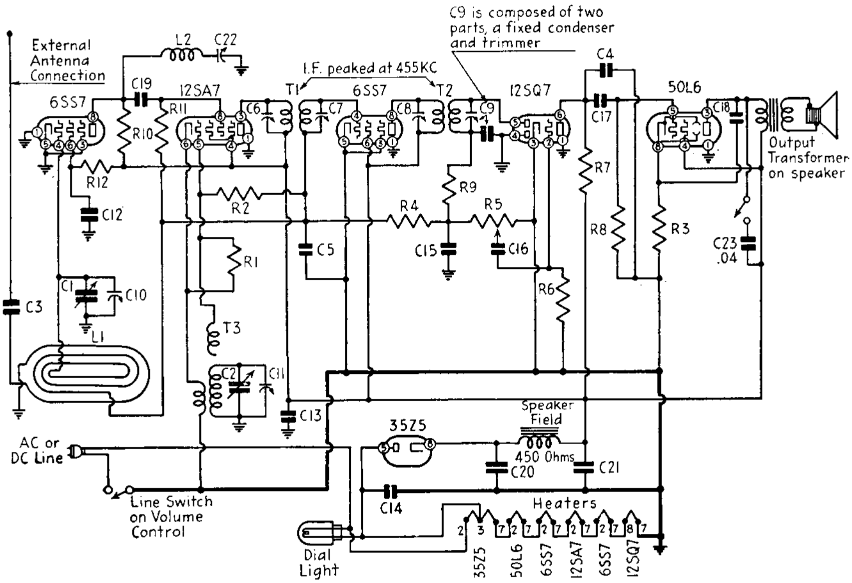


FIG. 10–13. Schematic diagram for Emerson Model G B receiver.

canceling out harmonic distortions. Inverse feedback is always accompanied by a loss in gain, but the amplifier is designed for higher than normal gain to compensate for this loss.

In Fig. 10–13, the cathode by-pass condenser has been omitted to provide degeneration through self-bias resistor R-3, which is common to both the input and output circuits of the 50L6 tube. Since the input and output circuits of a tube are 180 deg out of phase, degeneration is automatic. Condenser C-18, the high-frequency by-pass condenser, is returned directly to cathode rather than to ground, so that the degenerative effect is greater at the higher frequencies (especially the high harmonic frequencies), thereby making for more uniform response for the

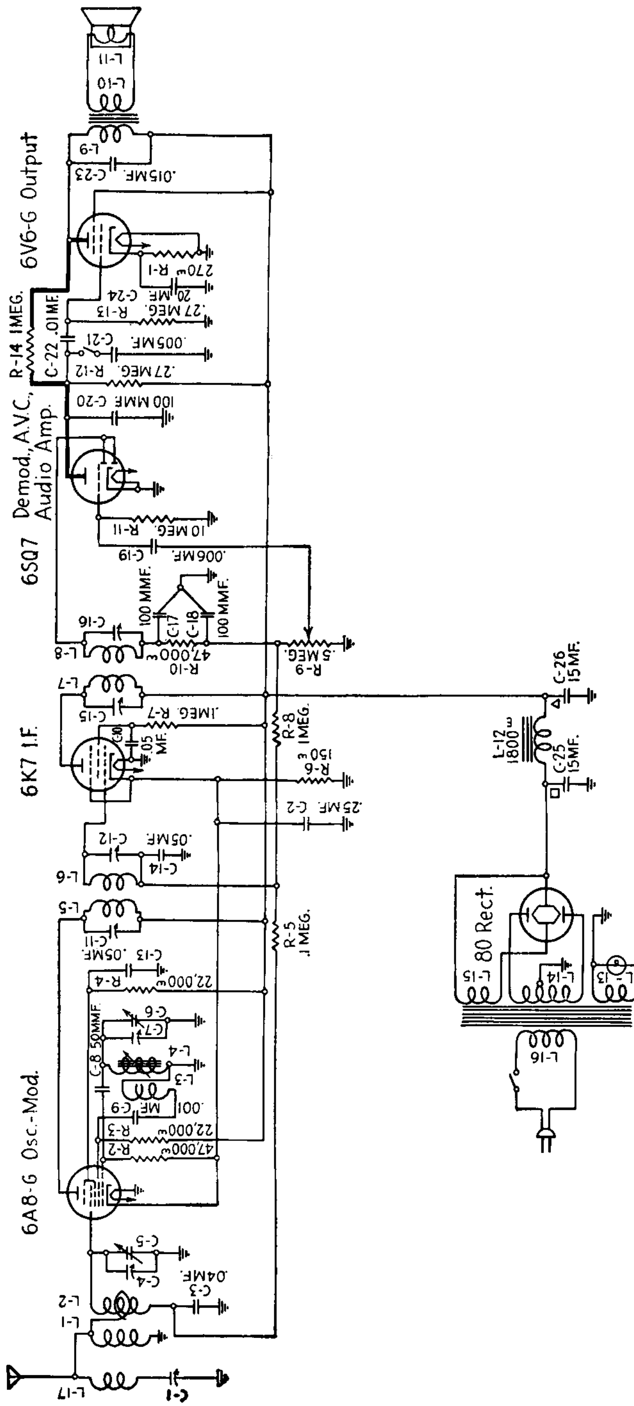


FIG. 10–14. Schematic circuit of the Stromberg-Carlson No. 400 receiver.

stage. In Fig. 10–14 the inverse feedback circuit is shown by the heavy lines. The feedback voltage is taken from the plate of the 6V6-G output tube and fed through resistor *R*-14 back to the plate of the first AF section of the 6SQ7 tube.

As a general rule, inverse feedback circuits do not cause many complications to the serviceman. All tests and service notes pertaining to the standard amplifier circuit may be applied. Resistor *R*-14 in the feedback circuit, represented in Fig. 10–14, will rarely cause any service difficulty.

A servicing problem pertaining to inverse feedback circuits occurs when the feedback voltage is taken from the output transformer secondary, as shown in Fig. 10–15. In this case, the feedback voltage is reintroduced into the cathode circuit of the first AF tube, which has no by-pass condenser. Another variation of this same circuit introduces the

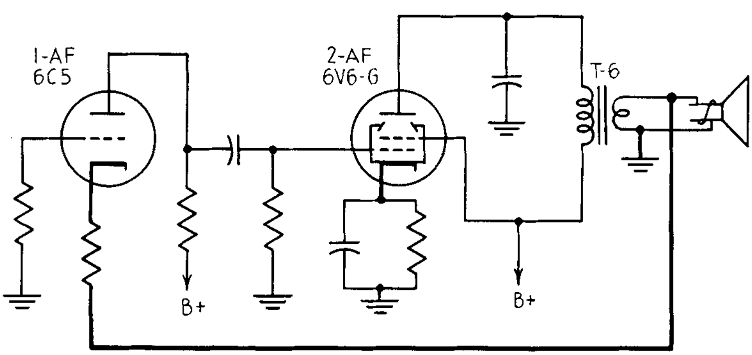


FIG. 10–15. Inverse feedback circuit where the feedback is taken from the secondary of the output transformer.

feedback voltage into a tap in the grid load of the first AF tube. In either case, if the output transformer leads should become reversed, as may easily happen when the output transformer is replaced, the feedback voltage will be in phase with the signal voltage rather than out of phase. This will produce regeneration rather than degeneration, and the audio amplifier becomes an audio oscillator. The oscillation appears in the speaker, usually as a high-pitched squeal, and will, of course, be unaffected by tuning the receiver. The serviceman must be aware of this possibility when replacing the output transformer, since the usual service procedure for oscillation will not disclose it. Reversing the primary or secondary leads, whichever is simpler, will clear up the difficulty.

Fixed bias in the second AF stage. The fixed-bias circuit is found in radios where the negative leads of the filter condenser are not at chassis potential, as shown in Fig. 10–16. In this circuit the cathode is grounded, and negative grid bias is obtained by connecting the grid return to a point in the power-supply stage more negative than ground, and therefore more negative than cathode. Various circuits for the power supply stage are given in Chap. 8. Resistor *R*-113 and condenser *C*-113 form a filter circuit for the bias voltage. Representative values are 0.5 megohm (500,000 ohms) for *R*-113 and 0.1 mfd for *C*-113. This filter circuit may be omitted.

Normal test voltage data for this type of circuit will be different from the standard circuit and are given below.

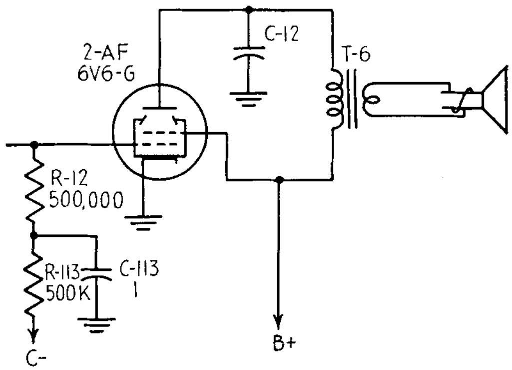


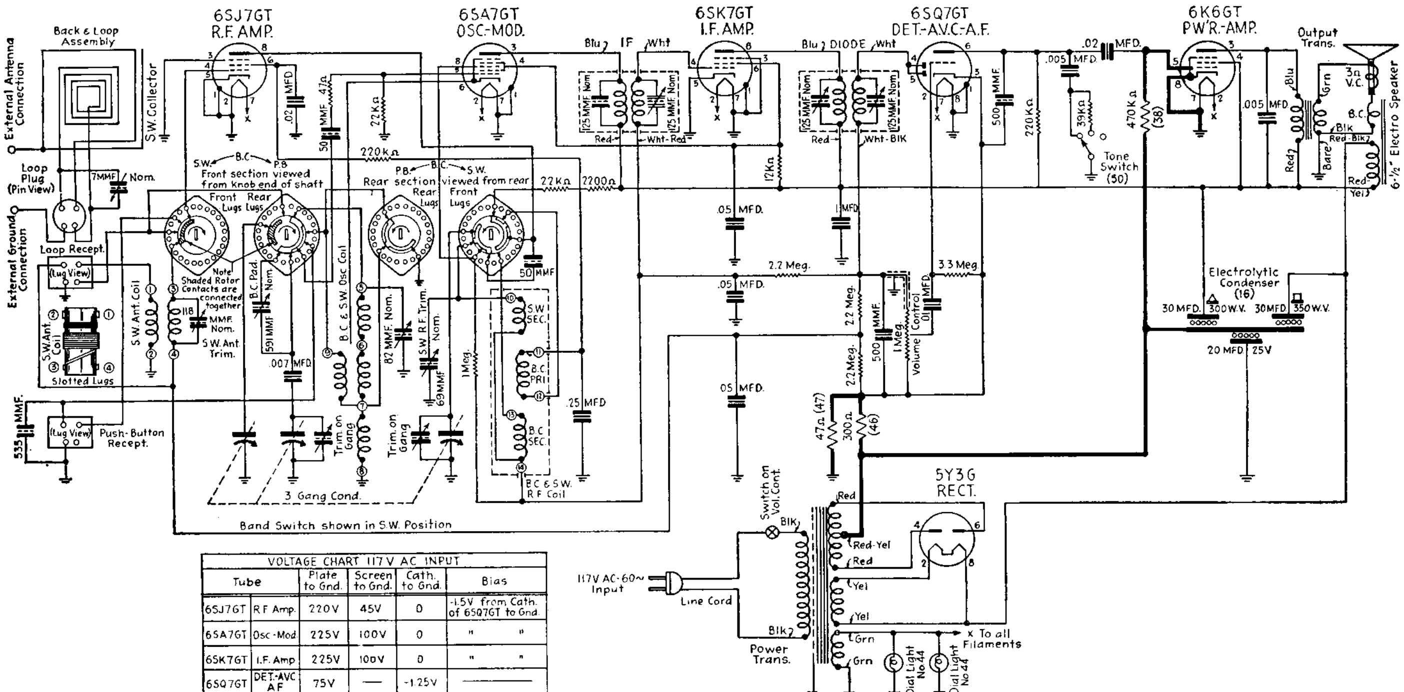
FIG. 10–16. Fixed bias circuit in the second AF stage.

Normal voltage data for fixed-bias second AF stage. Voltages are measured from chassis to tube terminal indicated. In some AC/DC receivers, where the circuit insulates *B* minus from the chassis, the negative terminal of the voltmeter is connected to the common negative. This is most easily found at the line switch. See Chap. 18 on AC/DC Power Supply.

	AC receivers, volts	*AC/DC receivers, volts*
Plate voltage	235	90
Screen voltage	250	95
Grid voltage	Negative	Negative
Cathode voltage	0	0

The measured negative grid voltages will depend on the ohms-per-volt rating of the test voltmeter, owing to the high resistance in the circuit involved. High-resistance meters will show more voltage than low-resistance meters. All meters, however, will show some negative indication. The actual bias voltage can be measured more accurately from *C* minus to chassis in the power supply, a low-resistance circuit.

All parts have the same functions, values, and likely troubles as in



VOLTAGE CHART 117 V AC INPUT					
Tube		Plate to Gnd.	Screen to Gnd.	Cath. to Gnd.	Bias
6SJ7GT	R F Amp.	220V	45V	0	-1.5V from Cath. of 6SQ7GT to Gnd.
6SA7GT	Osc-Mod	225V	100V	0	" "
6SK7GT	I.F. Amp	225V	100V	0	" "
6SQ7GT	DET.-AVC AF	75V	—	-1.25V	—
6K6GT	PW'R Amp	215V	225V	0	16.5V from B- to Gnd.
5Y3G	RECT.	AC	—	295V from Fil.	—

Note.- All voltages measured with a 1,000 Ohm per volt voltmeter. Line voltage -117 volts. Band switch in B.C. position. Maximum power output -3.5 watts.

FIG. 10–17. Schematic diagram of the Motorola Model 61T23 receiver.

the standard circuit. Of the parts peculiar to this circuit, there is little likelihood of trouble from *R*-113 in the *C*-minus bias filter. The associated condenser *C*-113 is a paper tubular condenser. Since it is in a high-resistance circuit, any leakage will cause decreased bias voltage, resulting in various degrees of distortion and power handling capacity. The condition would be found in a voltage check, since the decreased bias would cause high plate current, a large voltage drop across the primary of the output transformer, and a greater than normal difference between plate and screen voltages.

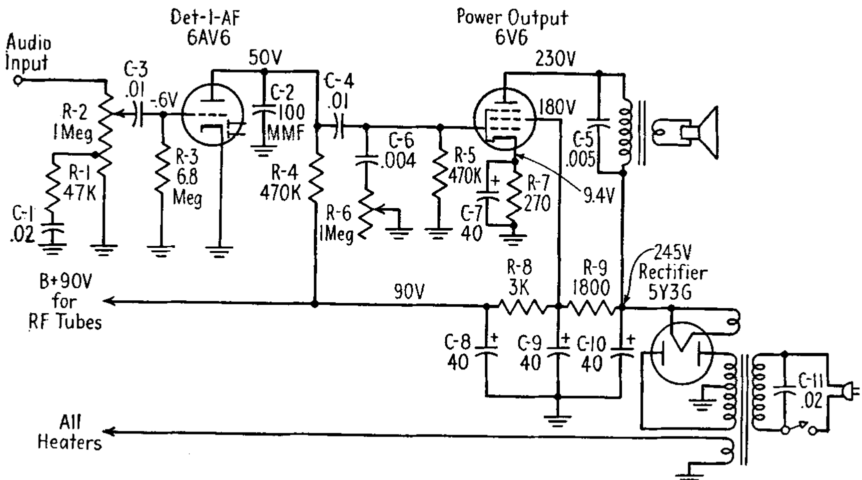


FIG. 10–18. Audio section and power supply of the Airline 15 BR-2757A. A-M/F-M receiver.

The schematic diagram of the Motorola Model 61T23 receiver, shown in Fig. 10–17, is an example of the fixed-bias type of second AF stage. The bias circuit has been indicated by the heavy lines. Note the following conditions: The common terminal of the filter condenser block is connected to the center tap of the high-voltage winding. The cathode of the 6K6-GT second AF tube is connected to the chassis. The grid-load resistor, part number (38), is connected to the negative end of the bias voltage divider, parts numbers (46) and (47). The bias voltage is filtered by the 20-mfd/25-volt condenser section of the electrolytic condenser block (16). And the bias voltage for the second AF tube is indicated in the voltage chart as being measured from *B* minus to ground. Note also the 3-point tone switch (50) in the input circuit of the second AF stage.

Voltage distribution in receivers with R-C filters. When the receiver is of the type where the power supply makes use of R-C filters, the voltage distribution to the rest of the tubes is different from the standard circuit. The schematic diagram of the audio section and power supply of the Airline 15BR-2757A A-M/F-M receiver is given in Fig. 10–18 as an example of this type of circuit. The power supply filter circuit consists of a two-section R-C filter made up of resistors *R*-8 and *R*-9 and condensers *C*-8, *C*-9, and *C*-10. All the latter have a capacity of 40 mfd.

The plate circuit of the 6V6 power output tube is fed directly from input filter condenser *C*-10, making for a normal potential of 230 volts at the plate of the tube, as indicated in the diagram. The filtering at this point is insufficient for the screen of the output tube, so this is fed from the output of the first R-C filter section, making a potential of 180 volts normal for the screen. Even more filtering is required for the rest of the receiver, which is therefore fed from the output of the second R-C filter section. The potential at the *B* plus point for most of this receiver is only 90 volts.

In the second audio-amplifier stage, note that self-bias resistor *R*-7 is 270 ohms—very close to the 300 ohms of the standard circuit. But the lowered screen voltage causes the tube to operate at lower plate and screen currents. As a result, the voltage across the bias resistor is given as 9.4 volts rather than the 12.5 volts of the standard circuit. The tube will therefore handle input signals up to 9.4 volts, producing a speaker output of something less than 4 watts. Note the tone control circuit consisting of condenser *C*-6 and resistor *R*-6 in the input circuit of the 6V6 tube.

When servicing a set of this type, its normal voltage distribution must be kept in mind. In all other respects, the signal tests and service notes pertaining to the standard amplifier circuit are equally applicable.

SERVICE DATA CHART FOR THE SECOND AF STAGE

Symptom	*Abnormal reading*	*Look for*
No signal from the speaker	Plate voltage = 0. Screen voltage = 0	Trouble in the power supply. See Chap. 8
	Plate voltage = 0. Screen voltage low	Short-circuited high AF by-pass condenser C-12
	Plate voltage = 0. Screen voltage normal or high. (Screen of a glass second AF tube glows)	Open primary winding of output transformer *T*-6
	Plate voltage normal or high. Screen voltage same as plate	Weak second AF tube. Open self-bias resistors *R*-13
Poor tone quality	Plate voltage low. Screen voltage normal (large difference between plate and screen voltages)	Defective second AF tube. Short-circuited cathode by-pass condenser C-13. Open grid-load resistor *R*-12. Shorted or leak coupling condenser C-32 (see Chap. 11)
	Voltages normal	Open cathode by-pass condenser C-13. Mismatched replacement output transformer
Motorboating		Open output filter condenser C-16. Open grid-load resistor *R*-12
Squeal or oscillation	Voltages normal	Open output filter condenser C-16. Open high AF by-pass condenser C-12. Degenerative feedback connection from replacement output transformer incorrectly phased

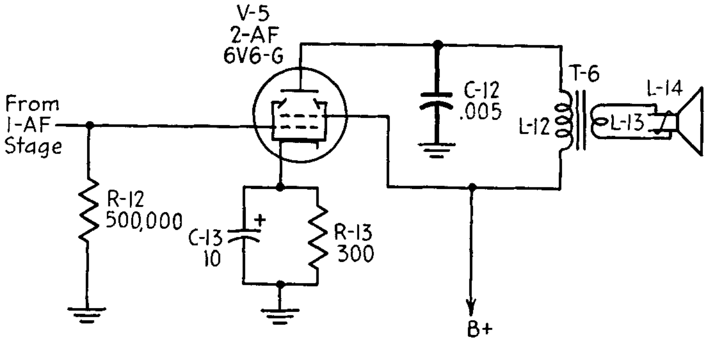
SUMMARY

Test for normal operation of the second AF stage

The tip of a plugged-in soldering iron applied to the grid of the tube causes a growl to be heard in the speaker.

Diagram of a typical second AF stage

The accompanying figure shows the typical second AF stage.



Normal voltage data

Voltage is measured from the chassis or common negative lead. Voltage data are given in the accompanying table.

Tube terminal	*25L6 and 6V6-G pin No.*	*AC receiver, volts*	*AC/DC receiver, volts*
Plate	3	235	85
Screen	4	250	90
Grid	5	0	0
Cathode	8	12.5	6

Normal second AF stage resistance data

Chassis to cathode	300 ohms
Chassis to control grid	500,000 ohms
Plate to *B* plus	200–600 ohms

The 300 ohms of resistance from chassis to cathode is the ohmic value of self-bias resistor *R*-13. When a tube other than the 6V6-G is used a different value will be found. Refer to the diagram of the receiver being tested or to the table on page 100.

The plate to *B* plus reading measures the resistance of *L*-12, the primary of the output transformer.

QUESTIONS

1. A receiver is brought in for repairs, the complaint being "no reception." Visual inspection shows a red-hot screen grid in the type 6F6-G power tube. What is likely to be wrong? Indicate the tests that should be made to confirm your assumption.

2. In a dead receiver, the power supply is found to be operating normally. A voltage check of the second AF stage shows the following:

Plate	300 volts
Screen	300 volts

What are the likely causes of the trouble? Indicate the tests that should be made to confirm the actual cause of the trouble.

3. An AC receiver, using a 6V6-G tube in the second AF stage, gives a high-pitched squeal regardless of the setting of the volume control or tuning dial. What are the possible causes of the trouble? How would you check for each?

4. The receiver of Fig. 10–17 has an open output transformer. If an original replacement is not obtainable, use the universal output transformer chart of Fig. 10–11 for reference and choose (1) the type of transformer that should be used, and (2) the secondary taps that should be used.

5. The receiver of Fig. 10–14 has low volume and sounds tinny. A voltage check shows normal voltage readings. Substitution of the bench test speaker causes no improvement. What should the next check be?

6. The receiver of Fig. 10–14 motorboats. Bridging the output filter condenser *C*-26 with a 20-mfd/450-volt condenser causes no improvement. What should the next check be?

7. The receiver of Fig. 10–13 begins to distort after it has been playing for 15 min. What would you suspect is wrong? How would you confirm your suspicion?

8. A distorting receiver gives the following voltage check for the 6V6-G tube in the second AF stage:

Plate	200 volts
Screen	250 volts
Grid	0 volts
Cathode	2 volts

What is likely to be the cause of the distortion? How would you confirm your assumption?

9. The receiver of Fig. 10–13 is brought in as dead and gives the following voltage readings for the second AF stage:

Plate	95 volts
Screen	95 volts
Cathode	30 volts

What is likely to be the cause of the trouble? How would you confirm your assumption?

10. What precautions should be observed in replacing a shorted high-AF by-pass condenser?

11 FIRST AUDIO-AMPLIFIER STAGE

Quick check. If a wet finger or a plugged-in soldering iron is applied to the input of the first AF stage and a very strong growl comes out of the speaker, the stage is probably functioning properly, and the serviceman moves on to the next stage.

Function of first AF stage. The control grid circuit is the stage input and is coupled to the detector output circuit. The plate circuit is the stage output, which is in turn coupled to the grid or input circuit of the second AF stage. The detector has an output of roughly 1 volt of AF signal. The second AF stage, if it contains a 6V6-G beam-power amplifier, requires an input signal of 12.5 volts to drive the speaker to full volume. It is therefore the function of the first AF stage to build up the detector output signal voltage (1 volt) to the level necessary to drive the second AF stage (12.5 volts).

Theory of operation, functions, and values of component parts. From the function of the stage, to amplify 1 volt of signal to 12.5 volts, it would seem that a voltage amplification of 12.5 for the stage would be sufficient. However, the detector output may be less than 1 volt, in which case there would be insufficient volume. The first AF stage, therefore, is usually designed for high voltage gain, 50 or higher, so that low input signals can be amplified to the required level to operate the second AF stage. Then, should the input be excessive, the detector signal level feeding the first AF stage is reduced through a potentiometer, which is the manually operated volume control of the receiver.

The first AF stage is called a "voltage amplifier," while the second AF stage is called a "power amplifier." The reason for these descriptions lies in their functions. The second AF stage drives the speaker and must furnish power to vibrate the speaker cone and the surrounding air. Electric power is measured in watts, which incorporates both voltage and amperage. The second AF tube, the output transformer, and the speaker are all rated in watts. The second AF stage, therefore, is a power amplifier developing enough power to drive the speaker. The first AF stage, on the other hand, furnishes the grid excitation for the second AF tube. The grid of the second AF tube is always kept at a negative potential by the bias voltage supply, and the signal voltage does not normally exceed the bias voltage. As a result, the grid circuit does not draw current from the previous stage, and the signal grid excitation therefore requires voltage but not current. For this reason, the first AF stage, which furnishes the grid excitation for the second AF stage, is called a "voltage amplifier." If the signal voltage at the second AF grid should exceed the bias voltage and grid current result, the first AF stage would also be furnishing power. Likewise, if the first AF stage were used to drive a pair of headphones, it would be operating as a power amplifier.

The tube used as the first audio amplifier is usually a high-mu triode. Most often, it is the triode section of a dual-purpose diode and high-mu triode, like the 6SQ7, which will be used in our standard circuit. The diode section is used as the detector and will be described in Chap. 12.

Standard circuit. Potentiometer *R*-27 is the manual volume control for the receiver. Its usual value is 500,000 ohms. The detector signal output

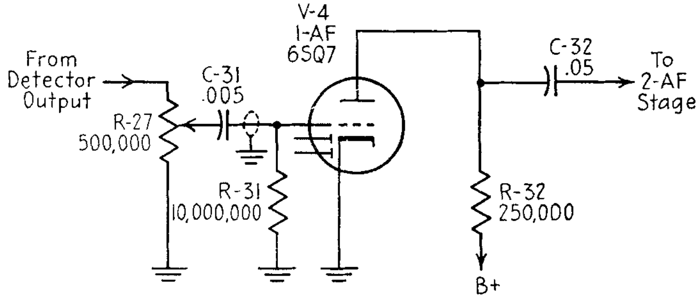


Fig. 11–1. Typical first audio-frequency amplifier stage.

is connected across *R*-27, and the position of the potentiometer arm determines how much of the detector signal output voltage is fed to the audio amplifier. For example, if the arm is near the grounded end, little of the detector output voltage developed across *R*-27 gets amplified, and this is the low-volume position. If the arm is nearer the ungrounded end, more of the available signal voltage gets amplified, and this is the high-volume position.

Condenser *C*-31 is the coupling condenser. It feeds the audio signal voltage from the volume control to the grid or input circuit of the tube and is usually 0.005 mfd. It may vary in different receivers from 0.001 to 0.02 mfd.

Resistor *R*-31 is the grid load. It returns the grid directly to the cathode in a circuit known as "contact bias." As will be explained, the grid-load resistor in a contact bias circuit usually is high: 2 to 15 megohms. The average size for the standard circuit is 10 megohms.

Operation of contact bias. When the schematic diagram is studied, it would seem at first glance that there is no grid-bias voltage on the triode section of *V*-4, since the grid goes to ground through *R*-31 and the cathode is also at ground potential. To understand how a bias voltage is developed between grid and cathode, first assume a condition of no signal input. In the tube, the cathode is emitting electrons which are attracted by the positive plate, as shown in Fig. 11–2. Some of these electrons impinge on the grid located between cathode and plate, as shown in Fig. 11–3. These will flow through the grid load *R*-31 back to cathode. Since *R*-31 usually has a high resistance, it will not require very much grid current flow to develop a voltage across it. By applying Ohm's law, $E = I \times R$, a current of only 0.1 microampere (0.0000001 amp) will de-

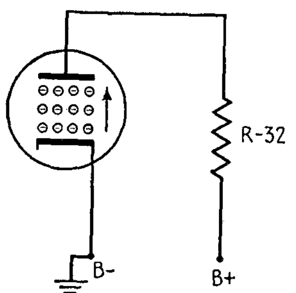


FIG. 11–2. Electrons being attracted from the cathode to the positive plate.

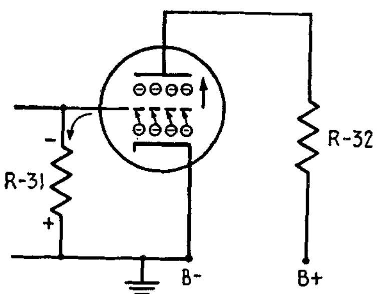


FIG. 11–3. Electrons impinging on the grid of a tube in developing contact bias.

velop 1 volt across 10 megohms, the usual size of *R*-31. Note the arrow showing direction of electron flow through *R*-31 in Fig. 11–3. Since electrons flow from negative to positive, the grid end of *R*-31 is negative, with respect to the ground or cathode end, by this voltage drop. Therefore, a small negative bias is established on the grid. This negative bias remains constant for a particular circuit because, as fast as electrons leak off the grid across *R*-31, new electrons impinge on it, and therefore a condition of equilibrium is set up whereby a slight negative bias is maintained on the grid. Condenser *C*-31 prevents electrons from leaking across *R*-27 to ground.

In amplifiers used in radio receivers, grids are maintained at all times at a negative potential. When the signal voltage is placed on the grid, it drives the grid more negative or less negative with each alternation. If the signal voltage should be larger than the steady negative grid-bias voltage, the grid will be driven positive on the positive half of the signal cycle, resulting in serious distortion. For this reason, the signal voltage must always be lower than the grid-bias potential. In the case of contact bias, the grid-bias potential is low, and as a result the signal handling capacity is low. Contact bias, therefore, is used only in the first audio stage where the input signal is at a low level of potential.

Tubes used in the first AF stage. Vacuum tube *V*-4 is the voltage amplifier tube. The one most often used in the first AF stage is the high-mu triode section of the type 6Q7 or 6SQ7 tube. Receivers equipped with locking-base tubes use the similar 7C6 loctal type. Receivers with miniature tubes use the similar 6AT6 tube. When lower gain for the stage is desired or the stage is to be followed by transformer coupling, the type 6R7 tube is employed. Where a separate diode is used for the detector stage, the tube employed for the first AF stage is a 6F5 or 6SF5; these have the same characteristics as the triode section of the 6SQ7. Even in

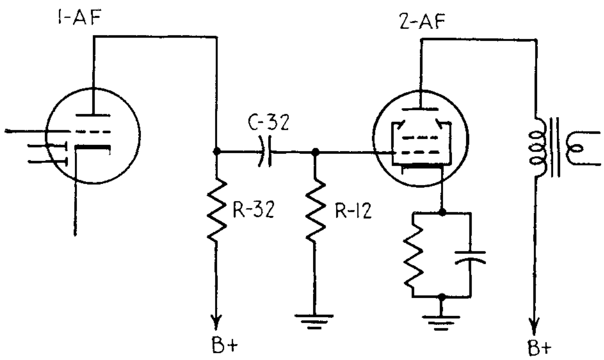


FIG. 11–4. Resistance coupling between the first AF and second AF stages.

the latter case, the 6SQ7 is often used with the diode plates grounded. Older receivers used the 75 type of tube in a similar circuit arrangement.

Receivers of the AC/DC type use the 6Q7 and 6SQ7 in circuits employing 0.3-amp filament tubes, and the 12Q7 or 12SQ7 types in 0.15-amp filament tubes.

Coupling circuit to the second AF stage. Resistor *R*-32 is the plate load of the first AF tube. The value most often found is 0.25 megohm (250,000 ohms). It may go as high as 0.5 megohm and as low as 0.1 megohm. Higher values would give somewhat greater gain; lower values would result in reduced gain. When the first AF tube is a low-mu triode like the 6SR7, resistor *R*-32 is lower in value, 50,000 to 100,000 ohms being usual. In all cases, wattage dissipation is relatively unimportant. The resistors generally in use are the ½-watt size.

Condenser *C*-32 is the audio coupling condenser. This condenser, plate-load resistor *R*-32, and grid-load resistor *R*-12 of the following stage make up a resistance coupling circuit between the two stages, as shown in Fig. 11–4. Its function is twofold: It conducts the AF signal from the plate circuit of the first AF tube to the grid of the second AF tube; at the same time, it keeps the positive plate potential of the first AF tube from affecting the grid of the second AF tube.

The capacity of coupling condenser *C*-32 varies considerably with different receivers. Capacities ranging from 0.01 to 0.1 mfd are common. The standard receiver uses 0.05 mfd. The larger capacities give better bass frequency response. Some receivers purposely use a small-capacity condenser at *C*-32 and are generally designed to give a poor response to low audio frequencies so as to minimize the hum frequency (120 cycles for a full-wave and 60 cycles for a half-wave rectifier).

The insulation of condenser *C*-32 must be good, since any leakage would put a positive bias on the second AF grid from the first AF plate. Paper tubular condensers are usually used with a voltage rating of 400 or 600 volts DC.

NORMAL TEST DATA FOR THE FIRST AF STAGE

Signal check. In the signal-substitution method of service procedure, only the final audio stage is measured as a single unit. Thereafter, as each stage is added, the test is over-all. In the case of the first AF stage, the test signal is applied to the first AF stage input circuit while the output indication is taken from the speaker.

Most signal generators provide a pair of terminals, where a 400-cycle current is available for the testing of AF circuits. When this test signal is applied to the input of an AF amplifier, a 400-cycle note is heard in the speaker.

When the audio output from a signal generator is not readily available, a good substitute is found on every service bench. The tip of the soldering iron is a length of copper rod, partly enclosed in a heating coil, which is energized by 60-cycle current. The heating coil induces a small voltage in the tip, which is usable as a source of signal input voltage for AF amplifiers. The test frequency is low, 60 cycles, which accounts for the note heard in the speaker being described as a growl. Also, the human body seems to pick up some 60-cycle voltage, and many practical servicemen use a moist finger as their signal source. This last procedure is not recommended for beginners, who might accidentally touch a plate lead at 300 volts instead of a grid lead at zero volts.

Quick check for the first AF stage. If a wet finger or a plugged-in soldering iron tip is applied to the ungrounded (called the "hot") end of the volume control with the control in the full ON position, a very strong growl should be heard in the speaker. If it is not heard or if it is not considerably stronger than the growl heard when the second AF stage was checked, the trouble is in the first AF stage.

The quick signal check can also be used for further narrowing down the location of the trouble. Assume normal response from the second AF grid (a low growl) and no response from the ungrounded (hot) end of the volume control, as in Fig. 11–5.

Then, if the test signal is applied to the plate of the first AF tube, normal response (a low growl in the speaker) indicates that coupling condenser *C*-32 is functioning and the trouble is before the first AF plate. No response at this point indicates an open coupling condenser, or a first AF plate-to-ground short.

If there is normal response from the first AF plate, the test signal is shifted to the first AF grid. Normal response (a strong growl) from this point indicates trouble in the volume control or coupling condenser *C*-31.

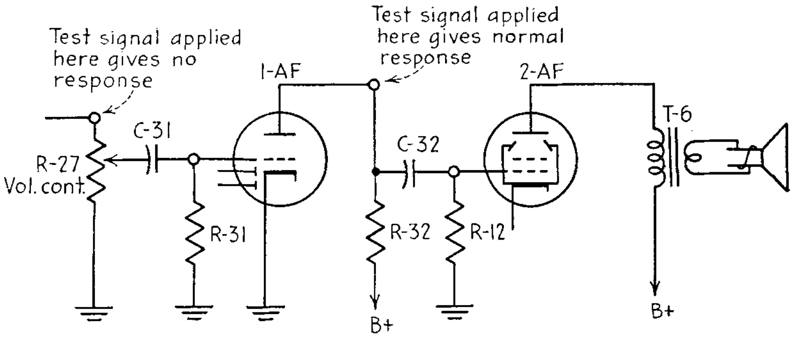


FIG. 11–5. Trouble shooting an inoperative first AF stage by a signal check.

No response means that the trouble is between the first AF grid and the plate. The likely causes are:

1. *An inoperative first AF tube.* Confirm by substituting a good tube.

2. *A grounded grid lead.* Confirm with an ohmmeter. (The ground is probably caused by defective shielding.)

3. *An open plate-load resistor R-32.* Confirm by voltage and resistance checks.

Use of output meter. The ear, judging differences in sound intensity, can make only a rough estimate. Except at very low sound levels, the judgment of the ear is not very reliable. A more quantitative check for all receiver testing is to measure the actual signal power that is put into the speaker.

Radiomen usually work to a definite level of output from any receiver and then make comparisons of input signal necessary to attain that output. This reference level is called "standard output" and is defined as 50 mw (0.05 watt) of signal power into the speaker. Note that the 50 mw is well below the output capabilities of any radio receiver and, therefore, the test signal level at any point in the receiver, necessary to attain standard output, will not overload any tube.

The output power may be determined by measuring the signal voltage across the speaker voice coil with an AC voltmeter. For example, if we have a 5-ohm voice coil, 0.5 volt will correspond to standard output.

$$W = \frac{E^2}{R} = \frac{0.5 \times 0.5}{5} = \frac{0.25}{5} = 0.05 \text{ watt}$$

A reading of 0.5 volt may be read on a meter which has a low AC voltage range of 0–5 volts or less. A diagram showing how such a meter may be used to measure standard output is shown in Fig. 11–6A.

Some multimeters, however, are not equipped with so low a range. In this case, a more easily read output indication is obtainable at the

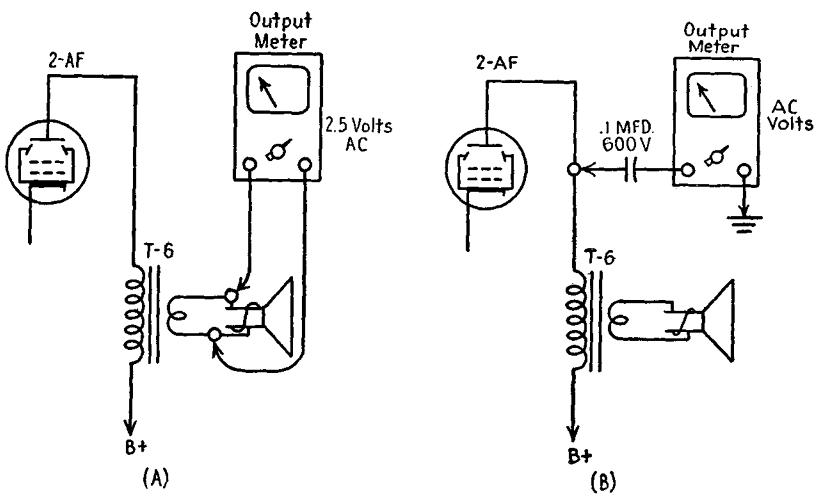


FIG. 11–6. Connection of an AC voltmeter as an output meter.

primary of the output transformer where, owing to the turns ratio of the transformer, standard output will correspond to approximately 16 volts. The primary of the output transformer, however, is in a circuit where direct current, the plate current of the second AF tube, is flowing. The signal itself is a pulsation of this current. To keep the direct current of the plate circuit from affecting the AC meter, a condenser must be inserted in series, so that the meter will read only the AC signal component. This is shown in Fig. 11–6*B*, which indicates the connections for an output meter. A convenient size for this series condenser is 0.1 mfd/600 volts. Some multimeters have the output condenser built in, in which case there will be test jacks on the instrument labeled OUTPUT METER, and the 0.1-mfd condenser need not be connected externally. The meter should be used on a suitable AC range where 16 volts will give a good indication. (About half scale is best.) It might be advisable for the serviceman to work to a reading of 15 or 20 volts as his reference level, to take advantage of a convenient marker on the meter scale. Then as far as his test bench is concerned, 15 or 20 volts, as the case may be, is standard output, and he will work at this level except where service notes issued by the manufacturer of the receiver concerned specify differently. The voltage chosen to represent standard output will not vary too much from 50 mw and is sufficiently accurate for any service work.

The serviceman would do well to provide himself with some special test leads for convenience in checking the output voltage. If the multimeter has a built-in output condenser, a pair of test leads terminating in alligator clips will be all that is needed. If the output condenser is not built in, one test lead is provided with a series 0.1-mfd/600-volt condenser, as shown in Fig. 11–7.

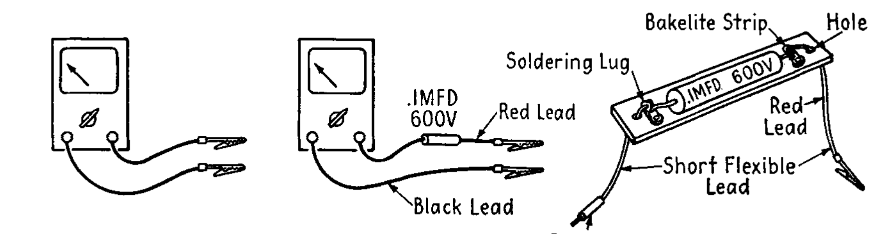


FIG. 11–7. Test leads for the output meter.

Stage-gain measurements. Now, having established standard output, let us make some gain checks on a receiver known to be perfect to determine how this information may be used in later servicing. Figure 11–8 shows the audio amplifier of the standard receiver. The output meter and the AF output of the signal generator are connected to make gain checks. The condenser in the hot lead of the signal generator (which may be connected internally) serves to keep DC plate potentials out of the signal generator circuit when the hot lead is connected to a plate terminal in the radio. The receiver volume control is set for maximum output (full ON) and the tone control, if any, is set for the minimum bass position.

The gain per stage is approximately 50 for the first AF stage and 10 for the second AF stage, as is indicated in Fig. 11–8. Now let us assume our test bench works to a reference level of 20 volts at the second AF plate as standard output indication. Then when the hot lead of the signal generator is connected to point (1), the second AF grid, a 2-volt signal will be needed to give standard output from this point, since 2 volts input times 10, the amplification of the stage, equals 20 volts output. It is not necessary to measure the input signal voltage. Accurate stage-gain measurements would call for expensive test equipment and, although this would be of advantage in design engineering, service work to find a poorly operating stage does not require anything more than comparative data. For an idea of 2 volts input, simply note the position of the attenuator on the AF signal generator to obtain standard output on this perfect receiver.

When the test signal is connected to point ②, the first AF plate, the signal-generator attenuator will have to be advanced slightly to maintain

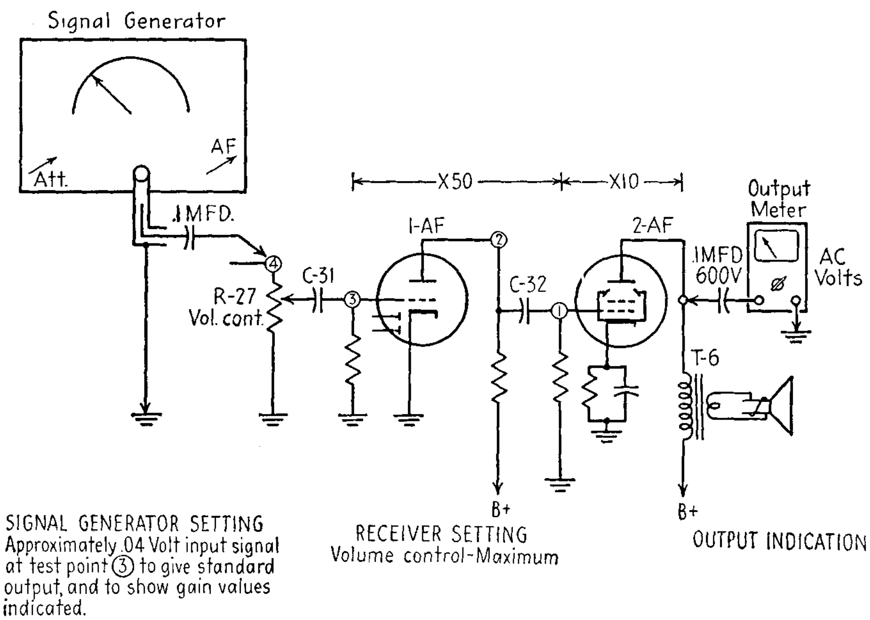


FIG. 11–8. Audio stage-gain measurements.

20 volts on the output meter, to compensate for the loss caused by coupling condenser C-32.

When the test signal is connected to point ③, which is the grid of the first AF tube, only 0.04 volt will be needed to give standard output, since

Input volts	×	gain of first AF stage	×	gain of second AF stage	=	output volts
0.04	×	50	×	10	=	20

The signal-generator attenuator position is again noted for the 0.04-volt position.

Moving the test signal to point ④, the hot end of the volume control, will again require a slight increase in signal input voltage to compensate for the loss caused by coupling condenser C-31.

Having established comparative reference points on his signal generator and output meter, by trying the above procedure on a number of perfect receivers, the serviceman is in a position to determine the normal gain to be expected from any audio stage of a receiver brought in for servicing.

Normal first AF voltage data. Voltages are measured from chassis or common negative to tube terminal indicated. In some AC/DC receivers where the circuit insulates *B* minus from the chassis, the negative terminal of the voltmeter is connected to the common negative. This is most easily found at the line switch. Normal data are given in the accompanying table.

Tube terminal	*12SQ7 and 6SQ7 pin No.*	*AC receivers, volts*	*AC/DC receivers, volts*
Plate	6	100–170	40–60
Grid	2	0	0
Cathode	3	0	0

Voltages vary with different receivers and also with the ohms-per-volt rating of the multimeter. Since the plate-load resistor *R*-32 has an average value of 250,000 ohms, the plate circuit is a high-resistance circuit, and the plate voltage as read by a meter will depend on the extent to which the meter loads the circuit. In general, a 1,000-ohms-per-volt meter will read considerably less in this circuit than a 20,000-ohms-per-volt or vacuum-tube voltmeter.

Normal first AF resistance data. These data are given in the following table:

Chassis to cathode (pin 3)	0 ohms
Chassis to grid (pin 2)	10 megohms
B plus to plate (pin 6)	250,000 ohms

COMMON TROUBLES IN THE FIRST AF STAGE

Troubles common to the volume control. Volume controls sometimes open. Since a signal check may give normal response even with an open volume control, this difficulty may not be found until the detector stage is checked, the volume control being also an important component of the detector stage.

More often, volume controls are noisy in operation, usually because of dirt between the sliding arm and its contact ring. Although a temporary repair is often possible by a cleaning, such procedure is questionable, since a noisy control is also a possible cause of intermittent operation or fading. Debit the control to normal wear and tear of a moving part and replace it with a new one.

In replacing the volume control for electric and mechanical defects, it is best to obtain an exact replacement. When this is not possible, a replacement control as similar to the original as possible must be selected.

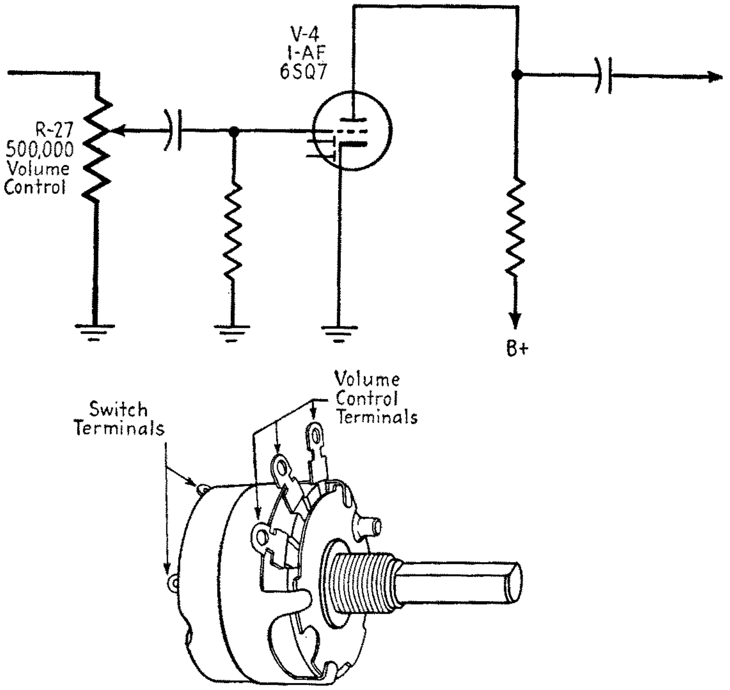


FIG. 11–9. Typical volume control and its position in the first AF circuit.

When choosing the replacement control, the serviceman must keep several factors in mind:

1. Space requirement. The replacement must not be physically larger than the original unless there is room for it.

2. Length of shaft. The shaft of the replacement control may be longer but not shorter than the original. The excess can be cut off. If the original has an unusually long shaft, an extension shaft (see Fig. 11–10) may be used.

3. Flat side of shaft. The volume-control knob should be examined. If it fastens with a setscrew, any shape of shaft may be used. If it is a spring push-on type of knob, the knob must fit the shaft snugly with spring tension. Too small a shaft will not do, since the knob will be loose. A round shaft or one with a small flat section will do, since it can be filed to shape.

4. *Resistance and Taper.* The total resistance and taper of the replacement control should be the same as the original. The wrong taper will cause the control to bunch all its action in a small segment of the control rotation, while the rest of the turn has very little effect. The serviceman need not concern himself too much about the taper, however, since the replacement-control manufacturers have gone into the matter thoroughly and specify the proper taper to use in accordance with the circuit arrangement of the control.

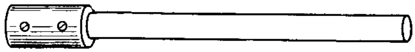


FIG. 11–10. A volume-control extension shaft.

5. *Switch.* Volume (or tone) controls are usually combined with the line ON-OFF switch in one unit. When this is the case, if the volume control is defective, the switch is replaced at the same time. Similarly, if the switch is defective, the volume control is replaced at the same time..

How to replace a volume control

1. Choose a proper replacement control as described above.
2. Do not remove the wiring from the old control. Loosen the mounting nut, slip the shaft through the hole, and let the old control dangle from its leads.

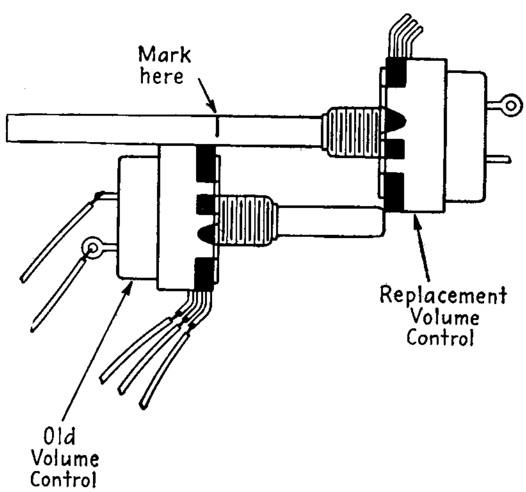


FIG. 11–11. Measuring the replacement volume control for length.

3. If necessary to cut the shaft of the replacement control, proceed as follows:
   a. Measure it against the original as shown in Fig. 11–11 and mark the proper length.

b. Clamp excess portion in vise with mark showing and cut to the mark with a hack saw, as shown in Fig. 11–12.
c. Remove saw burr with a file.

4. If shaft is to be filed for a push-on type of knob, proceed as follows:
a. Measure against the original, as shown in Fig. 11–13, and indicate with a mark the amount of shaft to be removed.

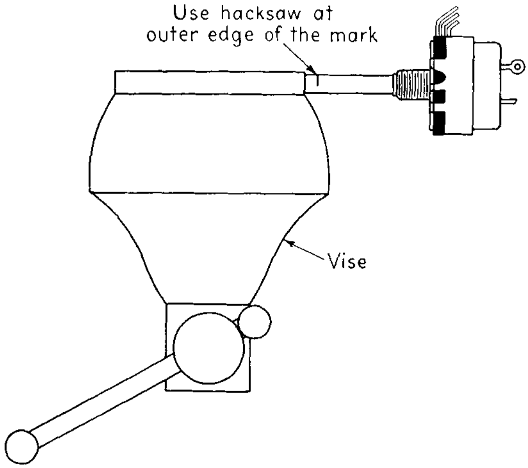


FIG. 11–12. Cutting the volume-control shaft to size.

b. Clamp in vise with mark showing. Cut vertically at *A* with a hack saw, as shown in Fig. 11–14. Stop cutting before reaching the horizontal line. File the material away, almost down to the line with the file held horizontally.

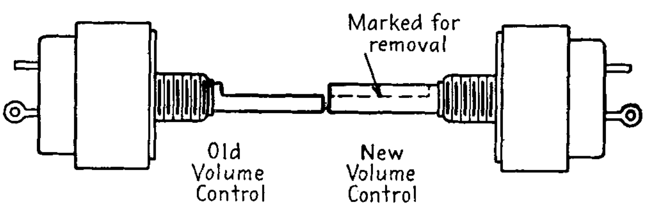


FIG. 11–13. Marking the volume-control shaft for a push-on knob.

c. Try the push-on knob. If too tight, one or two file strokes will bring the shaft down to the line where the knob spring should fit just right.

5. Slip the replacement control through the chassis hole, using a lock washer or locating pin, as shown in Fig. 11–15. If there is no hole for the locating pin, bend it down if it is metal or snap it off if it is bakelite. If this is not done, the locating pin will force the control at

an angle when the nut is tightened up, either damaging it or giving the control erratic action. Tighten the mounting nut with an open-end wrench. An open-end wrench marked ½ in. on one end and 9⁄16 in. on the other will handle most volume-control mounting nuts. A hollow-shaft socket wrench of the proper size will be a more convenient tool for the purpose.

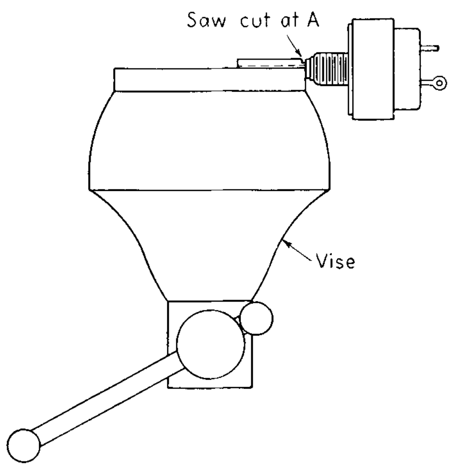


FIG. 11–14. Cutting the volume-control shaft for a push-on knob.

6. Remove the wires from the old control, one at a time. Each wire is to be soldered to the corresponding terminal lug on the replacement control.

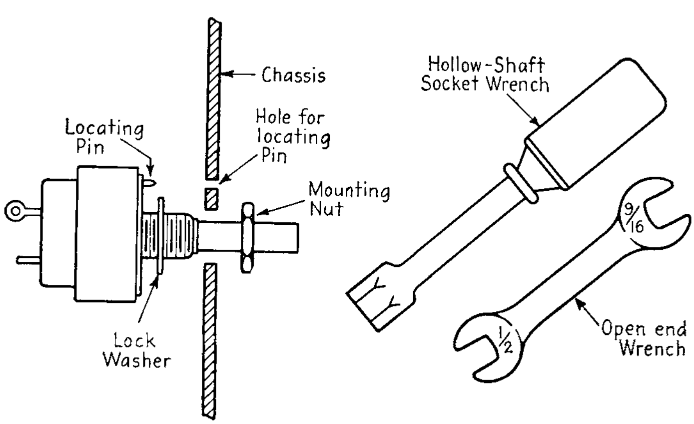


FIG. 11–15. Mounting the volume control.

If the wiring has been disturbed before the new control is in place, it will be necessary to trace the leads before soldering them into place. First the switch leads are traced, one to the line cord and the other to the power-transformer primary. Next the wire to the first AF control grid through condenser C-31 is found and soldered to the center terminal of the potentiometer. The last two leads go to ground and the detector circuit, and the serviceman must be careful not to reverse them or the control will work backward. The easiest way to be sure is to turn the control to the full ON position and imagine the position of the arm inside the control. At the full ON position the arm is stopped at the detector circuit end of the control, and the detector lead is soldered to the lug that stopped the arm. The final soldering lug connects to the chassis. These connections are illustrated in Fig. 11–16.

To check the volume-control action, tune the receiver to a strong local station. Turn the volume control to the position just before the switch shuts off power. The sound from the speaker should be just a whisper or completely off. As the volume control is rotated in a clockwise direc-

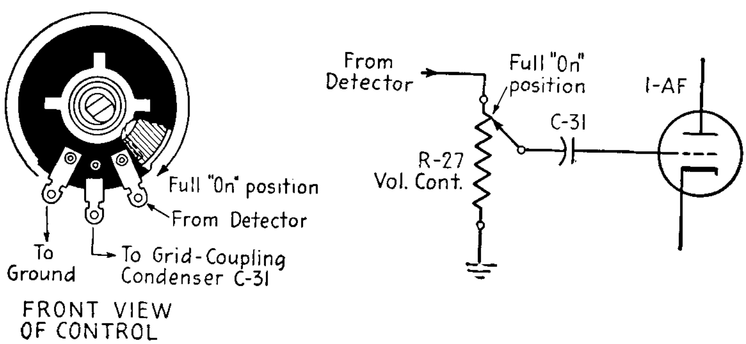


FIG. 11–16. Volume-control connections.

tion, the volume should gradually increase. At the halfway point, the volume should be just about right to fill the average home living room. As the rotation is continued, the volume should increase. Beyond the three-quarter point there will probably be distortion, rattling of the speaker, and microphonics.

To check the volume control for noisy action, the RF section of the receiver is made inoperative by removing the IF tube and rotating the volume control while listening for noise. In the case of an AC/DC receiver, where a tube cannot be removed without stopping all operation, the RF section of the receiver may be made inoperative by grounding the IF grid or the oscillator condenser stator. Grounding the oscillator condenser stator is a standard servicing procedure. A description of how the oscillator section of the gang tuning condenser may be easily recognized is given on page 158.

Troubles common to the input coupling condenser. Coupling condenser C-31 rarely causes any service difficulties. It may open, in which case the condition would be found by a signal check: normal response from the grid of the first AF tube and no response from the arm of the volume control.

When replacing the condenser, be sure to use one with the same capacity as the original. Place the condenser in the same position as the original and dress the leads in the same manner. The positioning of the condenser and leads is stressed because any hum picked up at this point is amplified by the entire audio amplifier that follows. Also follow the original for the placement of the outside foil lead, although this procedure may be unimportant, since either end of the condenser is equally "hot."

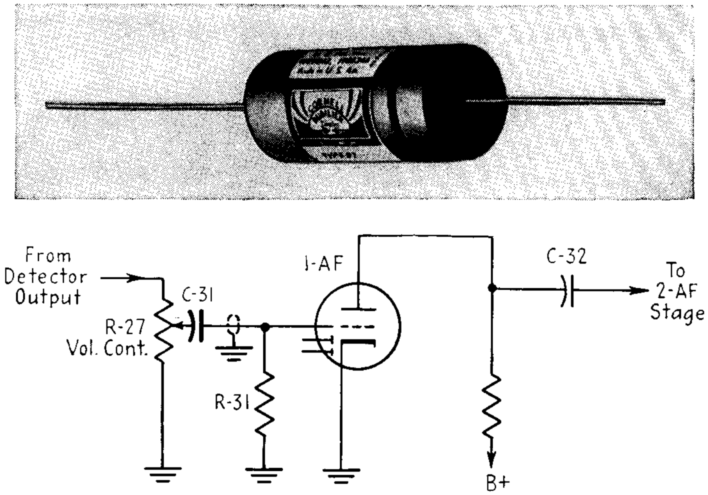


FIG. 11–17. The input coupling condenser and its position in the input circuit of the first AF stage.

Control-grid wiring. Any of the wiring from the detector output to the first AF grid is likely to pick up hum and, as a result, should be either carefully routed or shielded. Where shielding is not used, the wiring is usually kept close to the chassis and away from filament leads that carry 60-cycle current. Often, when a top grid contact tube like the 75 or 6Q7-G is used, the wire goes up to the grid, *inside* the tube shield. In replacing tubes, people sometimes leave the grid lead off, replace the shield, and bring the grid wire up outside of the shield. Besides increasing the possibility of hum, the shield also may cut through the insulation of the grid wire grounding the signal. When a shielded wire is used, an end of the shielding may work its way through the wire insulation and likewise ground the signal.

In either case, the trouble would be found by means of a signal check:

normal response from the first AF plate and no response from the first AF grid. An ohmmeter check from grid to ground will confirm the trouble.

In repairing the radio where the tube shield has cut through the insulation, it would be safest to replace the entire lead, since any repair job so close to the chassis is likely to work away and ground the grid wire again.

When a radio with a defective shielded lead is repaired, replacement of the entire lead is also necessary.

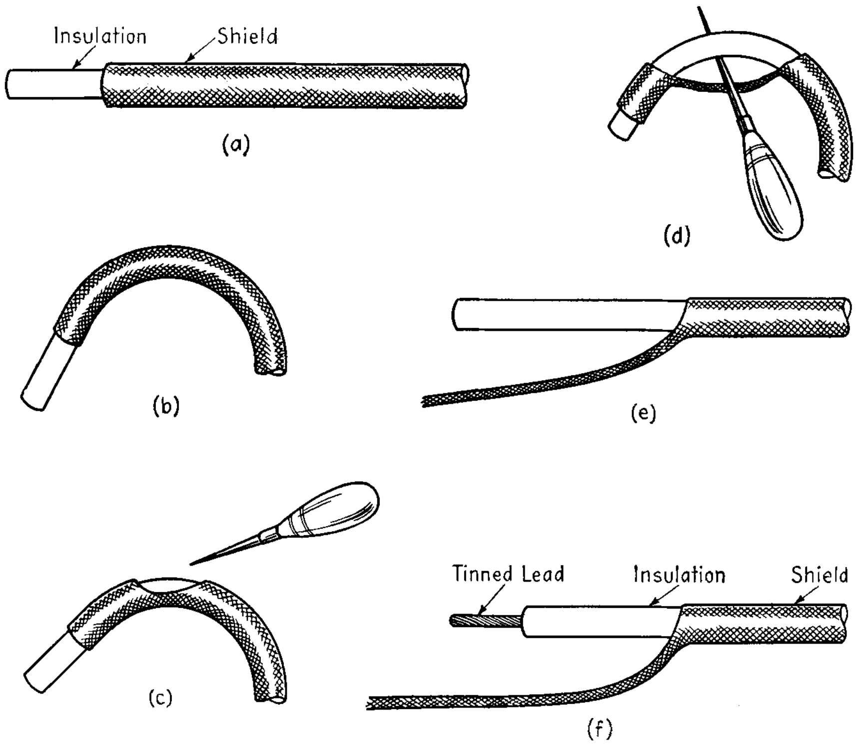


FIG. 11–18. How to prepare shielded wire for use: (*a*) push back the shielding to loosen the weave; (*b*) bend a loop in the lead; (*c*) work the weave back and forth with a pointed instrument until the hole is large enough to pull the wire through; (*d*) pull the end of the wire through the hole; (*e*) pull out the empty piece of sleeving; (*f*) strip and tin the ends of the lead.

How to prepare shielded wire for use

1. Cut off the proper length. Include allowance for connections.
2. Push back the shielding to loosen the weave, as shown in Fig. 11–18*a*.
3. Bend a loop in the lead, as shown in Fig. 11–18*b*.

4. Work the weave back and forth with a pointed instrument at the top of the loop, until the hole made is large enough to pull the wire through. See Fig. 11–18*c*.
5. Slide the scriber under the wire and pull the end through the hole, as shown in Fig. 11–18*d*.
6. Pull out the empty piece of sleeving, as shown in Fig. 11–18*e*.
7. Repeat steps 1 to 6 at the other end of the shielded wire.
8. Strip and tin the ends of the lead ready for connecting, as shown in Fig. 11–18*f*.

When a shielded cable is replaced, use the prepared ends of the sleeving for the connection to the chassis. Do not attempt to solder the shielding in the middle of the lead to the chassis. The heat of the iron will probably ruin the insulation inside the shield.

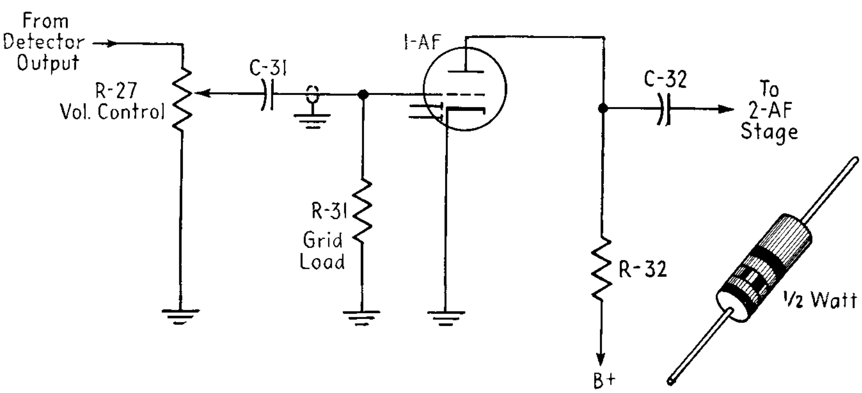


FIG. 11–19. The first AF grid-load resistor and its position in the circuit.

Troubles common to the grid-load resistor. Grid-load resistor *R*-31 may open, resulting in motorboating as was described for *R*-12, the grid-load resistor of the second AF stage on page 104. This would be found by the standard check for motorboating, which is to check the filter condensers in the power supply and then to look for an open grid circuit.

When replacing *R*-31, be sure to use the same ohmic value as is called for in the receiver diagram. A wrong value here would change the contact bias (see page 126) and result in poor tone.

Troubles common to the first AF amplifier tube. The first AF amplifier tube *V*-4 is the most likely source of trouble in the stage. Hum, no reception, weak reception, noisy reception, and intermittent reception might all be due to the tube. The best check is to substitute a similar tube known to be good. When the signal check shows normal response from the first AF plate and weak or no response from the first AF grid, the tube is a likely suspect.

Troubles common to the plate-load resistor. Plate-load resistor *R*-32 sometimes opens. The signal check would show normal response from the first AF plate and no response from the first AF grid. A voltage check would then show no voltage at the first AF plate.

Troubles common to the output coupling condenser. Coupling condenser *C*-32 is subject to many ills that impair performance of the receiver. It opens, shorts, becomes leaky, and opens intermittently.

An open condenser would result in a dead receiver and is found by a signal check. There would be a normal response from the second AF grid and no response from the first AF plate. Such a response could also be caused by a plate-to-ground short, which should be checked. This last possibility would be eliminated by a normal plate-voltage reading. The open condenser would then be confirmed by substituting a test condenser.

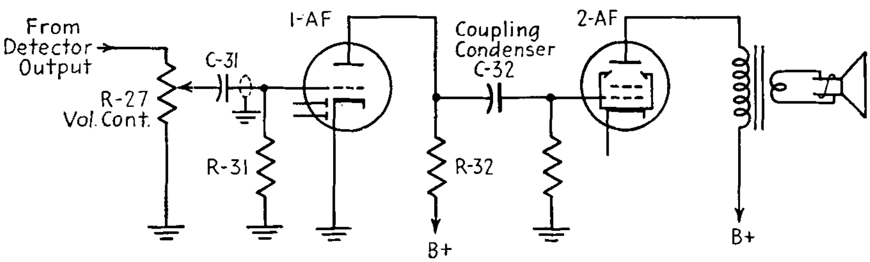


FIG. 11–20. Coupling condenser C-32 between the first AF and second AF stages.

If *C*-32 is shorted or has low leakage resistance, the tone quality would be badly affected. Positive voltage from the first AF plate would leak over the defective coupling condenser to the second AF grid, disturbing the bias voltage on the second AF tube, with distortion as a result. The condition would be found in a voltage check of the second AF stage. Insufficient or positive bias on the second AF tube grid would cause heavier than normal plate current and result in an abnormally large potential across the output transformer primary and an unusually large potential difference between plate and screen voltages. This check is more reliable than a positive indication on the second AF grid, which may be small and therefore missed in the case of high leakage resistance. In the latter case, even though a small positive voltage leaks across the coupling condenser, it will still decrease the applied bias voltage, with consequent increased plate current and reduced signal handling capabilities. Since a leakage resistance of several megohms would be hard to measure on the average ohmmeter but would still cause distortion, a good confirmation check would be the following: Open the coupling condenser from its grid connection, and check for voltage to ground, as shown in Fig. 11–21. With a good condenser, the voltmeter needle will swing up as the condenser charges and return to the zero position, when the condenser is fully charged. Leakage resistance in the condenser will cause the voltmeter needle to remain at some position higher than zero. Owing to the high activating voltage at the first AF plate, a leakage resistance of several megohms will cause a readable deflection on even a 1,000-ohms-per-volt voltmeter.

If the coupling condenser is intermittently open, fading will result; the receiver will not operate when it is open and will resume operation when it is closed. This condition is due to a poor contact between one of the condenser leads and the tin foil of the condenser plates. Usually the condition can be confirmed by yanking gently on the condenser leads, thereby starting and stopping reception. Parenthetically, it may be added

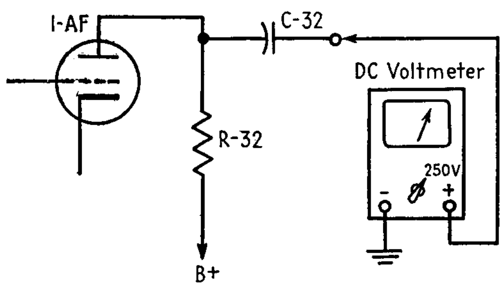


FIG. 11–21. How to check an audio coupling condenser for leakage.

that, when a receiver is serviced for fading, all coupling condensers should be replaced as a matter of course.

When coupling condenser *C*-32 is replaced, a good-quality condenser should be used. The condenser should have a rating of 600 volts. Although a 400-volt condenser is sufficient for the voltages normally found in this circuit, the thicker dielectric of the 600-volt size makes for less likelihood of leakage. The capacity used should be the one called for in the receiver diagram. If a different capacity is used, the serviceman should remember that a higher capacity will give a better low-frequency audio response.

CIRCUIT VARIATIONS IN THE FIRST AF STAGE

Bass compensation circuit. It is characteristic of the human ear to be less sensitive to low audio frequencies than to high ones at reduced volume levels. To compensate for this deficiency, the circuit of Fig. 11–22 is found in many receivers.

Potentiometer *R*-27 is a tapped volume control with the tap located in the low-volume area. When the arm is in the high-volume position near the ungrounded end of the volume control, *C*-127 has little effect. As the volume is reduced and the arm approaches the tap, *C*-127 by-passes some of the high AF signal from the amplifier, thereby making the low audio frequencies seem stronger. The effect is greatest at the tap which will be

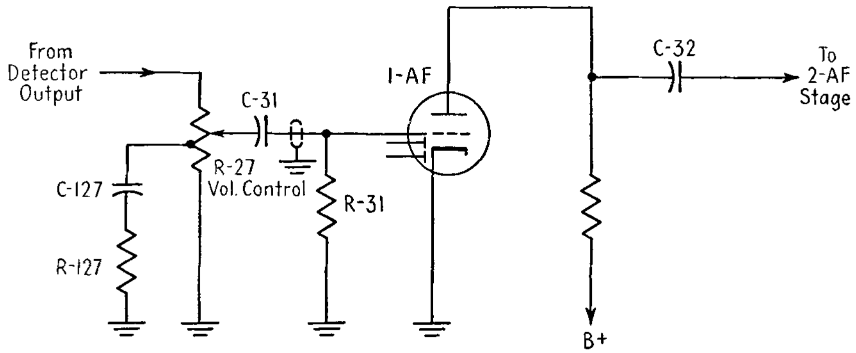


FIG. 11–22. Bass compensation at the first AF stage.

at the low-volume position for the particular receiver. Resistor *R*-127, which may be omitted from some circuits, is to keep the by-passing effect from being too pronounced at the tap and to broaden the region around the tap where the bass compensation circuit is effective.

Some receivers carry out the tone compensation at two points on the volume control, as shown in Fig. 11–23. The volume control is tapped at

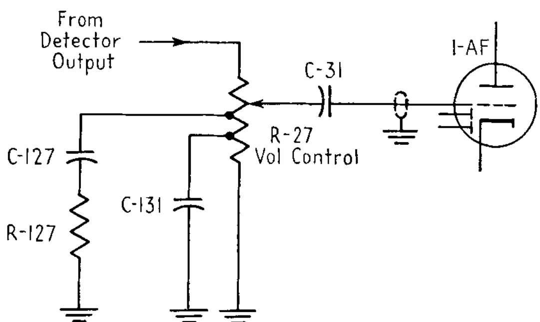
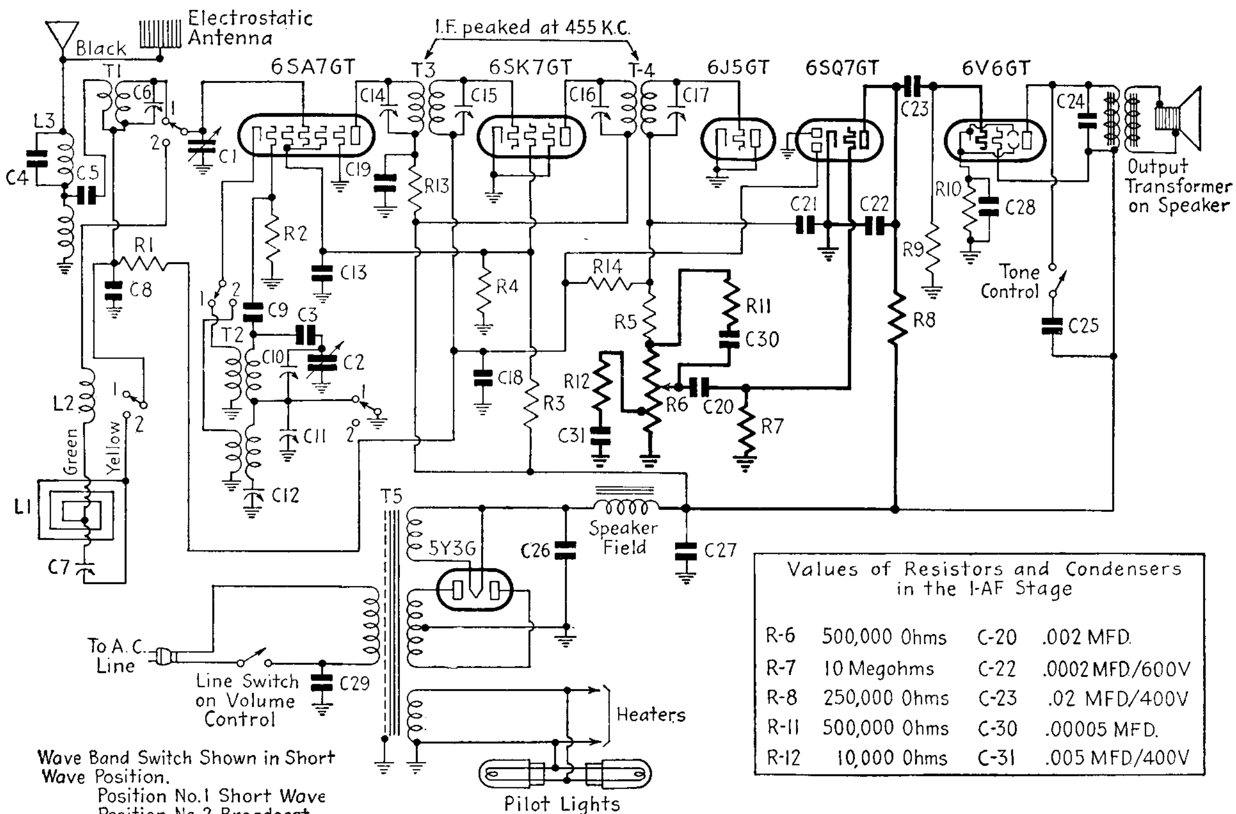


FIG. 11–23. Bass compensation at two points in the volume range.

two points. Again, at the high-volume position the high-frequency by-pass circuits have little effect. As the volume is reduced, a slight amount of bass compensation is attained through *C*-127 and *R*-127. As the volume is reduced further, more bass compensation is attained through condenser *C*-131. All checks and operations are the same as for the standard circuit.



Values of Resistors and Condensers in the I-AF Stage

R-6	500,000 Ohms	C-20	.002 MFD.
R-7	10 Megohms	C-22	.0002 MFD/600V
R-8	250,000 Ohms	C-23	.02 MFD/400V
R-11	500,000 Ohms	C-30	.00005 MFD.
R-12	10,000 Ohms	C-31	.005 MFD/400V

FIG. 11–24. Emerson Model EQ-368 receiver. The first AF circuit is shown in heavy lines.

Condensers *C*-127, *C*-131, and resistor *R*-127 rarely if ever give any service difficulty. Volume control *R*-27, however, is subject to all the ills of volume controls. In replacing *R*-27, the serviceman must find an exact replacement for proper operation of the bass compensation circuit.

Figure 11–24 illustrates some of the points taken up in this chapter on the first AF stage. Note the tone-compensation circuit connected to the volume control *R*-6. At high-volume levels the filter is ineffective. When the potentiometer arm is in a low-volume position near the tap, condenser *C*-31 and resistor *R*-12 by-pass high audio frequencies to ground. Since the attenuation of very high audio frequencies will be excessive, the circuit composed of *R*-11 and *C*-30 restores some of these frequencies to the arm of the volume control. The net result is an increase in low AF response at low-volume levels without entirely removing the high audio frequencies.

Note also the use of a separate detector tube, the 6J5-GT, with the plate tied to the cathode as one diode element while the grid functions as the other. The rest of the first AF circuit follows the standard circuit closely except for the use of condenser *C*-22 across the plate circuit of the tube. This limits the high-frequency response. Note that *C*-22 is a 600-volt condenser and will therefore give little service difficulty. If condenser *C*-22 were shorted, the trouble would be narrowed down to the first AF stage by signal check, since there would be normal response from the second AF grid and no response from the first AF grid. A voltage check would show no plate voltage at the first AF plate. Since this condition could also be caused by an open plate-load resistor *R*-8, an ohmmeter check would finally confirm *R*-8 open or *C*-22 shorted.

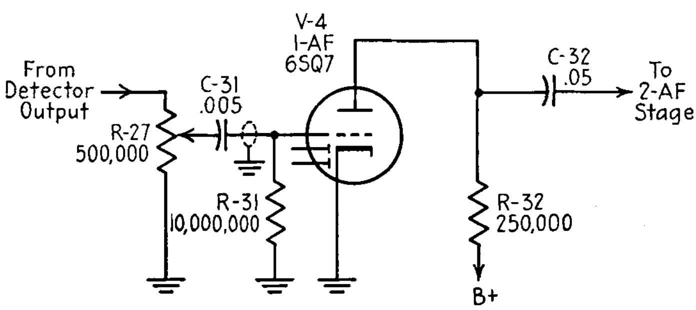
SUMMARY

Quick check for normal operation of the first AF stage

A wet finger or a plugged-in soldering-iron tip applied to the ungrounded end of the volume control causes a very strong growl to be heard in the speaker.

Standard first AF diagram

The accompanying figure shows the standard first AF diagram.



Normal first AF voltage data

Voltage is measured from chassis or the common negative in an AC/DC receiver. Data given in the accompanying table.

Tube terminal	*12SQ7 and 6SQ7 pin No.*	*AC receivers, volts*	*AC/DC receivers, volts*
Plate	6	100–170	40–60
Grid	2	0	0
Cathode	3	0	0

Normal first AF resistance data

Chassis or common negative to cathode	0 ohms
Chassis or common negative to grid	10 megohms
Plate to *B* plus	250,000 ohms

SERVICE DATA CHART FOR AN INOPERATIVE FIRST AF STAGE

Assume an inoperative first AF stage as shown by normal response when an AF test signal is applied to the second AF grid, and no response when the test signal is applied to the ungrounded end of the volume control. The following service procedure is recommended.

Step	*Signal check*	*Response*	*Trouble*
1	Apply AF test signal to first AF plate	None or weak	Look for open coupling condenser C-32 or first AF plate short-circuiting to chassis
		Normal	Proceed to step 2
2	Apply AF test signal to first AF grid	None or weak	Look for plate voltage on first AF plate (open *R*-32). Substitute a good first AF tube. Look for a shorted grid lead (shielding)
		Normal	Proceed to step 3
3	Apply AF test signal to volume control arm	None or weak	Look for open coupling condenser C-31. Look for grounded volume-control arm (shielding)
		Normal	Open volume control. Grounded "hot" end of volume control

SERVICE DATA CHART FOR OTHER SYMPTOMS

Symptom	*Abnormal reading*	*Look for*
Poor tone quality	First AF plate voltage low	Short-circuited or leaking coupling condenser C-32
	Voltages normal	Short-circuited or leaking coupling condenser C-31. Incorrect value of grid load *R*-31
Motorboating		Open grid load *R*-31
Hum	Voltages normal	Defective first AF tube. Incorrectly dressed grid leads. Positioning of coupling condenser
Intermittent reception (fading)		Coupling condensers C-31 and C-32 may open intermittently. Defective first AF tube. Defective volume control

QUESTIONS

1. A receiver is being serviced for weak reception. A signal check shows no gain for the first AF stage. Outline a test procedure for determining the cause of the trouble.

2. The receiver of Fig. 11–24 has poor tone quality. A voltage check shows 50 volts on the first AF plate. What is likely to be wrong and how would you confirm your assumption?

3. The receiver of Fig. 11–24 has a noisy volume control. After the volume control is replaced with an exact replacement, the volume remains at one level regardless of the position of the control arm. What is wrong? How would you check to prove it?

4. A receiver very much like the standard superheterodyne motorboats. How would you check to find the cause in the power supply? In the second AF stage? In the first AF stage?

5. An AC receiver hums excessively. When the first AF tube is removed from its socket, the hum level drops to normal. How would you check the various possibilities for hum in the first AF stage?

6. What are the possible causes of intermittent reception in the first AF stage? How would you check for each?

7. A receiver gives normal response when an AF test signal is applied to the first AF grid and a very weak response when the test signal is shifted to the hot end of the volume control. What are the possible causes of the defect and how would you check for each?

8. A receiver gives normal response when an AF test signal is applied to the second AF grid and no response when the test signal is shifted to the first AF grid. What are the possible causes of the trouble and how would you check for each?

9. What is a good test for high leakage resistance in a coupling condenser between a first AF plate and a second AF grid?

10. The receiver of Fig. 10–14 has been completely overhauled and reconditioned. As part of the servicing procedure the first AF grid-load resistor *R*-11 had been found to be open and replaced. However, it had been replaced with a 1-megohm resistor in error. The customer later complains that his radio does not sound so clear as before. Could the incorrect first AF grid-load resistor be the cause of this condition? Explain your answer.

11. The receiver of Fig. 10–18 does not play. A 400-cycle test signal applied to the second AF grid produces a normal note in the loudspeaker. When the test signal is shifted to the first AF grid, no response is heard in the speaker. A voltage check of the first AF stage shows 0.5 volt negative at the grid pin, and zero at the plate pin. What are the likely causes of the trouble, and how would you check for each?

12 DETECTOR STAGE—AVC

Quick check for operation of the detector stage. A modulated signal at the intermediate frequency of the receiver being checked is applied to the IF control grid. If the signal-generator modulation note is heard in the speaker, the detector stage is probably functioning properly, and the serviceman moves forward to the next stage.

Since the AVC (automatic volume control) action is dependent on the operation of the RF converter and IF stages, there is no quick check for AVC operation at this point.

Function of the detector and AVC stage. In modern receivers, detection and automatic volume control are accomplished in one circuit and, although they are two separate functions, must be treated together.

The input signal, normally fed to the detector stage, is an alternating voltage at the intermediate frequency of the receiver and modulated by the audio component of the original signal picked up by the antenna. The signal that appears across the output of the detector stage is the audio component only. One function of the detector and AVC stage, therefore, is to demodulate the signal; that is, to remove the audio component and pass it on to the audio amplifier.

The detector stage or tube is sometimes called the "demodulator," the reason for which is obvious from its function. It is also sometimes called the "second detector" to distinguish it from the mixer tube, an old name for which was "first detector."

AVC action can be described as follows: A strong local station delivers a strong signal to a receiver. A station at some distance away will deliver a much weaker signal to it. Yet it is desirable for each of these stations to produce approximately the same volume from the speaker. This effect could be performed manually by means of a volume control, but it is far superior if this effect is performed automatically. That is the function of the AVC system.

The upper limit of sensitivity of a receiver is set by the design characteristics of the receiver itself. However, the AVC circuit reduces the sensitivity of the receiver more or less below the upper limit—more for a strong signal and less for a weaker signal. This effect is produced by the use of remote-cutoff (variable-mu) tubes in the RF and IF stages of the receiver. The gain of these tubes changes with different control grid-bias voltages: at greater negative bias, the gain is lower; at lower negative grid bias, the gain is greater. In an AVC circuit, the station signal itself develops negative bias voltage for the control grids of the remote-cutoff tubes. A strong signal develops a large negative bias voltage which reduces the gain of the controlled tubes. A weak signal develops a smaller negative bias voltage which does not reduce the gain of the controlled tubes so much. As a result, a fairly constant volume is

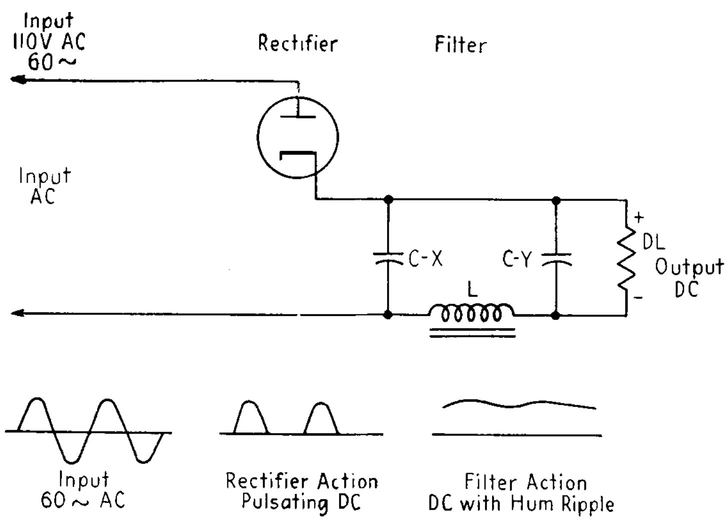


FIG. 12–1. Half-wave *B* power supply.

obtained from the speaker, regardless of the original strength of the receiver signal within the limits of the sensitivity of the receiver.

Theory of operation. The detector and AVC stage in modern receivers performs its functions in a circuit arrangement very similar to that of a power supply; that is, it also employs a diode rectifier and filter circuit. Since power-supply circuits are generally understood, a parallel will be drawn to explain the operation of the detector and AVC stage.

Consider the half-wave rectifier circuit shown in Fig. 12–1, common in AC/DC receivers. The input is 110 volts AC. Only when the positive phase of the input voltage is impressed on the plate will current flow through the tube. The circuit is completed through load resistor *DL*. Condensers C_x and C_y and choke *L* make up the smoothing filter. The wave forms of Fig. 12–1 show the complete action of the circuit. Note the polarity of the voltage across load resistor *DL* and the hum ripple that is present. If it is desired to eliminate the hum ripple, a second section *L*-*C* filter would be added, as in Fig. 12–2.

In the detector stage, to draw a parallel, the input voltage is across the tuned secondary of the IF transformer *T*-5, as shown in Fig. 12–3. The graph below *T*-5 represents the input voltage at the intermediate frequency and modulated by its audio component. Similar to the action in the power supply, the rectifier chops off the negative half of the input voltage, as represented in the graph under the rectifier tube V-4A. Now let us examine the filter circuit. A filtering resistor *R*-26 has been substi-

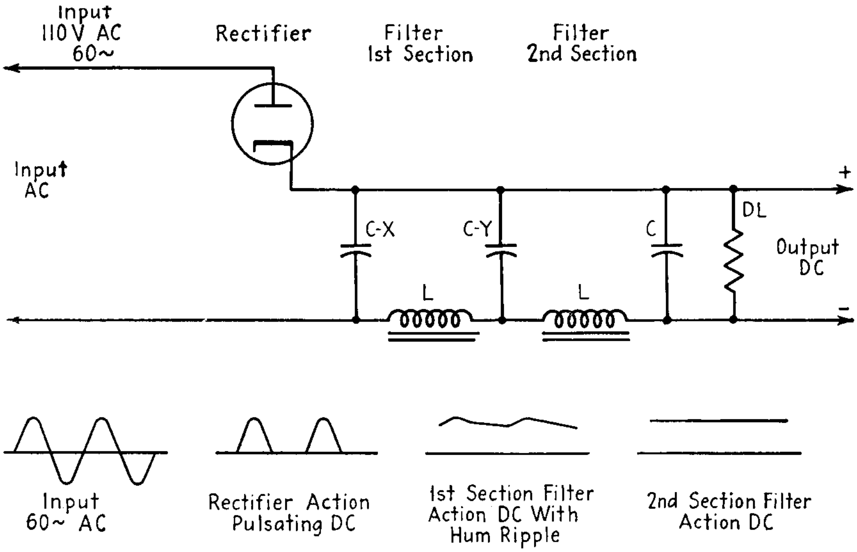


Fig. 12–2. Eliminating hum ripple by means of a second section filter.

tuted for the choke. It serves a similar function. In the power supply, the filter condensers are usually 20 mfd each. In the detector filter circuit, *C*-26 and *C*-27 are usually 0.0001 mfd apiece. This filter circuit will not give unvarying direct current as its output but will make an effective filter at the intermediate frequency (455 kc). The output at this point will be the audio component of the signal which is impressed across the resistor *DL*, since the audio signal cannot be by-passed across the low-capacity condensers *C*-26 and *C*-27. Resistor *DL* is called the "diode load" and is usually the manual volume control of the receiver. With the audio signal across the volume control, the position of its arm determines the strength of the signal fed to the audio amplifier.

The audio signal, owing to its strong pulsations, is not suitable for use as an automatic bias voltage, since any bias voltage should be pure direct current. Therefore a second section filter, *R*-28 and *C*-28, is added

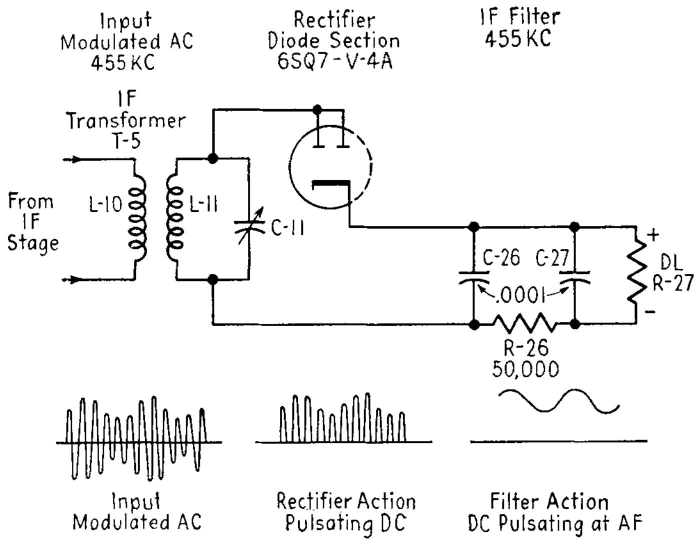


Fig. 12–3. Diode detector operation—developing the audio output signal from the modulated IF input signal.

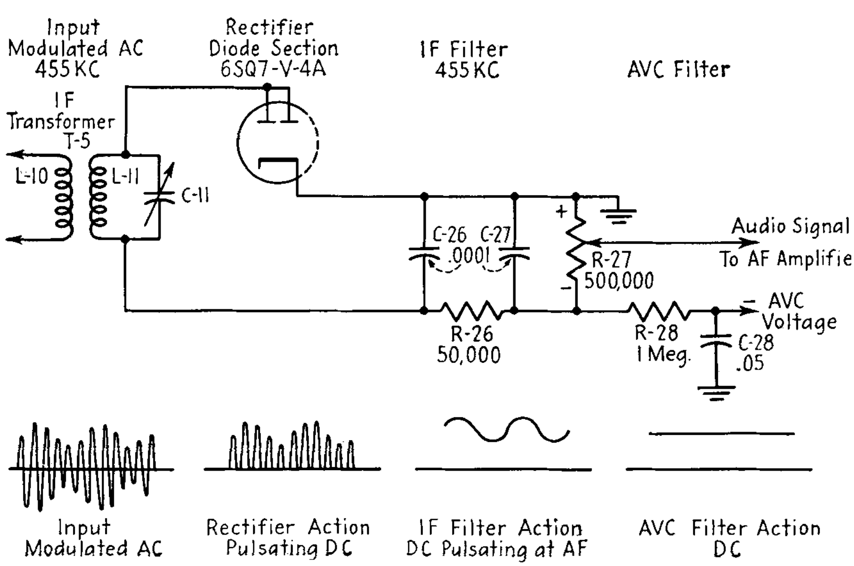


Fig. 12–4. Developing audio signal and AVC voltage from the modulated intermediate-frequency signal.

after the audio circuit to smooth it to direct current, as shown in Fig. 12–4. The capacity of *C*-28 is 0.05 mfd to make it effective at audio frequency.

Now note again the polarity of the voltage across the diode load. If the diode cathode is grounded, the voltage at *R*-28 will be negative with respect to ground, and therefore suitable for use as bias voltage. The amount of voltage available at *R*-28 will depend on the voltage of the signal impressed across the secondary of the IF transformer *T*-5, since it is the rectified and filtered output of the signal voltage. For strong signals, the signal voltage across *T*-5 is high, the AVC bias voltage is high, and the amplification of the controlled RF and IF tubes is reduced. For weak signals, the signal voltage across *T*-5 is low, the AVC bias voltage is low, and the amplification of the controlled tubes is greater.

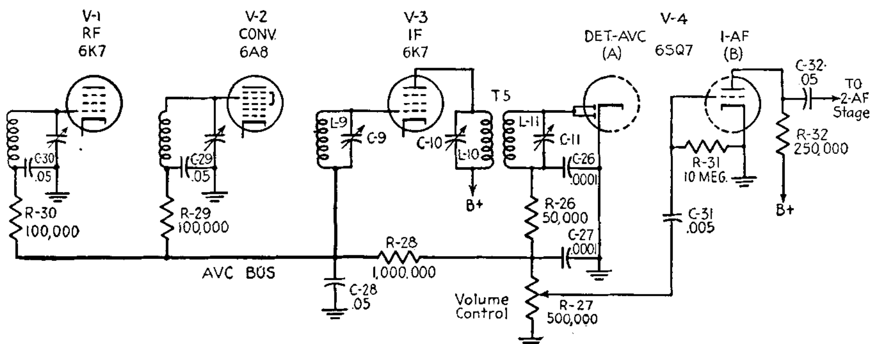


FIG. 12–5. Typical detector and AVC circuit.

Figure 12–5 shows the detector and AVC system, including the control-grid circuits of the controlled tubes, and the coupling to the first AF stage. The wire that feeds the AVC voltage to the controlled tubes is known as the "AVC bus."

Resistor *R*-30 and its associated condenser *C*-30 in the RF grid return lead isolate the RF stage from the other stages. This is called a "decoupling" filter, which will be described in a later section. Resistor *R*-29 and condenser *C*-29 serve a similar function for the converter stage.

Functions and values of component parts. Potentiometer *R*-27 is the manually operated volume control for the receiver. In the detector stage, it acts as the diode load resistor, and the audio component of the signal voltage is developed across it. A portion of this voltage is taken off at the volume-control arm and is amplified as was described in Chap. 11. The ohmic value of *R*-27 is usually 500,000 ohms, although higher values are sometimes found in circuits where, at the increased load resistance, a higher value of audio output voltage is possible.

Condensers *C*-26 and *C*-27 and resistor *R*-26 make up the IF filter circuit. In this circuit, the IF pulsations are removed, leaving the audio envelope. Resistor *R*-26 is usually 50,000 ohms, and condensers *C*-26 and *C*-27 are usually 0.0001 mfd for an intermediate frequency of 450 to 480 kc. Sometimes these capacities are a little higher, not so much for more efficient filtering as for attenuation of high audio frequencies with resultant improvement of the apparent low AF response.

Resistor *R*-28 and condenser *C*-28 form the additional filter for the AVC voltage. In this circuit, audio pulsations are removed. Since the controlled grid circuits do not require current, *R*-28 can have a high value of resistance for efficient filtering of the AF pulsations, and *C*-28 by-passes the remainder to ground. In receivers containing an RF stage and decoupling filters, *R*-28 is usually 0.5 or 1 megohm. In receivers that do not employ an RF stage, *R*-28 is usually higher, 2 megohms being the average size. *C*-28 is almost always 0.05 mfd.

The diode employed in the detector and AVC stage is the duo-diode section of the 6SQ7 tube, with the diode plates connected together, and the triode section functioning as the first AF amplifier tube. Some receivers use a 6Q7 duo-diode high-mu triode which is very similar to the 6SQ7, the difference being in the location of the audio grid pin. Receivers that use the local type of tubes employ the 7C6, and receivers with miniature tubes use the 6AV6. When a separate tube is used for the detector, it is the 6H6 or 6AL5 twin diode.

Occasionally, the detector diode is combined with the IF amplifier in one tube, as is the case with the 6B8 duplex-diode pentode. In these receivers, the following AF tube is usually a twin triode like the 6SC7 which combines the first AF and inverter functions in one tube.

Older varieties of the circuit combined the detector, AVC, and first AF functions in the 75 tube. Older circuits, using a separate tube, use the 37 triode with cathode and plate tied together to form one diode electrode while the grid functions as the other. An early issue of the 6B8 is the 6B7 duplex-diode pentode, where the detector, AVC, and IF amplifier functions are combined in one tube.

In AC/DC receivers employing 0.3-amp heaters, the 6Q7 and 6SQ7 are widely used. Where the 0.15-amp heater tubes are used, the 12AT6, 12SQ7, and 14B6 duplex-diode, high-mu triodes are found.

IF transformer *T*-5 couples the IF stage output signal to the detector stage. Usually both primary and secondary are tuned to the intermediate frequency by trimmer condensers *C*-10 and *C*-11. The latter are usually part of the transformer assembly. Sometimes condensers *C*-10 and *C*-11 are fixed, and tuning is accomplished by varying the position of powdered-iron core plugs inserted in the coils of the transformer. The latter method is known as "permeability tuning." Typical transformer assemblies are shown in Figs. 12–8 and 12–9.

NORMAL TEST DATA FOR THE DETECTOR AND AVC STAGE

Signal check. The input of the detector stage is the IF transformer *T*-5. However, when the stage is checked, the signal generator is connected to the grid of the IF tube, as shown in Fig. 12–6. There are several reasons for this connection:

1. Since the detector input is the last step in the RF chain, the signal voltage at this point is high, higher than the RF output of most signal generators, and the amplification of the IF tube may be needed to make the signal more easily heard in the speaker.
2. If the added capacity of the signal-generator leads were connected to the IF plate, the normal input of the detector stage, it would seriously detune the primary circuit of *T*-5, making the response broad and possibly at an off-frequency setting.

The 0.1-mfd condenser in the hot lead of the signal generator acts to isolate the signal generator from DC receiver potentials in case the signal input is connected to a plate lead. It is also the standard dummy

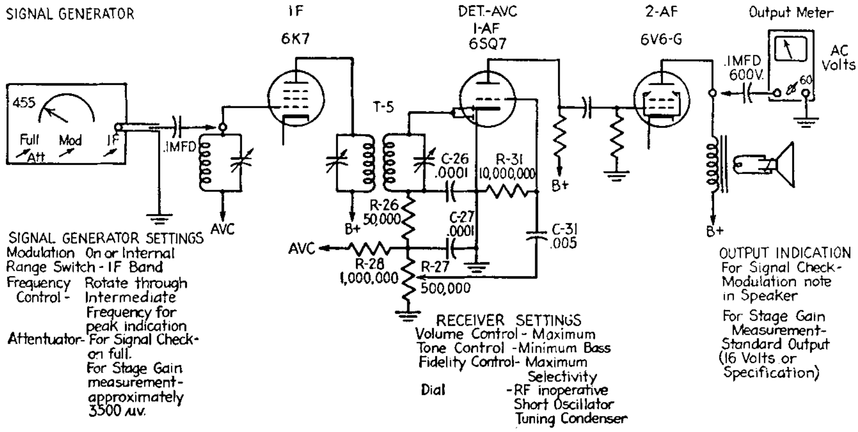


FIG. 12–6. Signal check connections for the detector and AVC stage.

antenna capacity (coupling device) between the signal generator and the receiver for IF measurements. The output indication is the signal-generator modulation note in the speaker. This can be measured by connecting the output meter (35- to 60-volt AC range of the multimeter with a 0.1-mfd/600-volt condenser in series) from the second AF plate to ground, as was discussed on page 131.

When the signal check is made, it is also wise to check the intermediate frequency of the receiver, which is always listed in the manufacturer's service notes. In modern receivers it is usually 455 kc. For several years, the intermediate frequency chosen by the receiver manufacturers has varied between 450 and 480 kc. In very old receivers intermediate frequencies of 260, 175, and 130 kc have been used. In checking the alignment and operation of the stage, the previous stages of the receiver should be made inoperative. This is done by shorting the oscillator section of the tuning condenser. To determine which of the sections of the gang tuning condenser is the oscillator, the serviceman should trace the circuit; or it is sometimes possible to locate the oscillator section by faster methods. In some receivers, the oscillator rotor plates are smaller than the other rotor plates in the gang condenser. Another method that can be used when the receiver is operating on a station is to touch only the stator plates of the various sections. When the RF and converter sections are touched, there will be little difference observed. When the oscillator section is touched, the added capacity of the body will cause the station to disappear. A short piece of flexible wire with a clip at each end will serve as the short. One end is clipped to either stator terminal lug; the other is clipped to the condenser frame.

To check alignment, the signal-generator dial is rotated through the intermediate frequency, while the output meter reading is observed. The presence of two peaks, broad tuning, too low an output, or the peak at a considerable difference from the specified frequency—all indicate misalignment.

Sensitivity measurements for the detector stage. When making sensitivity and stage-gain measurements, since it is unlikely that the test oscillator has a calibrated output, the serviceman should run checks on several receivers in perfect condition, as was done for the audio amplifier (see Chap. 11), until he has a basis of comparative data for normal gain to be expected from the stage.

The signal generator, receiver, and output meter are hooked up, as shown in Fig. 12–6. The receiver is adjusted for maximum output as follows: The volume control is set at maximum; the tone control is set at the minimum bass position; the fidelity control (if present) is set for maximum selectivity. The RF portion of the receiver is made inoperative by shorting the oscillator section of the gang variable condenser.

The signal generator is adjusted to give a modulated signal at the intermediate frequency of the receiver. The signal-generator dial is rotated back and forth through the intermediate frequency while the output meter is being watched, and is carefully adjusted for peak deflection. If the output meter deflection goes off scale, the signal input is reduced by adjusting the signal-generator attenuator. After the peak deflection has been obtained, the signal-generator attenuator is further adjusted to give the standard output of 50 mw in the speaker. Standard output corresponds to an output meter reading of 16 volts (see page 130).

The average signal input at the IF grid necessary to give standard output is 3,500 microvolts. The attenuator setting just obtained, therefore, corresponds to 3,500 microvolts. After several perfect receivers have been checked by the above procedure, a reference point corresponding to 3,500 microvolts has been duly established. It would be more important for the serviceman to remember this average attenuator setting for his signal generator rather than the corresponding 3,500 microvolts. For example, if his average attenuator setting turns out to be 50 × 100, or 5,000, he knows that a setting of approximately 5,000 on the attenuator of his signal generator should produce standard output when connected to the IF grid of any receiver. Any substantial variation from his average or normal attenuator setting indicates trouble in the stage.

Normal voltage data for the detector stage. The voltages normally present in the detector and AVC stage are the signal voltage and the developed AVC voltage. Normal-voltage data are usually given as an aid in determining the cause of defective operation. Since measurements of these voltages would require expensive equipment and are therefore not easily obtained, normal voltages will not be given, and defects for this stage will be localized by means of resistance measurements.

Standard circuit for the detector and AVC stage. A typical detector and AVC stage is illustrated in Fig. 12–7.

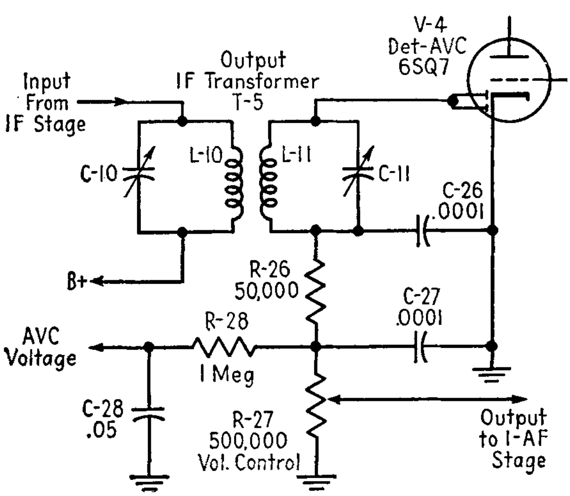


FIG. 12–7. Typical detector and AVC stage.

Normal resistance data. These data are given in the table on the next page.

Primary (L-10) of output IF transformer (T-5)	Iron core Air core	5–15 ohms 30–50 ohms
Secondary (L-11) of output IF transformer (T-5)	Iron core Air core	5–15 ohms 30–50 ohms
Chassis to diode plates (pin Nos. 4 and 5)		550,000 ohms
Across entire volume control		500,000 ohms
Chassis to AVC bus		1,500,000 ohms

COMMON TROUBLES IN THE DETECTOR AND AVC STAGE

Troubles common to the output IF transformer assembly. The trimmer condensers C-10 and C-11 are parts of the transformer assembly and will be considered with it. From a service standpoint, the trimmer condensers do not often cause difficulty, except in relation to alignment. At worst, they collect dust or a trimmer screw is lost because of careless alignment. The cures for these conditions are obvious. In permeability-tuned transformers, the alignment screws and fixed mica condensers cause even less trouble.

In operation, IF transformers open and cause noisy reception. Should either winding of the transformer open, the receiver would become inoperative. A signal check would locate the stage; a resistance check would show the open winding. Noisy reception, when it is caused by the transformer, is due to corrosion of the fine wire in the windings. A resistance check discloses this condition also, since the resistance of a corroded winding is several hundred ohms instead of the 5 to 50 ohms that the winding should read.

There is a rather wide divergence in the design of individual IF transformers, and the serviceman should make every effort to secure an original replacement. Where this is impossible, coil manufacturers offer a rather large variety of universal replacement IF transformers. These are listed by the following factors:

1. Size of the shield can.
2. Type of core (air or iron).
3. Type of aligning adjustment (trimmer or permeability tuning).
4. IF range of the transformer (scope of trimmer).
5. Type of transformer (input, interstage, output). These are the factors that the serviceman should have in mind when replacing an IF transformer.

Sometimes the IF filter circuit composed of R-26, C-26, and C-27, or part of it, is mounted with the transformer and trimmer assembly inside

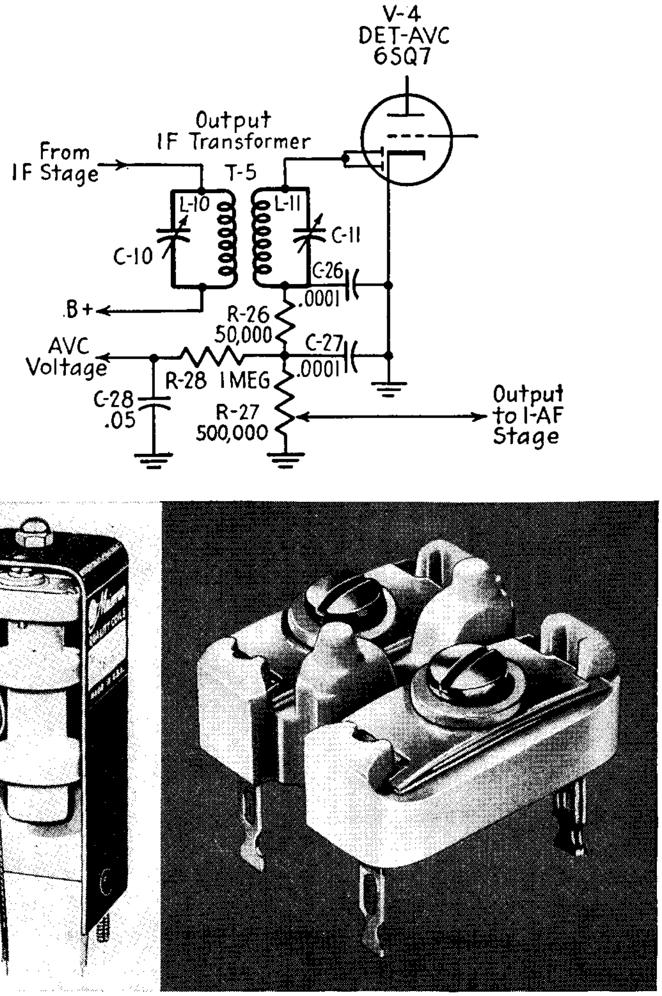


FIG. 12–8. Typical output IF transformer assembly and its position in the detector stage. Enlarged view of trimmers is shown at lower right.

the shield can. When this is the case and an exact replacement is unobtainable, provision should be made to reinsert the filter circuit which was discarded with the defective transformer.

Replacement IF output transformers are usually color-coded in accordance with the R.M.A. specifications as follows:

Blue	Plate lead
Red	*B* plus lead
Green	Diode plate lead
Black	Diode return

Before removing an IF output transformer for replacement, the serviceman should study the wire dress of the leads, since oscillation can result from incorrectly dressed wiring. If the leads have already been disturbed, the following general notes should be observed. The leads are usually well separated as they come out of the shield can. In the case of a square shield can, the leads come out of the four corners. Before the replacement transformer is mounted, it should be so turned that the blue

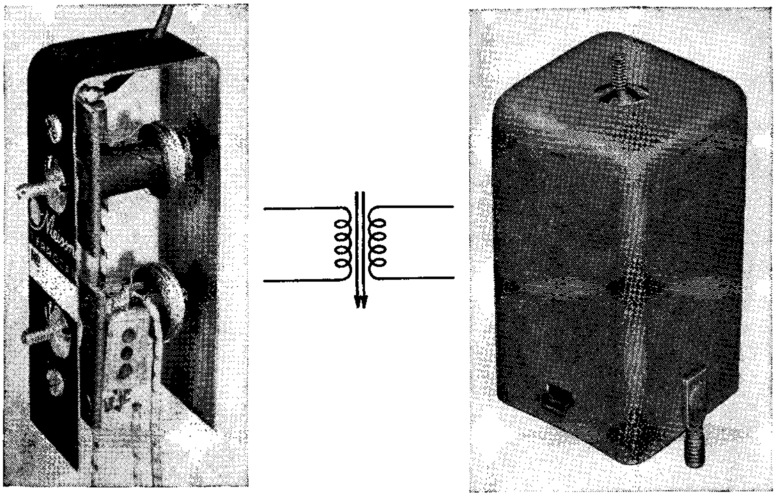


FIG. 12–9. Permeability-tuned IF transformers.

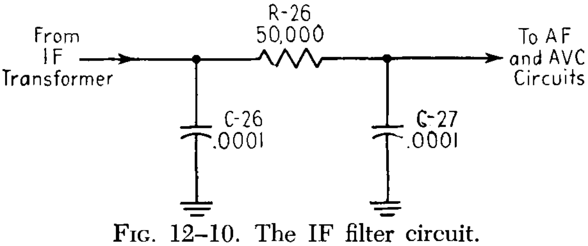


FIG. 12–10. The IF filter circuit.

plate lead points toward the IF tube socket and the green diode plate lead points toward the detector-tube socket. These are the "hot" leads. They should not cross, and they should be dressed close to the chassis and routed directly to their connection terminals.

When the transformer has been replaced, the trimmers should be aligned in accordance with the receiver manufacturer's service notes or the general alignment instructions given in Chap. 22.

Troubles common to the IF filter circuit. The voltages and currents encountered in this circuit are so small that there is no danger of burned-out resistors and condensers. The condensers sometimes develop leakage resistance. Check for this condition with an ohmmeter.

Troubles common to the volume control. The volume control sometimes opens. When this occurs, the receiver becomes inoperative. A signal check will show that the audio amplifier is working but the detector stage is not. A resistance check of the components in the detector stage will confirm the open control.

The volume control is also part of the audio amplifier. Replacement notes on the volume control are found on page 135.

Troubles common to the detector tube. The tube is the most likely source of trouble in the stage. A defective tube may cause hum, no signal, weak signal, or distortion. When checking for these symptoms, substitute a similar tube known to be good. In the case of a multiunit tube like the 6SQ7, which combines both the detector and the first AF functions, there is a possibility that the AF portion operates normally but that the detector does not. The serviceman should not assume that the tube is good because it shows normal operation as an audio amplifier.

Troubles common to the AVC filter and decouplers. Figure 12–11 illustrates the AVC circuit and shows it connected to the RF, converter, and IF stages. Resistor R-28 and condenser C-28 make up the AVC filter described previously.

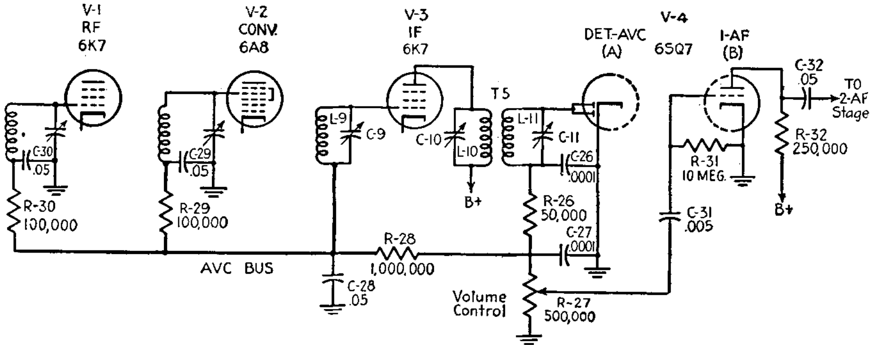


FIG. 12–11. The AVC circuit.

Strictly speaking, the purpose of the AVC circuit is to develop a biasing voltage, and it would seem best to test it by means of a voltage test. However, such a measurement would require a vacuum-tube voltmeter, since the instrument would be across a low-voltage high-impedance circuit. It would also require an accurately calibrated attenuator on the signal generator, and too often it is not accurate. Therefore, analysis of troubles in the AVC circuit will be made from the symptoms encountered.

Resistor R-28, being one of high resistance, may have a tendency to open. If it does so, the receiver will become inoperative and may develop hum because the grid returns to ground of the associated tubes will be open. Replace the resistor with one of similar value.

The AVC filter condenser C-28 may open or become leaky. If it opens, the signal will become weak and oscillation may result. This condition would be found in a signal check of the IF stage. The gain of this stage would be abnormally low. Also, the IF tuning would be very broad and possibly off true frequency, with adjustments of trimmer condenser C-9 ineffective.

If condenser C-28 becomes leaky, the AVC voltage would drop to an extent dependent on the resistance of the leak. This would result in insufficient bias to handle a strong signal. As a result, the receiver would overload and distort on strong local stations. Reducing the setting of the manual volume control would have little effect on this distortion. Whether the condenser is open or leaky, confirmation of the condition would be obtained by substituting a similar condenser that is known to be good. If the trouble disappears, the condenser was defective. In replacing C-28, the serviceman should be careful to use the same capacity value as the original condenser. Even though the voltage across it is quite low, it is advisable to use a condenser of high voltage rating so that the leakage resistance will be quite large.

Associated with the AVC circuit are the decouplers, C-29 and R-29 for the converter and C-30 and R-30 for the RF stage. As a rule, the resistors cause little trouble and are therefore of little consequence to the serviceman. However, condensers C-29 and C-30 can cause trouble. If either one opens, reception would be very weak. This condition would be confirmed with a signal check when their respective trimmer condensers would not produce a peak. Condenser C-30 is a particularly odd one. When it opens, the tuning circuit in the RF stage becomes inoperative, with a resulting drop in signal output. At the same time the loss of signal in the RF stage causes the AVC voltage to drop, resulting in high sensitivity so that the noise level goes up. The receiver sounds exceptionally lively even though strong local stations come in as weak ones do when the receiver is normal.

Condensers C-29 and C-30 may become leaky. When this is the condition, the developed AVC voltage will be low and the receiver will overload and distort. If the external antenna (when used) is disconnected and the sound of the receiver improves, the serviceman should hunt for leaky condensers.

VARIATIONS IN DETECTOR AND AVC STAGE

Use of electron-ray tuning indicator. Unless the superheterodyne receiver is tuned exactly to a station, serious distortion due to side-band cutting may result. Many receivers use some form of tuning indicator as an aid in tuning correctly, so as to avoid this distortion. The tuning indicator in most general use in modern receivers is an electron-ray (often called a "magic eye") tube like the 6U5/6G5. This is a cathode-ray tube which shows a wide deflection when a low voltage is applied to its grid. The deflection narrows as the applied grid voltage is increased. The magic-eye grid is connected to the AVC bus as shown in Fig. 12–12. At no signal, the AVC voltage is zero and the deflection is wide; as a signal is tuned in, the AVC voltage increases and the deflection narrows. When the signal is tuned accurately, the AVC voltage is at a maximum and the deflection is at its narrowest. To tune any station accurately, simply tune the receiver for the narrowest deflection of the magic-eye tube.

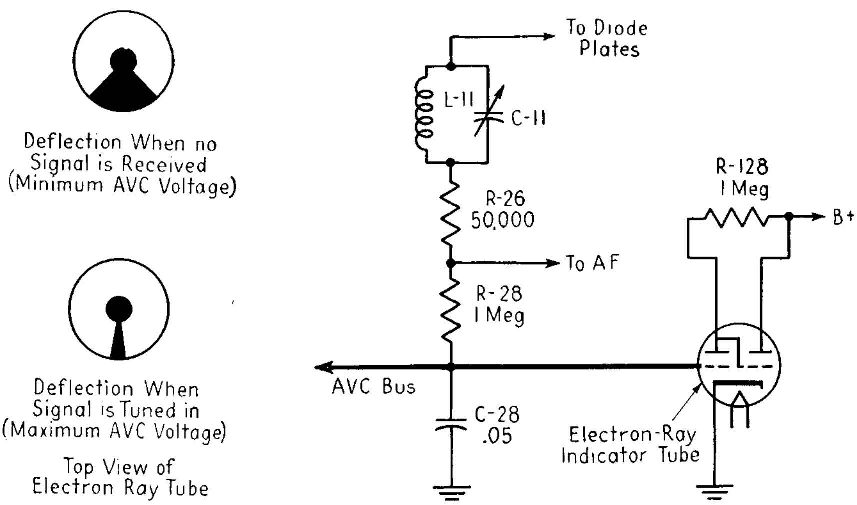


FIG. 12–12. Electron-ray tube connected to the AVC bus as a tuning indicator.

Since this tube must be located on the front panel of the receiver, its socket is not on the chassis. The tube is usually supported in position by a clamp, with a cable of connecting leads running down to the chassis.

Resistor *R*-128 is a 1-megohm/¼-watt resistor. In an AC/DC receiver, it is a ½-megohm/¼-watt resistor. In either case, it is usually located inside of the tube socket.

From a service point of view, the magic-eye tube adds few complications. All checks and tests are the same as for the standard receiver. If the tube does not glow, a new tube is needed; if the tube glows but the deflection does not change as stations are tuned in, and if the receiver operation is normal in all other respects, *R*-128 is probably open. To change *R*-128, the tube socket must be opened.

A receiver equipped with an electron-ray tube has a virtual vacuum-tube voltmeter already connected to the output of the RF and IF stages. It can be used as an indication of the AVC voltage and as an output meter for alignment purposes.

Delayed AVC. The standard circuit of the detector and AVC stage furnishes a type of control known as "simple AVC." Some receivers use a modified circuit known as "delayed AVC," shown in Fig. 12–13.

The diode plates are separated, and one is used for the detector function while the other develops the AVC voltage. In simple AVC circuits, all signals—even weak ones—will develop AVC bias voltage. As a result,

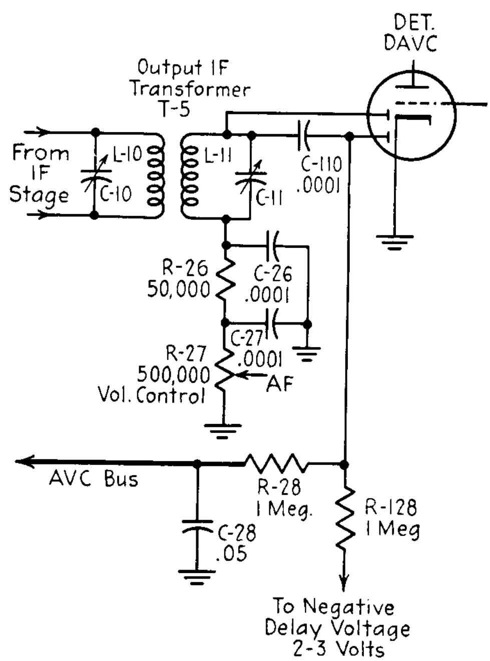


FIG. 12–13. Delayed AVC circuit.

all signals will reduce the gain of the RF and IF stages. Since weak signals require all available gain, the reduction of gain for weak signals is undesirable. In delayed AVC (DAVC), a negative delay voltage of about 2 to 3 volts is fed through resistor *R*-128 to the AVC diode plate of the tube. This fixed voltage is obtained from a tap at the proper point on the *C* voltage divider *R*-115/*R*-116 (see Fig. 8–21).

Part of the signal energy from the secondary of the IF transformer is coupled through condenser *C*-110 to the AVC plate. This plate is maintained at a small negative voltage, referred to above, which prevents it from rectifying and developing the AVC voltage until the peak voltage coupled to it through *C*-110 overbalances the negative voltage of this

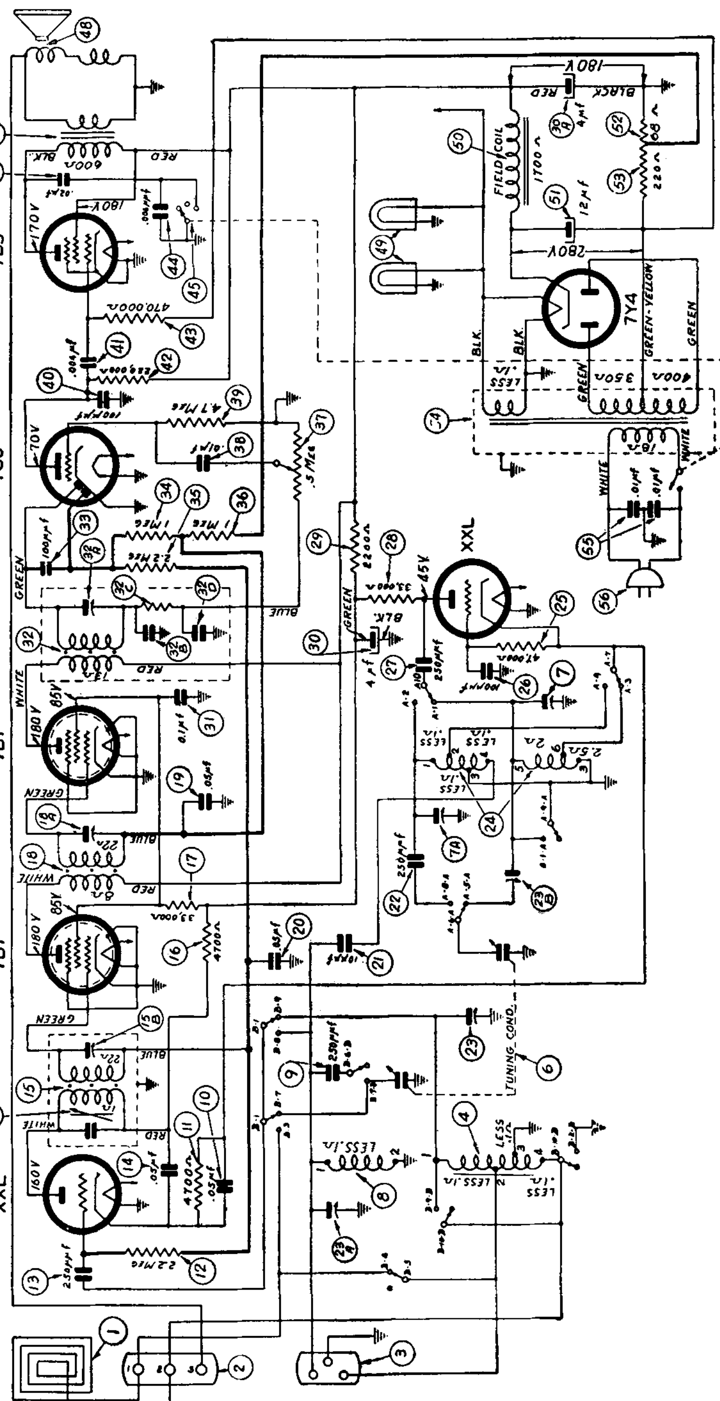


FIG. 12–14. Philco Model 42-340 receiver. The DAVC circuit is shown in heavy lines.

diode. When the signal is weak, enough voltage is not developed on the AVC diode plate to overcome the existing negative potential. No AVC voltage is developed, and the gain of the RF and IF stages remains the same as if AVC were not being used. But when strong signals are received, enough voltage will be coupled to the AVC diode to overcome the small negative plate potential and produce an AVC voltage drop across resistor *R*-128.

From the serviceman's point of view, operation of the DAVC stage and testing of components is the same as for the simple AVC circuit of the standard receiver.

Figure 12–14 is the schematic diagram of a receiver with a DAVC circuit. Note the following conditions. The delay voltage is developed across resistor (52) in the *C* voltage divider in the power supply and is applied through resistors (36) and (34) to the AVC diode plate of the 7C6 detector tube. Resistor (35) and condenser (20) form the filter circuit and carry the AVC voltage to the first IF and mixer stages. The second IF stage is fed a lower AVC voltage from the center tap of resistors (34) and (36). Condenser (19) filters this circuit. The 455-kc

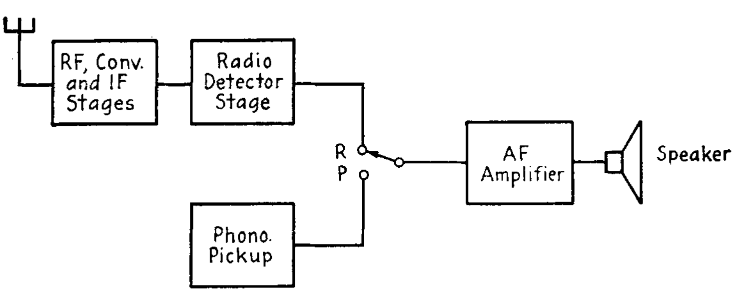


FIG. 12–15. Block diagram of radio-phonograph operation.

filter (part numbers 32B, 32C, and 32D) in the conventional detector circuit is enclosed in the IF transformer assembly (32).

Radio-phonograph operation. Many receivers are equipped with a phonograph in a radio-phonograph combination. Or the receiver may come equipped with a phonograph switch and input jack so that the phonograph turntable and pickup unit may be added when desired. The phonograph will utilize only an audio amplifier and therefore will use only the audio stages and speaker of the receiver. At such time, it would be undesirable to have the RF portion of the receiver in an operating condition. Therefore, a switch is used to block the radio signals from entering the audio stages. Likewise, when radio signals are being received, it is desirable that the phonograph pickup be disconnected from the audio stages. The setup is shown in the block diagram of Fig. 12–15, together with a simplified switching arrangement. The switch is shown in the RADIO (R) position used for the reception of radio signals.

The switching is usually arranged in the coupling between the detector and AF stages before the volume control so that the latter is operative for either the radio or the phonograph. A typical radio-phonograph switch hookup is shown in Fig. 12–16.

The switch is shown in the RADIO (R) position which is normal operation for the receiver. When the switch is changed to the PHONOGRAPH (P) position, the pickup feeds the audio amplifier through the volume con-

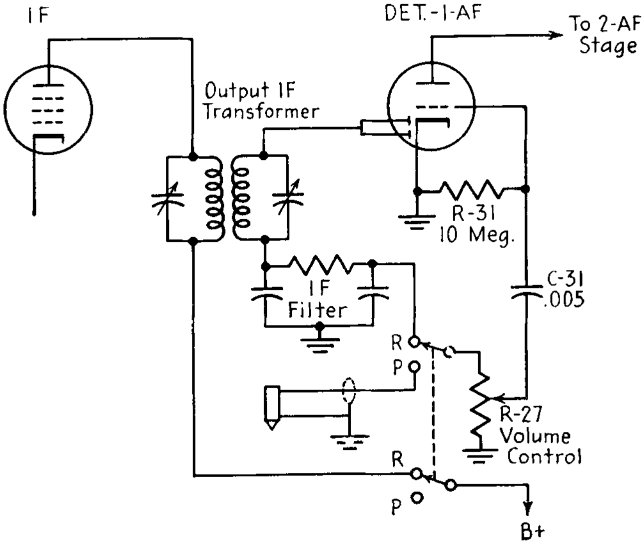


FIG. 12–16. Typical radio-phonograph switching circuit.

trol. Since some radio signals may leak through the switch and spoil the phonograph reception, provision is made to kill the radio when the switch is in the phonograph position. This is accomplished by opening the cathode, screen, or plate circuits of one or more of the tubes in the RF section of the receiver. The lower half of the double-pole switch in Fig. 12–16 opens the plate circuit of the IF tube when the switch is adjusted for phonograph operation.

The radio-phonograph switch is sometimes combined with other functions, making the switching arrangement somewhat complicated. As radiomen must service, replace, and sometimes design switching circuits, an example of a rather elaborate switching arrangement is chosen for detailed study.

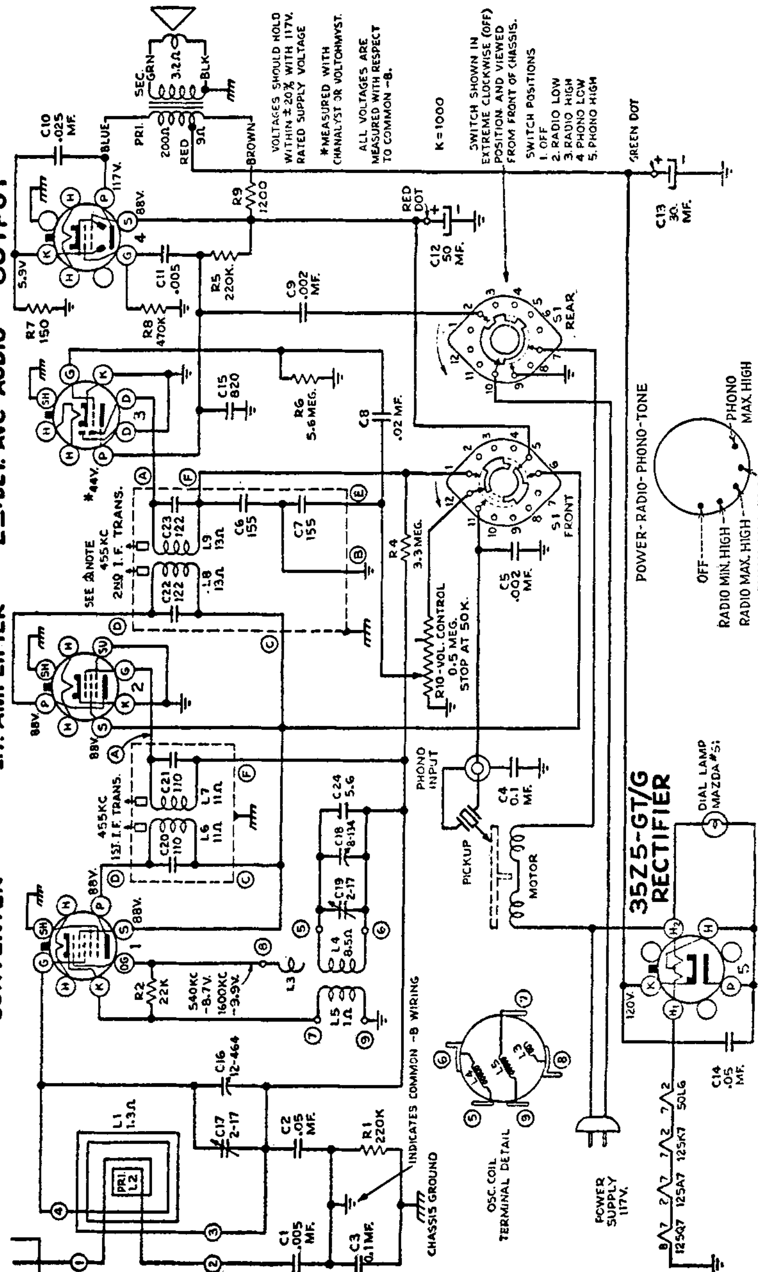


FIG. 12–17. RCA Victor 55 radio-phonograph combination. The radio-phonograph switching is shown in heavy lines.

The radio-phonograph combination of Fig. 12–17 combines the on-off switch, the phonograph-motor switch, and the tone control with the radio-phonograph switch. The switch used is of the 5-point, 2-gang wafer type. The front-panel view of the switch is shown below the wafers in the schematic diagram. The operation of the switch can be analyzed by a study of the diagram and the following table:

Switch positions as marked on the front panel:

1. OFF
2. RADIO MINIMUM HIGH (bass)
3. RADIO MAXIMUM HIGH (treble)
4. PHONOGRAPH MINIMUM HIGH
5. PHONOGRAPH MAXIMUM HIGH

Rear wafer terminal connections:

Terminal 10 is connected to the line cord.
Terminal 9 is connected to the common negative.
Terminal 7 is connected to the phonograph motor.
Terminal 2 is connected through the tone-control condenser C-9 to the first AF plate.

Front wafer terminal connections:

Terminal 12 is connected to the volume control (input of the audio amplifier).
Terminal 1 is connected to the audio output of the detector diode.
Terminal 11 is connected to the phonograph input jack.
Terminal 5 is connected to *B* plus.
Terminal 6 is connected to the plate and screen circuits of the IF and converter tubes.

The switch is shown in the OFF position. When it is turned to the next position, the rotating arms move one position in the direction of the arrows on the diagram.

Position 1. OFF
Position 2. RADIO MINIMUM HIGH (bass)

Rear Wafer:

Terminal 10 contacts 9.	Power is fed into the radio.
Terminal 2 contacts 9.	Tone condenser C-9 is shunted across the output of the first AF tube.

Front wafer:

Terminal 12 contacts 1.	Receiver RF section is connected to the audio amplifier.
Terminal 5 contacts 6.	*B* plus is connected to the IF and converter tubes.

Position 3. RADIO MAXIMUM HIGH (treble)

Rear wafer:

Terminal 10 still contacts 9.	Power connected to radio.
Terminal 2 is open.	Tone condenser C-9 is open.

Front wafer:

Terminal 1 still contacts 12.	Radio remains connected to audio amplifier.
Terminal 5 still contacts 6.	*B* plus remains connected to converter and IF tubes.

Position 4. PHONOGRAPH MINIMUM HIGH

Rear wafer:

Terminal 10 still contacts 9.	Power connected to radio.
Terminal 10 also contacts 7.	Power connected to phonograph motor.
Terminal 2 contacts 9.	Tone condenser C-9 shunted across the first AF output.

Front wafer:

Terminal 1 is open.	Receiver RF section is disconnected from the audio amplifier.
Terminal 12 contacts 11.	The audio amplifier is connected to the phonograph input jack.
Terminal 5 is open.	*B* plus is disconnected from the IF and converter tubes.

Position 5. PHONOGRAPH MAXIMUM HIGH

Rear wafer:

Terminals 10, 9, and 7 in contact.	Power is connected to the radio and phonograph motor.
Terminal 2 is open.	Tone condenser C-9 is open.

Front wafer:

Terminal 12 still contacts 11.	The audio amplifier remains connected to the phonograph input jack.
Terminal 5 is still open.	*B* plus remains disconnected from the IF and converter tubes.

Troubles common to radio-phonograph combinations. Radio-phonograph considerations present two main problems to the serviceman: the servicing of radio-phonograph combinations, and the rewiring of existing straight radios so that they may be used to play records through the radio loudspeaker. In the servicing category are troubles with the motor, the pickup, the wiring, and the switches.

The servicing of phonograph motors and record changers is a field in itself and lies outside the scope of this book. The radio serviceman, however, should be able to check a motor for proper operation and to make a proper installation of a replacement unit, as well as minor repairs.

Phonograph-motor maintenance notes. When a phonograph motor fails to operate, the line switch and wiring should be checked before condemning the motor. If the turntable speed is incorrect, the tone quality of the recording will suffer. The speed can be checked by means of a stroboscope disk, such as the one shown in Fig. 12–18. The turntable is operated under a single fluorescent or neon lamp. One of the circles of dots will appear to stand still. Reference to the number above the stationary circle of dots will give the number of revolutions per minute (rpm) of the turntable. If the turntable has a speed adjustment, it may be properly set with the aid of the disk.

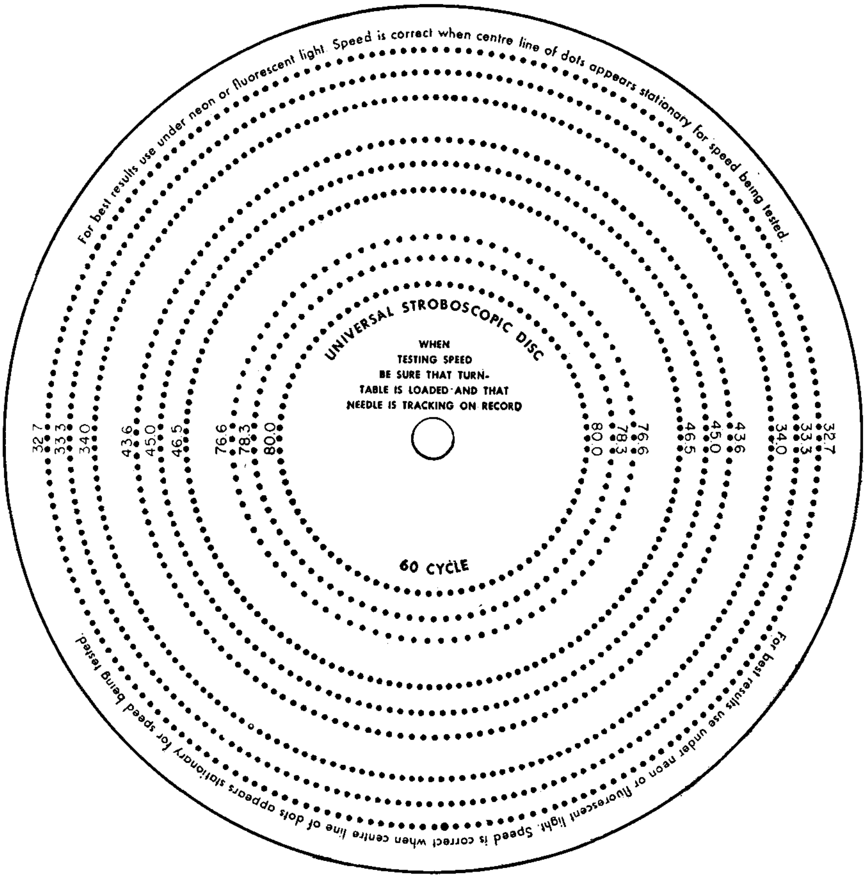


FIG. 12–18. Stroboscope disk used in regulating speed of phonograph motors.

If the proper circle of dots remains stationary for the most part but shows a periodic jump for some of the dots, erratic action of the motor or drive mechanism is indicated. A worn spot on a rubber-rim friction-drive wheel could cause such an effect.

When the phonograph motor is supplied with oil cups, they should be filled with light machine oil. In lubricating a motor, the serviceman should be careful that oil is not smeared on the motor spindle or the rubber-tired drive wheel of a rim-drive motor (see Fig. 12–19). These should be washed with alcohol to remove any oil or grease. The same applies to the inner rim of the turntable.

The phonograph motor and turntable should float freely on rubber or springs. In some cases the motor mounting is floating; in others, it is solid and the entire motor board is floated. Figure 12–20 shows the mounting details for a typical phonograph motor.

In case the spring or rubber suspension is inadequate, rumble might ensue. This is particularly important in combinations where the phonograph motor and speaker are housed in the same cabinet. The rumble is

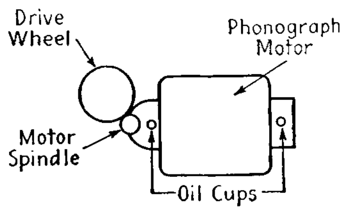


FIG. 12–19. Rim-drive phonograph motor showing location of oil cups.

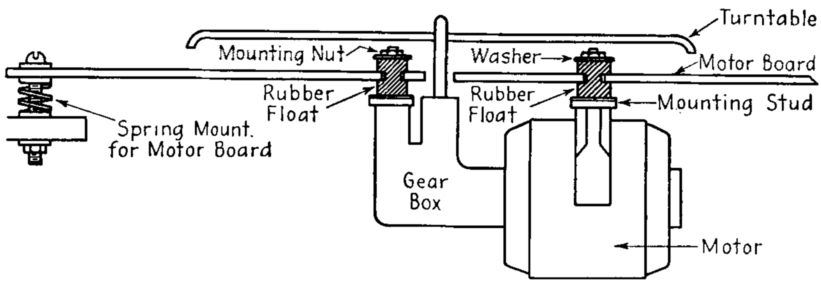


FIG. 12–20. Phonograph-motor board assembly showing rubber suspension mounting for the motor and spring mounting for the motor board.

caused by a sort of mechanical feedback between the speaker and the pickup. Speaker vibrations cause the turntable and the pickup to vibrate. The vibration is in turn amplified and builds up the rumble.

Troubles common to radio-phonograph switches. Radio-phonograph switches are subject to erratic action due to dirt between the contacts. This is almost always the case when it is necessary to flip the switch two or three times before positive contact takes place. A cleaning with carbon tetrachloride usually takes care of this difficulty. The usual procedure is to wet the switch arms and contacts with the carbon tetrachloride and then rotate the switch quickly. The procedure may be repeated if necessary.

Sometimes a switch contact or the entire assembly becomes broken with use. When this happens, the switch must be replaced. Owing to the large variety in radio-phonograph switches, it is essential that one similar to the original switch be obtained. In replacing the switch, considerable care must be exercised to make sure that the wiring is correct and that the heat of the soldering iron does not draw the temper from the spring contacts. For correct wiring on an identical switch, it would be best to remove the old switch with its wiring intact, install the new one, and then change the wires, one at a time.

In soldering the switch terminals, it would be best to solder "uphill" where possible, so that the solder or resin does not roll down to the switch contact. Production speed soldering will not draw the temper from the spring contacts. In this method of soldering, the resin-core solder is applied to the joint first, as shown in Fig. 12–22. Then the iron

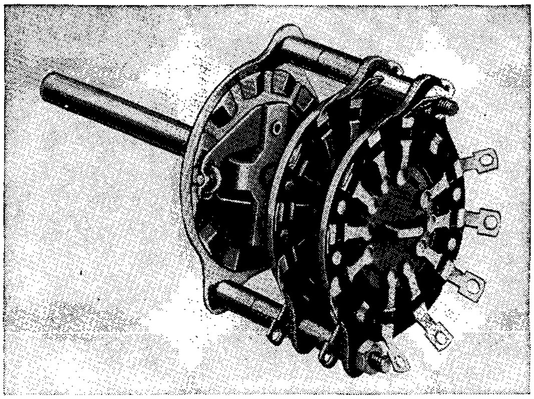


FIG. 12–21. Typical wafer-type switch used for radio-phonograph switching.

tip is pressed to both the joint and the solder. This makes a fast, clean joint that will not heat the contact unduly.

When an original replacement switch is unobtainable, the serviceman must exercise his ingenuity to perform the operations of the original radio-phonograph switch with whatever standard switch is available and will fit the space requirement. For an extreme example, assume a defective radio-phonograph switch in the receiver of Fig. 12–17 and that an original replacement is unobtainable. A two-deck, four-arm, five-position switch could be substituted in accordance with the diagram of Fig. 12–23.

The front wafer takes care of the radio-phonograph switching. The top half of the rear wafer takes care of the tone-control circuit. The bottom half of the rear wafer is the on-off switch for the radio. Switching the phonograph motor on and off cannot be done with the same switch. An auxiliary switch mounted on the motor board of the phonograph takes care of this function.

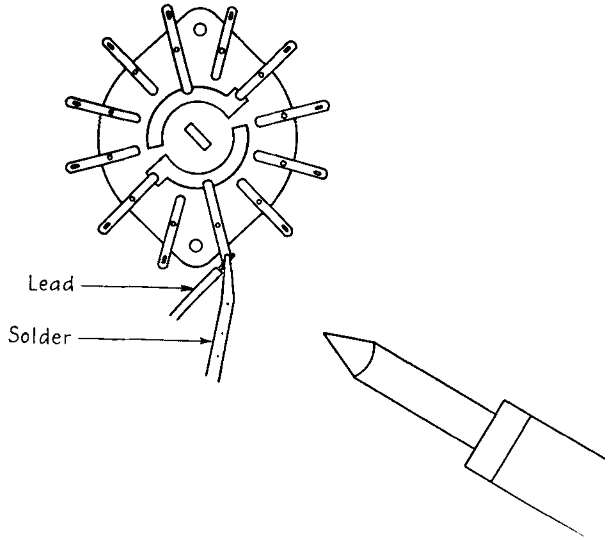


FIG. 12–22. Method of supplying solder when speed-soldering wafer-type switch connections.

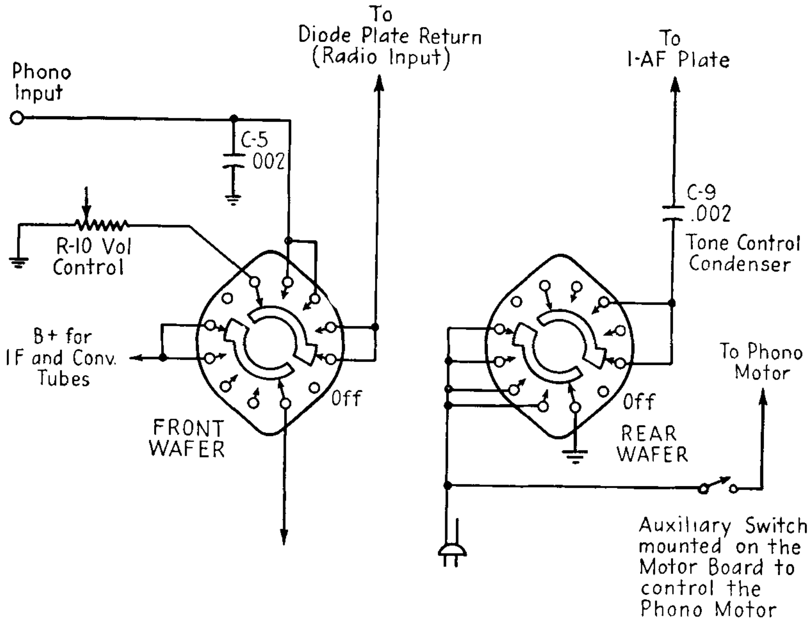


FIG. 12–23. Alternate radio-phonograph switching circuit for the receiver shown in Fig. 12–17.

Troubles common to the pickup unit. Most pickups in common use are of the crystal type. These develop troubles of no output, weak output, and distorted output. A good indication as to whether the pickup is at fault is to check the operation of the radio. If the tone quality and volume of the radio half of the combination are normal, the trouble lies in the phonograph unit, since the audio amplifier and speaker operate on both.

No output from the pickup might also be caused by a defect in the radio-phonograph switch or phonograph wiring. The switch operation may be checked by reference to the schematic diagram, visual inspection, and an ohmmeter. The wiring usually consists of shielded flexible leads, which may break, or the shielding may short through the insulation to

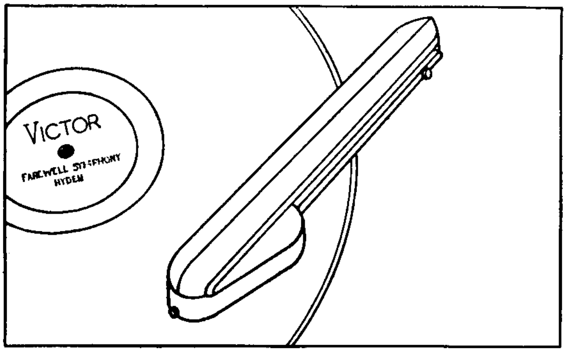


FIG. 12–24. Typical phonograph pickup unit.

the wire. In either case a visual inspection and an ohmmeter will check the wiring. The wiring is particularly vulnerable to defects near the point where it goes through the swivel of the pickup arm. A procedure for replacing shielded wiring is given in Fig. 11–18.

The best check to determine whether the pickup is operating properly is to substitute another crystal unit known to be in good condition. The test pickup should be temporarily connected to the handiest soldering lugs on the pickup line, and its operation should be tried on a record.

When a pickup unit is replaced, a replacement crystal cartridge is often obtainable. This should be the same as the original in weight, mounting details, and output. Where a new cartridge cannot be obtained, the entire pickup unit must be replaced. Again it is preferable to replace with one similar to the original unit. In cases where a different pickup unit must be used, an important detail in making the replacement is to place the arm so that the needle will describe approximately the same arc across the record as was done by the original. For example, when replacing the pickup of Fig. 12–25, a replacement with a longer arm will describe a different needle arc than the original, if the replacement is mounted in the same hole. Moving the replacement pickup farther back will allow the needle to describe more nearly the same arc across the record. Readjusting the rest to accommodate the new pickup is also a matter of importance, since carelessness in this item may result in the new crystal being jarred and ruined.

Some receivers are equipped with variable reluctance pickups. In this case, because of the low signal output, a preamplifier is included between the pickup and the audio section of the receiver. This pickup is checked and serviced in the manner just described for the crystal pickup. The preamplifier is serviced like ordinary audio amplifier stages.

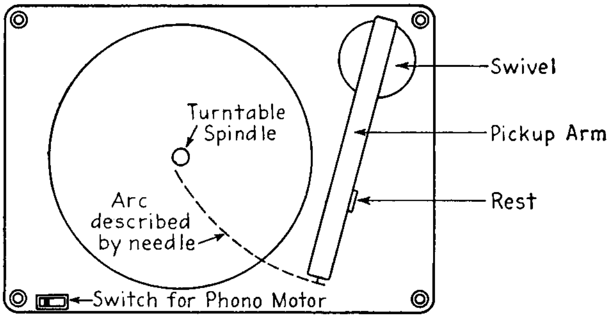


FIG. 12–25. Top view of a phonograph-motor board.

Rewiring radios for phonograph operation. The serviceman is often called upon to rewire an existing radio so that it may be used to reproduce recordings. When this is done, it would be wise to refer to the appropriate diagram manuals to see if the manufacturer also made a radio-phonograph combination similar to the radio being rewired. If such a diagram can be found, there will be several distinct advantages. In the first place, a diagram known to be satisfactory is available. Then also, the exact switches and outlets are often procurable as replacement parts. Finally, since the chassis are often stamped alike for both models, there may be unused chassis holes or knockouts to accommodate the parts that must be added. Such a procedure may mean drilling a hole in the front panel of the cabinet to accommodate the radio-phonograph switch, but this is best in any case. The switch should be readily accessible, and a workmanlike job on the front panel with a knob to match the others is far more desirable to the owner of the radio than the make-shift arrangement of a switch screwed to the back of the cabinet or dangling from wires.

The radio-phonograph service notes may even include a picture diagram, which would solve the problem of correct lead dress. Where this is not the case, the serviceman should remember that the pickup wiring is in the input circuit of the audio amplifier and that any coupling with other wiring may cause hum and oscillation. The wiring should be shielded and dressed close to the chassis and away from all other wiring.

In cases where a diagram of a radio-phonograph combination similar to the radio being rewired cannot be found, the serviceman must make up his own. This is not very difficult for modern superheterodyne receivers, since audio amplifiers usually follow a similar pattern of two

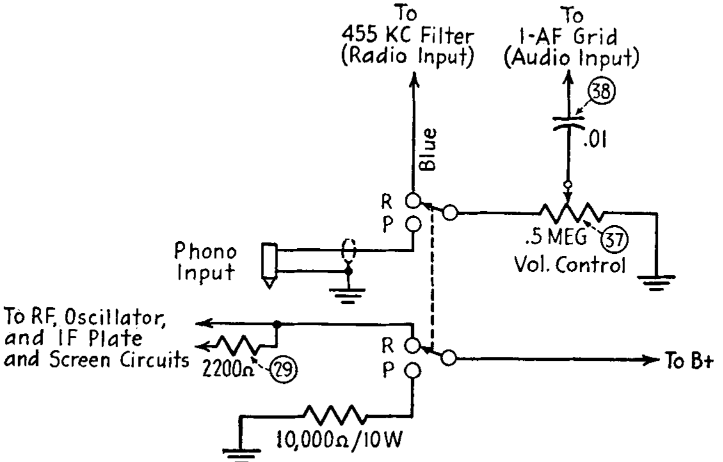


FIG. 12–26. Adding a radio-phonograph switching circuit to the receiver shown in Fig. 12–14.

stages of AF amplification with varying amounts of undistorted power output. The serviceman simply follows general principles; that is, he incorporates a switch that connects either the detector output or the pickup output to the input circuit of the audio amplifier. At the same time, the phonograph position of the switch breaks the plate, screen, or cathode circuit of the converter or IF tubes, so that the radio is completely inoperative when recordings are being reproduced. If possible, the switch will be mounted on the front panel of the radio, and the general instructions regarding lead dress and working with shielded wire will be followed.

As a concrete example, if the receiver of Fig. 12–14 were to be rewired for phonograph operation, the serviceman might make up a circuit similar to Fig. 12–26. The phonograph motor is operated from a switch on the motor board, as shown in Fig. 12–25.

Since this is a fixed-bias circuit, opening the plate circuits of the RF tubes will cause the total B current to drop, changing the voltage across resistors (52) and (53) in the fixed-bias circuit. This may seriously affect the tone quality in the phonograph position. The resistor marked 10,000 OHMS/10 WATTS has been added to replace the load of the tubes in the RF portion of the receiver. The serviceman should try several values for this resistor, using the one that shows no change in the bias voltage across resistors (52) and (53) in either position of the phonograph switch.

The above precaution need not be taken in the case of a circuit using self-bias circuits, unless it is felt that the decreased *B* loading on phonograph operation will reduce the magnetizing current through the speaker field.

Sometimes the rewiring job includes mounting the phonograph unit in an existing cabinet. In this case, the serviceman makes up a motor board similar to the typical mounting shown in Fig. 12–25. In laying out the motor board, he should remember to center the turntable spindle so that 12-in. records can be accommodated without chopping holes in the cabinet. The pickup often includes mounting instructions relating to the proper arc that the needle should describe on the record. If no instructions are included, the arc shown in Fig. 12–25, where the needle extends just beyond the turntable spindle, is about average for most installations. The motor or motorboard suspension is important for the reduction of rumble. Lining the phonograph compartment with felt may also help in this regard.

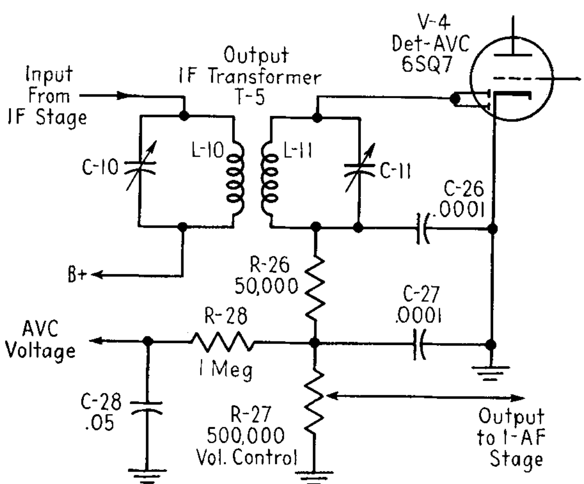
SUMMARY

Quick check for normal operation of the detector and AVC stage

The signal generator is adjusted for a modulated output at the receiver intermediate frequency and its output is applied to the grid of the IF tube. When the stage is functioning properly, the modulation note will be heard in the speaker.

Diagram of standard detector and AVC stage

A diagram of standard detector and AVC stages is given in the accompanying figure.



Resistance data

These data are given in the accompanying table.

Primary of output IF transformer	Iron core	5–15 ohms
	Air core	30–50 ohms
Secondary of output IF transformer	Iron core	5–15 ohms
	Air core	30–50 ohms
Chassis to diode plates		550,000 ohms
Across entire volume control		500,000 ohms
Chassis to AVC bus		1,500,000 ohms

SERVICE DATA CHART

Assume an inoperative detector stage, as shown by normal response when an AF test signal is applied to the ungrounded end of the volume control, and no response when a modulated test signal at the intermediate frequency is applied to the IF grid.

Step	*Check*	*Response*	*Trouble*
1	Advance the signal-generator attenuator and rotate the dial through the intermediate frequency	The modulation note is heard at an off-frequency setting	The IF transformer is out of alignment
		The modulation note is not heard	Proceed to step 2
2	Apply the IF test signal to the IF plate. Rotate the signal-generator dial and advance the attenuator to full output	The modulation note is heard in the speaker	The trouble is in the IF tube or its supply voltages. See Chap. 13 on the IF stage
		The modulation note is not heard	Defective tube. Substitute a detector tube known to be good. The trouble may be an open IF transformer winding, a shorted trimmer condenser, etc. Make a resistance check of all components in the stage

SERVICE DATA CHART FOR OTHER SYMPTOMS

Symptom	*Abnormal reading*	*Look for*
Hum		Defective detector tube. Substitute a good one. Poorly dressed leads in the diode plate and plate return circuits. Open wiring or shielding in the phonograph section
Weak reception and oscillation	If equipped with an electron-ray tuning-indicator tube, the eye will not close fully	Incorrect alignment. Open AVC by-pass condensers C-28, C-29, and C-30
Distortion on strong signals		Leaky AVC by-pass condensers C-28, C-29, and C-30

QUESTIONS

1. A dead AC receiver gives a normal response when checking the AF stages but gives no response when a test signal at the proper intermediate frequency is applied to the IF grid. Outline a service procedure to be followed in finding the cause of the trouble.

2. List the likely sources of trouble that will cause a receiver to give no response when an IF test signal is applied to the IF plate and normal response when an AF test signal is applied to the "hot" end of the volume control.

3. A radio-phonograph combination has a distorted output when it is tuned to local stations. The tone quality is normal when it plays phonograph recordings. Would you check the audio stages for the trouble? Why? What is likely to be wrong? How would you prove it?

4. When a receiver with weak reception is checked, it is noted that the trimmer across the input IF secondary has no effect on the output. What circumstances can cause this condition? How would you check for each?

5. Which components in the detector stage may cause hum? How would you check each?

6. The receiver of Fig. 12–7 has a defective phonograph-radio switch. An exact replacement is not obtainable. The customer indicates a desire to have the phonograph motor operated from the phonograph-radio switch and, since he always uses his radio in the position of maximum high, he is not interested in the tone control. Redraw the diagram of Fig. 12–23 to meet these conditions.

7. It is desired to rewire the receiver of Fig. 10–13 for phonograph operation. Design a circuit for the necessary rewiring. Include provision for the radio-phonograph switch to make the radio inoperative in the phonograph position.

8. After the rewiring of the receiver of question 7, it is found that the tone on phonograph operation is poor. Radio operation is normal, and the pickup is not at fault since the test pickup gives the same results. When the receiver is checked with the bench (P-M) test speaker, operation is normal for both the radio and phonograph. This indicates insufficient magnetizing current through the field coil of the radio loudspeaker. What circuit rearrangement would you advise to overcome this condition?

9. What precautions in regard to lead dress should be taken when replacing an output IF transformer? What conditions might result from improper lead dress?

10. A receiver equipped with an electron-ray tuning-indicator tube operates normally, but the magic-eye tube deflection does not change as stations are tuned in. What is likely to be wrong and how can it be checked?

11. A radio-phonograph combination has poor tone on phonograph and normal tone on radio operation. What factors can cause this condition? How can you check for each?

12. A radio is brought in with a complaint that reception is weak. The serviceman also notices that the noise level is high. What is likely to be wrong? How can this condition be checked?

13 IF AMPLIFIER STAGE

Quick check. If a modulated signal at the intermediate frequency is applied to the signal grid of the converter tube and the modulation note is heard in the speaker, the IF stage is probably functioning, and the serviceman proceeds to check the next stage.

Function of the IF stage. The input IF transformer couples the IF stage to the previous converter. The output IF transformer couples the IF stage to the succeeding detector stage. The signal at the input of the stage contains components at the oscillator frequency, the received signal frequency with its modulation, and sum and difference values of these two frequencies with the same modulation as the signal. The signal at the output of the stage should be at the difference or intermediate frequency and will also contain the modulation component of the original signal. The function of the IF stage, therefore, is to tune and amplify at the intermediate frequency.

THEORY OF OPERATION

Standard circuit. This is illustrated by Fig. 13–1.

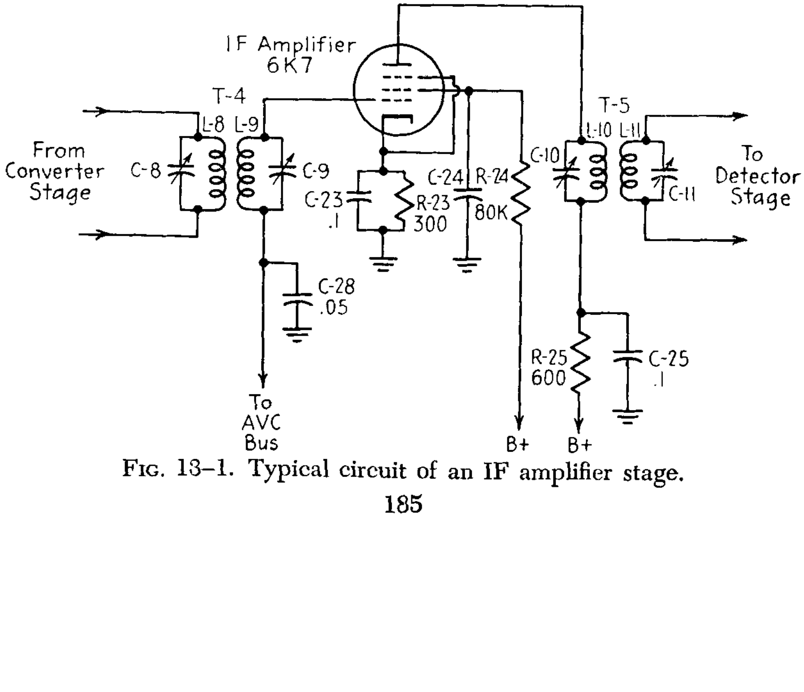


FIG. 13–1. Typical circuit of an IF amplifier stage.

Functions and values of component parts. The tuning function of the IF amplifier is accomplished by the action of the four tuned circuits of the input and output transformers: *L*-8 and *C*-8, *L*-9 and *C*-9, *L*-10 and *C*-10, and *L*-11 and *C*-11. All are tuned sharply to the intermediate frequency, and the four tuned circuits make possible the well-known selectivity of the superheterodyne receiver.

The amplification function of the IF amplifier is dependent on two factors: the design of the transformers *T*-4 and *T*-5, and the amplification of the tube. In a circuit of this type, the transformers are usually designed for high gain, and the voltage amplification of the 6K7 tube is roughly 100. A discussion of stage-gain measurements will be given in the section on the signal check.

Input IF transformer. Input IF transformer assembly *T*-4 includes the primary coil *L*-8 with its associated trimmer *C*-8, and the secondary coil *L*-9 with its trimmer *C*-9. This transformer is the coupling device between the converter and the IF stages. It is very similar to the output IF transformer *T*-5 and, although there may be some design differences between them, the input and output transformers are usually a matched pair. Both transformers are tuned to the intermediate frequency of the receiver. The tuning arrangement is usually by means of trimmer condensers on either air or iron-core coils. In some cases, condensers *C*-8 and *C*-9 are of the fixed mica type, and tuning is accomplished by varying the permeability of the cores by a screw arrangement that withdraws or inserts the core plug.

We might at this time refer to the intermediate frequencies in common use. Older receivers operate at an intermediate frequency of 130 or 175 kc. Later receivers operate at some frequency between 450 and 480 kc, to minimize image-frequency interference (see Chap. 16 on the RF stage). An intermediate frequency often encountered is 260 kc. The trend in modern receivers is to standardize at 455 kc. In almost all cases, the intermediate frequency used in a particular receiver is indicated on the schematic wiring diagram of that receiver.

IF tube. The tube employed in the IF stage is usually the metal 6K7 remote-cutoff pentode. Other remote-cutoff pentodes commonly used as IF amplifiers include the single-ended 6SK7, the miniature 6BA6, and the lock-in 7A7, all of which have similar characteristics. Older receivers use the 6D6 or 78 types, which are early editions of the same tube. When glass tubes are used as the IF amplifier, they are often enclosed in a metal shield. Where the IF amplifier tube is combined with a diode for detection purposes, the tube employed is the 6B8.

AC/DC receivers may use any of the above tubes in circuits where all the tubes draw 0.3 amp of filament circuit. Where the 0.15-amp filament tubes are used, the 12SK7, 12BA6, or 14A7 tubes are found.

Minimum-bias circuit: R-23, C-23. Components *R*-23 and *C*-23 form a self-bias circuit, similar to that of *R*-13 and *C*-13 in the second AF stage (see Fig. 10–1). To see the similarity more clearly, assume for the moment that the grid return goes to ground instead of the AVC bus, as

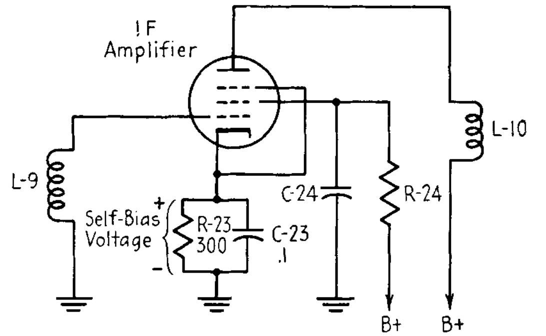


Fig. 13–2. Self-bias in an IF amplifier without automatic volume control.

in Fig. 13–2. Plate and screen currents flow through the cathode resistor *R*-23, making the cathode 3 volts positive with respect to ground. Since the grid is at ground potential, it is 3 volts negative with respect to cathode. This is the grid-bias voltage.

When the grid is returned to the AVC bus, as in Fig. 13–3, there is

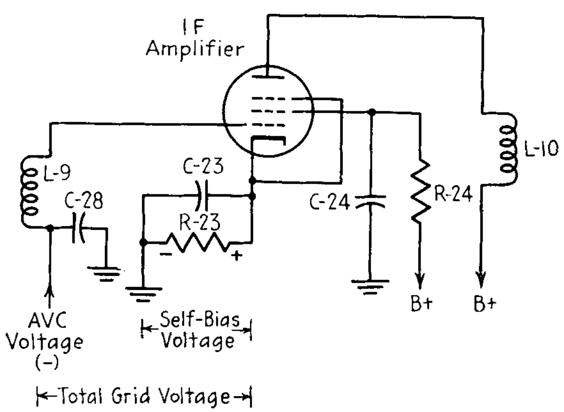


Fig. 13–3. The grid bias applied to the IF tube is the sum of the self-bias and AVC voltages.

no AVC voltage when no signal is present, and the grid is therefore at zero or ground potential. This makes the condition similar to that of a grounded grid return; that is, the grid is at ground potential, the cathode is at a potential of plus 3 volts due to the self-bias resistor *R*-23, and the grid is therefore 3 volts more negative than the cathode. When a signal is tuned in, it develops an AVC voltage, which is negative with respect to chassis, thereby making the grid negative with respect to chassis by an amount equal to the AVC voltage. The cathode is still positive with respect to chassis because of self-bias, and therefore the actual bias on the grid of the tube is the sum of the AVC and the cathode voltages. The weaker the signal, the lower the AVC voltage will be, and the less it will add to the minimum grid bias. However the grid-bias voltage cannot fall below the self-bias voltage, even when no signal is received. Since the self-bias circuit of *R*-23 and *C*-23 sets a minimum limit to the grid-bias voltage, it is called the "minimum-bias" circuit.

Cathode resistor *R*-23 is usually a ½-watt resistor, and its ohmic value is usually 300 to 600 ohms. A higher value would mean a higher minimum-bias voltage and less possible amplification for the stage.

Cathode condenser *C*-23 by-passes the signal from the self-bias resistor in the same way that *C*-13 by-passes the audio signal from *R*-13. However, in this case the signal is at the intermediate frequency, and a much smaller capacity will be effective. The usual capacity for *C*-23 is 0.1 mfd. The type of condenser most often used is the paper tubular type. Voltage rating is not important. A 200-volt value is satisfactory.

The AVC voltage is by-passed by condenser *C*-28, which is usually a 0.05-mfd/200-volt paper tubular condenser.

Screen voltage supply: C-24 and R-24. Resistor *R*-24 drops the *B* voltage, from the usual 250 volts available at *B* plus, to approximately 100 volts at which the tube screen operates. It is usually a ½-watt, 80,000-ohm resistor. There is considerable variation in this value in different models of receivers. In general, a higher resistance will make for a lower screen voltage, and a lower value of resistance makes possible a higher screen voltage.

Screen resistor *R*-24 is sometimes omitted and screen voltage is taken from the mid-point of voltage divider *R*-15 and *R*-16 (see Fig. 8-14).

Condenser *C*-24, the by-pass for the screen voltage, helps to filter the screen supply. Its usual value is 0.1 mfd/400 volts. Its most important function, however, is to keep the screen of the tube at ground potential as far as the signal is concerned, since *C*-24 offers little impedance to IF signals. This effectively shields the control grid from the plate, internally in the tube, and allows for stable amplification.

Sometimes screen condenser *C*-24 is not readily located in the receiver schematic diagram. This may be the case where the screens of other tubes are tied together with the IF screen for a common voltage supply. The screen by-pass condenser will then be found at one of the other screens. As a matter of fact, in some circuits, where an electrolytic filter condenser is used on the screen voltage supply, an additional paper screen by-pass condenser is often found in the RF or IF screen circuit, in parallel with the electrolytic condenser. This is to take advantage of the more effective RF filtering by the paper tubular condenser.

In AC/DC receivers, operating potentials for the IF tube are approximately 90 volts for both the plate and the screen. In this case, the dropping resistor *R*-24 is omitted and the screen is connected directly to *B* plus. Screen by-pass condenser *C*-24 may also be omitted, in which case its by-pass function is taken over by the output filter condenser *C*-16 in the power supply.

Output IF transformer T-5. Output IF transformer *T*-5 couples the output of the IF stage to the detector stage. Replacement notes for *T*-5 are found in Chap 12, which describes the detector and AVC stage (see page 160).

Decoupling filters. Whenever two or more stages are operated from the same voltage supply, there is a possibility of coupling between the stages through the common power supply. This is illustrated in Fig. 13–4.

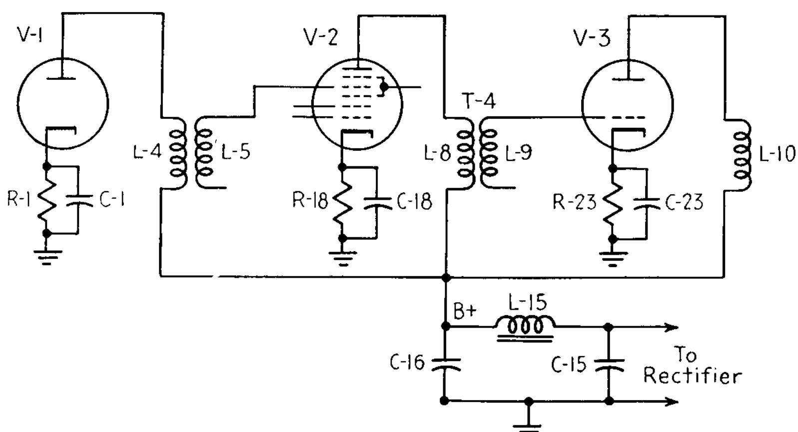


FIG. 13–4. Coupling in the plate circuit due to a common *B* power-supply component.

If we consider the signal voltage in the plate circuit as being from plate to cathode, the signal voltage of tube *V*-1 is across *L*-4, *C*-16 in the power supply, and *C*-1. The signal voltage of *V*-2 is across *L*-8, *C*-16 in the power supply, and *C*-18. The signal voltage of *V*-3 is across *L*-10, *C*-16 in the power supply, and *C*-23.

Let us consider the plate circuit of tube *V*-1. The greater part of the signal voltage will be where it is wanted—across the high impedance of *L*-4, where it will be transferred to *L*-5 and the grid circuit of the following tube. There will also be some signal voltage drop across the low impedance of *C*-16 in the power supply and *C*-1 in the cathode circuit.

Now let us consider the plate circuit of *V*-2. Again, the signal voltage will be mainly across *L*-8, but there will be some across *C*-16 and *C*-18. Note that the signal voltages of tubes *V*-1 and *V*-2 have a common circuit in *C*-16 in the power supply.

When we consider the plate circuit of *V*-3, again, most of the signal is across *L*-10, but a small part will be across *C*-16, which is common to all three plate circuits.

If the signals from any of the tubes are in phase, oscillation may result owing to regenerative feedback through the common coupling, *C*-16.

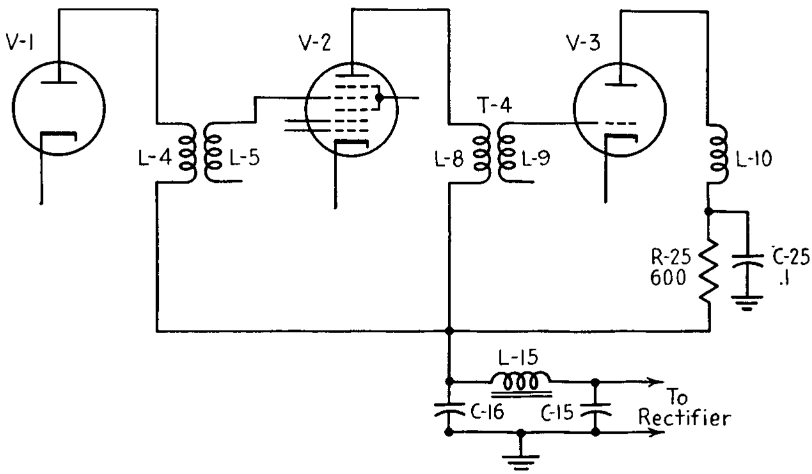


FIG. 13–5. Decoupling filter in the plate circuit of tube *V*-3.

The coupling through the common power supply is usually avoided by the addition of a resistor and condenser known as a "decoupling filter" or isolation circuit, as shown in Fig. 13–5.

The decoupling filter consists of *R*-25 and *C*-25. Condenser *C*-25 offers a low opposition path to ground for the signal, and *R*-25 offers a high opposition path to the signal. The net result is to keep the signal voltage of *V*-3 out of the power supply, so that it cannot mix with the signal from any other tube. An RF choke is sometimes used instead of *R*-25. This also offers high opposition to the signal.

The decoupling filter may be applied in the plate circuit of tube *V*-1 instead of tube *V*-3, as shown in Fig. 13–6. The result would be the same, since in this case the signal voltage of *V*-1 would be kept out of the power supply and therefore would not react with the signal from any other tube.

In different receivers, there is considerable variation as to the placement of the decoupling filter. Sometimes it is in the plate circuit of V-1, sometimes in the plate circuit of V-3, sometimes in both. Also, the plate circuit of V-2 may be tied to either that of V-1 or V-3, or have its own filter. Since there is no standardization in the placement of the decoupling filters, a decision as to the placement in the standard receiver circuit (Fig. 1–1), which attempts to show the most commonly used practices, has to be reached. In the standard receiver circuit, a decoupling filter is placed in the plate circuit of each tube, and servicing procedures are dealt with so as to include the filter. From the above discussion, it is to

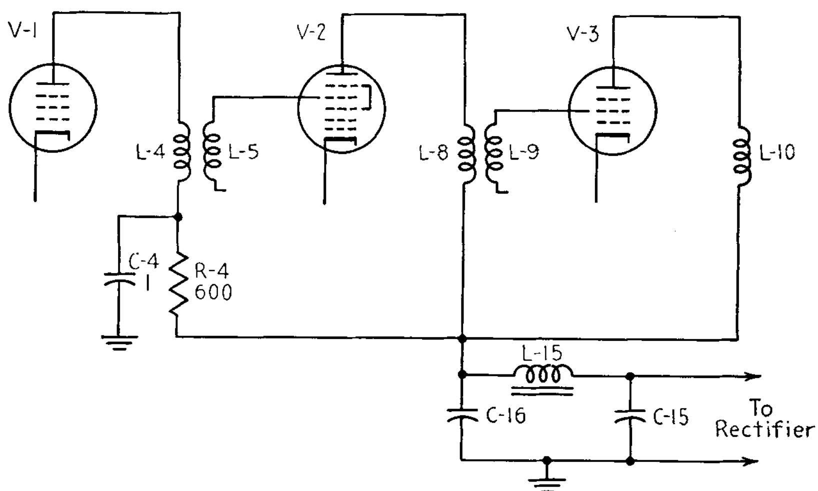


FIG. 13–6. Decoupling filter in the plate circuit of tube V-1.

be hoped that the serviceman will expect an individual receiver to differ somewhat from the standard in that one or more decoupling filters may be omitted.

By a similar line of reasoning, there could be undesirable regenerative coupling, if the cathodes of three stages were connected together and fed from a common cathode to ground resistor for equal self-bias voltages. The same thing could happen with the screen-voltage supply, or the grid returns through the AVC bus. Where we have three stages operating at similar frequencies through a common coupling, decoupling filters will be found in at least one of these circuits.

In the standard circuit, the cathodes of the RF, converter, and IF tubes have individual self-bias resistors to avoid coupling, as shown in Fig. 13–7. It is fairly common practice, however, to find the cathode of V-2 joined to V-1, and R-18 and C-18 omitted.

In the screen circuit, coupling is avoided, as shown in Fig. 13–8, where screen by-pass condensers, in conjunction with screen resistors, are used. It is most common practice to obtain screen voltage for the IF tube *V*-3 from a separate dropping resistor *R*-24 connected to *B* plus. The screens of *V*-1 and *V*-2 may be tied together, with *R*-14 and *C*-14 omitted. Or all three screens may be tied together and fed from a common voltage source.

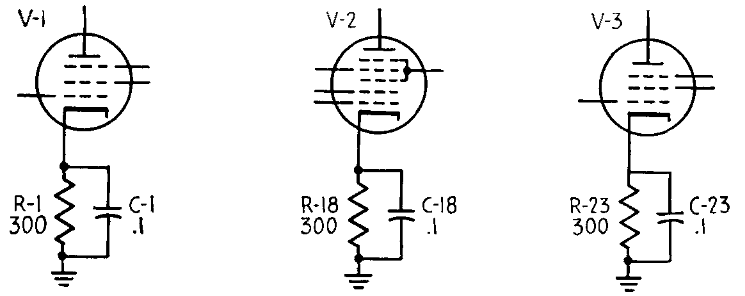


FIG. 13–7. Cathode circuits with individual self-bias resistors to avoid interstage coupling.

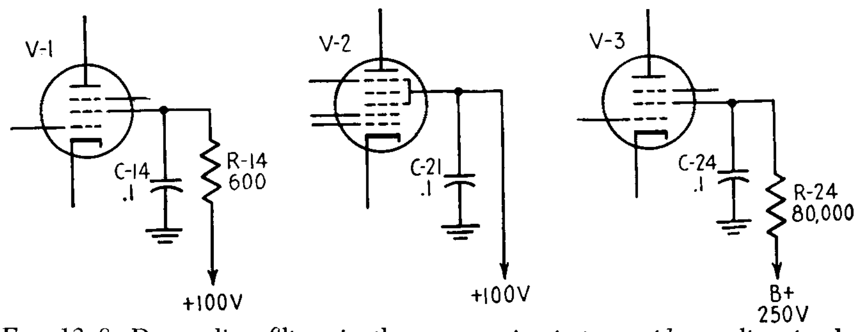


FIG. 13–8. Decoupling filters in the screen circuit to avoid coupling in the common power supply.

Decoupling filters in the grid returns of the RF and converter tubes are rarely omitted. In this case, the standard circuit is indeed standard. In Fig. 13–9, resistor *R*-30 and condenser *C*-30 make up such a decoupling filter for tube *V*-1, while *R*-29 and *C*-29 make up a similar filter for tube *V*-2.

A great many receivers do not use an RF stage. In this case, since there are fewer stages with a common coupling component, the probability of regenerative feedback is lessened, and there is little necessity for decoupling filters.

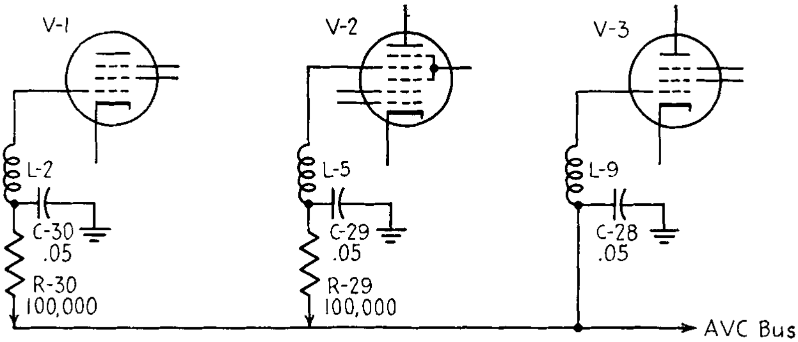


FIG. 13–9. Decoupling filters in the grid return circuit to avoid coupling in the common AVC voltage supply.

To get back to the IF stage, the plate decoupling filter consists of *R*-25 and *C*-25, as shown in Fig. 13–10. Resistor *R*-25 varies from 400 to 1,000 ohms in different receivers, and *C*-25 varies from 0.05 to 0.25 mfd. These values are not critical.

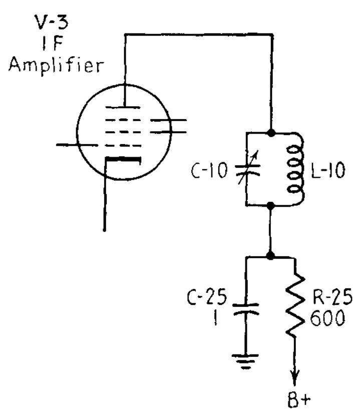


FIG. 13–10. Plate-circuit decoupling filter in the IF amplifier stage.

NORMAL TEST DATA FOR THE IF STAGE

Signal check. The test point for the signal check of the IF stage is the converter signal grid, as shown in Fig. 13–11. As was the case in the signal check for the detector stage, the input signal is applied to a previous tube, to avoid the detuning effect of the capacity in the signal generator. The converter-grid test point is readily available, either at the top contact of the 6A8 converter tube or at the stator-plates terminal of the converter tuning condenser, *C*-5. The output indication is the modulation note of the signal generator in the speaker, or its amplitude, as shown by the output meter. The output meter should be adjusted for a high-voltage range at the start of the signal check, since, from this test point, the amplification of the receiver is considerable. Until the signal generator's attenuator is adjusted, the output signal may be high enough to harm the meter, if it is at its usual 25- to 60-volt range for output measurements. The RF portion of the receiver is made inoperative by shorting the oscillator section of the gang tuning condenser, as explained on page 158.

The signal check consists in rotating the frequency control of the signal generator through the receiver's intermediate frequency, while listening for its modulation note in the speaker or observing the output meter reading. Unless the response is considerably stronger than that heard from the IF grid (quick check for the detector stage), the IF stage bears investigation for trouble. This is the quick check for the IF stage.

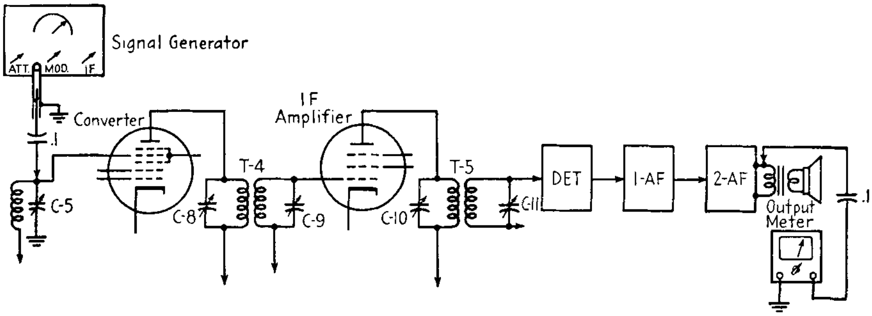


FIG. 13–11. Connections for the signal check of the IF stage.

At the same time, the signal check may be used to check alignment, operation at the proper intermediate frequency, and the presence of oscillation. The presence of two peaks close together is not necessarily an indication of misalignment. This may be the normal response from an overcoupled IF transformer. This is explained in the variations section dealing with broad-band IF amplifiers.

When the modulated IF signal is applied to the converter grid and there is no response or abnormally low response, the trouble may be in the converter tube or its operating potentials. This can be checked by shifting the signal generator test lead to the converter plate. In this case, normal response is a somewhat stronger signal from the converter plate than was obtained from the IF grid (quick check of the detector stage). Trouble in the converter tube or its operating potentials is handled in Chap. 14, which deals with the converter. If there is no signal response from the converter plate, the trouble is definitely in the IF stage.

Normal voltage data. Readings are taken from the chassis or common negative terminal to tube elements. The data are given in the accompanying table.

Tube elements	*AC receivers, volts*	*6K7 pin No.*	*AC/DC receivers, volts*
Plate	250	3	90
Screen	100	4	90
Cathode	3	8	3

Normal resistance data. These data are presented below.

	Resistance, ohms	
	Air core	*Iron core*
Across *L*-8, primary of *T*-4	30–50	5–15
Across *L*-9, secondary of *T*-4	30–50	5–15
Across *L*-10, primary of *T*-5	30–50	5–15
Across *L*-11, secondary of *T*-5	30–50	5–15
Cathode to chassis	300–600	
Control grid to chassis	1,500,000	
Screen grid to chassis	140,000*	
Screen grid to *B* plus	80,000*	
Plate to *B* plus	640†	

* These values are for the standard circuit. Owing to the wide divergence in methods of obtaining screen supply, these readings should be checked against the receiver schematic diagram.
† If there is no decoupling filter, this reading will be simply the DC resistance of *L*-10, the primary of the output IF transformer *T*-5.

A wide divergence is given for the coils *L*-8, *L*-9, *L*-10, and *L*-11, to allow for differences between receivers. In any one receiver, however, owing to the common use of matched transformers, these coils should all check very close to the same value within the limits given.

Sensitivity check of the IF stage. As was done for the previous stages, the serviceman should run some checks on receivers known to be good, so as to have a basis of comparative data as to the operation of his test equipment and the normal gain to be expected from the IF stage.

The receiver test oscillator and output meter are connected, as shown in Fig. 13–11. The receiver's RF section is made inoperative by shorting the oscillator section of the gang tuning condenser. The receiver is set to the full volume and minimum bass positions. A selectivity control, if any, is set for the maximum selectivity position. The test oscillator is adjusted for modulated output on the IF band. The output meter is set at a high AC voltage range for safety's sake, although the range will be reduced for the final check of the standard output voltage.

The signal generator is connected to the converter grid, and the frequency-control dial is rotated carefully through the receiver's intermediate frequency for peak deflection on the output meter. At peak, the attenuator of the signal generator is adjusted to give the standard output of 50 mw in the speaker. Standard output corresponds to an output meter reading of 16 volts (see page 129).

The average IF signal input at the converter grid, necessary to give standard output, is 50 microvolts for a modern high-gain receiver. The attenuator setting just obtained, therefore, corresponds to 50 microvolts. After several good receivers have been checked by the above procedure and the results have been compared, a reference point, corresponding to 50 microvolts, has thus been established on the signal-generator attenuator dial.

COMMON TROUBLES IN THE IF STAGE

Troubles common to the input IF transformer. Replacement notes and troubles of the input IF transformer T-4 will be outlined briefly here. For a more detailed discussion, the replacement notes on the similar output IF transformer are equally applicable (see page 160).

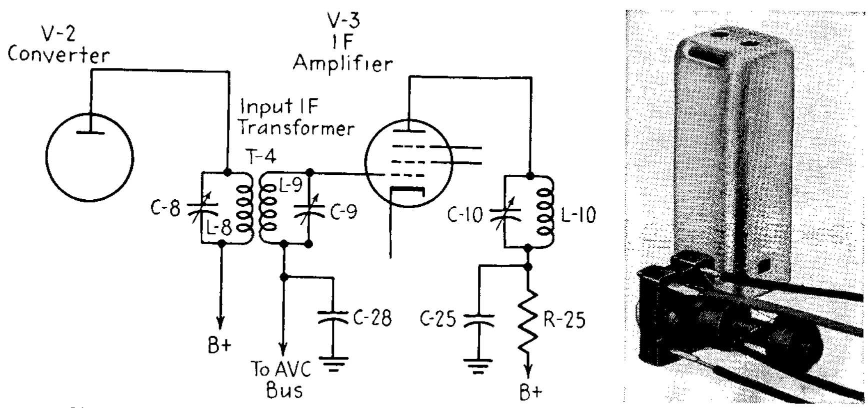


FIG. 13–12. The input IF transformer and its position in the circuit.

The IF transformers sometimes open. When this is the case, the receiver will not operate, and a signal check will indicate the defective stage. An ohmmeter check then shows the open transformer.

The IF transformers also cause noise. This condition is usually due to corrosion of the windings. It will be found by an ohmmeter check, since a corroded winding will check several hundred ohms instead of its normal value of 15 to 50 ohms.

If an exact replacement transformer is not available, the suggestions on page 161 should be helpful.

Input IF transformer color code. The R.M.A. color code given below will help to identify the leads.

Blue	Plate lead
Red	*B* plus lead
Green	Grid lead
Black	Grid return

When a new transformer is installed, grid and plate leads should be short and direct and away from each other and all other wiring.

Troubles common to the AVC by-pass condenser. Replacement notes on the AVC by-pass condenser *C*-28 are found in the detector and AVC stage on page 163.

Troubles common to the minimum-bias resistor. The voltages and currents encountered in the cathode circuit of the IF tube are such that there is no overload on minimum-bias resistor *R*-23, and the resistor rarely gives trouble. If it should open, the stage will not operate and the condition would be found in a voltage check. The cathode-to-ground voltage would check abnormally high, since the test voltmeter, with its high resistance, would bridge the open resistor in the circuit.

The original should be duplicated as to ohmage and wattage. If the exact ohmage value is not available, a considerable tolerance may be allowed, since the value is not critical and will cause little effect on the over-all performance of the receiver.

Troubles common to minimum-bias by-pass condenser. As with its associated resistor *R*-23, the low voltage encountered will rarely harm minimum-bias by-pass condenser *C*-23. Nor will leakage be overly important, since the condenser is in parallel with a low-ohmage resistor. Should the condenser open, however, there will be degeneration with a consequent loss in gain for the stage. If the open is intermittent, there will be intermittent loss in volume or fading. In either case, substituting a condenser known to be good and observing results is the best check. Sometimes wiggling the condenser leads will show up the intermittent open. When condenser *C*-23 is replaced, a large tolerance in capacity is allowable.

Troubles common to the screen by-pass condenser. In service, screen by-pass condenser *C*-24 sometimes opens and sometimes shorts. If it is open, the receiver will oscillate. Standard procedure for an oscillating receiver includes checking for open screen by-pass condensers. Bridging each screen to ground with a good 0.1-mfd condenser is the regular test.

If condenser *C*-24 is short-circuited, there will be no screen voltage and the receiver will not operate. The condition would be found in a voltage check and confirmed by a resistance check.

When a short-circuited *C*-24 is replaced, it would also be wise to replace the screen-dropping resistor *R*-24, which may have been harmed by feeding heavy current to the short-circuited screen by-pass condenser.

The replacement condenser should not be smaller than the original as to the capacity and voltage rating. A higher capacity will do no harm. Although the screen operates at about 100 volts, the voltage rating of the condenser should be considerably higher. This is because the condenser is at the full *B* plus voltage when the receiver is first turned on, owing to the dropping resistor circuit of *R*-24.

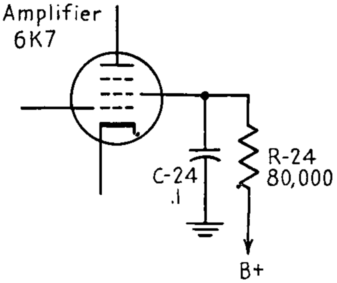


FIG. 13–13. The screen circuit of the IF amplifier stage.

Troubles common to the screen-dropping resistor. Screen-dropping resistor *R*-24 may change in value or open. A change in value might not be noticed until checking the screen voltage, since the over-all operation of the receiver would not be affected too much, unless the change is very great. If the resistor is open, screen voltage is zero and the stage is inoperative.

Before resistor *R*-24 is replaced, screen by-pass condenser *C*-24 should be checked, since a shorted screen by-pass may have originally caused the resistor to open.

The ohmic value of *R*-24 is not critical, and a fairly wide tolerance may be allowed, but the replacement should be at least a ½-watt size.

Troubles common to the plate decoupling filter. If present, the decoupling filter may be a source of trouble. Condenser *C*-25 may short, with the result that there will be no plate voltage, the receiver will be inoperative, and resistor *R*-25 will probably burn. This condition would be found very early in the trouble-shooting procedure, since the *B* plus voltage will be very low. To find the short, however, might be more difficult, since there are several circuits in parallel with the condenser. An overheating *R*-25 would be one indication. Another helpful device is to make a resistance check from all plates to ground. If condenser *C*-25 were shorted, the IF plate would check approximately 40 ohms to ground (the resistance of *L*-10), while all other plates would check their normal plate load plus the resistance of their decoupling filter, if any, plus the resistance of *R*-25.

It is not unusual to find only a by-pass condenser connected at *B* plus of an RF or IF tube, even though no other form of decoupling filter is used. This condenser therefore is connected from *B* plus to chassis and is in parallel with the power-supply filter condenser *C*-16. When this is the case, the ohmmeter check from each plate to ground would give no definite clue, since, with no decoupling resistors, all plate-to-ground readings would show their normal plate load. It would be necessary

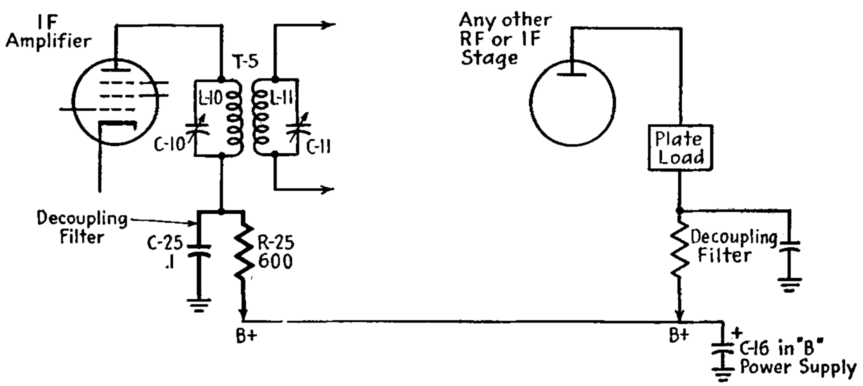


FIG. 13–14. The IF amplifier plate-decoupling filter.

then to open the *B* plus wiring, one circuit at a time, to find the short.

A decoupling filter condenser may also open. In this case, all voltages would show normal readings, but the receiver would have a tendency toward oscillation. Since it is common practice, in trouble shooting for oscillation, to bridge all by-pass condensers with a good condenser, the open decoupling condenser would be found in this manner.

When replacing condenser *C*-25, voltage rating is important. A 600-volt rating is recommended for all replacements. The capacity is not critical, so that a wide tolerance may be allowed. If a shorted *C*-25 is being replaced, the resistor *R*-25 in the decoupling filter should also be replaced, since it has been damaged by feeding heavy current to the short. Unless C-25 has been shorted, *R*-25 will, of itself, cause no service trouble.

Troubles common to the IF amplifier tube. The amplifier tube is the most common cause of trouble in the stage. The best check, of course, is to compare operation with a similar tube known to be good.

Since there are many similar tubes that will operate in the IF stage, a previous tube replacement may have put a different tube in the IF socket, and the serviceman would do well to check the tube type for which the receiver was originally designed. For example, 6K7-G, 6K7-GT, and 6K7 are all pretty much alike, and any one of them might work in some circuits. They cannot be interchanged in all circuits, however, since they differ as to shielding and interelectrode capacities. A receiver designed for a 6K7-G may not ground pin 1, and a 6K7 or 6K7-GT would show a tendency to oscillate in this receiver. Similarly, a 6K7-GT may oscillate in a receiver designed for a 6K7, unless equipped with a close-fitting shield in contact with the metal tube base. A 6K7-G would have to be shielded and the shield grounded.

CIRCUIT VARIATIONS OF THE IF STAGE

Minimum bias from delayed AVC. The IF stage in a receiver, using fixed bias and receiving AVC voltage from a delayed AVC circuit, is similar to the standard circuit. It differs primarily in the manner of ob-

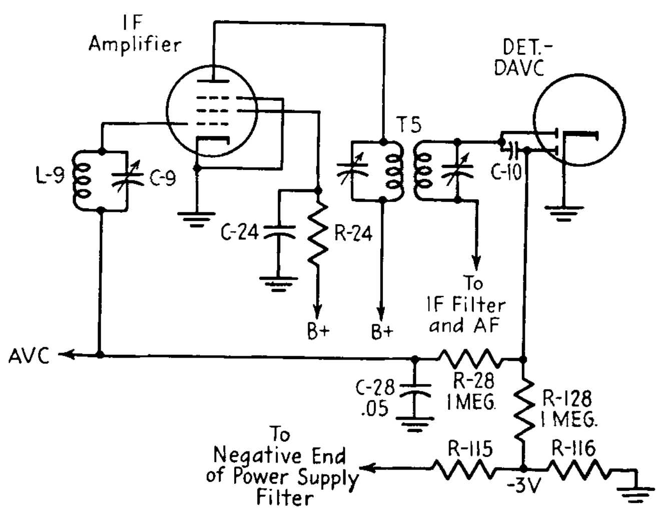


FIG. 13–15. The IF amplifier stage in a receiver using a DAVC circuit.

taining minimum bias for the IF tube. The cathode is grounded. Normal fixed-bias voltage for the IF tube, with no signal input, is obtained from the voltage drop across the *C* voltage divider *R*-116, through the grid return. This minimum bias is also the delay voltage, since the same end of *R*-116 is connected to the IF grid return and the delayed AVC diode plate, through resistor *R*-128. When a strong station signal is received on the diode plate and it overrides the delay voltage, a voltage drop takes place across *R*-128, which adds to the fixed minimum bias delivered to the IF grid. In this manner, station signals may increase the IF grid bias, but under no condition will the bias drop below the minimum bias furnished by the C voltage divider.

All service notes and tests for the standard IF stage apply here also, except for cathode-to-ground voltage. Owing to the high resistance of R-28, a voltage check from grid to chassis may not show any indication with the usual voltmeter. This voltage, however, can be measured across R-116.

Broad-band IF amplifiers. The IF transformers of receivers, like that of the standard, are designed for great selectivity and gain. Figure 13–16 shows the frequency-response curve for such transformers. However, such a circuit has a defect in that it is too selective and attenuates the high-frequency audio signals. This defect is known as "side-band cutting." In high-fidelity reproduction, where the high-frequency audio notes are desired, it is necessary to broaden the response curve of the IF transformers to that shown in Fig. 13–17.

In high-fidelity receivers, where the response curve of the IF amplifier is broadened, the amplification of the stage is reduced. Usually, a

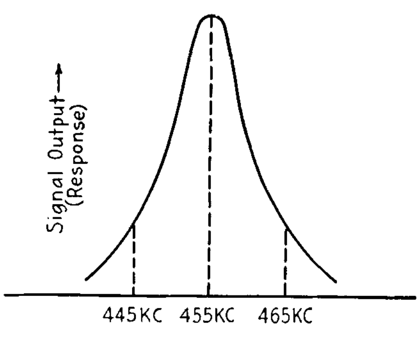


FIG. 13–16. Frequency-response curve of the usual IF transformer.

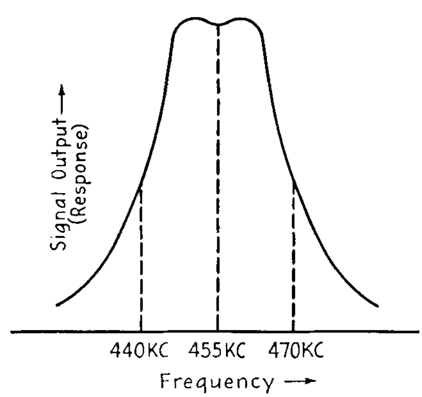


FIG. 13–17. Frequency-response curve of a high-fidelity IF transformer.

second broadly tuned stage is therefore added to make up for this loss. The over-all gain of the two-stage IF amplifier is somewhat greater than the gain of a single-stage amplifier, and the over-all selectivity is equally good owing to the extra tuning circuits of the added stage. Figure 13–18 is a graphic representation of the response curve of each stage of a two-stage IF amplifier and the over-all response of the amplifier.

Several methods are in common use to obtain the desired broad-band response. One method is known as "overcoupled" transformers. In any IF transformer, the relative position of the primary and secondary windings to each other is called the "coupling." When the two windings are far apart, the energy transfer from primary to secondary is small, and the transformer will give low gain and good selectivity. As the two windings are brought closer together, the gain of the transformer increases and the selectivity becomes somewhat broader up to a critical point, after which the gain is reduced and the selectivity becomes considerably broader, owing to the appearance of two peaks, one on each side of the resonant frequency. When the primary and secondary wind-

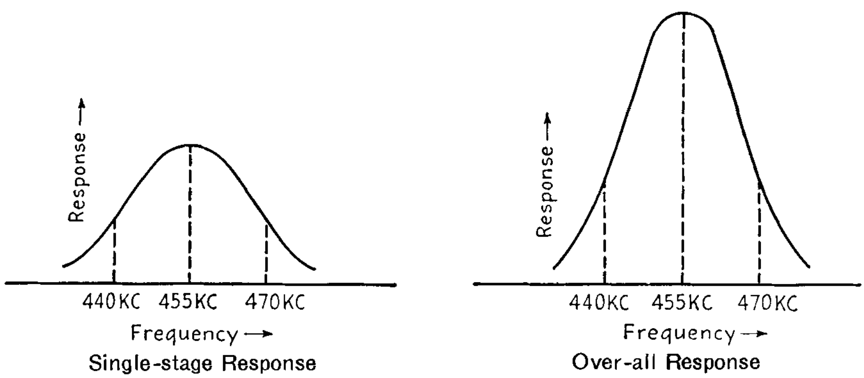


FIG. 13-18. Frequency-response curve of a high-fidelity IF amplifier.

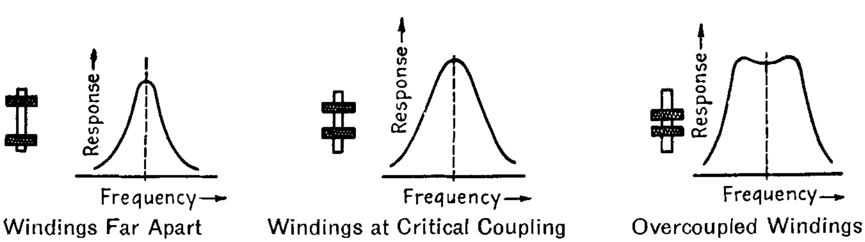


FIG. 13–19. Effect of coupling on the frequency-response curve of an IF transformer.

ings are closer than this critical point, the transformer is said to be "overcoupled." Figure 13–19 illustrates the effects of the coupling on the gain and selectivity of a transformer.

The design of the usual single-stage transformer makes some compromise as to coupling between the low and the critical points, so as to give high gain with good selectivity. Some receivers that feature broadband IF amplifiers make use of overcoupled IF transformers. Often the coupling is made variable by a mechanical arrangement that raises and lowers one winding by turning a knob on the front panel of the receiver.

The position of minimum coupling is labeled SELECTIVITY or SENSITIVITY, whereas the position of maximum coupling is labeled FIDELITY or TREBLE. This control is called a "fidelity" control.

Another method of broadening the response of the IF amplifier is to load the tuned circuits with resistors, as shown in Fig. 13–20. The resistors may be placed across the primary winding, the secondary, or both; or they may be placed in series with the trimmer condenser. In any case, the introduction of resistance loads the tuned circuit and re-

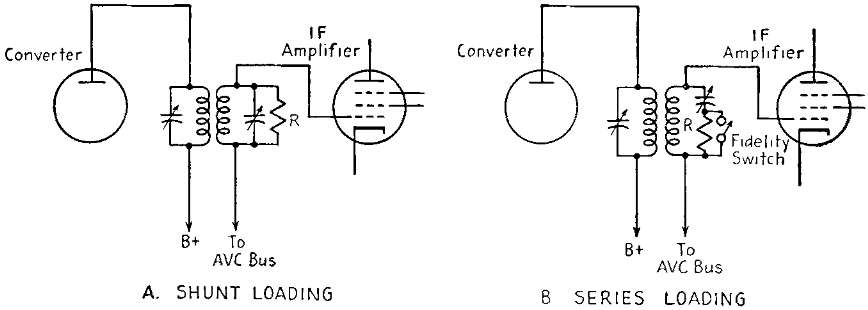


FIG. 13–20. Resistance loading to broaden response characteristic of an IF amplifier.

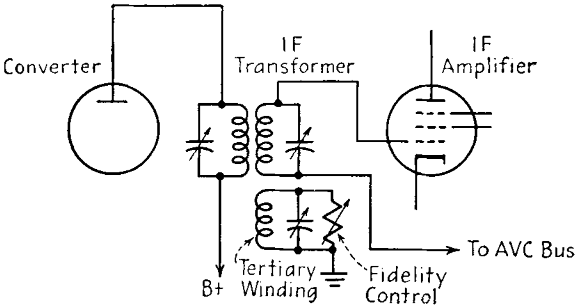


FIG. 13–21. Tertiary winding to broaden response characteristic of an IF amplifier.

sults in a decreased gain and a broader response curve. The amount of broadening is determined by the amount of loading; that is, the ohmic value of the resistor. The single-stage curve of Fig. 13–18 is typical for a resistance-loaded transformer.

A third method of broadening the response of the IF transformer is to use loosely coupled primary and secondary windings, and to introduce a third winding, known as a "tertiary" coil, closely coupled to the secondary winding. The tertiary is also tuned to the intermediate frequency and absorbs energy from the secondary winding, thereby acting as a load and broadening the response. A resistor, if used in the tertiary winding, increases the effect. Figure 13–21 shows a circuit for an IF transformer with a tertiary winding.

From the serviceman's point of view, a two-stage IF amplifier presents few complications. The signal check is about the same as for a single-stage IF amplifier, since the gain per stage is considerably lower. It merely adds another grid from which to check. The presence of two peaks close together is to be expected, especially where overcoupling is employed. The IF transformers are subject to the same ills as with a single stage. They open and become noisy because of corrosion; the same checks are applicable. However, when an IF transformer is replaced in a two-stage IF amplifier, it becomes more necessary to employ an exact replacement.

Because of an added stage, more decoupling filters will be used. However, the treatment of them will not vary from that given for our standard circuit.

The alignment of broad-band IF amplifiers can best be performed with an oscilloscope, but satisfactory alignment can be obtained with a standard signal generator and output meter. It is extremely important to follow the manufacturer's service instruction. Where such instructions are not obtainable, a generalized procedure may be followed. Set the receiver for maximum gain position (not high-fidelity); that is, minimum coupling where a coupling control is used (shunt resistors switched out where this is the method), and align for maximum response, as usual. Then switch to the high-fidelity position and rotate the signal generator about 10 kc on each side of the intermediate frequency, noting the output-meter deflection. If it remains fairly constant for about 5 kc on each side of the intermediate frequency, the alignment may be considered good. If the output meter fails to remain constant, alignment adjustments should be repeated.

Overcoupling and use of a tertiary coil may sometimes be used in a single-stage IF amplifier, where gain is sacrificed for fidelity of reproduction. The tertiary coil may be switched out here for greater gain at the expense of fidelity.

Broad-band IF amplifiers are not usually employed in AC/DC receivers, where emphasis is on simplicity, low cost, and maximum gain from the fewest tubes.

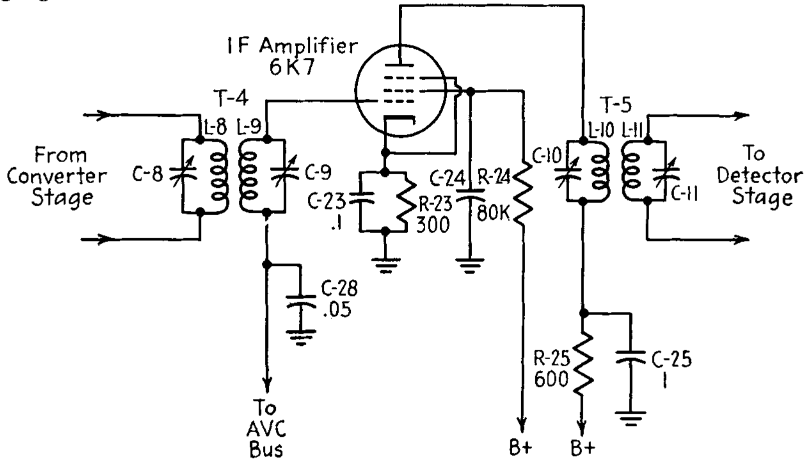
SUMMARY

Quick check

Introduce a modulated signal at the intermediate frequency to the signal grid of the converter tube. When the IF stage is functioning properly, the modulation note will be heard in the speaker. The response will be much stronger than that heard when the detector stage is checked; that is, when the signal is applied to the IF grid.

Diagram of typical IF amplifier stage

A diagram of the typical IF amplifier stage is given in the accompanying figure.



Voltage check

Readings are taken from chassis or common negative terminal. Normal voltage data are given in the accompanying table.

Tube elements	*AC receivers, volts*	*6K7 pin No.*	*AC/DC receivers, volts*
Plate	250	3	90
Screen	100	4	90
Cathode	3	8	3

Normal resistance data

Normal resistance data are given in the table on the next page.

	Resistance ohms	
	Air core	Iron core
Across *L*-8, primary of *T*-4	30–50	5–15
Across *L*-9, secondary of *T*-4	30–50	5–15
Across *L*-10, primary of *T*-5	30–50	5–15
Across *L*-11, secondary of *T*-5	30–50	5–15
Cathode to chassis	300–600	
Control grid to chassis	1,500,000	
Screen grid to chassis	140,000*	
Screen gird to *B* plus	80,000*	
Plate to *B* plus	640†	

* These values are for the standard circuit. Owing to the wide divergence in methods of obtaining screen supply, these readings should be checked against the receiver schematic diagram.
† If there is no decoupling filter, this reading will be simply the DC resistance of *L*-10, the primary of the output IF transformer *T*-5.

A wide divergence is given for the coils *L*-8, *L*-9, *L*-10, and *L*-11, to allow for differences between receivers. In any one receiver, owing to the common use of matched transformers, these coils should all check very close to the same value within the limits given.

Signal-substitution test procedure for an inoperative IF amplifier

The test oscillator, receiver, and output meter are connected as shown in Fig. 13–22. The signal generator is adjusted for modulated output on the IF band. The receiver is adjusted for maximum volume, minimum bass response, and maximum selectivity (if there is such a control); the RF portion is made inoperative by shorting the oscillator section of the gang tuning condenser. Let us assume normal operation of the audio amplifier, as proved by a normal response when an audio test signal is applied to point ⑤, the input of the AF amplifier, and no response or weak response when a modulated signal at the intermediate frequency is applied to point ①, the converter signal grid.

Step 1. The test lead from the signal generator is moved to point ②, the converter plate.

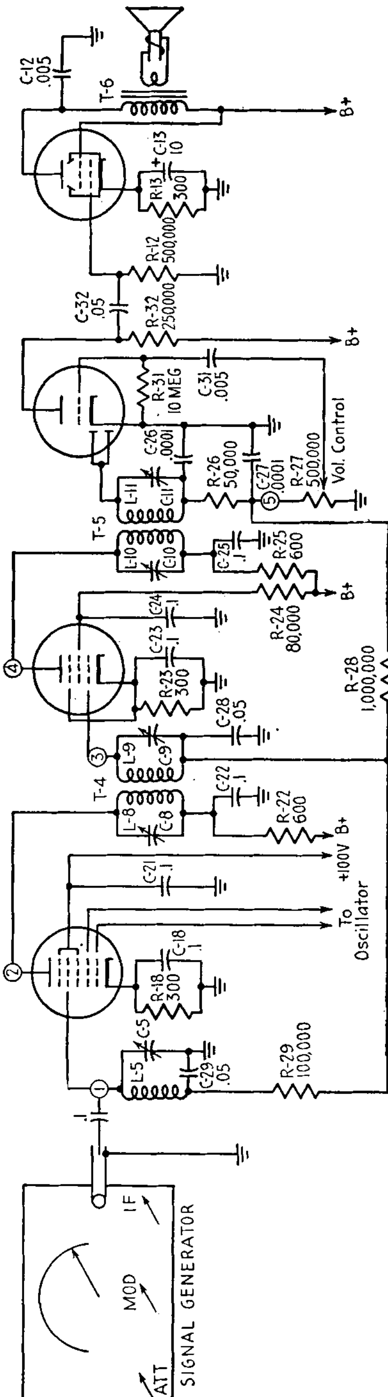


FIG. 13–22. Signal check for locating trouble in an IF amplifier.

1. If a normal response results, the trouble may be
   a. A shorted converter signal grid (most likely a short in the gang tuning condenser).
   b. A defective converter tube (substitute a good one).
   c. Open or shorted plate, screen, or cathode circuit in the converter tube (detected by voltmeter check).
2. If the signal does not come through or remains very weak, move on to step 2.

Step 2. The test lead from the signal generator is moved to point ③, the IF grid.

1. If a normal response (3,500 microvolts input for standard output) results, the trouble may be
   a. A defective input IF transformer (detected by ohmmeter check).
   b. An open AVC by-pass condenser *C*-28. (Bridge it with a good one and recheck from point ①.)
   c. Input IF transformer *T*-4 badly misaligned (check alignment).
2. If the signal does not come through or remains very weak, move on to step 3.

Step 3. The test lead from the signal generator is moved to point ④, the IF plate. The attenuator is advanced, and the frequency control is wobbled through the intermediate frequency.

1. If the signal comes through, the trouble may be
   a. A shorted IF grid. (Detected by ohmmeter check. The short would most likely be between the grid wire or trimmer and the IF shield can.)
   b. A defective IF tube (substitute a good one).
   c. Open or short in the plate, screen, or cathode circuits of the IF tube (detected by voltmeter check).
2. If the signal does not come through, check the detector stage (see Chap. 12).

SERVICE DATA CHART

Symptom	*Abnormal reading*	*Look for*
No reception	Plate voltage = 0	Open IF output transformer. Shorted plate by-pass condenser C-25. Open plate circuit decoupling resistor *R*-25. Plate-to-ground short in IF can
	Screen voltage = 0	Shorted screen by-pass condenser C-24. Open screen voltage-dropping resistor *R*-24
	High cathode voltage	Open minimum-bias resistor *R*-23
	All voltage checks are normal	Dead IF tube *V*-3. Shorted trimmers in the IF cans. Open IF transformer secondaries. Open AVC by-pass condenser C 28
Weak signal	All voltage checks are normal	Weak IF tube *V*-3. Open AVC by-pass condenser C-28. Open cathode by-pass condenser C-23. Open plate circuit by-pass condenser C-25. Misalignment
Noise	All checks are normal	Noisy IF tube *V*-3. Corrosion in the IF transformer windings
Squeal or oscillation	All checks are normal	Open screen by-pass condenser C-24. Open ground connection to shielding. Incorrect IF tube *V*-3. Open AVC by-pass condenser C-28. Open plate circuit by-pass condenser C-25. Incorrect wire dress

QUESTIONS

1. A receiver does not play. Signal check shows normal operation when a test signal is applied to the IF plate; no response when the test signal is shifted to the IF grid. List the likely sources of trouble, and explain how you would check for each.

2. A receiver does not play. Signal check shows normal operation when the proper test signal is applied to the IF grid; no response when the test signal is shifted to the converter plate. List the likely sources of trouble, and explain how you would check for each.

3. The receiver of Fig. 12–17 is inoperative. A signal check shows that the trouble is in the IF stage. A voltage check gives normal readings for the stage. List the likely causes of the trouble, and explain how you would check for each.

4. A receiver gives the following voltage readings for the IF stage:

Plate	250 volts
Screen	130 volts
Cathode	50 volts

What is the probable trouble, and how would you check for it?

5. A receiver gives the following voltage readings for the IF stage:

Plate	0 volt
Screen	95 volts
Cathode	1 volt

What are the probable troubles? What should the next checks be?

6. An AC superheterodyne receiver oscillates badly. The oscillation continues when the converter tube is removed but stops when the IF tube is removed. This indicates that the cause of the trouble is probably in the IF stage. What checks and adjustments should be made to track down the trouble?

7. What factors in the IF stage can cause noisy reception? How would you check for each?

14 CONVERTER: MIXER AND OSCILLATOR STAGES

After the IF check, the next area for investigation is the converter, which consists of two distinct stages: the mixer and the oscillator. Their functions are so closely interrelated that they are best handled as one unit—the converter. In most receivers, the two stages are combined in one pentagrid converter tube, although some receivers use separate mixer and oscillator tubes. Service analysis is similar for both types of receivers.

The modulated RF signal from the stage before the converter is fed to the mixer grid of the converter tube, where it is mixed with the unmodulated RF signal from the local oscillator stage. The signal on the mixer grid, regardless of frequency, is changed by the converter to a signal with the same frequency, the intermediate frequency of the receiver. The signal at the intermediate frequency retains the same audio modulation that is present in the RF signal fed to the mixer grid. The IF signal is then fed to the input of the IF amplifier.

Many superheterodyne receivers do not incorporate an RF stage. In receivers of this type, the antenna is coupled to the converter mixer grid. In the signal-substitution method of servicing, where the trouble shooter works from the speaker back to the antenna, the converter will be the last area of investigation for receivers of this type.

Quick check for the operation of the oscillator stage. Tune the receiver to 600 kc. Connect the signal-generator output to the converter signal grid through a 0.1 mfd condenser, and rotate the signal-generator dial through 600 kc. If the signal-generator modulation note is heard in the speaker at or near 600 kc, the oscillator is functioning.

Quick check for the operation of the mixer stage. Tune the receiver to 1,400 kc. Connect the signal-generator output to the RF grid (antenna if there is no RF stage) through a 0.00025-mfd condenser, and rotate the signal-generator dial through 1,400 kc. If the signal-generator modulation note is heard in the speaker at or near 1,400 kc, the mixer stage is functioning.

Function of the converter. The function of the converter is fourfold:

1. It tunes and amplifies the received signal.
2. It generates an unmodulated RF signal of its own at a frequency different from the received signal.
3. It mixes the locally generated signal with the received signal.
4. It maintains a constant frequency difference (the intermediate frequency) between the locally generated signal and any signal to which the receiver is tuned.

Standard circuit of a converter. This circuit is shown in Fig. 14–1.

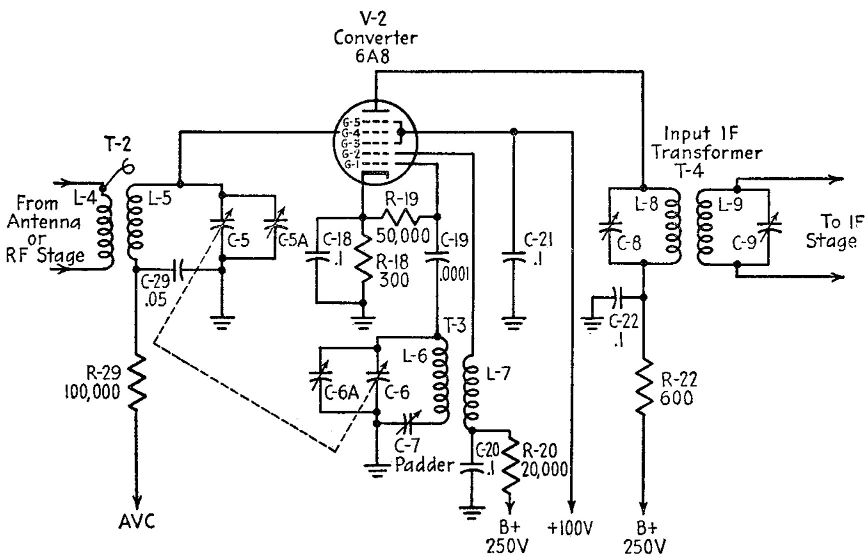


FIG. 14–1. Typical pentagrid converter circuit.

Theory of operation of the converter. The theory of operation of the converter can be explained by elaborating the four functions listed above.

1. It tunes and amplifies the received signal. The input of the stage is RF transformer *T*-2, which couples the preceding RF stage or antenna to the converter tube. Tuning is accomplished by the circuit composed of *L*-5 and *C*-5, which feeds the signal to *G*-4, the signal grid of the converter tube. Grids *G*-3 and *G*-5 are tied together and act as a screen, so that this section of the converter tube plus cathode and plate is a tetrode amplifier. Condenser *C*-5 is one section of the ganged tuning condenser.

2. It generates an unmodulated RF signal of its own at a frequency different from the received signal. The cathode and grids *G*-1 and *G*-2 act as a triode oscillator. This can be more easily seen by redrawing the oscillator stage of the converter, as shown in Fig. 14–2. Grid *G*-1 acts as the oscillator grid while grid *G*-2 acts as the oscillator plate or anode. Coil *L*-6 and its associated condenser *C*-6 are located in the oscillator grid circuit and make up the tuning section for the oscillator. Condenser *C*-6 is the oscillator section of the gang tuning condenser. Feedback from the plate circuit is obtained by coupling between *L*-6 and *L*-7, the latter coil being in the oscillator anode circuit. The feedback is in proper phase and of sufficient strength to maintain oscillation, the frequency of which is controlled by *L*-6, *C*-6, *C*-6*A*, and *C*-7. The function of condenser *C*-7 will be explained in more detail in the section on tracking.

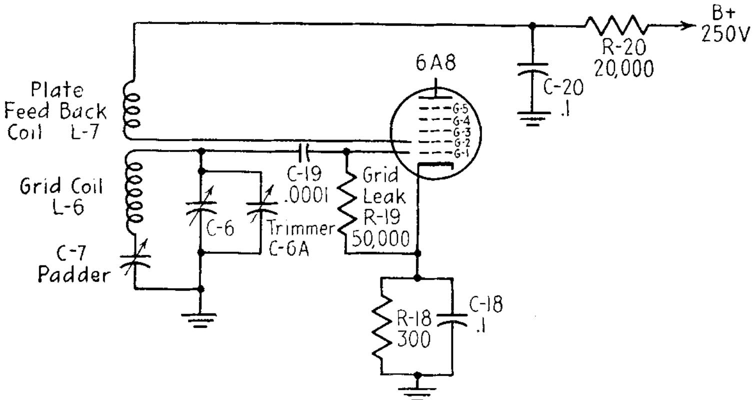


FIG. 14–2. Oscillator circuit in the 6A8 pentagrid converter.

3. *The converter mixes the locally generated signal with the received signal.* The electron stream coming from the cathode is caused to pulse by the oscillator action of grids *G*-1 and *G*-2, at a rate determined by the values of *L*-6, *C*-6, *C*-6*A*, and *C*-7. Since the oscillator anode is not a solid plate but a pair of rods, most of the pulsing electron stream will go right through the oscillator anode *G*-2 to the rest of the converter tube. The received signal is applied at *G*-4, where it contributes its own effect on the pulsing electron stream, thereby mixing the signal and oscillator output in the converter tube. Grid *G*-4 in the converter tube is sometimes called the "converter signal" grid, and sometimes called the "mixer" grid. The plate output circuit of the converter tube, therefore, will contain a signal with components at the received signal frequency, the oscillator frequency, the sum of these two frequencies and the difference of these frequencies. This type of mixing of two signals is known as "electron" mixing.

4. *The locally generated signal must maintain a constant frequency difference (the intermediate frequency) with any signal to which the*

receiver may be tuned. Of all the signals present in the converter plate circuit, the IF amplifier accepts only the one to which it is tuned. This is the signal that is at the difference frequency between the received signal and the locally generated signal. The oscillator frequency is usually higher than the frequency of the received signal. A few examples may clear this up. The most commonly used intermediate frequency is 455 kc. This will be used in the examples. Let us assume that the wanted station signal is 1,000 kc, approximately in the center of the broadcast band. Then the signal tuning circuit (*L*-5, *C*-5) will be at 1,000 kc. The frequency of the oscillator section, controlled by *L*-6, *C*-6, *C*-6*A*, and *C*-7, will be 455 kc higher, or 1,455 kc.

The converter plate circuit will contain various frequency components:

1,000 kc	Received signal
1,455 kc	Oscillator signal
2,455 kc	Sum of the above
455 kc	Difference between the first two

The sharply tuned IF amplifier will accept the signal at 455 kc, amplify it, and pass it on to the detector.

If the desired signal is near the low-frequency end of the broadcast band at 600 kc, the signal input circuit (*L*-5, *C*-5) will be tuned to 600 kc, and the oscillator tuning circuit composed of *L*-6, *C*-6, *C*-6*A*, and *C*-7 will be tuned to 1,055 kc, making the difference frequency 455 kc.

At the high-frequency end of the broadcast band, the oscillator must be adjusted to 1,955 kc to receive a signal at 1,500 kc. The two signals are mixed in the converter tube, giving, among others, the same difference frequency of 455 kc.

From the above examples, it can be seen that the prime function of the converter is to change any received signal to a signal at 455 kc, the intermediate frequency. It follows as a corollary that the oscillator frequency must be greater by 455 kc, the intermediate frequency, than the desired station signal frequency. An oscillator frequency 455 kc lower than the desired signal frequency could also be used. This is sometimes done in reception on the short-wave bands.

Tracking. In a receiver operating on the broadcast band, condenser *C*-5 tunes coil *L*-5 from 550 to 1,600 kc in the received signal circuit (the mixer grid circuit). In the oscillator tuning circuit, condenser *C*-6 tunes coil *L*-6 from 550 plus 455, or 1,005 kc to 1,600 plus 455, or 2,055 kc, where the IF amplifier is tuned to 455 kc. Since condensers *C*-5 and *C*-6 are parts of the same tuning gang, there is considerable design work needed to make these two tuning circuits always 455 kc (or the intermediate frequency) apart. The ability of a receiver to perform equally well on all parts of the tuning range is dependent on this factor, which is known as "tracking." Alignment instructions often include tracking adjustments on both ends of the tuning range and a tracking check in the center. The usual check points on the broadcast band are 600 kc for the low-frequency end, 1,000 kc for the middle, and 1,400 or 1,500 kc for the high-frequency end.

Oscillator tuning circuit. The RF tuning circuits have a tuning range for the broadcast band of 550 to 1,600 kc. The oscillator tuning circuit for the same band must have a tuning range of 1,005 to 2,055 kc. The two tuning circuits must, therefore, be considerably different.

The oscillator tuning circuit can perhaps be better understood if it is redrawn, as in Fig. 14–3. It can now be recognized as an *L-C* circuit, the *L* being the oscillator coil. The *C* of the *L-C* circuit is composed of the main tuning condenser *C*-6 with its shunt trimmer *C*-6*A*, both of

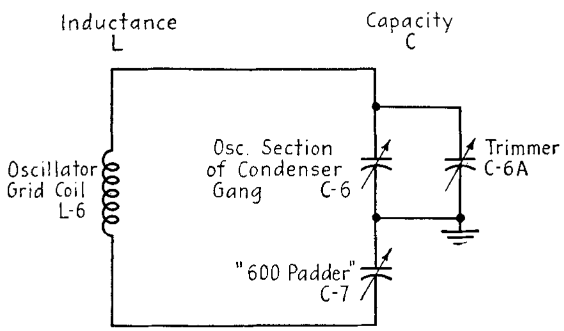


FIG. 14–3. Oscillator tuning circuit.

which are in series with condenser *C*-7. The latter is an adjustable condenser of comparatively high capacity. Trimmer *C*-6*A* is a low-capacity unit. Now we need only remember that the capacity of condensers in series is lower than the individual condensers, whereas the capacity of condensers in parallel is additive.

When tuning condenser *C*-6 is in a low-capacity position, the lumped *C* in the tuning circuit is small (series condensers). Trimmer condenser *C*-6*A* is an important cog at this position since its small capacity is added to the small capacity of the tuning condenser. The setting of trimmer condenser *C*-6*A*, therefore, controls the low-capacity (high-frequency) end of the tuning range. This trimmer is often called the "high-frequency oscillator aligner."

When tuning condenser *C*-6 is in a high-capacity position, the lumped *C* in the tuning circuit is high since it is composed of two comparatively large condensers in series. Trimmer condenser *C*-6*A* has little effect in this position since its small capacity is added to the large capacity of the tuning condenser. At this time, the setting of adjustable condenser *C*-7 becomes of greater importance since its capacity, now of about the same order as that of the tuning condenser, will have a greater effect on the lumped *C* in the circuit. The setting of adjustable condenser *C*-7, therefore, controls the high-capacity (low-frequency) end of the tuning range. Since this adjustment is usually performed at 600 kc, condenser *C*-7 is often called the "600 padder."

Cut-plate oscillator tuning condensers. In some receivers oscillator tuning condenser *C*-6 has been designed to maintain the 455-kc difference without a low-frequency padder adjustment. In this case, the rotor plates of condenser *C*-6 are smaller and differently shaped than the rotor plates of the other condensers in the tuning gang, as shown in Fig. 14–4.

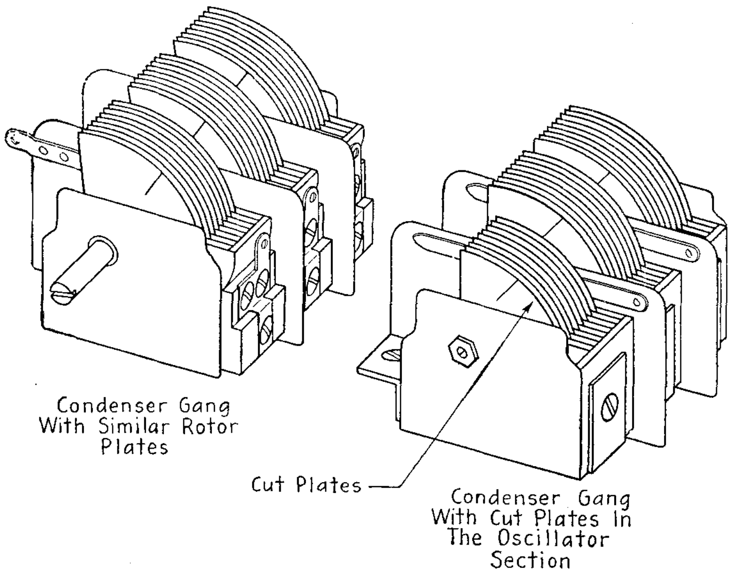


FIG. 14–4. Comparison between condenser gangs with similar rotor plates and with a cut-plate oscillator section.

When the oscillator rotor plates are shaped in this manner, the gang condenser is known as one having a "cut-plate oscillator" section. The shape of the cut plates is so designed that tracking is automatic, in that the capacity in the oscillator circuit maintains its frequency at a value 455 kc higher than the frequency of the received signal.

Functions and values of parts in the converter. From the above discussion, it can be seen that the values of the component parts in the tuning section of the receiver are an important part of the design of any receiver. The serviceman rarely, if ever, changes the values of any of these parts, since any such changes will seriously affect the operation of the receiver in selectivity, sensitivity, and dial calibration. Defective components in the tuning circuit usually require the serviceman to obtain the original manufacturer's replacement parts. As a result, values of parts need not be given, and it merely remains to state the functions of parts not yet mentioned.

The oscillator grid leak and condenser, *R*-19 and *C*-19, develop the oscillator grid-bias voltage. When a tube is in an oscillating condition, there is considerable grid current. This flows through *R*-19 and causes a voltage drop across it. The grid end of the resistor is negative, giving the bias voltage for the oscillator section of the tube.

The voltage developed across *R*-19 is also important from a service point of view, since it makes a good check as to whether the oscillator is operating.

Oscillator grid-leak resistor *R*-19 is usually a 50,000-ohm/½-watt resistor. Oscillator grid condenser *C*-19 is usually a 0.0001-mfd mica or ceramic condenser. Occasionally, a paper tubular condenser is used for *C*-19.

Minimum-bias circuits were described in some detail in connection with *R*-23 and *C*-23 in the chapter dealing with the IF stage. Resistor *R*-18 and condenser *C*-18 form a similar circuit for establishing a minimum-bias voltage to be applied to the signal grid of the pentagrid converter, where AVC operation is used.

Resistor *R*-18 is usually a 300-ohm/½-watt resistor. In some circuits, *R*-18 is made somewhat larger, 500 to 600 ohms. In these circuits, the tube is being operated at a higher minimum-bias voltage. The by-pass condenser *C*-18 is usually 0.05 to 0.1 mfd. The voltage rating of this condenser is unimportant since it is a low-voltage circuit. In some circuits, *C*-18 may be omitted to provide some degeneration in the converter.

Finally, both *R*-18 and *C*-18 may be omitted, and the cathode of the converter tube is tied to the cathode of either the RF or IF tube, resulting in a common minimum-bias voltage for both tubes.

The AVC decoupling filter (*R*-29 and *C*-29) has been described in the detector and AVC stage. Typical values are 100,000 ohms/½-watt for *R*-29, and 0.05 mfd/400 volts for *C*-29. When there is no RF stage, *R*-29 and *C*-29 are usually omitted, and the signal grid return of coil *L*-5 is connected directly to the AVC bus.

The tube used is the metal 6A8 pentagrid converter. The 6A8-G or 6A8-GT are also used in similar circuits. In the latter case, the tube is usually covered by a closely fitting metal shield. Receivers using loctal-type tubes use the 7B8 or 7B8-LM. An older variety of the same tube is the 6A7.

Another tube very commonly employed is the 6SA7 or the 6BE6 pentagrid converter. In this case the circuit is somewhat different. A circuit using the 6SA7 will be described in Chap. 15.

AC/DC receivers may use any of the above tubes in circuits where the filament drain is 0.3 amp. In circuits utilizing a 0.15-amp filament line, 12-volt/0.15-amp tubes like the 12BE6, 12SA7, and 14Q7 pentagrid converters are used.

The oscillator anode filter circuit, *R*-20 and *C*-20, also acts as a voltage-dropping device for the oscillator anode. *R*-20 is usually a 20,000-ohm/½-watt resistor and *C*-20 is a 0.1-mfd/400-volt condenser. Where the total *B* voltage of the receiver is 200 volts or less, *R*-20 and *C*-20 may be omitted.

The converter-plate-circuit decoupling filter consists of *R*-22 and *C*-22. Resistor *R*-22 is usually 400 to 1,000 ohms, while condenser *C*-22 is 0.05 to 0.1 mfd. Like all decoupling or isolating circuits, *R*-22 and *C*-22 may be omitted.

The input to the mixer stage of the converter is the RF transformer *T*-2. The primary *L*-4 is in the plate circuit of the RF tube, or antenna circuit where no RF stage is used. The secondary *L*-5, which is tuned by *C*-5 of the ganged variable condenser, feeds the signal to the signal grid of the pentagrid converter tube. In some receiver circuits, RF transformer *T*-2 is replaced by an untuned resistance-coupled stage.

In receivers that do not use an RF stage, RF transformer *T*-2 couples the antenna to the signal grid of the pentagrid converter tube. In this case, *L*-4 the primary of the transformer is connected to the antenna and ground. In loop-operated receivers that do not use an RF stage, RF transformer *T*-2 is replaced by the loop antenna. Coil *L*-5 is the main part of the loop, which is still tuned by condenser *C*-5 in the usual way. Primary coil *L*-4 consists of two or three turns on the loop, which may be connected to an external antenna and ground when it is desired to obtain greater signal pickup. Figure 15–2 shows a loop-operated receiver of this type.

NORMAL TEST DATA FOR THE CONVERTER

Signal check for normal operation of the oscillator. When the operation of the oscillator is checked, the test signal is applied to the converter mixer grid (sometimes called the "signal" grid). This is the same point that was used in checking the IF amplifier. Before the oscillator check is made, any short that had been placed on the oscillator tuning condenser for previous tests is removed. The receiver is tuned to 600 kc. The signal-generator dial had been set at 455 kc for checking the IF amplifier. At this position, the modulation note will still be heard in the speaker. The signal-generator dial is then rotated past 600 kc. As the dial leaves 455 kc, the modulation note should die out, and it should be heard again, at about the same volume as before, when the signal-generator dial pointer passes 600 kc. This is the signal check for normal operation of the oscillator portion of the converter.

If the modulation note is not heard, the oscillator section is inoperative. If the note is considerably weaker than the note at 455 kc, the converter tube is probably weak. If the note is heard when the signal-generator frequency control is at a considerable distance from 600 kc, the oscillator circuit is probably out of alignment.

This check could be performed at any position in the tuning range. However, it is recommended that the check be performed at 600 kc, since oscillator action is normally weaker at the low-frequency end of the tuning range.

Signal check for normal operation of the mixer. When normal operation of the oscillator section has been found, the next step is to check for normal operation of the mixer portion of the converter. The test signal

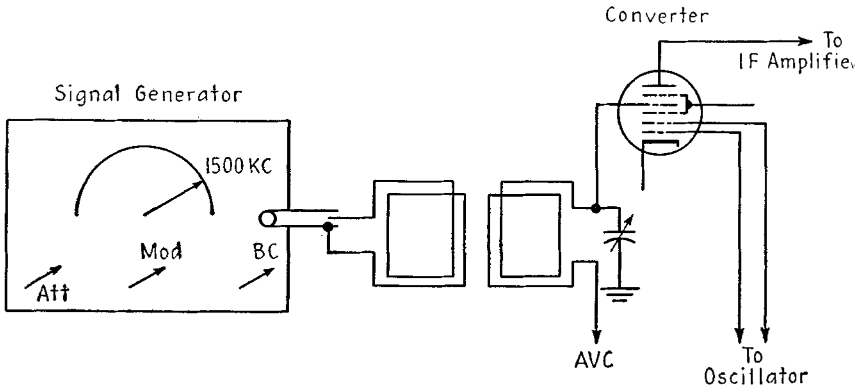


FIG. 14–5. Method of connecting a signal generator to a loop-operated receiver.

is applied through a 0.00025-mfd condenser to the control grid of the RF tube. Where there is no RF tube, the test signal is applied to the antenna lead of the receiver. The antenna lead is, of course, readily available. The same applies to the control grid of the RF tube in the case of a 6K7 where it is the top contact. Where a single-ended RF tube is employed, the test point is most easily available at the stator connection of the RF section of the gang tuning condenser. Where the receiver has no RF stage and is loop-operated and where there is no antenna terminal on the receiver, the signal generator is fed into a loop made up of a few turns of wire. This loop, known as an "injection loop," is then placed near the loop antenna of the receiver, as shown in Fig. 14–5.

The receiver dial is set to 1,400 kc. If an output meter is connected to the receiver, it should be switched to a high-voltage range. This is important since the amplification from the RF grid is very high and even a moderate test-signal input may furnish sufficient output voltage to bend the output meter pointer.

The signal generator frequency control is rotated a few points each side of 1,400 kc. When the receiver is functioning normally, the signal generator modulation note should be heard in the speaker as its dial pointer passes 1,400 kc. It should be considerably louder than the last check (the oscillator section), where the test signal was applied to the mixer grid.

If the signal-generator note is not heard, the mixer section must be checked. The same applies if the check shows no gain over the check from the mixer grid. If the note appears at a considerable distance from 1,400 kc on the signal-generator dial, alignment is indicated.

Normal voltage data for the converter. Readings taken from indicated terminals to the chassis or common negative terminal of the receiver are given in the accompanying table.

	6A8 pin No.	*AC receiver, volts*	*AC/DC receiver, volts*
Plate	3	250	90
Screen	4	100	50
Oscillator anode	6	200	90
Oscillator grid	5	−15	−10
Cathode	8	3	3

Normal resistance data for the converter. Resistance data are given in the following table.

Across *L*-4, primary of the signal input transformer *T*-2	40 ohms
Across *L*-5, secondary of the signal input transformer	5 ohms
Across *L*-6, grid coil of the oscillator transformer *T*-3	5 ohms
Across *L*-7, feedback coil of the oscillator transformer	3 ohms
Cathode to chassis	300 ohms*
Signal grid (*G*-4) to chassis	1,600,000 ohms
Screen grid (*G*-3 and *G*-5) to chassis	30,000 ohms*
Plate to *B* plus	640 ohms*
Oscillator grid (*G*-1) to chassis	50,000 ohms
Oscillator anode (*G*-2) to *B* plus	20,000 ohms

* These readings are for the standard circuit and should be checked against service notes for any particular receiver.

In receivers where the signal input transformer *T*-2 is a loop antenna, the grid coil of the loop will measure 1 to 3 ohms. The antenna winding will measure less than 1 ohm.

Sensitivity checks for the converter from the converter signal grid. The serviceman should run some checks on receivers known to be in perfect

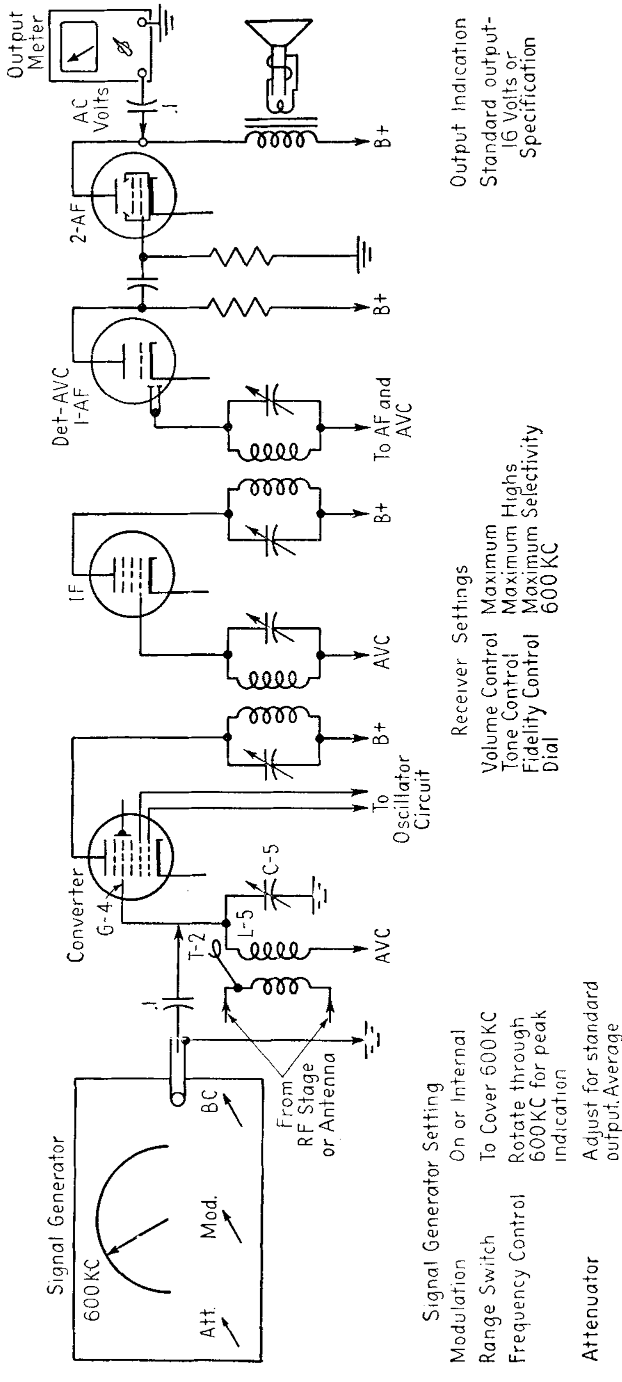


FIG. 14–6. Sensitivity measurements from the mixer grid.

operating condition, so that he has a basis of comparative data on his bench test equipment, and normal gain data to be expected from the converter. In addition, he should tabulate his experience with each of the various types of converters.

There are two check points for the converter: the converter signal grid *G*-4, and the RF grid or antenna, if the receiver does not use an RF stage. The receiver, signal generator, and the output meter are connected, as shown in Fig. 14–6, to check from the converter signal grid. The receiver is adjusted as follows: The volume control is set to the maximum-volume position; the tone control to the minimum bass position; the selectivity control is set for the position of maximum selectivity; and the receiver dial is adjusted to 600 kc. Any short placed across the oscillator section of the tuning condenser gang for previous tests should be removed. The output meter is switched to a high-voltage range. The signal-generator output leads are connected shield to chassis, and the "hot" lead through a 0.1-mfd condenser to the converter signal grid. The signal generator is adjusted to give a modulated signal on the broadcast band. The attenuator setting is kept comparatively low, since approximately 50 microvolts will give standard output from the receiver.

The frequency-control dial on the signal generator is rotated through 600 kc for peak output from the receiver. When the peak position is found, the attenuator on the signal generator is adjusted to give the standard output of 50 mw from the receiver. When the output voltage is low enough, the range switch of the output meter is reduced so that the 16 volts which correspond to 50 mw can be read more accurately.

The average 600-kc signal strength necessary to give standard output from the converter signal grid is 50 microvolts. In making sensitivity checks for the IF amplifier (see page 196), it was seen that the average IF signal strength necessary to give standard output from the converter signal grid was also 50 microvolts. From the above it may be seen that the gain of the receiver from the converter signal grid should be approximately the same for a signal at the intermediate frequency as for the RF signal to which the receiver is tuned. Any great difference in signal input (attenuator setting) for standard output would indicate a defective converter tube.

Sensitivity checks for the converter, including the tuned signal grid input. Since the capacity of the signal generator will detune the converter signal grid circuit, measurements to include the tuned circuit must be made, as was done in all other checks, from a previous point in the receiver. Figure 14–7 shows the connections for a receiver with an RF stage. Note that the condenser in the "hot" lead of the signal generator is 0.00025 mfd. When the receiver has no RF stage, measurements are made from the antenna terminal, as shown in Fig. 14–8. When a loop-operated receiver has no antenna terminal, coupling the signal to it through an injection loop, while satisfactory for signal checks, is unreliable for sensitivity measurements. In either case, the receiver is adjusted for maximum gain; that is, the volume control is set to the full ON position, tone control to the minimum bass, and the selectivity-fidelity control to the position of maximum selectivity. The receiver dial

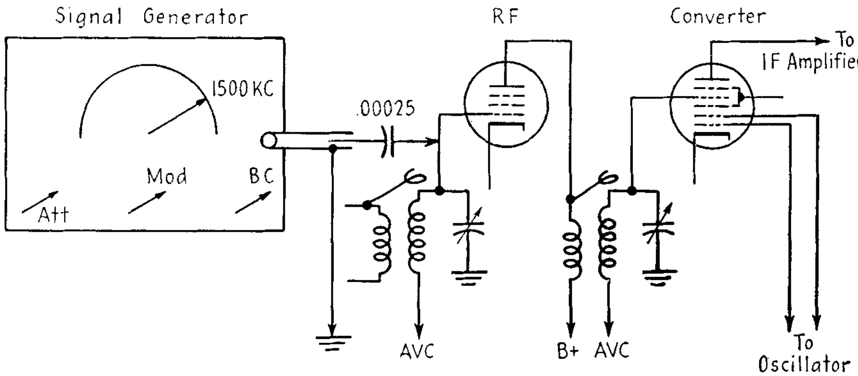


FIG. 14–7. Signal-generator connections for sensitivity measurements of the converter when the receiver incorporates an RF stage.

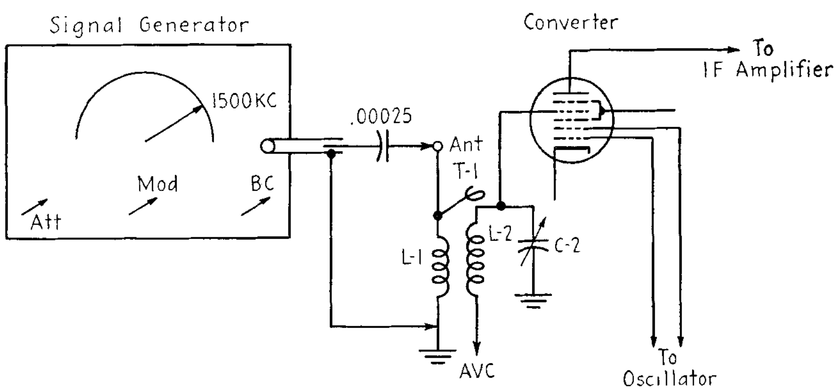


FIG. 14–8. Signal-generator connections for measurements of converter gain when the receiver does not include an RF stage.

is tuned to 1,500 kc. (If a station is received at this frequency, it will interfere with the check. When this is the case, the receiver is tuned to a quiet part of the dial between 1,400 and 1,600 kc.) The output meter is set for a high-voltage AC range. The signal generator is adjusted for a modulated output on the broadcast band.

The frequency-control dial on the signal generator is then carefully rotated through 1,400 to 1,600 kc for peak response from the receiver.

When the peak position is found, the attenuator is adjusted to give the standard output of 50 mw in the speaker. When the standard output has been obtained, the signal-generator frequency control is again adjusted for peak response on the output meter, and the attenuator readjusted if a response greater than 50 mw was obtained. This repetition is necessary because a high-level signal input would bring AVC action into play with a consequent broadening of the peak.

The average signal strength at 1,500 kc needed to give the standard output of 50 mw from the antenna of a receiver that does not use an RF stage is 20 microvolts. When a receiver uses an RF tube, the average input signal (at 1,500 kc) applied to the RF grid is 5 microvolts for standard output from the receiver. The added gain is due to the amplification of the RF tube.

Sensitivity checks at signal levels of 5 or 20 microvolts are unreliable because of leakage in the attenuator circuits, insufficient shielding, and noise pulses. Just look for a reduced attenuator setting from the previous 50-microvolts setting obtained at the converter grid. The reduced setting indicates the gain.

Having established comparative gain data with several good receivers, the serviceman is in a position to judge the gain characteristics of any converter stage. He should remember, however, that these checks are approximate and that there will be considerable variation shown when different receivers are checked.

COMMON TROUBLES IN THE CONVERTER

Troubles common to the RF input transformer. The RF input transformer, *T*-2, is likely to be an interstage RF transformer coupling the RF stage to the converter, an antenna coil coupling the antenna to the converter, or a coil loop acting as the antenna for the receiver, depending on the type of receiver. The three types of coupling units all have one common trouble—that is, the windings open—but they present different service problems and will be handled separately.

Service notes for an interstage RF transformer. An open secondary winding of an interstage RF transformer will be found on signal check. At such time, when a test signal, either at RF or IF, is fed into the converter signal grid, the signal will come through to the speaker, but the gain will probably be low. In addition, the modulation note of the signal generator will have a rough tone due to the open grid circuit. When the test signal is applied to the RF grid, the response will be very low. The condition is then confirmed with an ohmmeter check.

When the primary of the interstage RF transformer is open, the receiver will operate normally when the test signal is applied to the converter signal grid but will not operate at all when the test signal is shifted to the RF grid. A voltage check will then show no voltage at the RF plate, and a continuity check will confirm the trouble.

Before a defective interstage RF transformer is replaced, it would be wise to examine the coil, since the break is often at or near a terminal lug and is easily repaired. Even removing a turn to effect a repair is permissible.

An exact replacement of the RF interstage transformer is necessary, since tuning circuits will not bear wide tolerances. However, at times, the coil is beyond repair, an original replacement cannot be obtained, and a general replacement transformer is the only alternative. In this case, the serviceman should choose the replacement transformer carefully, so that it matches the original as closely as possible in physical

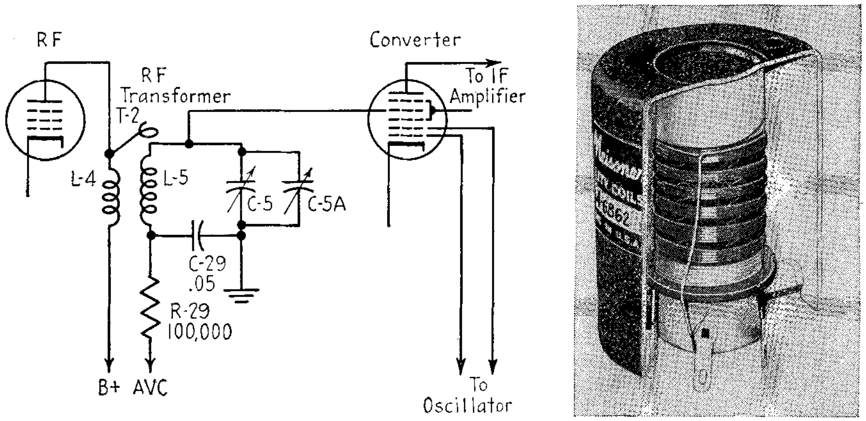


FIG. 14–9. A typical interstage RF transformer and its position in the circuit.

characteristics. The important points to keep in mind are the size of the shield, length and diameter of the coil form, and size and location of the windings.

When the replacement transformer has coded leads, the color coding is the same as for an IF transformer.

Blue wire	Plate
Red wire	*B* plus
Green wire	Grid
Black wire	Grid return

The placing of the green grid lead can easily be altered to conform to the placing in the original transformer. For example, assume that the replacement transformer is designed for a single-ended converter tube with all leads coming out of the bottom and is to be used with a top-cap 6A8 tube. Remove the coil from the can, drill a hole in the top of the can, and reroute the green lead when replacing the coil.

When the replacement-transformer coil leads are brought to unmarked soldering terminals, the terminals can be identified as described in the next section.

How to identify RF transformer coil leads. For the identification of RF transformer coil leads, see Fig. 14–10 and the following notes.

Plate lead. Look for the gimmick loop. Trace it to the coil terminal lug. This is the plate lead, which connects to the RF plate.

B plus lead. Look for the leads on the primary coil. One goes to the

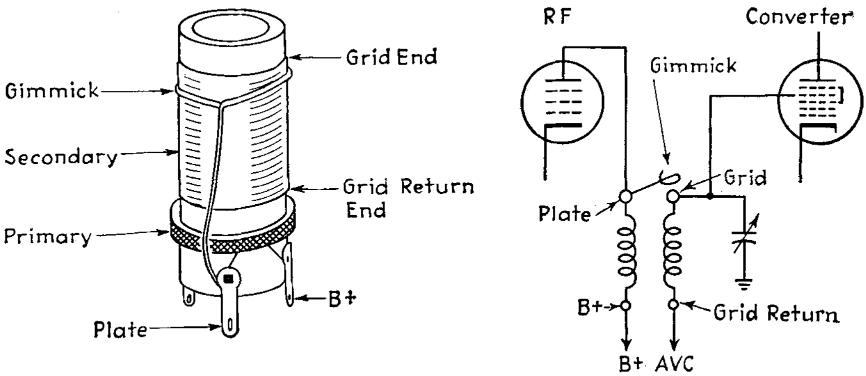


FIG. 14–10. Interstage RF transformer leads.

plate lead. Trace the other lead to its terminal lug. This is the *B* plus lead.

Grid lead. Look for the secondary coil leads. Trace the top end of the secondary winding (near the gimmick loop) to its terminal lug. This is the grid lead, which connects to the tuning condenser stator and converter signal grid.

Grid return lead. Check to see that the remaining terminal lug goes to the bottom end of the secondary winding. This is the grid return lead, which connects to the AVC circuit.

Service notes for an antenna RF transformer. An open secondary of an antenna RF transformer will be found by a signal check. The radio will operate at reduced gain and possible hum, when a test signal, either RF or IF, is applied to the converter signal grid, and at greatly reduced gain when the test signal is applied to the antenna terminal. An ohmmeter check then confirms the condition.

An open primary winding may or may not cause any appreciable difference in operation. The capacity of the gimmick loop may transfer sufficient energy from the antenna to the secondary winding, so that operation is apparently normal for local reception, and the trouble would not be found unless sensitivity measurements or routine ohmmeter checks are made. In receivers where the open primary winding causes a large difference in reception, even a rough signal check will show a loss in gain between the antenna and the converter signal grid.

All the service notes pertaining to the RF transformer can be applied to the antenna transformer, by making allowance for the fact that the primary connects to antenna and ground, instead of RF plate and *B* plus.

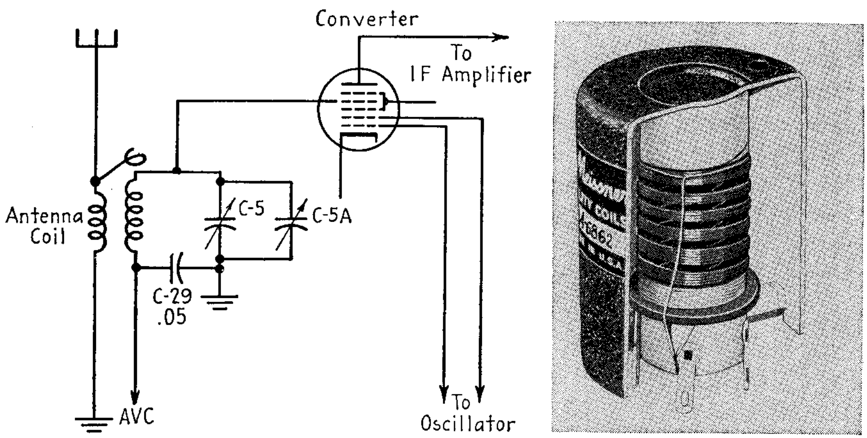


FIG. 14–11. A typical antenna coil and a circuit showing antenna input to the converter tube.

Antenna transformer color code. The R.M.A. color code for the antenna transformer follows:

Blue lead	Antenna
Red lead	Ground
Green lead	Grid
Black lead	Grid return

How to identify antenna transformer leads. For the identification of antenna transformer leads, see Fig. 14–12 and the following notes.

Antenna lead. Look for the gimmick loop. Trace it to the coil terminal lug. This is the antenna lead, which connects to the antenna terminal of the receiver.

Ground lead. Look for the leads on the primary coil. One goes to the antenna terminal. Trace the other lead to its terminal lug. This is the ground lead.

Grid lead. Look for the secondary coil leads. Trace the top end of the secondary winding (near the gimmick loop) to its terminal lug. This is the grid lead, which connects to the tuning condenser stator and converter signal grid.

Grid return lead. Check to see that the remaining terminal lug goes to the bottom end of the secondary winding. This is the grid return lead, which connects to the AVC circuit.

Replacement notes for antenna and RF transformers. When replacing an antenna or RF transformer, the serviceman should be careful of the placement of the leads. Improper lead dress may cause oscillation. The leads should be routed as they were in the original transformer of the receiver. If the wiring has been disturbed, the following general rules should be observed. The blue (plate or antenna) and the green (grid) leads are the "hot" wires. The transformer should be so mounted that the green lead or grid terminal points to its connection point on the tuning condenser stator or signal grid terminal of the converter tube. At the

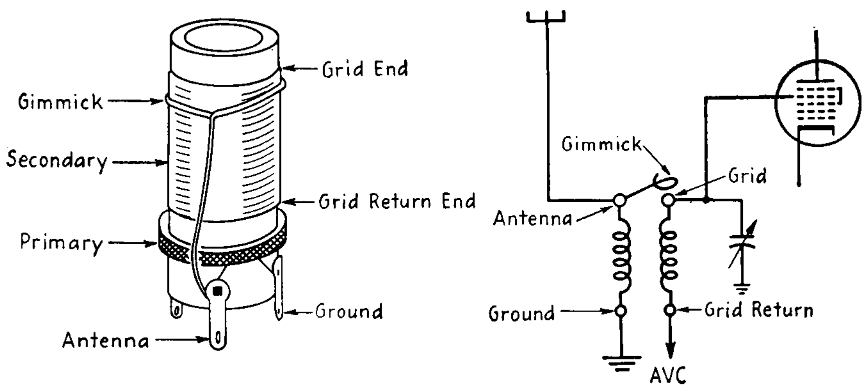


FIG. 14–12. Antenna coil leads.

same time the blue lead (RF plate or antenna terminal) points to its connection point, the plate terminal of the RF tube socket or the antenna terminal. The leads are dressed close to the chassis and away from each other and all other wiring. The dress of the other two leads is not quite so important, but they should also be routed close to the chassis and directly to their connection points.

When an antenna transformer is being replaced in an AC/DC type of receiver, the transformer antenna terminal connects to the hank of wire that acts as the antenna or leadin of the receiver through a condenser. The purpose of this condenser is to insulate the receiver from accidental grounds through the antenna wire. The condenser is usually a paper tubular type that almost never gives any service difficulties. However, the moving of leads, coincidental with the replacement of the antenna transformer, may have caused one of the condenser terminal leads to break away from the tin foil of the plates, causing an intermittent or fading condition. It is a good idea, therefore, when replacing an antenna transformer in an AC/DC receiver to examine carefully the associated condenser terminal leads. If they appear to move under the wax, or if a gentle pull causes the receiver to fade, the condenser should be replaced. The capacity of the condenser is unimportant. Any capacity over 0.002 mfd will be satisfactory.

When the antenna or RF transformer is replaced, the circuit will have to be re-aligned as must be done when any component in any tuned circuit is changed. It is usual practice to re-align the entire receiver.

When universal adjustable replacement antenna and RF transformers are employed, it is necessary to alter the standard alignment procedure somewhat, so that the replacement transformer may be adjusted to work

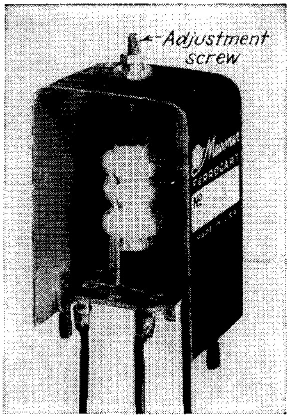


FIG. 14–13. Universal adjustable replacement RF or antenna coil.

properly in the circuit in which it is being placed. The adjustable feature of these coils is permeability tuning with a screw adjustment similar to that used in IF transformers, so that the inductance of the coil may be varied to suit the receiver. An adjustable replacement coil of this type is shown in Fig. 14–13.

The alignment procedure specified for the receiver being serviced, or the standard alignment procedure given on page 448, is followed down to the adjustment of the oscillator trimmer and padder condensers. At this point, the receiver dial is correctly calibrated. The hot lead of the signal generator is connected through a 0.00025-mfd condenser to the antenna terminal of the receiver, the signal generator and receiver dials are both turned to 600 kc, and the permeability adjustment screw of the replacement transformer is tuned for maximum response on the output meter. The receiver and signal-generator dials are then turned to 1,400 kc, and the RF or antenna trimmers on the gang condenser are aligned for maximum output in the usual way. The permeability adjustment-screw setting is then checked at 600 kc and, if readjustment is required, the procedure at 1,400 kc is repeated.

Service notes pertinent to a loop antenna. Loop antennas used with receivers are of many types, but they develop troubles that may be catalogued together. Loops are usually wound with heavy wire and, as a result, are rarely troubled with corrosion, which is the main cause of trouble in all other coils in the receiver. However, the position of the loop in the back of the receiver makes it vulnerable to troubles of a

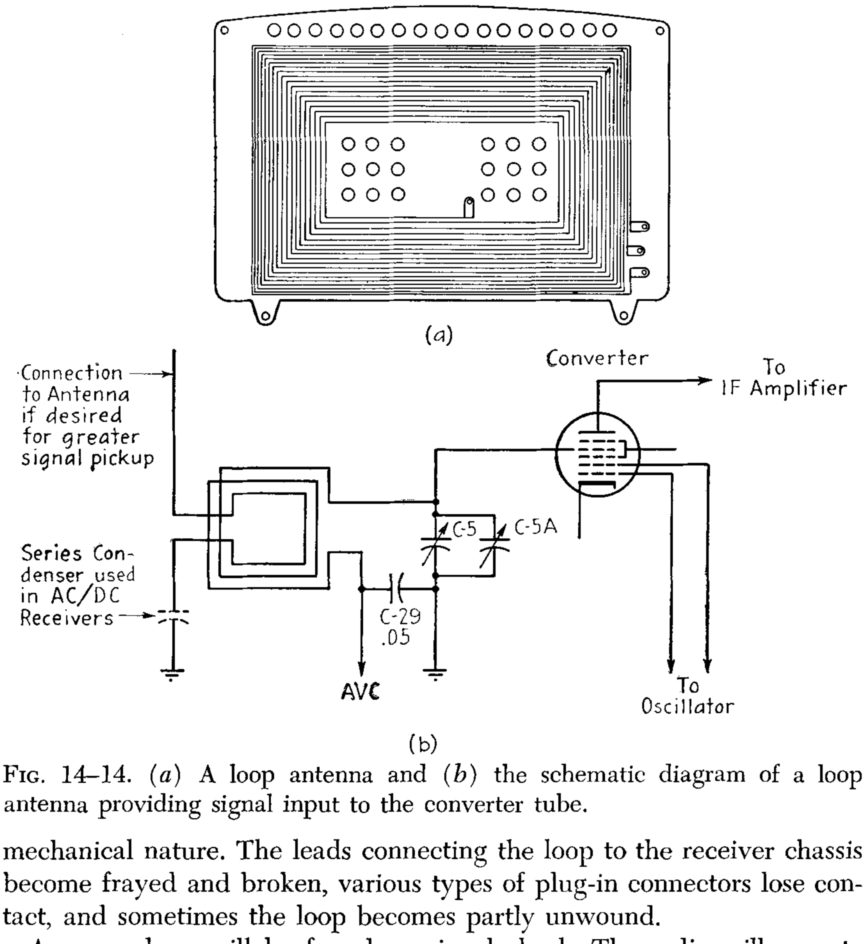


FIG. 14–14. (*a*) A loop antenna and (*b*) the schematic diagram of a loop antenna providing signal input to the converter tube.

mechanical nature. The leads connecting the loop to the receiver chassis become frayed and broken, various types of plug-in connectors lose contact, and sometimes the loop becomes partly unwound.

An open loop will be found on signal check. The radio will operate at reduced gain and possible hum when a test signal, either at modulated radio frequency or at modulated intermediate frequency, is applied to the converter signal grid. When the test signal is shifted to the antenna lead, the radio may operate at greatly reduced gain or not at all. An ohmmeter check then confirms the condition.

It is rarely necessary to replace the loop. The broken lead or loose contact is found by inspection and repaired. A partly unwound loop is rewound, and the wire is held in place with coil dope.

If several leads have broken away, there is likely to be some confusion as to where they should be replaced. The manufacturer's service notes are helpful in this regard, since they often include a wiring diagram of the loop connections. When this information is not available, the serviceman should examine the loop antenna to determine whether the primary antenna winding (one or two turns) is on the outside or the inside of the loop winding. After that, the conventional connections for both types are shown in Fig. 14–15. The outside and inside leads are

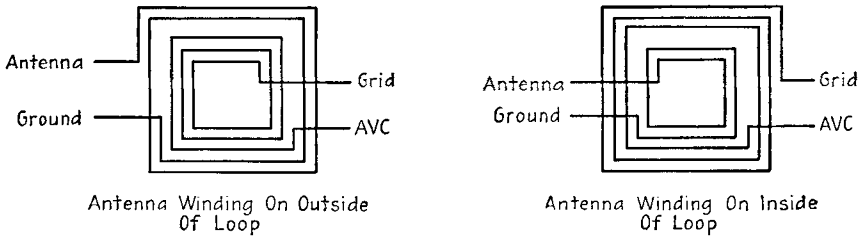


FIG. 14–15. Identifying loop antenna leads.

always easily located. The two inner leads may not be so readily distinguished by visual inspection. A continuity check with the ohmmeter, however, will positively identify the inner leads. In the case of the AC/DC type of receiver, the serviceman should remember to check the insulating condenser, which should be in the antenna or ground lead.

Troubles common to the tuning-condenser gang assembly. Tuning condensers usually develop troubles of a mechanical nature which may be repaired by the serviceman. Replacement of a tuning gang with anything but the original part would be extremely difficult, since the replacement would have to match the condenser drive mechanism, and the dial and pointer. Also the plates would have to be so shaped that the dial calibrations would be reasonably accurate; in addition there are the usual considerations of size, capacity, etc. For this reason, maintenance notes on tuning-condenser gangs will be in considerable detail.

A very common trouble is slipping or failure of the condenser and dial drive mechanism. Since there are such a large number of different types of drive assemblies in common use, the information under this heading will be generalized.

Sometimes the drive mechanism operates the dial pointer but the condenser rotor plates do not turn, resulting in no stations or one station all over the dial scale, depending on the position of the rotor plates. This is usually due to loose setscrews between the condenser drive and the rotor shaft. The cure is obvious—tightening the setscrew. Before doing so, however, the serviceman should refer to the receiver service notes to see if there are definite instructions about the positioning of the dial pointer. This information is usually given as part of the alignment instructions. If no reference can be found, the usual procedure is to rotate the gang tuning condenser until the plates are fully engaged, set the dial pointer to the last calibration mark on the low-frequency end of the dial scale, and tighten the setscrew in this position (see Fig. 14–16).

The trend in modern receivers is to use silk fish cord for the dial drive mechanism. Fortunately, receiver manufacturers are now issuing instructions for restringing the dial drive cords, as part of their service literature (see Fig. 15–2). Where this is not available, the serviceman must

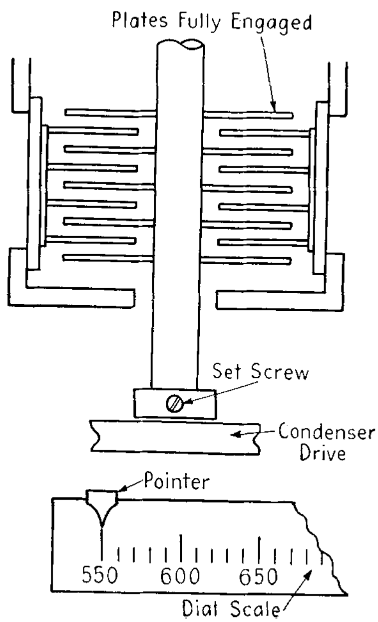


FIG. 14–16. Position of condenser drive, setscrew, and dial pointer.

work out the mechanical details for himself. After some experience, a man with average mechanical ingenuity will have little difficulty with any of the multiplicity of dial drives in common use.

Servicing condenser contact springs. Another common trouble with tuning condenser gangs develops in the contact springs, often called "wipers." Figure 14–17 shows the location of this item. The wiper makes contact between the rotor plates and the condenser shields that are grounded. Sometimes a ground wire is soldered to the contact spring, and sometimes no wire is connected. In either case, when dirt gets between the contact spring and the rotor, there will be resistance between the rotor plates and the ground. This may cause noisy reception, and even no reception over parts of the tuning range. In TRF receivers, poor contact at this point is a cause of oscillation. The cure is to remove the wipers, clean them, readjust the spring tension, and return them to their positions. When the wipers are riveted in place, the spring can be pried back at the point of contact with a screw driver that has been dipped in carbon tetrachloride. The screw driver is then removed, and the drop of cleaning solution is worked back and forth by rotating the condenser gang quickly. When this procedure is repeated a couple of times for each wiper, the contact between the rotor plates and ground is reestablished.

At this time, it might be well to add a word about the general use of cleaning solutions, lubricants, and abrasives in radio service work. Wood alcohol makes a good general-purpose cleaning solution, since it dissolves grease, loosens dirt, dries quickly, and is not harmful to radio parts. Carbon tetrachloride is also used. A light machine oil should be used for

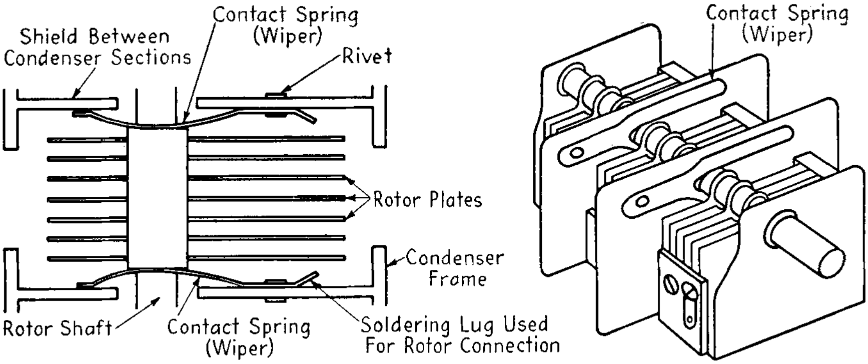


FIG. 14–17. Location of contact springs (wipers) for the rotor plate connection on a variable condenser.

lubricating bearings, pulleys, shafts, etc. Tuning-condenser bearings should not be lubricated, since they are self-lubricating, and any oil at this point may work its way into the condenser contact springs and insulate the rotor from the ground. Where an abrasive is needed, sandpaper should be used. Steel wool and emery cloth should not be used on or near a receiver. Although steel wool will do a good cleaning job on a condenser contact spring, particles of it getting into the tuning gang or into the speaker will cause considerable trouble. The abrasive material in emery cloth is also a conductor and will cause similar troubles. Special-purpose cleaning agents are prepared by some manufacturers and marketed under trade names. "Contactene" is used for switch contacts and condenser wipers. "Lubriplate" is used where a grease-type lubricant is desired.

Shunt resistance and shorts in variable gang condensers. Condensers, especially when not covered by shielding, collect a considerable amount of dust and dirt. When a bakelite stator-plate support or a trimmer condenser is dusty, the dust will act as a shunt resistor between the stator and the ground. The shunt resistance may cause very little effect on the operation of the antenna and RF stages, but it can seriously impair the operation of the oscillator. Dusting with a soft brush usually takes care of the trimmer condenser, and a wash with carbon tetrachloride cleans the stator insulator.

A short between the stator and the rotor plates of any condenser in the tuning gang will cause noisy reception and dead spots in the tuning range. The short may be due to a number of causes: one or more bent plates (usually in the rotor), shifted stator plate, dirt and dust between the plates, and, in the case of plated condenser plates, slivers of plating sometimes peel, causing shorts as the condenser is rotated. A detailed procedure for locating and removing these shorts is given as part of the general overhaul procedure that follows.

General reconditioning procedure for variable gang condenser

1. Clean. Blow out the dust by applying a gentle air pressure as from a bicycle pump, to all parts of the variable gang condenser. Go over the trimmer condensers and stator supports with a soft brush. Wash the stator supports with carbon tetrachloride. Clean the condenser contact spring as described on page 233. Clean and lubricate the dial drive mechanism.

2. Tighten and align the stator plates. Examine the insulators that hold the stator plates in position. Figure 14–18 shows a common method of supporting the stator plates. Most condensers have a similar arrangement. The machine screws that hold the assembly together may loosen, making for poor contact with the stator soldering lug and also allowing the stator plates to slip out of parallel alignment. Figure 14–19 represents a condenser where this has happened. To repair this condition, pry the stator plates back into parallel alignment with the rotor plates, making sure at the same time of equal spacing between the plates, and then tighten the screws. Even if the plates have not slipped out of position, the screws usually require retightening. In condensers where the spacing between plates is very small and parallel alignment and equal spacing cannot be judged by eye, spacing shims can be made by cutting stiff paper into strips. An ordinary business card is of about the right thickness. The shims are inserted between the plates on both sides of the rotor shaft, the screws are tightened, and the shims removed.

3. Check the tension on the rotor. The friction bearing on the rear of the rotor shaft should be tight enough to hold the rotor in any position, even if the radio is jarred, and should be loose enough so that the condenser rotor shaft can be turned easily by hand. If the tension is wrong, it should be adjusted. Most variable gang condensers have a tension adjustment screw similar to that shown in Fig. 14–20. The lock nut is loosened and the adjusting screw is turned. Tightening the screw tightens the tension. The screw should be turned about a quarter turn in the correct direction, while the rotor is held stationary. The lock nut is then tightened and the tension is checked. If further adjustment is needed, repeat procedure. The front bearing of the rotor rarely requires attention.

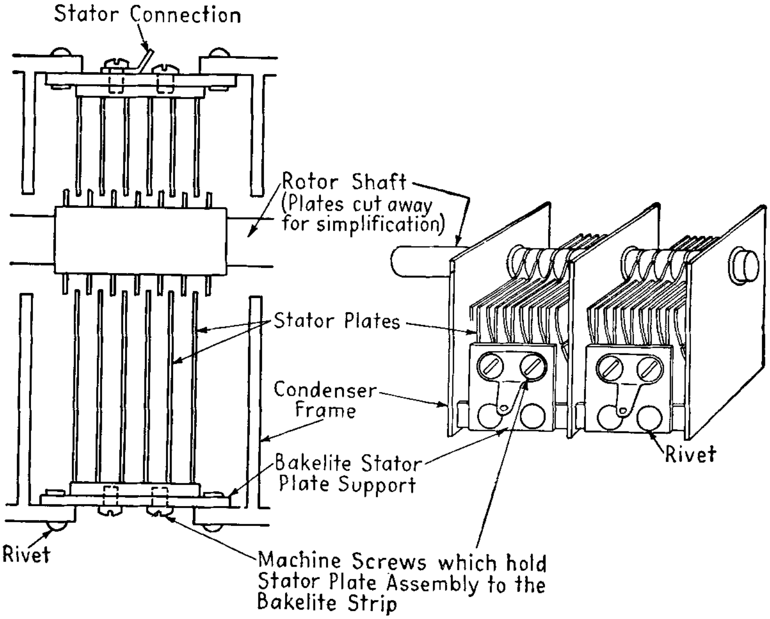


FIG. 14–18. Method of fastening stator plates in a variable condenser.

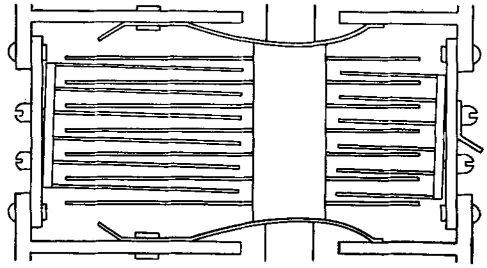


FIG. 14–19. Stator plates out of parallel alignment because of loosened holding screws.

4. *Locate and remove any shorts.* The cleaning of the trimmer condensers and stator insulators and the correct aligning of the stator plates removed some of the possibilities for shorts and shunt resistance in the variable gang condenser. There are still dust between plates, bent rotor plates, and slivers of plating to be considered. To find these, remove the

wiring from the condenser stator soldering lugs, and then apply high voltage between the stator connection and the chassis while turning the rotor. The high voltage will show an arc at any shorting position. The arc will probably burn up any dust or sliver of plating that caused the short (thereby automatically removing it) and will show the position of a bent plate. The high voltage is most easily obtained from the rectifier plate terminal. Use a test lead with an alligator clip on one end and an insulated test prod on the other. Clip the alligator to one of the plate leads of the full-wave rectifier (socket terminal 4 or 6 for a 5Y3-G rectifier) and keep the test prod where it can reach the condenser stator terminals. Switch the set on, touch the test prod to one of the stator lugs momentarily while watching for an arc either in the condenser or at the stator terminal. Turn the rotor plates in and out of mesh while the prod is connected. If a bent plate is discovered, turn the current off, straighten

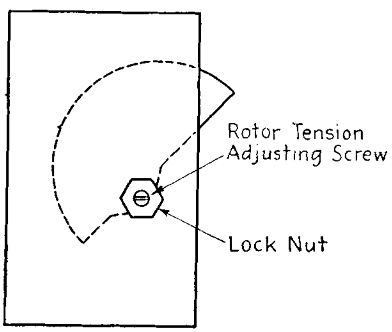


FIG. 14–20. Rear view of tuning condenser, showing rotor tension adjustment.

the plate, and then resume the procedure until all signs of shorts have disappeared. The procedure is then repeated for the other condensers in the tuning gang.

In this procedure, it must be emphasized that the serviceman is working with a live lead at 300 or more volts, which is quite dangerous. He should have the current on only when needed, the test lead should be well insulated, and he should exercise care and alertness in his movements. He should also remember that shorting the high-voltage winding may ruin the transformer. That is why the test prod is touched to the condenser stator *momentarily* for checking the location of a short. It should not be left on a shorted condenser for any length of time.

When an AC/DC receiver is serviced, the transformer high-voltage winding is not available right on the same chassis. In this case, a separate transformer may be used, connecting one high-voltage lead to the chassis, and the other to the test lead. The same procedure is then followed.

When all shorts have been removed, the stator leads are then resoldered.

5. *Check the dial drive.* The dial drive mechanism is then checked. If it is the cord or belt type and shows signs of wear, replace it. If it is the type that uses a friction rim drive, it will usually respond to a thorough cleaning. Finally check the position of the pointer, as described on page 232.

Troubles common to the oscillator coil. As with all other coils in the receiver, the main difficulty encountered with oscillator coils is open windings. If either winding opens, the oscillator will not function and the receiver will not pick up any stations. Signal check will isolate the oscil-

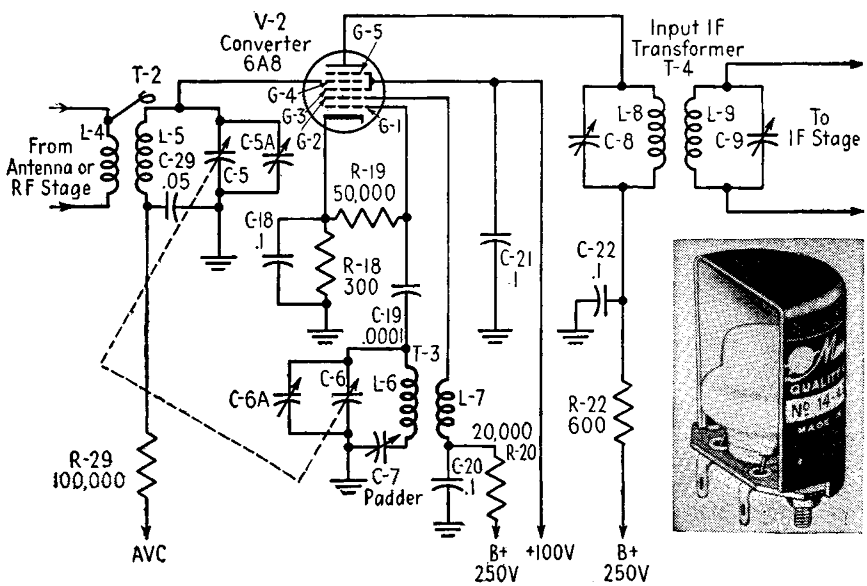


FIG. 14–21. A typical oscillator coil and its position in the converter circuit.

lator stage as the field of trouble, since when a modulated test signal is applied to the converter signal grid at the intermediate frequency, there will be normal response from the receiver, whereas when the signal generator test frequency is shifted to radio frequency, there will be no response. An open feedback winding will be indicated in a voltage check, when no voltage appears at the oscillator anode. Since an open *R*-20 or a shorted *C*-20 can also cause no voltage at the oscillator anode, an ohmmeter is used for the final check. The ohmmeter check will also show up an open grid winding on the oscillator coil.

If the oscillator coil proves defective, it is usually necessary to obtain an exact replacement of the original, since the oscillator circuit controls the calibration of the dial scale. When an exact replacement is used, it is necessary only to connect the wiring to the new coil without disturbing the lead dress and to re-align. It is, of course, necessary to connect the leads correctly, since a reversal of the connections to either winding will reverse the phase of the feedback coil, and the circuit will not oscillate. A good way to make sure that the rewiring is correctly done is to follow the procedure suggested for replacing volume controls. The old coil is loosened with the wiring intact, the new coil is mounted, and the wiring is shifted one wire at a time to its corresponding soldering lug.

When an exact replacement oscillator coil is not obtainable, it is possible to use a universal adjustable replacement coil, where the inductance of the coil may be varied by means of a permeability adjustment screw. When this is done, it is necessary to follow the instruction sheet with reference to identifying the coil terminals, since oscillator coils are rarely color-coded. It is also difficult to determine the ends of the windings, since the windings are usually wax-impregnated and closely coupled.

The replacement coil is mounted in such a way that the oscillator grid and anode leads are short. The replacement coil is then wired and the receiver is re-aligned. However, it is necessary to alter the alignment procedure, so that the universal replacement oscillator coil may be adjusted to work properly in the receiver in which it is placed.

Aligning a universal replacement oscillator coil. When the receiver is of the type that uses cut plates in the oscillator section of the variable gang condenser and there is no 600 padder, the alignment procedure is as follows: First, the IF transformers are aligned in the usual way. Then the "hot" lead of the signal generator is connected through a 0.00025-mfd condenser to the antenna, and the generator is adjusted to give a modulated signal at 600 kc. The receiver dial is turned to 600 kc, and the permeability adjustment screw on the replacement oscillator coil is aligned to give maximum response. The signal generator and the receiver dials are shifted to 1,500 kc, and the high-frequency trimmer on the oscillator section of the gang condenser is adjusted for maximum response. The procedure is repeated at 600 and 1,500 kc for optimum results. The RF and antenna trimmers are then aligned in accordance with the standard alignment procedure.

When a universal adjustable replacement oscillator coil is placed in a receiver that uses a 600 padder, the alignment procedure is somewhat more involved.

Possibly, it would be best to review the function of each of the adjustments in the oscillator tuning circuit, in the hope that the procedure may become more understandable and usable. This is done in Fig. 14-22. Condenser *C*-6 is the main tuning condenser, which is the oscillator section of the gang. The condenser *T* is the high-frequency trimmer. The condenser labeled *P* is the series 600 padder. The adjustment screw on the universal replacement oscillator coil controls its inductance and is labeled *L*. It will be remembered that the high-frequency trimmer *T* controls the frequency of the oscillator tuning circuit at the high-frequency end of the dial, and the series padder controls the low-frequency setting of the oscillator tuning circuit. The actions of these controls are not entirely independent, since each will have some effect on the opposite end of the tuning range. This explains why alignment procedures always recommend repeating the setting of these adjustments until they are at their correct positions, as proved by no further need for readjustment.

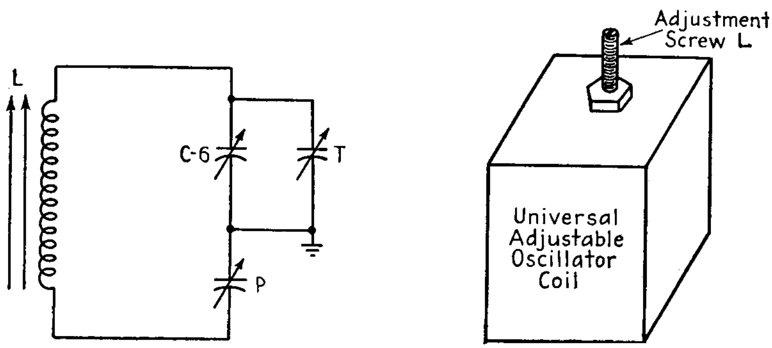


FIG. 14–22. Oscillator tuning-circuit adjustments when a universal adjustment replacement oscillator coil is used: *T*, high-frequency trimmer; *P*, series 600 padder; C-6, main tuning condenser.

When the inductance of the oscillator coil is also variable, as is the case when a universal replacement is used, its adjustment will control the frequency of the oscillator circuit all over the tuning range, since this depends on the inductance as well as the lumped capacity of the circuit. As a corollary, any adjustment of the inductance by means of its permeability screw *L* will necessitate readjustment of the series padder and shunt trimmer. With all three controls variable and dependent upon each other, proper alignment will be extremely difficult, unless a planned procedure is followed closely.

If the 600 padder has been undisturbed, one of these variables will be eliminated, since the padder will be close to its correct setting. In this case, the 600 padder is neglected entirely, and the receiver realigned by the procedure just given for a circuit that uses cut plates in the oscillator section of the gang condenser, and no 600 padding adjustment.

If the serviceman is not sure of the setting of the 600 padder, two alignment procedures may be used. In the first, the settings of the three adjustments are first made roughly and, then by repeated readjustments, are brought to their final positions. This procedure, although simple, is not always operative, owing to varying circuit constants and limited trimmer ranges in many receivers. The second procedure is more difficult, but it is always successful. In it, the alignment of the receiver is carried out at several prefixed positions of the 600 padder, each one is checked, and finally the position of best tracking is chosen.

Alignment procedure no. 1 for an oscillator circuit with variable trimmer, padder, and inductance

1. *Check IF alignment.*

2. *Connect the "hot" lead of the signal generator to the antenna terminal of the receiver through a 0.00025-mfd condenser.* Adjust the signal generator for a modulated output on the broadcast band.

3. *Set the trimmer and padder to center-capacity range.* The average trimmer and padder condensers require three full turns of the adjustment screw from full to low capacity. For approximate center-capacity setting, tighten the screws fully, then loosen one complete turn.

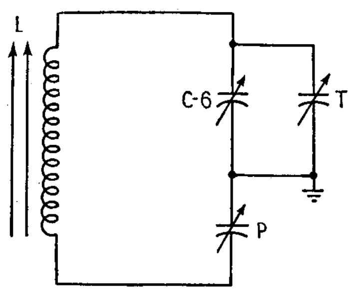


FIG. 14–23. Oscillator tuning-circuit adjustments.

4. *Adjust L at 1,000 kc.* Tune the signal generator and receiver to 1,000 kc, and adjust the permeability screw *L* on the oscillator coil for maximum output.[1]

5. *Adjust P at 600 kc.* Tune the signal generator and receiver to 600 kc, and adjust the 600 padder *P* for maximum output.[1]

6. *Adjust T at 1,500 kc.* Tune the signal generator and receiver to 1,500 kc, and adjust the high-frequency trimmer *T* for maximum output.[1]

7. *Repeat steps 4, 5, and 6 in sequence until each screw requires no further readjustment.*

8. *Align the RF and antenna trimmers in the usual way.*

Aligment procedure no. 2 for an oscillator circuit with variable trimmer, padder, and inductance

1. *Check IF alignment.*

2. *Connect the "hot" lead of the signal generator to the antenna terminal of the receiver through a 0.00025-mfd condenser.* Adjust the signal generator for a modulated output on the broadcast band.

[1] If the signal cannot be tuned in, the adjustment range is not large enough, or the first rough setting for center capacity is too far from the correct setting. Try the second alignment procedure.

3. *Set P for minimum capacity.* Examine the 600 padder and the action of its adjustment screw. Set the adjustment screw in the position where the plates begin to move together. This is the low-capacity setting of the 600 padder.

4. *Adjust L at 600 kc.* Tune the receiver and signal generator to 600 kc, and adjust the permeability screw on the oscillator coil for maximum response. If the signal cannot be heard over the range of this adjustment, increase the capacity setting of the 600 padder by a quarter turn and try again. Repeat this until the signal-generator note can be heard.

If the receiver does not have an RF stage, and the signal-generator attenuator is well advanced, there is a possibility of tuning the oscillator stage to the second harmonic of the 600-kc signal. To make sure that this

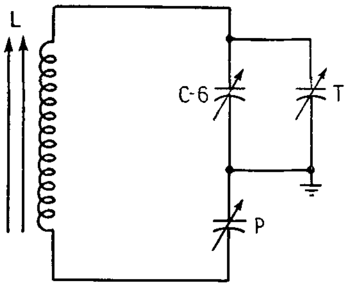


FIG. 14–24. Oscillator tuning-circuit adjustments.

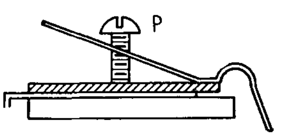


FIG. 14–25. Low-capacity setting for padder *P*.

error does not spoil the alignment when the 600-kc note is first heard, tune the signal generator to 1,200 kc. If the signal is not heard at this point, *L* is correctly adjusted for 600 kc. If the signal is heard and with a stronger note, *L* has been adjusted for 1,200 kc. More inductance and probably more capacity are needed in the circuit.

5. *Adjust T at 1,500 kc.* Tune the receiver and signal generator to 1,500 kc, and adjust the high-frequency trimmer on the oscillator section of the gang condenser for maximum response. If the test signal cannot be heard, increase the capacity of the padder *P* by an eighth turn of its adjustment screw. Then readjust *L* at 600 kc and try again to adjust *T* at 1,500 kc. Repeat this until the signal-generator note can be heard. The receiver is now tracking at 600 and 1,500 kc.

6. *Measure sensitivity at 1,000 kc.* Tune the receiver to 1,000 kc. Rotate the signal generator through 1,000 kc, while watching the output meter for maximum deflection. At peak response adjust the attenuator for standard output. Note the attenuator setting. This gives the sensitivity of the receiver at 1,000 kc.

7. *Adjust for maximum sensitivity at 1,000 kc.* Tighten the padder another eighth turn. Adjust *L* for maximum response at 600 kc. Adjust *T*

for maximum response at 1,500 kc. Measure sensitivity at 1,000 kc. Note the reading. The receiver should show an improvement over the reading taken in step 6.

Repeat with another eighth turn on *P*. Readjust *L* at 600 kc, *T* at 1,500 kc, and measure sensitivity at 1,000 kc. Continue until the sensitivity decreases. The previous adjustment of the 600 padder was the correct one. Loosen *P* an eighth turn and complete the alignment.

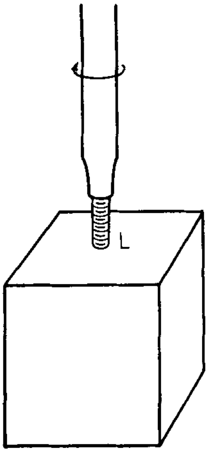


FIG. 14–26. Adjust *L* at 600 kc.

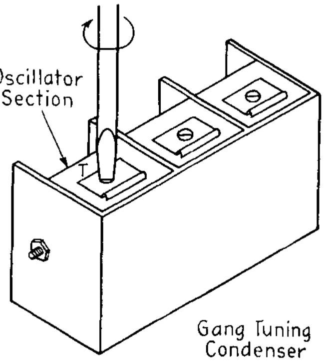


FIG. 14–27. Adjusting the high-frequency trimmer *T*.

Troubles common to the pentagrid converter tube. The converter tube is a common cause of trouble in the stage. Tube checkers are not very reliable in indicating an inoperative tube, since the tube may show adequate emission but still not oscillate. If the signal check shows normal response when a test signal at the intermediate frequency is applied to the converter signal grid, but no response or weak response when the test signal is shifted to 600 kc, there is a sure indication that the oscillator is not functioning. The most probable reason is the tube. The best check is to substitute another similar tube that is known to be good.

Another trouble often experienced with pentagrid converters is modulation hum, caused by cathode-to-heater leakage. Again the best check is substituting a similar tube known to be good.

Sometimes a receiver is encountered where conditions for maintaining oscillations are critical, and the oscillator circuit will not operate over the entire tuning range. Substituting another pentagrid converter tube usually clears this up. The original tube may not be defective and may operate perfectly in another receiver. This matter is treated in greater detail in the next section.

Critical oscillator conditions. Superheterodyne receivers sometimes develop a peculiar trouble. Reception is normal on the high-frequency end of the tuning range, erratic at the middle frequencies, and dead on the low-frequency end. Such a condition could be caused by shorts in the gang tuning condenser; more often it is due to failure of the oscillator at the low-frequency end of the tuning range. Which of the two possibilities is responsible can be quickly determined by the following procedure: Start at the low-frequency end of the tuning range, and tune toward the high-frequency end, noting the frequency of the first station received. Let us assume that it is at 1,100 kc. Then starting at the high 1,600-kc end, tune toward the 540-kc end, noting the stations as they are passed. If the 1,100-kc station comes in, followed by stations at 1,000 and 900 kc, and no stations after that, the trouble is sure to be in the oscillator circuit. The stations at 1,000 and 900 kc cannot be tuned in unless the radio is being tuned from high to low frequencies.

It is normal for oscillator operation to be more efficient at high frequencies than at low. Then if we assume, for example, an oscillator tube with weak electron emission, it may oscillate at the high-frequency end of the tuning range, but not at the low. Also, when the circuit is in an oscillating condition, the oscillation may continue as the operating frequency is reduced beyond the point of a normally nonoscillating position. Such operation might be called "critical oscillating conditions."

A condition of critical oscillator operation may be caused by other factors than a weak tube. The tube, however, is the most easily checked, since we can substitute another that is known to be good. If the new tube does not entirely clear up the trouble but causes the oscillation to stop at a lower frequency than before, it may be advisable to try still another tube, with the hope of finding one that will continue to oscillate all over the tuning range.

At this point, it might be well to add that a condition of oscillation is easily determined by a check of the voltage between the oscillator grid and the chassis. When the circuit is oscillating, the oscillator grid voltage will be negative with respect to chassis. When oscillation stops, the oscillator grid will check zero or slightly positive.

When replacement of the tube fails to clear up the trouble, all components of the oscillator circuit should be carefully checked. This includes cleaning the oscillator section of the gang tuning condenser, since a dusty shunt across the oscillator tank may be the cause of the condition.

If all components seem to be in good condition, refer to the receiver manufacturer's service notes, to see if later changes incorporated in the receiver include any change in the oscillator circuit. Often the condition is widespread for a particular receiver, and later changes include remedial measures. The change may be a different value for the cathode resistor or for the oscillator grid resistor; or, the oscillator coil may have been changed, as indicated by a new part number. If any such alterations can be found, incorporating this same change in the receiver being serviced will clear up the difficulty.

Where the receiver service notes do not indicate any such changes, the serviceman should experiment with the ohmic value of the cathode self-bias resistor. When this is reduced, a stronger electron flow in the tube is assured, with consequent better chance for maintaining oscillations at the low-frequency end of the tuning range.

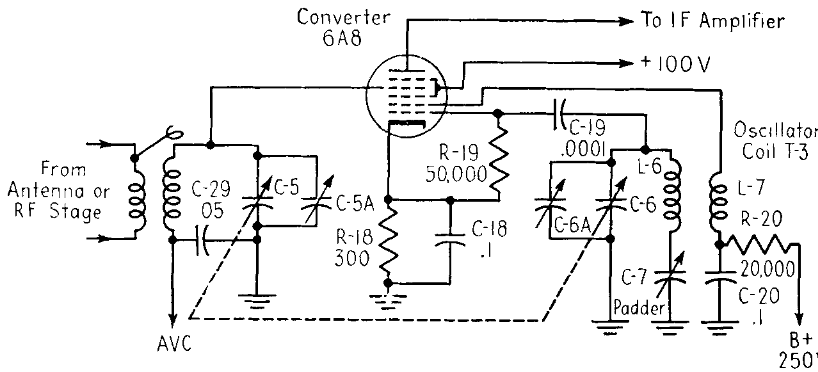


FIG. 14–28. The oscillator circuit in a 6A8 pentagrid converter.

Miscellaneous oscillator troubles. When the signal check indicates trouble in the oscillator section, any of the component parts might be at fault. The tube, oscillator coil, and tuning condensers, which are the most common offenders, have been covered in previous sections. The resistors and condensers in the cathode, oscillator grid, and anode circuits remain as possible sources of faulty operation.

Trouble in the cathode circuit would appear before the oscillator circuit is suspected, since it would interfere with the operation of the pentagrid converter as an amplifier and would therefore cause trouble when the IF amplifier is checked from the converter signal grid. The usual trouble is an open bias resistor *R*-18. This would be found on voltage check, since the cathode voltage would be abnormally high, 50 volts or thereabouts, depending on the sensitivity of the voltmeter, instead of the normal value of approximately 3 volts. Self-bias by-pass condenser *C*-18 rarely gives any trouble.

In the oscillator grid circuit, resistor *R*-19 and condenser *C*-19 rarely give any trouble. Occasionally, a paper tubular condenser for *C*-19 may cause oscillator trouble owing to leakage. When replacing condenser *C*-19, use a mica condenser of the proper capacity.

In the oscillator anode circuit, resistor *R*-20 and condenser *C*-20 are in high-voltage circuits, where troubles and breakdown are more common. If condenser *C*-20 should short, the oscillator would not function owing to the absence of anode voltage. Signal check would show the inoperative oscillator, voltage check would show no voltage at the oscillator anode, and a resistance check would show a shorted *C*-20. Since no voltage at the oscillator anode might also be caused by an open *R*-20 or an open feedback winding, the resistance check would also disclose these defects. If the trouble is a short in condenser *C*-20, resistor *R*-20 should also be replaced, since it has been forced to feed heavier than normal current to the shorted condenser.

An open anode by-pass condenser *C*-20 would also cause the oscillator stage to be inoperative. Voltage check would show low voltage on the oscillator anode, and no or little voltage on the oscillator's grid, the exact voltages depending on the stray capacity in the circuit. In addition, checking the oscillator anode voltage may cause the radio to play, since the capacity of the meter leads is added to the stray capacity in the circuit.

SUMMARY

Quick check for normal operation of the oscillator

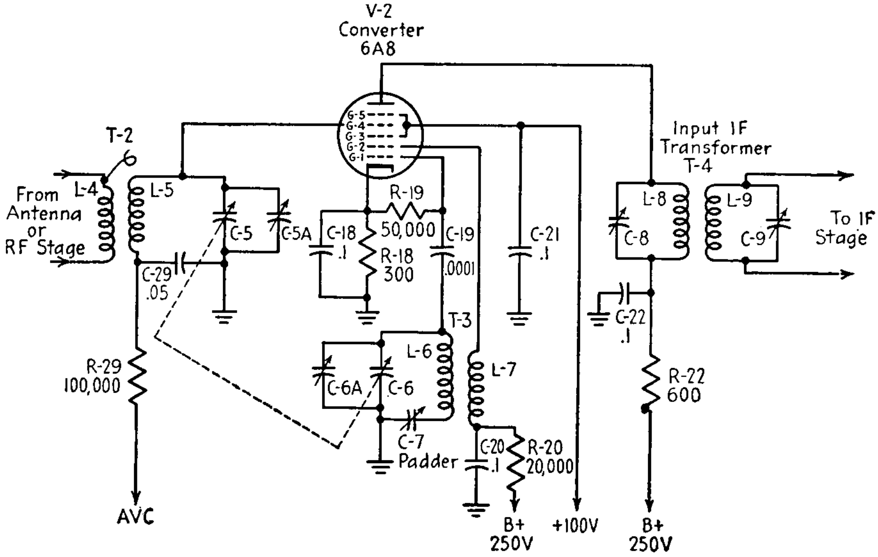
Tune the receiver to 600 kc. Connect the signal-generator output to the converter signal grid (mixer grid) through a 0.1-mfd condenser, and rotate the signal-generator dial through 600 kc. If the signal-generator modulation note is heard in the speaker at or near 600 kc, the oscillator is functioning.

Quick check for normal operation of the mixer

Tune the receiver to 1,400 kc. Connect the signal-generator output to the RF grid (antenna if there is no RF stage) through a 0.00025-mfd condenser. Rotate the signal generator dial through 1,400 kc. If the signal-generator modulation note is heard in the speaker, at or near 1,400 kc, the mixer stage of the converter is functioning.

Standard diagram

This circuit is shown in the accompanying figure.



Normal resistance data for the converter

Across *L*-4, primary of the signal input transformer *T*-2	40 ohms
Across *L*-5, secondary of the signal input transformer	5 ohms
Across *L*-6, grid coil of the oscillator transformer *T*-3	5 ohms
Across *L*-7, feedback coil of the oscillator transformer	3 ohms
Cathode to chassis	300 ohms*
Signal grid (*G*-4) to chassis	1,600,000 ohms
Screen grid (*G*-3 and *G*-5) to chassis	30,000 ohms*
Plate to *B* plus	640 ohms*
Oscillator grid (*G*-1) to chassis	50,000 ohms
Oscillator anode (*G*-2) to *B* plus	20,000 ohms

In receivers where the signal input transformer *T*-2 is a loop antenna, the grid coil of the loop will measure 1 to 3 ohms. The antenna winding will measure less than 1 ohm.

Normal voltage data for the converter

Readings taken from the indicated terminals to the chassis or common negative terminal of the receiver are given in the accompanying table.

	6A8 pin No.	AC receiver, volts	AC/DC receiver volts
Plate	3	250	90
Screen	4	100	50
Oscillator grid	5	−15	−10
Oscillator anode	6	200	90
Cathode	8	3	3

* These readings are for the standard circuit and should be checked against service notes for any particular receiver.

SERVICE DATA CHART FOR AN INOPERATIVE OSCILLATOR STAGE

Assume an inoperative oscillator section in a dead receiver, as shown by normal response when an IF test signal is applied to the mixer grid, and no response when the test signal frequency is changed to RF. The following test procedure is recommended.

Procedure	*Reading*	*Trouble and subsequent check*
Make a voltage check	Oscillator grid reads zero or positive	Confirms the inoperative oscillator
	Oscillator anode reads zero	Feedback coil is open. Oscillator anode dropping resistor R-20 is open. Oscillator anode by-pass condenser C-20 is short circuited. Confirm with a resistance check
	Oscillator anode reads low	Oscillator anode by-pass condenser is open
	Voltages normal except for oscillator grid	Nonoscillating converter tube. Substitute one that is known to be good. If the trouble still persists, it is in the oscillator grid circuit. Make ohmmeter check as shown below

Make a resistance check. Check for the following conditions:

Open oscillator coil grid winding *L*-6.

Shorted oscillator section of the gang tuning condenser *C*-6.

Leakage across the oscillator tuning condenser *C*-6 or the shunt trimmer *C*-6*A*.

Open padder condenser *C*-7.

Open or leaking oscillator grid condenser *C*-19.

Open or wrong resistance value for oscillator grid leak *R*-19.

SERVICE DATA CHART FOR AN INOPERATIVE MIXER STAGE

Assume an inoperative mixer in a dead or weak receiver, as shown by normal response when an RF test signal is fed to the mixer grid, and no or weak response when the RF test signal is fed to the RF grid.

Procedure	*Reading*	*Trouble and subsequent check*
Apply the test signal to the RF plate.	Normal response	Trouble is in the RF tube or its associated circuit. Substitute an RF tube known to be good. Make a voltage check and a resistance check of the RF stage to find the defective component
	No or weak response	Trouble is in the mixer grid circuit. Check the mixer input transformer *T*-2 for opens. Check the AVC decoupling filter *R*-29 and C-29 for opens

SERVICE DATA CHART FOR THE CONVERTER

Symptom	*Look for*
Hum	Open mixer grid coil *L*-5
Modulation hum	Defective converter tube. (Cathode-to-heater short or leakage)
No reception on LF end of the tuning range	Weak converter tube. Check oscillator circuit for critical oscillator conditions
Distortion	Short-circuited AVC condenser C-29
Weak reception	Open cathode by-pass C-18. Open plate by-pass C-22. Misalignment
Weak reception—high noise level	Open AVC condenser C-29
Squeal	Open screen by-pass C-21. Open plate by-pass C-22. Shielding improperly grounded. Leads improperly dressed
Squeals or birdies when tuning certain stations	Image frequency interference. See Chap. 16
Noisy, intermittent operation	Defective converter tube. Corrosion in input transformer *T*-2 and oscillator transformer *T*-3. Check gang tuning condenser for shorts and poor wiper contacts. Check wiring for loose connections and rosin joints
One station all over the tuning range	Condenser gang not tuning. IF amplifier tuned to the wrong frequency
Receiver will not track on alignment	Tuning-condenser stator plates incorrectly spaced

15 FURTHER NOTES ON THE CONVERTER—VARIATIONS

There are probably more variations in the converter than in any other stage of the receiver. Some receivers use separate mixer and oscillator tubes. Others use different converter tubes. In addition, there are a large number of oscillator circuits other than the anode feedback type, shown in the standard circuit for the 6A8 pentagrid converter tube. And finally, the mixing of the received signal and the locally generated signal can be accomplished in other ways than the electronic mixing described for the 6A8 tube. However, in all cases, the functions of the components remain the same, the signal check remains the same, and the service notes, applying to the main component parts of the stage, can be equally well applied to identical or similar components, regardless of the type of mixer and oscillator stage employed.

The variations chosen for this section will be those commonly found, or those requiring a special service procedure. They will include the popular 6SA7 or 12SA7 converter tubes, multiband receivers, push-button tuning, and permeability tuning.

Receivers using the 6SA7 or 12SA7 pentagrid converter. Many receivers employ a 6SA7 instead of a 6A8 for the converter tube. The 6BE6 is the miniature equivalent of the 6SA7. The signal input circuit and the IF output circuit are the same for either tube. There are some important differences in the oscillator circuit. The oscillator circuit employed is the Hartley type, using a tapped coil with the feedback winding in the cathode circuit. The oscillator anode and the screen are combined in the second and fourth grids.

From the serviceman's point of view, the following differences should be kept in mind. The signal input grid is pin No. 8 rather than the top cap. Signal-generator test signals, therefore, are most conveniently applied to the stator terminal of the tuning condenser *C*-5. Since the oscillator anode and screen are combined, one voltage measurement suffices for both and is usually called "screen" voltage. In AC/DC receivers, the screen voltage of the 6A8 averages 50 volts, whereas the 6SA7 or 12SA7 averages 90 volts. The oscillator grid-leak *R*-19 is approximately 20,000 ohms in circuits using a 6SA7, whereas grid-leak values approximating 50,000 ohms are found in circuits designed around the 6A8 tube. Adjustments of the 600 padder condenser *C*-7 must be performed with a special aligning screw driver made of insulating material, since both sets of

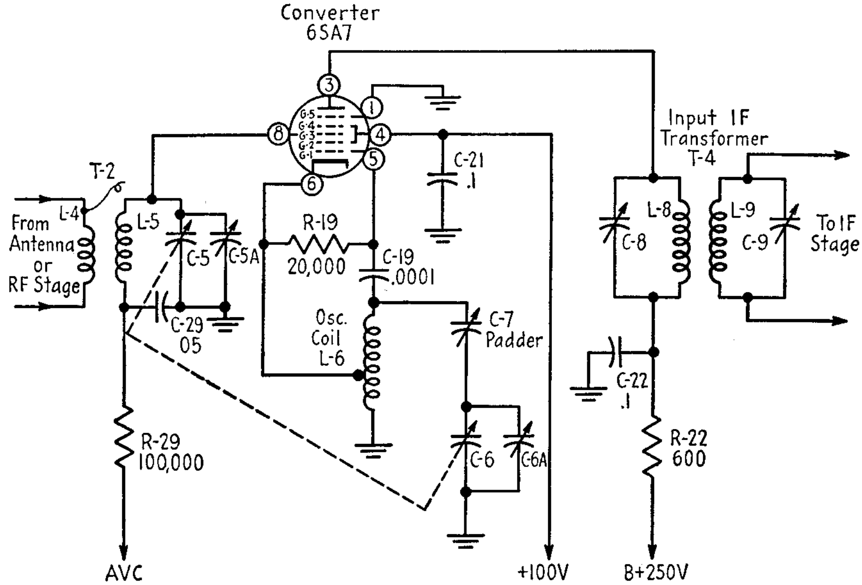


FIG. 15–1. Schematic diagram of a 6SA7-type pentagrid converter.

plates are at high RF potential and, as a result, any adjustment will be affected by hand capacity.

Normal voltage data for a 6SA7 converter. Readings are taken from the indicated terminal to the chassis or common negative terminal. Data are given in the accompanying table.

Test terminal	*6SA7 or 12SA7 pin No.*	*AC receivers, volts*	*AC/DC receivers, volts*
Plate	3	250	90
Screen	4	100	90
Oscillator grid	5	−15	−10
Cathode	6	0	0

The signal check and the approximate sensitivity measurements are the same as those given for the standard circuit.

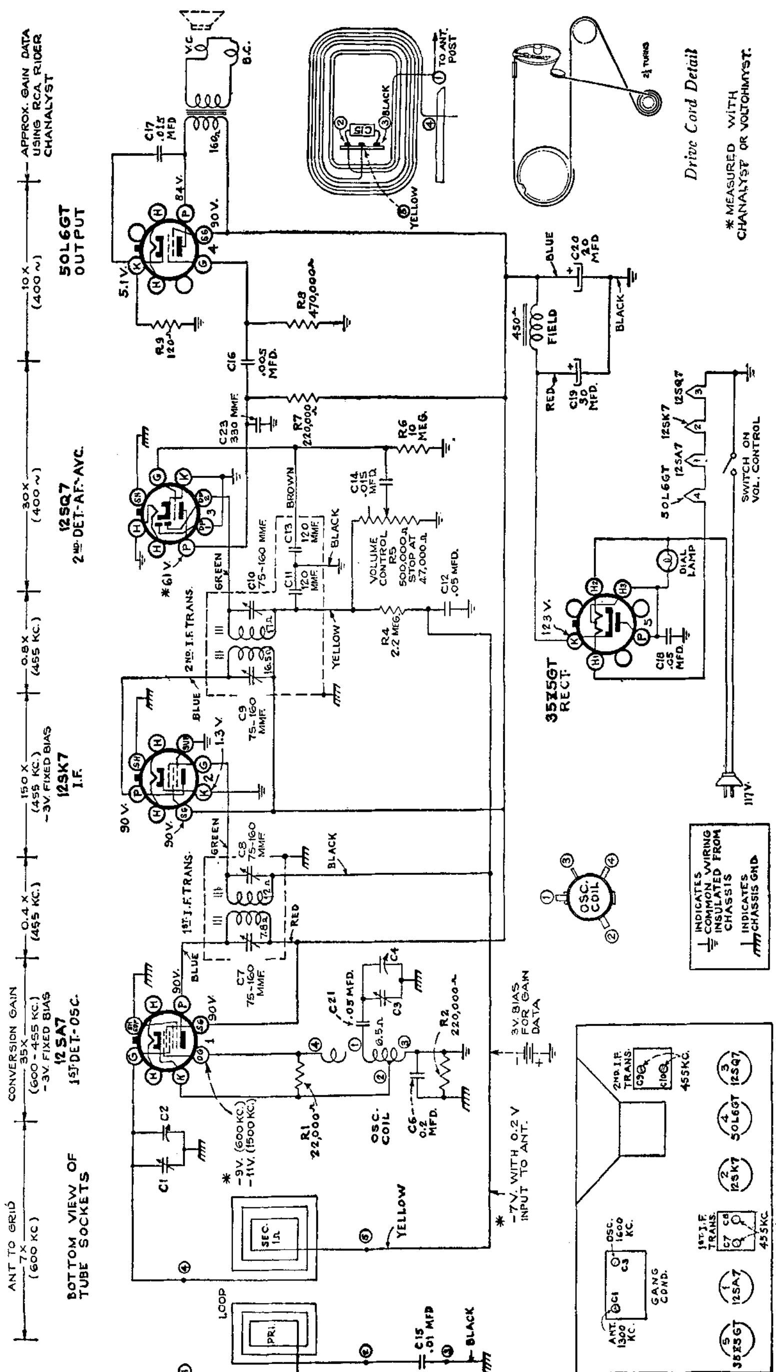


FIG. 15-2. The RCA 45X18 receiver diagram.

Figure 15–2 shows the service data wiring diagram of the RCA 45X18 receiver which uses a 12SA7 pentagrid converter. Note the following points in the converter stage. The tube is labeled 1ST DET. OSC. Condenser *C*-21, between the oscillator coil and the tuning condenser, is a fixed condenser, which means that there is no 600 padder, and the oscillator section of the gang-tuning condenser has cut plates. The oscillator grid condenser is replaced by a capacitive winding on the oscillator coil, connected to terminal ④ of the oscillator coil. The capacitive winding is often called a gimmick or bifilar winding. The oscillator grid voltage is minus 11 volts at 1,500 kc and minus 9 volts at 600 kc, indicating greater

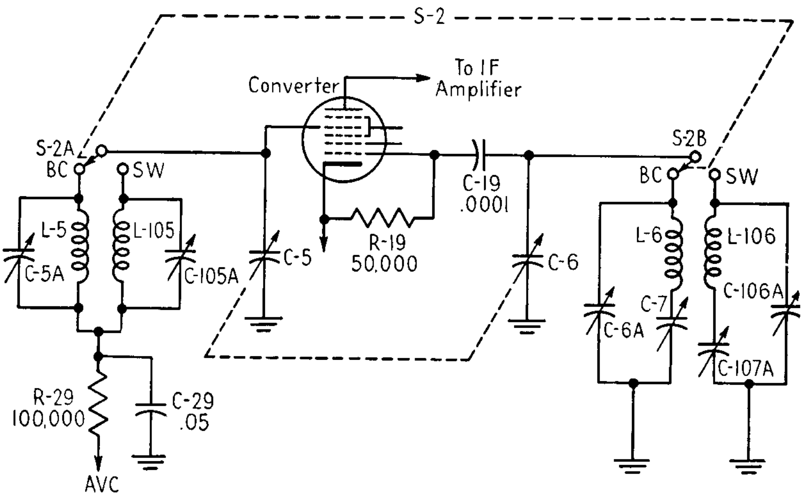


FIG. 15–3. Simplified switching circuits for a multiband receiver.

oscillator output at the high-frequency end of the tuning range. The signal input transformer is a loop so that the receiver may be operated without an antenna for local reception. For reception of weak signals, an antenna may be connected as indicated to the primary winding of the loop. Condenser *C*-15, connected between the primary loop winding and the chassis, insulates the receiver against accidental short circuits in the power line, if the antenna should become grounded.

Note also the following points of general interest in this diagram. The arrangement of the tube elements may make the diagram more difficult to read, but it facilitates the finding of tube pins for voltage checking. The voltages are marked for easy reference right at the socket terminal. Gain data are included above the diagram and, although the figures given are for the RCA Rider Chanalyst, they may be interpolated for any system of measuring gain.

Multiband receivers. In multiband receivers, the inductances in the tunable circuits are switched, so that the receiver may operate over more than one band of frequencies. A simplified circuit indicating how this may be accomplished is shown in Fig. 15–3.

The gang tuning condensers *C*-5 and *C*-6 are permanently connected across the signal grid and oscillator grid circuits. Switch S-2 is the wave-band switch. In the broadcast (*BC*) position shown, coil *L*-5 with its trimmer *C*-5*A* is connected in the signal grid circuit. In the oscillator grid circuit, for broadcast, the *B* section of the switch throws coil *L*-6 with its low-frequency padder *C*-7 and its high-frequency trimmer *C*-6*A* across the main oscillator tuning condenser *C*-6.

When the switch is thrown to the short-wave (*SW*) position, coil *L*-105 with its associated trimmer *C*-105A is connected in the signal grid circuit, while coil *L*-106 with its associated low-frequency padder *C*-107A and high-frequency trimmer *C*-106*A* is connected across the oscillator tuning condenser *C*-6. An arrangement such as the above makes it possible to align each wave-band position individually.

By using more positions on the wave-band switch, each one throwing in a different set of coils with their associated trimmers, it is possible to have a multiband or all-wave receiver. The common bands used for radio receivers are as given in the accompanying table.

Band	*Approximate frequency range*	*Type of program*
X or *LF*	150—400 kc	Maritime and aircraft
A or *BC*	540—1,600 kc	Standard broadcast
B or police	1.5—4.6 mc 2—6.2 mc	Police, amateur
C or SW	5.8—18 mc	U.S. and foreign short wave

The *B* or police band has either of the two frequency ranges shown, depending on whether it is desired to include state police at 1,600 to 1,800 kc or the United States and foreign broadcast stations at 6 to 6.2 megacycles. When the latter range is chosen, the broadcast band is usually extended to 1,750 kc to include the state police broadcasts.

Multiband receivers usually include two or three of the frequency ranges listed above. All-wave receivers include all bands, and sometimes add a fifth which extends the high-frequency range to approximately 40 megacycles.

The circuit of Fig. 15–3 is simplified in that it makes no provision for shorting the unused coils (a usual procedure), and does not show the primary of the coil in the signal grid circuit or the feedback winding of the oscillator coils, either or both of which may also require switching.

Practical multiband receivers use a variety of switching and coil arrangements. In addition to changing coils, the switch may include extra sections which accommodate auxiliary functions. For example, pilot lights may be switched on and off so that the proper frequency range on the dial scale is illuminated. Another common practice is to increase sensitivity and to alter the tone response, when the receiver is switched to short-wave reception.

Figure 15–4 is a three-band superheterodyne receiver. *C*-1 and *C*-2 are the gang tuning condenser. The antenna coil assembly includes the antenna transformer *T*-1, the broadcast loading coil *L*-2, and the three trimmer condensers, *C*-3, *C*-4, and *C*-5. The proper coil, with its associated trimmer, is switched to the tuning condenser *C*-1 and the signal grid of the 6SA7-GT converter by the *A* section of the band switch. The oscillator coil assembly includes the oscillator coils, all labeled *T*-2, with their associated high-frequency trimmers, *C*-6, *C*-7, and *C*-8. Note the low-frequency padder *C*-21 for the broadcast coil, the fixed condenser for the police coil, and no condenser for the short wave coil. The *B* section of the wave-band switch connects the proper coil with its trimmer and padder to the main oscillator tuning condenser *C*-2 and the oscillator grid circuit. The *C* section of the band switch connects the proper feedback coil to the cathode circuit of the 6SA7-GT converter tube. Note the shorting arm on all three sections of the wave-band switch.

Figure 15–5 is a two-band superheterodyne receiver. The range switch has four decks or wafers, labeled *A*-1 to *A*-4. The switch has three positions: broadcast band (antenna), broadcast band (loop), and short-wave band. In the position shown, broadcast band (antenna), range switch sections *A*-1 and *A*-2 connect the antenna to the center tap of antenna coil *L*-3; antenna tuning condenser *C*-4 is connected across *L*-3 with its trimmer *C*-1; and the tuning circuit, composed of *L*-3 and *C*-4, is connected in the grid circuit of the RF amplifier tube, which is a 6SK7 type. Oscillator tuning condenser *C*-5 is connected through switch sections *A*-3 and *A*-4 to broadcast oscillator coil *L*-6 and the oscillator grid circuit of the 6SA7 tube. The cathode of the 6SA7 tube connects through the tap on short-wave oscillator coil *L*-7 to the tap on broadcast oscillator coil *L*-6. Terminals 6 and 7 on switch deck *A*-3 throw a short across condenser *C*-28*A* in the grid circuit of the lower 6V6-GT tube through the wires labeled *Y*-*Y*. This is a tone-compensation circuit which will be open on short-wave reception.

When the range switch is moved one position to broadcast (loop), switch section *A*-2 opens the antenna circuit, and *A*-4 shorts out the minimum-basis resistor in the cathode circuit of the RF 6SK7 tube. The other connections remain the same in the broadcast (antenna) section.

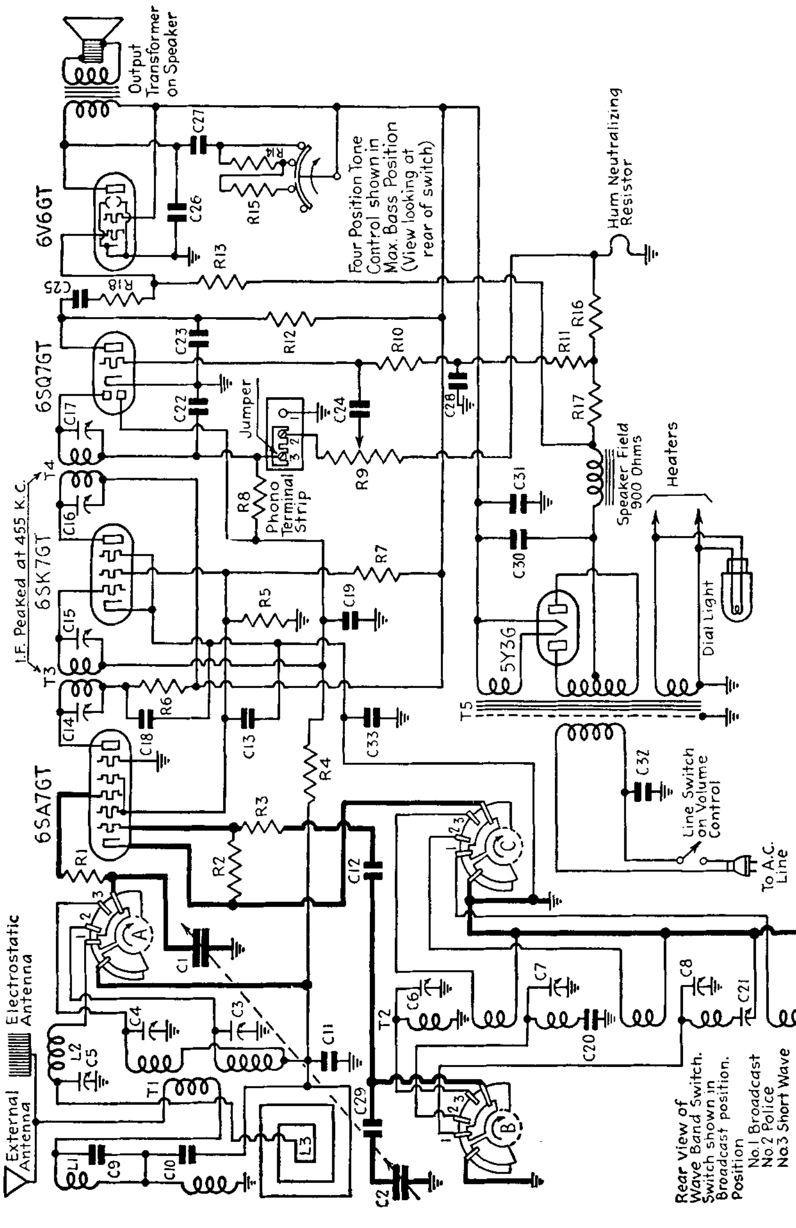


FIG. 15–4. Schematic diagram of the Emerson DX-356 three-band receiver.

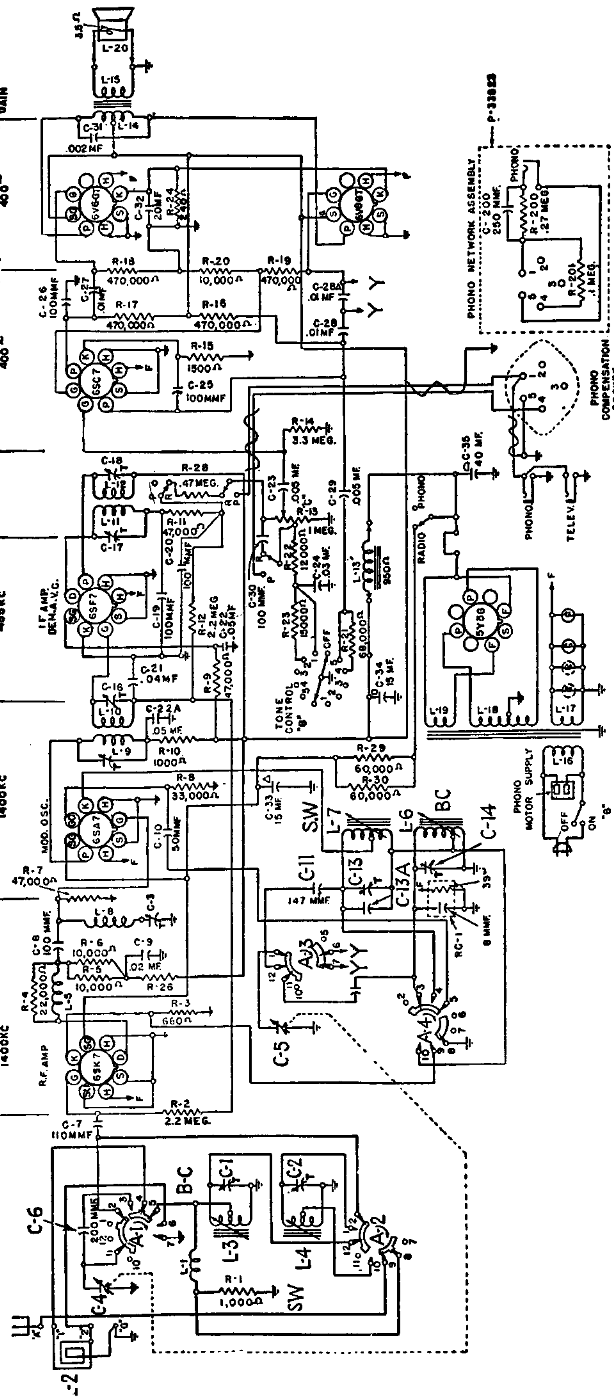


FIG. 15–5. Schematic diagram of the Stromberg-Carlson No. 1020–1120 receiver.

When the range switch is moved to the short-wave position, the following changes take place: The antenna is connected to the center tap of short-wave antenna coil *L*-4 through terminals 9 and 10 on range-switch section *A*-2. Terminals 1 and 2 on the same section connect short-wave antenna coil *L*-4 to the 6SK7 grid circuit. Terminals 7, 6, and 5 on the *A*-1 section of the range switch short the lower halves of the loop and broadcast antenna coil. Terminals 2 and 3 on the same section connect antenna tuning condenser *C*-4 through *C*-6 to the grid circuit of the 6SK7 tube. Condenser *C*-6 is for band-spread purposes. In the oscillator section, terminals 8, 9, and 10 of section *A*-4 keep the RF tube in the sensitive position by shorting out the cathode resistor, and by grounding the bottom lead of the short-wave oscillator coil *L*-7 as well as the bottom half of the broadcast oscillator coil *L*-6. Oscillator tuning condenser *C*-5 is connected through band-spread condenser *C*-11 to the top lead of short-wave oscillator coil *L*-7 and the oscillator grid circuit of the 6SA7 tube. Switch terminals 6 and 7 of section *A*-3 connect the condenser in the grid circuit of the 6V6-GT tube for tone compensation.

Servicing multiband receivers. Although multiband receivers look more complicated than a single-band unit and may take a little longer to service, they are no more difficult. As a matter of fact, the range switch opens a possibility of faster diagnosis in some ways. When a receiver is dead on the broadcast band but operates normally on other bands, the defective condition is more quickly narrowed down to defective coils in the RF or oscillator portions of the receiver.

Servicing procedures for the multiband receiver are the same as for any other, until the RF portion of the receiver is reached. At this point the serviceman need only make sure that the range switch is in the broadcast position in order to continue in the usual way.

There are, of course, some service problems connected with multiband receivers that will not be present in single-band radios. These include the short-wave coils, the range switch, and alignment.

Short-wave coils are usually wound as a single-layer inductance using heavy wire. This type of winding rarely gives any service trouble. The serviceman, however, should be able to check the windings with an ohmmeter. This may not be so easy as it sounds, since it is sometimes difficult to determine which lead is which on a multiunit coil assembly. Also, the serviceman may not be sure as to whether the winding is being shorted by the range switch.

A better method would be to work with the schematic diagram and check the coils and switch at the same time. For example, in checking the receiver of Fig. 15–4, the feedback winding of the oscillator coils could be checked as follows: Connect one ohmmeter terminal to chassis, the other to the cathode of the 6SA7 tube, and rotate the range switch.

The ohmmeter would read the resistance of each winding, which would be approximately 2 ohms for the broadcast position, ½ ohm for the police band, and "short" for the short-wave band. The other coils could be checked in a similar manner. To check the oscillator grid coils, one ohmmeter terminal would connect to the junction of condensers *C*-29 and *C*-12, while the other ohmmeter prod would be moved with the band switch. It would connect to the 600 padder when checking the broadcast band, *C*-20 when checking police, and ground when checking the short-wave range. Because of the diversity of range switches, no standardized procedure can be arranged for checking coils and switches. However, the examples given will help to clarify the method of procedure.

When an open coil is found, the serviceman should first make sure that the defect is not due to a broken lead wire. If the coil must be replaced, it is necessary to obtain an exact duplicate from the manufacturer of the receiver. Even if it is necessary to replace an entire coil assembly for one open winding, this must be done since the chances of finding a usable section are very slim.

The lead dress between the range switch and the short-wave coils is very important. In high-frequency circuits, stray capacity of the wiring represents a considerable portion of the total capacity of the circuit. Very often, the wiring in these circuits makes use of heavy bus bar, so that the positioning will be maintained. Any replacement of switch or coils should be accomplished with a minimum of bending or rearranging of the wiring, so as to avoid undesirable coupling or changes in the stray capacity.

Range switches become covered with a layer of dust and dirt, resulting in poor contact and sometimes leakage between terminals. Dusting with a soft brush and then cleaning with carbon tetrachloride comprise the usual service procedure. A good way to clean the contacts is to wet them and the contact arms with carbon tetrachloride and then rotate the switch rapidly.

If a switch contact or wafer becomes broken, it is necessary to replace the entire switch. Again, an exact duplicate must be obtained from the manufacturer. Service notes on the replacing of switches were given in connection with radio-phonograph switches (see page 174).

Aligning multiband receivers. In realigning a multiband receiver, the manufacturer's instructions should be followed to the last detail. This advice is given whenever the word "alignment" is mentioned. However, in the case of multiband receivers, it is of more than usual importance for two reasons. One is that the alignment on one wave band may affect the alignment on the other ranges, and the proper alignment sequence should be followed. The other is the fact that some receivers are so designed that the oscillator frequency should be 455 kc lower than the signal frequency on the short-wave band, while the conventional 455 kc higher signal on the other bands is maintained. Often both frequencies are within the scope of the trimmer adjustment, and it is important to use the peak at the lower or higher capacity setting, as instructed, in order to maintain proper tracking. If alignment instructions are not obtainable, the following suggestions may be of value.

IF alignment. First turn the range switch to the broadcast position, short the oscillator section of the gang tuning condenser, and align the IF trimmers in accordance with the general alignment instructions given in Chap. 23. Then remove the short from the oscillator section of the tuning condenser and check the position of the dial pointer, by turning the gang tuning condenser to full capacity (full mesh). The dial pointer should be in line with the last calibration mark on the low-frequency end of the dial scale.

As for the sequence of range alignment, when trimmer settings of one band affect another, it is suggested that the broadcast band be aligned last, because the cumulative effect will be most noticeable on the lowest frequency band. In addition, the owner of a receiver is usually most concerned about the operation of the broadcast band. For these reasons, when more exact instructions are not available, it is advisable to align the broadcast band last.

Short-wave alignment. Connect the signal generator through a dummy antenna of 400 ohms to the antenna and ground of the receiver. Turn the range switch to the highest frequency band on the receiver, and set the dial at a convenient mark near the high-frequency end of the scale. Adjust the signal generator to a modulated output at the same frequency as shown on the receiver dial. Adjust the short-wave oscillator coil trimmer for maximum response. If only one peak is obtained, the oscillator is adjusted to the proper frequency. If two peaks are obtained, choose the peak at minimum capacity. This sets the oscillator to a higher frequency than the signal.

If the receiver has an RF stage, the interstage coil trimmer is next to be aligned. If there is no RF stage, the antenna-coil trimmer follows the oscillator adjustment. In either case, the trimmer is adjusted for maximum response. If two peaks are obtained, the one that maintains the oscillator at the higher frequency is the peak that is nearer the maximum capacity setting of the trimmer. If the peak is unobtainable or if the receiver does not track at the low-frequency end of the dial, the alignment should be tried with the oscillator set for a lower frequency than the signal. This is done by choosing the maximum capacity peak for the oscillator trimmer and the minimum capacity peak for the antenna trimmer.

If the receiver has more than one short-wave band, the next lower frequency range should be aligned. The same procedure is followed as for the highest frequency band except that the oscillator circuit should be adjusted for a higher frequency than the signal. However, it is doubtful if two peaks are obtainable on any but the highest frequency band. This band may or may not include a low-frequency padder.

Broadcast alignment. Set the range switch at the broadcast position and adjust the tuning condenser until the dial reads 600 kc. Connect the signal generator to the antenna and ground, using a 0.00025-mfd condenser as the dummy antenna. Adjust the signal generator for a modulated signal at 600 kc. Adjust the 600 padder for maximum response. Then set the receiver dial to 1,500 kc and adjust first the oscillator-coil high-frequency trimmer, then the RF coil trimmer (if present), and finally the antenna-coil trimmer for maximum response. Return both dial and signal generator to 600 kc and readjust the 600 padder, if necessary. Then return to 1,500 kc and check alignment. If readjustment is necessary, repeat the alignment at 600 kc and check at 1,500 kc until further readjustment is unnecessary.

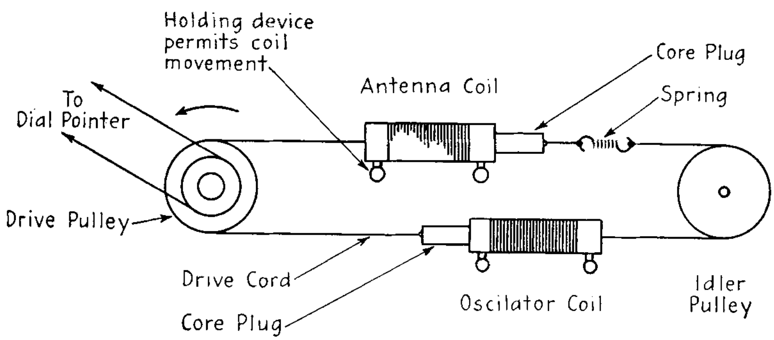


FIG. 15–6. Drive-cord type of permeability tuner.

Permeability tuning systems. In the conventional receiver, tuning is accomplished by changing the capacity of a variable condenser connected across a coil, thereby changing the resonant frequency of the combination. The same effect can be brought about by allowing the condenser capacity to remain fixed and changing the inductance of the coil. This is the basis of permeability tuning systems, where the inductance of the coil is changed by varying the position of an iron-core plug in the coil.

Coils with adjustable cores are used as IF transformers, and for the fixed-tuned antenna and oscillator coils of the circuit-switching type of push-button tuners. In these cases, the inductances of the coils are adjusted during the alignment procedure or when setting up the push buttons, and remain undisturbed thereafter. In some receivers, instead of using a variable condenser, the antenna and oscillator core plugs are ganged, and their adjustment is brought out to the front control panel as a continuously variable adjustment of the tuning range of the receiver. Such a tuning system is known as a "permeability" tuner. Figure 15–6 shows a tuner of this type, where the positions of the core plugs are varied by means of a drive cord.

The coils, drive pulley, and idler pulley are fastened to a subassembly. The coil mounts are so arranged that either coil may be shifted slightly to the right or left for tracking purposes. Ordinary dial-drive cord is used to vary the position of the core plugs. Note that when the drive shaft is rotated in the direction shown, both core plugs are pulled into their respective coils.

From the servicing point of view, any trouble in the permeability tuner would be found in the same way that a similar trouble would be found in a conventional tuner, since the circuits are alike. The alignment pro-

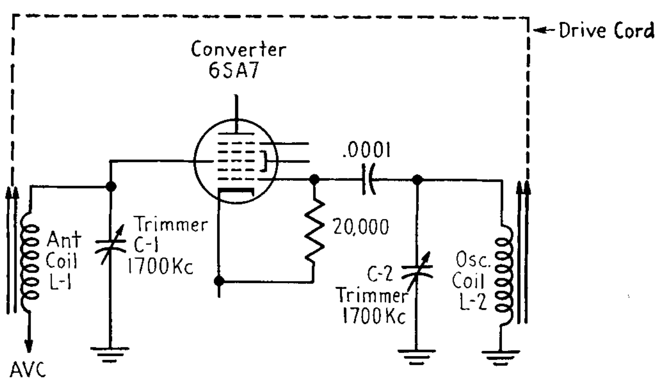


FIG. 15–7. Skeleton diagram of drive-cord type of permeability tuner.

cedure is somewhat different, and the manufacturer's service notes should be followed closely in this regard. Another difference lies in the fact that restringing the drive cord calls for re-alignment, since the restringing process will slightly alter the relative positions of the tuning slugs.

If specific restringing and alignment notes are not available from the receiver manufacturer, the following generalized procedure should be of help. The skeleton schematic diagram of Fig. 15–7 is included as an aid in locating and identifying the trimmers.

Restringing and alignment procedure for drive-cord permeability tuners

1. Restring the tuning slugs, using the frayed or torn pieces of the old drive cord as a guide, so that the relative positions of the tuning slugs are as close as possible to their original settings.

2. Set the antenna coil in the center of its positioning range, so that it may be shifted either to the right or left.
3. Rotate the drive so that the antenna core plug is completely out of the winding.
4. Set the oscillator coil so that its core plug is in the same relative position as the antenna coil and its core plug. Set the dial pointer to the highest frequency division on the dial scale.
5. Rotate the drive to make sure that the dial pointer and tuning slugs move together and cover the entire tuning range.
6. Check the alignment of the IF amplifier and, if necessary, align in the usual manner.
7. Connect the signal generator to the receiver antenna, using a 0.00025-mfd dummy antenna. Rotate the drive to the high-frequency end of the dial scale, and adjust the signal generator for a modulated output at the same frequency. Adjust the oscillator trimmer *C*-2 to a maximum response. Then adjust the antenna trimmer *C*-1 to a maximum response.
8. Rotate the drive to 1,400 kc, and adjust the signal generator frequency control to a peak. This should occur at 1,400 kc. If it is too far off, the starting position of the oscillator core plug was incorrectly adjusted. This should be corrected and steps 7 and 8 repeated.
9. When the peak at 1,400 kc in step 8 has been obtained, the antenna coil is shifted to the right or left for a maximum tracking peak.
10. Return the dial and signal generator to the highest frequency reading on the dial scale, and check the adjustment of the antenna trimmer *C*-1. If no appreciable change is needed, the antenna coil is in track. If a considerable change has been made, repeat steps 9 and 10.

Screw-drive permeability tuners. Another type of permeability tuner uses a screw for driving the ganged tuning slugs. Figure 15–8 shows a tuner of this type. The proportions have been altered to permit viewing the operation of the unit.

The coils *L*-1, *L*-2, and *L*-3 are mounted on the back plate of the carriage. The bakelite strip is threaded to take screws attached to the core plugs. Adjusting these screws permits adjustment of the relative positions of the individual core plugs with respect to their coils. Rotating the drive shaft causes the bakelite strip to move in and out, carrying the core plugs with it, and thereby changing the inductance of the coils. The drive shaft is the tuning control for the radio. The gear ratio is usually chosen to allow several turns of the drive shaft for complete coverage of the tuning range, thereby giving vernier tuning. A similar ratio on a drive pulley (not shown in the diagram) operates a conventional dial pointer from the same tuning shaft.

A tuner of this type, employing three coils, may be used for a receiver with an RF stage. It may also be used in a receiver with a converter

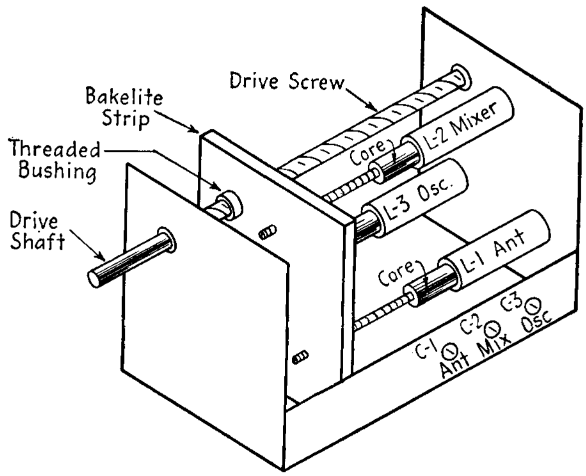


FIG. 15–8. A permeability tuner of the screw-drive type.

stage only, the antenna coil being used in a preselector circuit. Figure 15–9 shows a receiver of the latter type.

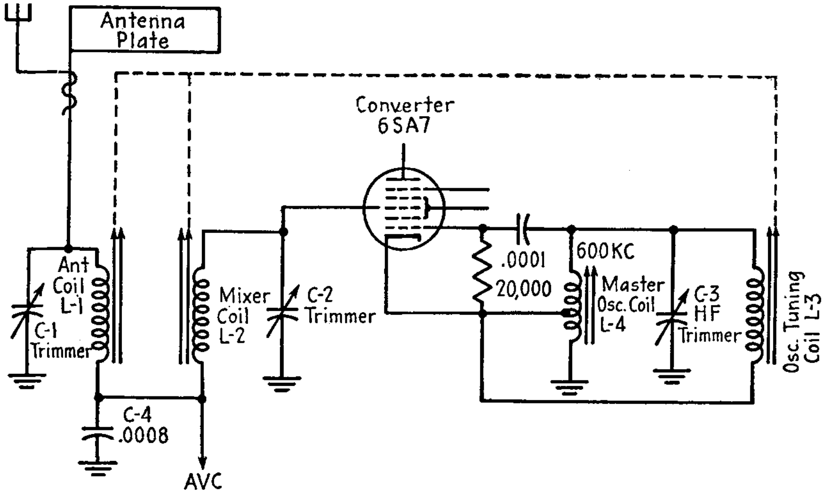


FIG. 15–9. Three-coil permeability tuner with a preselector circuit.

Coils *L*-1, *L*-2, and *L*-3, with their core plugs ganged in the permeability tuning unit, are identified as the antenna, mixer, and oscillator coils, respectively. Actually, coil *L*-3 is not the oscillator coil with a function similar to the one in the standard receiver. The actual oscillator coil that furnishes the feedback voltage for operation of the oscillator circuit is coil *L*-4, which is outside the permeability tuning unit. This coil, *L*-4, is referred to as the "master oscillator coil." Coil *L*-3, in the tuner, is shunted across a portion of the master oscillator coil and acts to tune it. Trimmer condenser *C*-3 is the high-frequency aligner for the oscillator circuit. The 600-kc aligner is the permeability adjustment screw on the master oscillator coil *L*-4.

The antenna plate is a sheet of metal, insulated from the chassis, and acting as a self-contained antenna for the receiver. It is usually mounted behind the chassis so that it also acts as the back of the cabinet. The lead

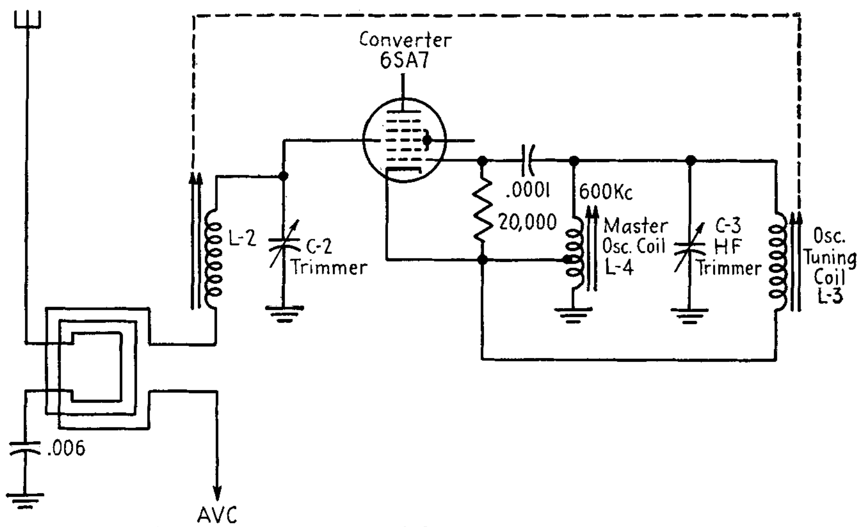


FIG. 15–10. Two-coil permeability tuner fed by a loop antenna.

for a standard antenna is capacitively coupled, as shown, by a few turns of the antenna lead around the antenna plate lead. The antenna signal is impressed across the antenna coil *L*-1 and condenser *C*-4. The condenser acts as the common coupling to feed the mixer coil *L*-2 in the converter signal grid circuit. Trimmer condensers *C*-1 and *C*-2 are the alignment controls for the antenna and mixer circuits.

Antenna plates are commonly used in receivers employing permeability tuners. However, there are some receivers that employ a loop antenna. Figure 15–10 shows a two-gang permeability tuner of the screw-drive type fed by a loop antenna.

From the servicing point of view, the screw-driver type of permeability tuner likewise offers no new problems, except from the standpoint of alignment. A generalized alignment procedure follows.

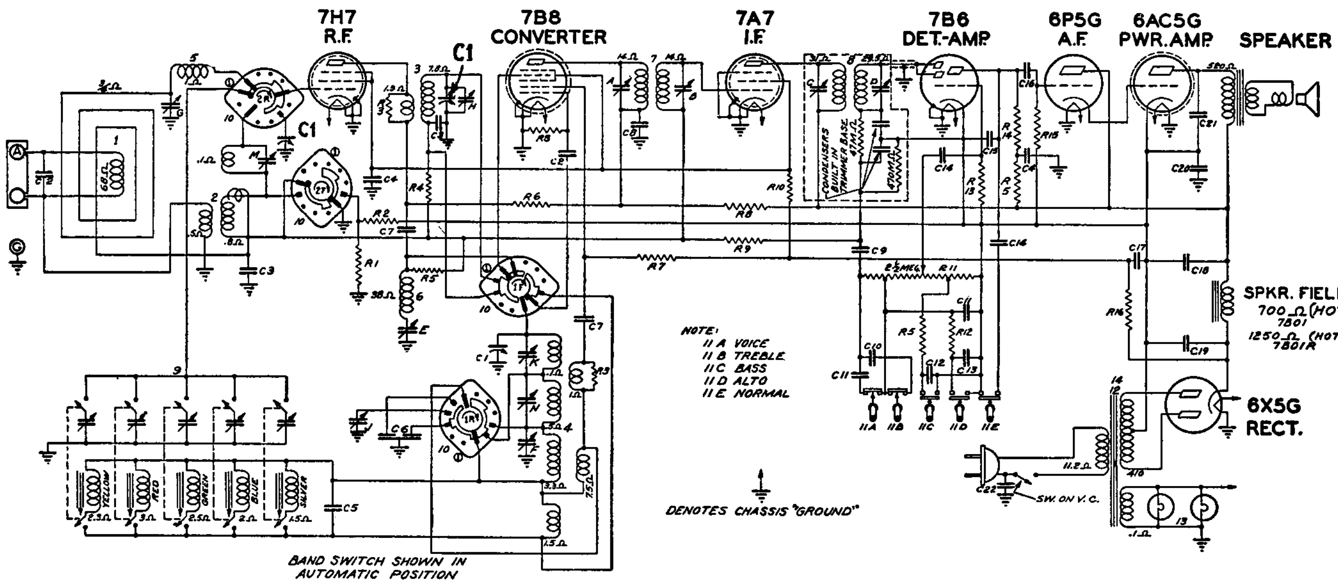
Alignment procedure for screw-drive permeability tuners

1. Align the IF amplifier in the usual way.
2. Check the dial pointer setting and positioning of the core plugs by the following steps.
   a. Rotate the tuning shaft to the low-frequency stop.
   b. Rotate the core plugs by means of the screws in the bakelite rack until they are fully engaged in their respective coils.
   c. Set the dial pointer at the lowest frequency calibration mark on the dial scale.
3. Connect the signal-generator output lead to the antenna connection through a 0.00025-mfd dummy antenna. Do not connect to the antenna plate.
4. Set the signal generator to feed a modulated signal at 600 kc, rotate the tuning shaft to read 600 kc on the receiver dial, and align the master oscillator-coil permeability adjustment for maximum output.
5. Tune the receiver to a quiet point near the high-frequency end of the tuning range, adjust the signal generator to feed the same frequency as that shown on the receiver dial scale, and align the oscillator high-frequency trimmer for maximum output. This trimmer is labeled *C*-3 in Figs. 15–8, 15–9, and 15–10.
6. Check the 600-kc adjustment by repeating step 4. If considerable re-adjustment is necessary, re-align the high-frequency adjustment by repeating step 5 and then recheck at 600 kc.
7. Tune the signal generator and receiver to a peak near 1,400 kc, and align first mixer and then the antenna trimmers for maximum output.

Receivers with push-button tuning. Many receivers, particularly auto sets, use push buttons for tuning favorite stations. There are two general types of push-button arrangements, mechanical and switching. In the mechanical type, when the button is pushed, the tuning dial is moved to predetermined positions by means of an electric motor, a solenoid system, or lever action. In the switching method, when the button is pushed, the dial-operated tuning circuit is switched out, and a separate tuning circuit, preset to the desired station, is switched in.

There is a large number of both types of arrangements. For best servicing procedures, refer to the manufacturer's service notes. Some typical examples will be described, together with applicable notes.

Switched push-button tuning circuits. Figure 15–11 shows the schematic diagram of the Zenith Model 7S633R receiver. Push-button tuning is inaugurated by turning the range switch to the automatic tuning position. This disconnects the gang tuning condenser, all three sections of which are labeled *C*-1, throws a row of preset trimmers across the



DIAG. No.	PART No.	DESCRIPTION	
C1	22-1205	THREE GANG VARIABLE	
C2	22-289	50 MMFD.	600V.
C3	22-829	.05 MFD.	200V.
C4	22-828	.05 MFD.	400V.
C5	22-868	COMPENSATING COND.	
C6	22-1037	DUAL PADDER	
C7	22-182	.00025 MFD.	600V.
C8	22-825	.1 MFD.	400V.
C9	22-327	.02 MFD.	200V.
C10	22-954	.00035 MFD.	600V.
C11	22-470	.00015 MFD.	600V.
C12	22-229	.005 MFD.	600V.
C13	22-887	.001 MFD.	600V.
C14	22-448	.004 MFD.	600V.
C15	22-854	.0005 MFD.	600V.
C16	22-890	.02 MFD.	600V.
C17	22-1035	5 MFD. ELECTROLYTIC	450V.
C18		15 MFD. "	350V.
C19		15 MFD. "	450V.

DIAG. No.	PART No.	DESCRIPTION	
C20	22-827	.1 MFD.	200V.
C21	22-1119	.005 MFD.	1000V.
C22	22-1041	.005 MFD.	600V.
R1	63-1100	52 OHM WIREWOUND	½W.
R2	63-733	33 OHM	¼W.
R3	63-590	15 M OHM	¼W.
R4	63-715	100 M OHM	¼W.
R5	63-593	47 M OHM	¼W.
R6	63-587	4700 OHM	¼W.
R7	63-150	10 M OHM	½W.
R8	63-605	1000 OHM	½W.
R9	63-599	1.5 MEGOHM	¼W.
R10	63-1192	27 M OHM	1W.
R11	63-1122	VOLUME CONTROL	
R12	63-5[illegible]	68 M OHM	⅛W.
R13	63-976	15 MEGOHM	⅛W.
R14	63-296	220 M OHM	¼W.

DIAG. No.	PART No.	DESCRIPTION	
R15	63-271	1 MEGOHM	¼W.
R16	63-1191	8200 OHM	2W.
1		WAVE MAGNET ASSEMBLY	
2	S9657	ANTENNA COIL	
3	S9585	DETECTOR COIL	
4	S9658	OSCILLATOR COIL	
5	S9589	LOOP LOADING COIL	
6	S8326	WAVE TRAP COIL ASSEMBLY	
7	95-708	1ST I.F. TRANSFORMER	
8	95-709	2ND I.F. "	
9	S9808	AUTOMATIC TUNING	
10	85-290	BAND SELECTOR SWITCH	
11	S9805	TONE CONTROL SWITCH ASSEM.	
12	95-710	PWR. TRANS. 115V. 50-60~ (7B01)	
13	100-36	DIAL LIGHT 6.3V. .25A.	

DIAG. No.	PART No.	DESCRIPTION
14	95-882	PWR. TRANS. 115V. 50-60~ (7B01 R)
A		1ST I.F. TRANS. PRI.
B		1ST I.F. " SEC.
C		2ND I.F. " PRI.
D		2ND I.F. " SEC.
E	22-1015	WAVE TRAP
F		BROADCAST OSC. (NOTE 1)
G		BROADCAST ANT. (NOTE 2)
H		BROADCAST DET. (ON GANG)
J.		BROADCAST PADDER (NOTE 2)
K		SHORT WAVE OSC. (NOTE 1)
M		SHORT WAVE ANT. (NOTE 2)
N		POLICE BAND OSC. (NOTE 1)
	NOTES	(1) TRIMMERS F, K & N ARE MOUNTED ON STRIP #22-1091 (2) TRIMMERS G, J & M ARE MOUNTED ON STRIP #22-1278

MODEL	SPEAKER
7S633	49-460 6"
7S634	49-460 6"
7S657	49-457 12"
7S633R	49-505 6"
7S634R	49-505 6"
7S657R	49-397 12"

I.F. FREQUENCY 455KC.
7 TUBE SUPERHETERODYNE
CHASSIS No. 7B01 & 7B01R 3 BAND A.C.
ZENITH RADIO CORPORATION
CHICAGO, ILL.

FIG. 15–11. Schematic diagram of the Zenith Model 7S633R push-button receiver.

antenna tuning circuit, eliminates the converter signal-grid tuning circuit by converting it into an untuned resistance-coupled circuit, and throws any one of a row of permeability-tuned coils in the oscillator grid circuit.

The predetermined station is then tuned in by depressing the proper push button. The buttons are sprung so that they are normally in the OFF position. Then as any button is depressed, a catch holds this button in place while automatically releasing any button previously depressed. Each button controls a double-pole switch, one pole of which connects one of the permeability-tuned coils in the oscillator grid circuit, while

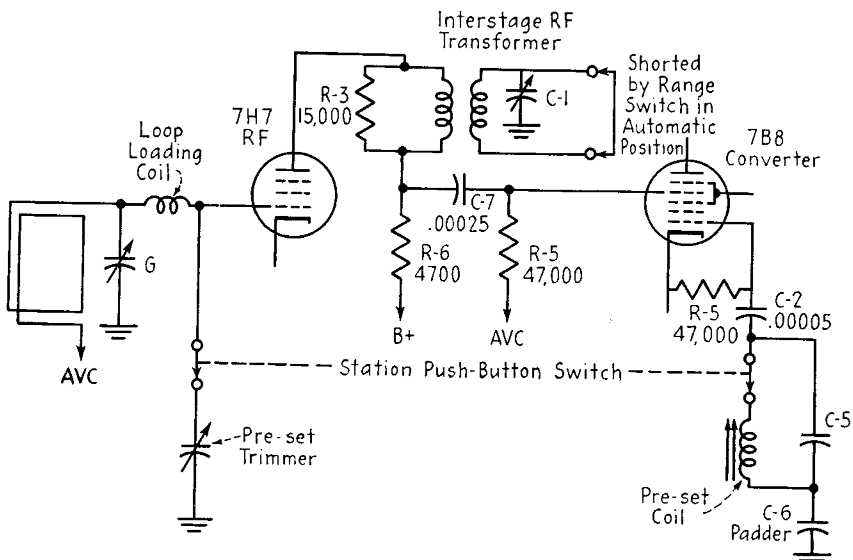


FIG. 15–12. Simplified diagram of the tuning circuit of the Zenith receiver shown in Fig. 15–11.

the other pole connects the proper associated trimmer in the RF grid circuit.

The trimmers and coils in the automatic tuner have a limited range (approximately 400 kc), so that each button cannot tune many desired stations in the broadcast band. However, the values of coils and condensers are staggered, so that any station can be tuned in on some one button. The tuning range of each button is usually marked near the adjustment screws.

Figure 15–12 shows a simplified drawing of the tuning circuit of the Zenith receiver of Fig. 15–11, when the range switch is in the automatic position. One push button is depressed, showing one preset trimmer connected across the RF tuning circuit and one preadjusted permeability coil in the oscillator tuning circuit. The coupling between the RF and converter tubes is of the resistance-capacity type. This coupling also remains the same for the short-wave position of the range switch. The circuit is tuned only in the manually operated broadcast position of the range switch.

The system just described is typical for push-button tuners of the switching type. These systems differ mainly in the number of preset stations available. In some cases, switching from manual to automatic tuning is taken care of by an extra similar push button, rather than a position on the range switch. Often the radio-phonograph switch is also an extra similar push button. In addition, some types provide two sets of trimmer condensers, instead of one set of trimmers and one set of permeability-tuned coils. In these types, the regular broadcast oscillator coil is used, the oscillator tuning condenser is switched out of the circuit, and one of the preset trimmer condensers is substituted for it.

Servicing push-button tuners of the switching type. Push-button systems of the switched tuning-circuit type give very little service difficulty. Occasionally, the switches do not make good contact. When this happens, the following cleaning procedure is effective: Dust the entire switch assembly with a soft brush. Depress the first switch, and apply carbon tetrachloride to its contacts and also the arm and contacts of the next switch. Then depress the two switches alternately: first the second, then the first. Repeat the procedure for the first and second switches, this time depressing the second button before applying the carbon tetrachloride to it. Repeat on the next pair, making sure that each switch has been washed in both the open and the closed position.

Another service problem is resetting the adjustment screws, which may change their position with time. When doing this, the receiver should be allowed a warm-up period of about 15 min, to allow all components to reach normal operating temperature. The oscillator control is adjusted first, followed by the antenna adjustment. If the adjusting screws are not marked, the serviceman can identify them by checking the wiring diagram or by the operation of the adjustments. The oscillator adjustment is critical—a fraction of a turn will bring the station in or out. The antenna adjustment is broad in comparison. If the receiver is equipped with a magic eye, it should be used to indicate exact resonance. An output meter cannot be used for this purpose, since the reading will vary with the modulation of the program. A vacuum-tube voltmeter, if available, connected to the AVC bus, can also be used as the resonance indicator. If neither the magic eye nor a vacuum-tube voltmeter is available, the adjustments are set for best volume and tone by ear. A good check for correct settings is to tune to the same station with the switch set for manual operation, and then switch from manual to push button and note any difference. Operation should be the same, except in the case of a receiver like that of Fig. 15–11, where the manual switch throws in an extra tuning circuit.

When push buttons are set up or when the adjustment screws are far from their correct alignment positions, it would be timesaving to use the signal generator for finding the desired stations.

Figure 15–13 shows the method of connecting the signal generator to the receiver. Adjust the signal generator for a modulated output at the frequency of the first desired station. Depress the first push button, and adjust the associated oscillator control until the signal-generator note is heard. It will be accompanied by a squeal, caused by the beating action between the generator signal and the signal from the desired

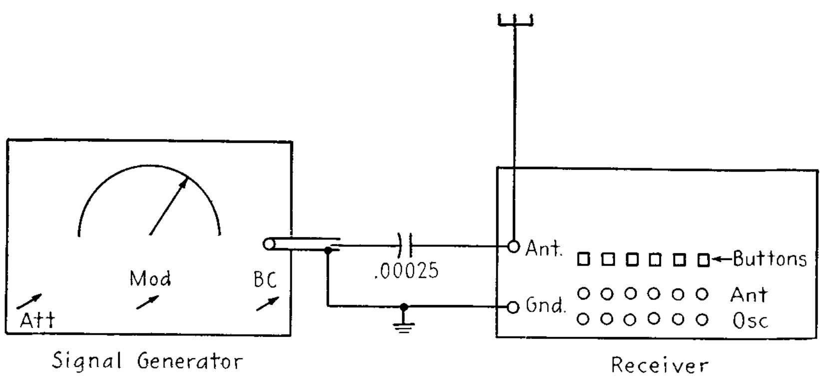


Fig. 15–13. Using a signal generator as an aid in quickly presetting push buttons.

station. Disconnect the signal-generator "hot" lead. If the squeal does not stop because of leakage, detune the signal generator. Then readjust the oscillator control for maximum response from the station. Finally, adjust the antenna trimmer. Repeat the procedure for the other buttons.

Mechanically operated push-button tuners. Figure 15–14 shows two views of a typical mechanically operated push-button tuning system. This type is known as a "rocker-bar" mechanism. Each button depresses a preset pawl, which turns the rocker bar as far as the pawl setting will allow. A gear connected to the rocker bar rotates the gang tuning condenser. The tuning knob and dial pointer rotate with the condenser gang. The return spring maintains the push button in its normal out position and, at the same time, keeps the pawl away from the rocker bar.

When a button is set up, the locking screw is loosened. A screw driver is kept pressed against the loosened locking screw, thereby depressing the push bar and pushing the pawl against the rocker bar. The desired station for each button is tuned in manually, thereby pushing the pawl to its proper setting. The locking screw is then tightened, fixing the pawl firmly between the shoe and push rod. Subsequently, when the button is depressed, the pawl pushes the rocker bar to its set position, thereby bringing in the desired station.

From the servicing point of view, loosened adjustments are about the

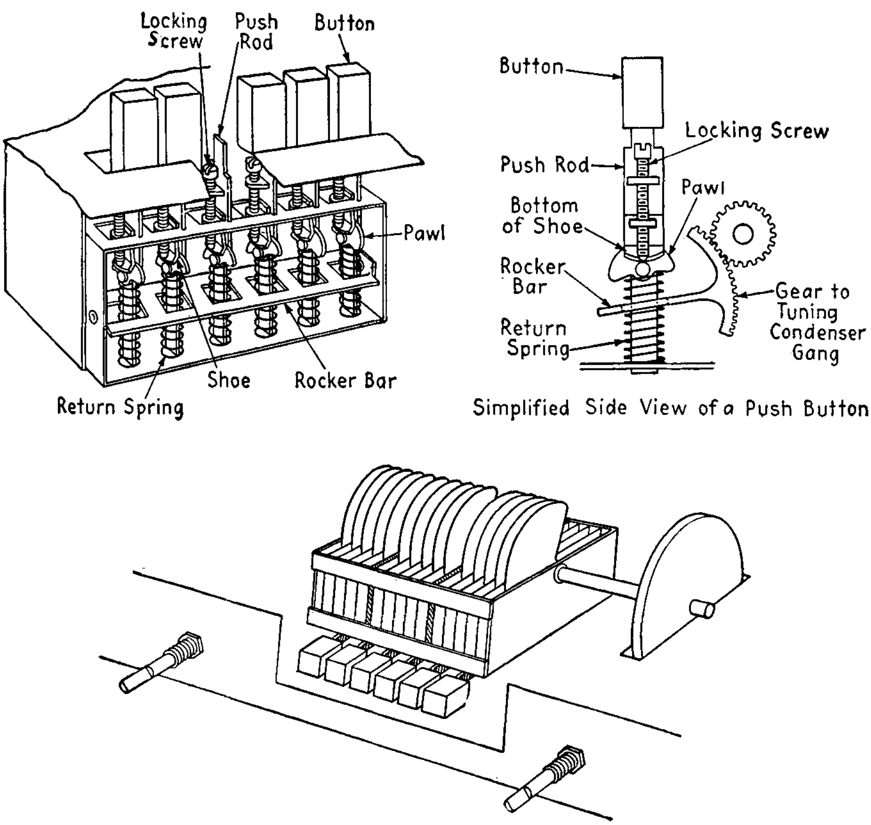


FIG. 15–14. Mechanically operated push-button tuner of the rocker-bar type.

only difficulty experienced with mechanical buttons of this type. A complete adjustment procedure follows.

Adjustment of push buttons for rocker-bar tuners. Rotate the range switch to the broadcast position. Select the stations desired for automatic tuning. Choose one of these stations and any button to be adjusted for it. Follow the procedure outlined below:

1. Grasp the button firmly and remove it from its shaft by pulling straight out (see Fig. 15–15A).

2. Insert a screw driver into the slot of the locking screw. Press in and loosen the screw 1 to 1½ turns (see Fig. 15–15*B*).
3. With the screw driver seated in the screw slot, press the screw in as far as possible. Hold it in firmly with one hand, and tune in the desired station with the other hand by pressing in and rotating the selector knob (see Fig. 15–15*C*).
4. Release the selector knob and tighten the screw firmly.
5. Check the adjustment by tuning well past the station, using the selector knob and then pushing in the button shaft. The station should come back in again clearly and with maximum volume. After the adjustment is tested, check to see that the locking screw is tightened firmly. Replace the button on its shaft.
6. Adjust the remainder of the buttons in the same manner as outlined above.

Figure 15–15*D* shows a common method of inserting station tabs.

Mechanical automatic permeability tuners. The Motorola Tuner AT-84, illustrated in Fig. 15–16, is a push-button control of associated permeability tuners. It is similar to the rocker-bar arrangement just described, except that powdered-iron cores are inserted to different extents in the antenna, RF, and oscillator coils by the depression of each of the buttons.

Like the rocker-bar system, about all the trouble that develops is a falling out of adjustment. The tuner is then reset as described below:

1. Turn on the receiver and allow it to warm up for a few minutes.
2. Pull out any station-selector push button to unlock the tuner.

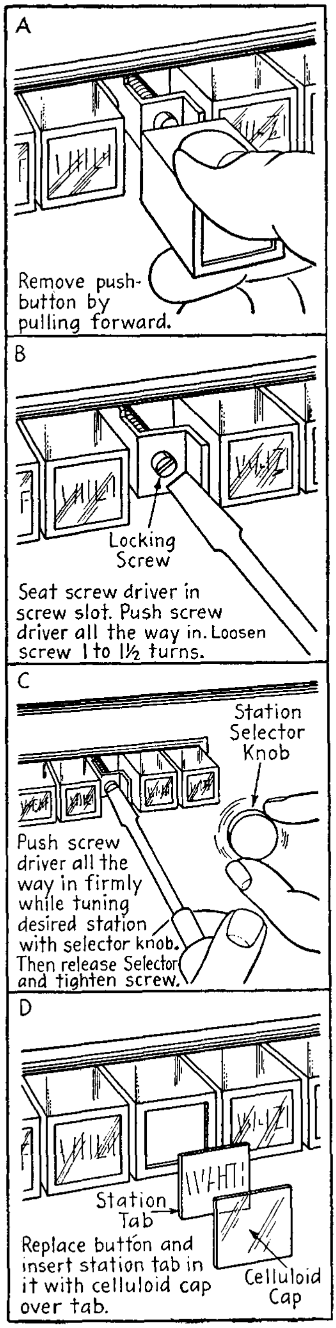


FIG. 15–15. Adjustment of push button for mechanical automatic tuners.

3. Tune manually to the station you desire to set up. Be sure you tune for clearest reception.
4. Push the button back on and depress to lock the tuner. This push button is now set for the station you just selected.

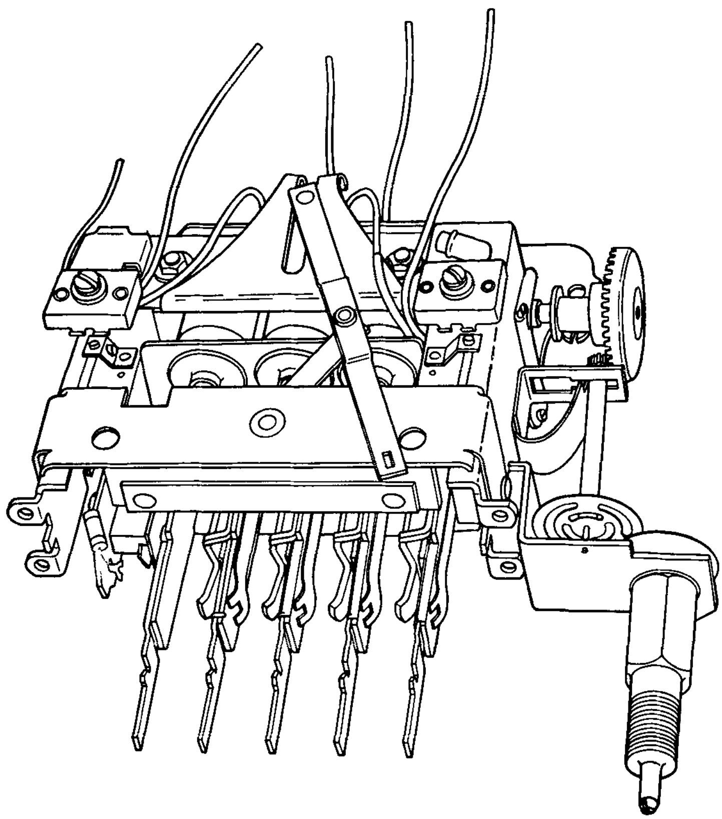


FIG. 15–16. Mechanical automatic permeability tuner.

5. Follow the same procedure for the remaining push buttons and other desired stations.
6. It is usual to set the push buttons for higher-frequency stations as you move from the left to the right.

Mechanically operated push-button tuners of the motor-driven type. Motor-driven push-button tuners are too varied in their operation, adjustment, and service problems for any generalized treatment in a book of this nature. The serviceman is referred to the manufacturer's service notes when he experiences difficulty with any of these devices.

QUESTIONS

1. Outline a procedure for determining the cause of a defective oscillator circuit in a dead receiver.

2. Outline a procedure for determining the cause of a defective mixer circuit in a dead receiver.

3. A receiver operates on the high-frequency end of the broadcast band but not on the low-frequency end. List the probable causes and state how you would check for each.

4. The receiver of Fig. 15–2 does not operate. Signal check shows normal response when checking with an IF signal at the 12SA7 mixer grid, and no response when checking with an RF test signal from the same point. Voltage check shows no reading at the oscillator grid and normal readings for the 12SA7 plate and screen. Resistance check on the oscillator coil shows a reading of 6.5 ohms. Where is the trouble likely to be? How would you check for it? How would you remedy the condition?

5. The receiver of Fig. 15–4 operates normally on both short-wave ranges but not on the broadcast band. Outline a procedure to locate the cause of the trouble.

6. The receiver of Fig. 15–5 gives no reception. Signal check shows normal operation when a test signal, either RF or IF, is applied to the 6SA7 signal grid, and no reception when an RF test signal is applied to the RF grid. Voltage check on the RF tube shows a reading of zero at the plate terminal. What are the probable causes of the trouble? How would you check each?

7. The receiver of Fig. 15–11 operates normally on the manual and short-wave positions of the range switch, but gives no reception on any push button. What is the most likely cause of the trouble? How would you check for it? How would you remedy the condition?

8. What is the function of *L*-4 in Fig. 15–10? What is the function of *L*-3 in the same drawing?

9. What are the important points to remember when replacing an oscillator coil?

10. A receiver has a tunable hum. The line filter is checked and found to be O.K. What else is likely to cause this condition? How would you check for it?

11. A superheterodyne receiver squeals all over the tuning range How would you check the converter stage for this complaint?

12. The receiver of Fig. 15–2 does not operate. When a test signal, either RF or IF, is applied to the converter signal grid, the response is heard weakly and with a rough note. What is likely to be wrong? How would you check for it?

13. The receiver of Fig. 18–19 operates, but reception is a little weak and the noise level is high. Stage-gain measurements show a normal response when an RF test signal is applied to the converter signal grid, and a loss in gain when the test signal is applied to the antenna lead. What is likely to be the cause of the trouble? How would you check for confirmation?

14. The receiver of Fig. 15–4 is inoperative. Signal check shows a normal response when a 455-kc test signal is applied to the 6SK7-GT grid. There is no response when the 455-kc test signal is shifted to the 6SA7-GT grid. A resistance check of the converter tube shows the following abnormal readings:

Plate to chassis	40 ohms
Plate to *B* plus	open

What is wrong?

16 RF AMPLIFIER STAGE

Many receivers incorporate a stage of RF amplification ahead of the converter. It is called the "RF" stage, or sometimes the "antenna" stage. It requires no quick check for operation. Since it is last in a line of stage checks, if all others check perfect for a defective receiver, the RF stage must be defective by a process of elimination.

Of course, the entire receiver may be normal and the trouble may lie in the antenna system, which is the first link in the signal chain. This possibility, however, should not occur on a test bench setup. Only at the customer's home will such trouble arise, and the alert serviceman will recognize the condition. Checking the antenna is usually a routine part of the home service call. Service notes relating to antennas will be included later in this text.

Function of the RF stage. The RF stage receives energy from the antenna, tunes the desired signal (station), amplifies the signal, and passes it on to the converter. Because of these functions—tuning and amplification—it increases the selectivity and sensitivity of the receiver. The RF stage provides other advantages. One is the reduction of the noise level when a stronger signal is fed to the converter. Another is the improvement of the AVC action, since another controlled tube is added in the RF and IF chain. A third is the elimination of image-frequency interference—peculiar to superheterodyne receivers.

Image-frequency interference. Examine the operation of a superheterodyne receiver. The antenna picks up station signals broadly at all frequencies. Where a receiver has no RF stage, the antenna energy is fed through a tuned circuit to the signal grid of the converter tube. For example, suppose the tuning circuit is set to receive a desired signal at 1,000 kc. The local oscillator of the receiver will then have an output at 1,455 kc if the IF amplifier of the receiver is fix-tuned to 455 kc. The station and oscillator signals are mixed in the converter tube and the output from the latter is many frequencies. The IF amplifier, usually sharply tuned by four resonant circuits, accepts only the signal that is the difference in frequency between the station and the oscillator signal—

in this case 455 kc, the intermediate frequency. This IF signal is then amplified and sent on to the detector and AF amplifier.

Any signal at 455 kc in the converter plate circuit will be accepted by the IF amplifier and passed on. We have just seen how one 455-kc signal is developed at the input of the IF amplifier. Is it possible for a second one to be present at the same time?

Reexamine the converter signal grid. It is tuned to 1,000 kc, by means of one tuned circuit that is somewhat broad. As a result, the grid may receive signals of widely different frequencies picked up by the antenna. Normally, these signals mix with the local oscillator signal (1,455 kc) and produce difference frequencies which are rejected by the sharply tuned IF amplifier. However, there might be one station signal at 1,910 kc on the converter grid which, after mixing with the local oscillator signal of 1,455 kc, will produce a difference frequency at 455 kc. This 455-kc signal will be accepted by the IF amplifier and result in two stations at the speaker output—1,000 and 1,910 kc.

Similarly, if the receiver is tuned to a station at 600 kc, the oscillator will be tuned to $600 + 455$, or 1,055 kc, and an intermediate frequency of 455 kc will be produced at the IF amplifier grid. And a station signal at 1,510 kc at the converter signal grid will mix with the oscillator signal and again produce a difference, or IF frequency, of 455 kc which will appear as an interfering station. Thus, any desired station is likely to experience interference from another station that happens to have a frequency which is higher than that of the desired station by twice the intermediate frequency (as much above the oscillator frequency as the desired station is below the oscillator frequency). This defect of superheterodyne receivers is known as "image-frequency interference."

Since the two stations are rarely exactly twice the intermediate frequency apart, they will beat with the oscillator signal to produce intermediate frequencies very close to 455 kc and to each other. These two intermediate frequencies will be accepted by the IF amplifier, where they will beat with each other to form a difference frequency which will be AF and result in a high-pitched squeal. Thus, image-frequency interference appears in the receiver in a form called "birdies" or "whistles," which mar reception on certain stations.

Early superheterodyne receivers employed an intermediate frequency of 175 kc. Here, image-frequency interference would occur from stations 350 kc from the desired ones (twice the intermediate frequency, or 2×175 kc). If there were only one tuned circuit before the converter, that tuned circuit would not be sufficiently sharply tuned to eliminate image frequencies 350 kc from the desired signal and interference would be troublesome. Modern practice employs an intermediate frequency of 455 kc, thereby placing the image frequency much farther away, 910 kc from the desired station. As a rule, with such a wide spread between desired and image frequency, even one RF tuning circuit is adequate to keep a station 910 kc away from affecting the converter signal grid.

A preselector circuit is an added tuning circuit between the antenna and the converter signal grid, the purpose of which is to sharpen the tuning to reduce image-frequency response. Figure 16–1 shows a typical preselector circuit together with its over-all selectivity curve.

Preselector circuits are rarely used in modern receivers, since they reduce the sensitivity, and the same reduction in image-frequency response is possible by increasing the intermediate frequency.

A tuned RF stage, ahead of the converter, combines the added selectivity of the preselector in reducing image-frequency response and, be-

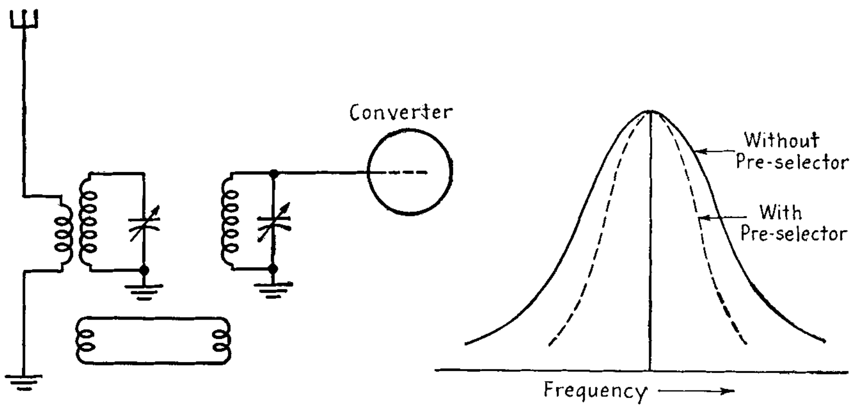


FIG. 16–1. A preselector circuit and its effect on selectivity before the converter signal grid.

cause of the amplification of the tube, adds to the sensitivity of the receiver.

Standard circuit. The standard circuit is shown in Fig. 16–2.

Functions and values of component parts. The antenna transformer *T*-1 couples the energy picked up by the antenna to the grid of the RF tube. The secondary winding *L*-2 is tuned by *C*-2, the antenna section of the gang tuning condenser. As explained before in connection with the components of the converter stage tuning system, the values of parts in any tuning system are important parts of the design of the receiver and cannot be changed without altering the calibration and tracking.

When the receiver is of the loop-operated type, antenna transformer *T*-1 is replaced by the loop antenna. In this case, the main portion of the loop winding acts as the antenna for the receiver and is tuned by condenser *C*-2. Should it be desired to connect an external antenna for greater sensitivity, the loop is equipped with a primary winding of one or two turns which is connected to the antenna and ground.

IF wave traps. Any superheterodyne receiver is especially sensitive to its intermediate frequency. With an intermediate frequency adjusted to 455 kc, if a signal at or near this frequency gets to the converter grid, it will be present in the converter plate and be accepted by the IF

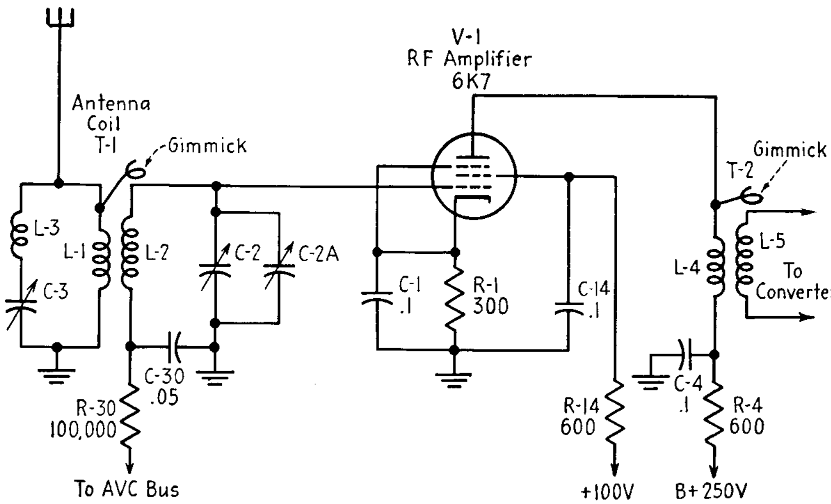


Fig. 16–2. Schematic diagram of a typical RF stage.

amplifier and cause interference with the desired station. In areas near the seacoast, many powerful shore-to-ship stations operate at frequencies close to 455 kc. These cause interference that blankets the low-frequency half of the broadcast band and, in severe cases, covers the entire tuning range.

A wave trap located in the antenna circuit of the receiver will minimize this effect. In the standard circuit of Fig. 16–2 a series-resonant wave trap, composed of *L*-3 and *C*-3, is shunted across the primary of the antenna coil. The trap circuit is tuned to the intermediate frequency of the receiver, and offers a low-impedance path to ground for signals of that frequency present in the antenna.

In most cases the trap is tunable by means of trimmer condenser *C*-3, as shown in the standard circuit. In some cases, the wave trap is fixed-tuned to the intermediate frequency of the receiver, and the condenser corresponding to *C*-3 is a fixed condenser. Sometimes, the trap is tunable by means of an adjustable permeability plug in the coil in conjunction with a fixed mica condenser. In loop receivers, the trap is usually placed in the converter signal grid circuit, where it serves a similar purpose by providing a low-impedance path to ground for signals at the intermediate frequency, which may be present in the converter signal grid circuit. Coil *L*-12 and condenser *C*-28 make up this type of wave trap in the receiver of Fig. 16–10.

In some receivers, especially where the primary of the antenna transformer is of the low-impedance type, the wave trap is a parallel resonant circuit connected in series with the antenna transformer primary, as shown in Fig. 16–3. The wave trap is tuned to the intermediate frequency of the receiver. This trap offers a high-impedance path to signals at the

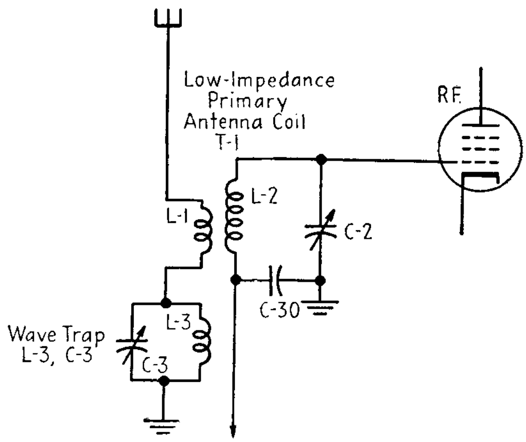


FIG. 16–3. Wave trap in series with antenna circuit.

intermediate frequency appearing across the antenna circuit, and tends to dampen them.

Decoupling filters in the RF stage. When a receiver incorporates an RF stage, there is more likelihood of undesirable coupling. As a result, there must be more decoupling filters not only in the RF stage, but also throughout the receiver. The RF cathode may be tied to the converter cathode or IF cathode, but rarely to both. In some receivers the RF cathode resistor *R*-1 is variable. This provides a variable minimum-bias resistor for the RF tube, and acts as a sensitivity control for the entire receiver. Such a sensitivity control is usually 25,000 ohms.

The screen-supply voltage may also be common with that of the converter or IF tube, but again rarely to both. The most common screen supply consists of a suitably by-passed voltage-dropping resistor in series with *B* plus for the IF tube and a voltage-divider arrangement for the RF tube. The converter screen is then usually tied to the RF screen. The standard circuit connects the RF screen to the voltage divider through the decoupling resistor *R*-14. Condenser *C*-14 by-passes the screen to ground, and its usual value is 0.1 mfd/400 volts.

The plate supply also usually includes decoupling filters for one or more of the RF, IF, and converter plate circuits. The decoupling resistor *R*-4 for the RF plate is usually 600 to 1,000 ohms. The plate by-pass condenser *C*-4 is usually 0.05 to 0.1 mfd/600 volts.

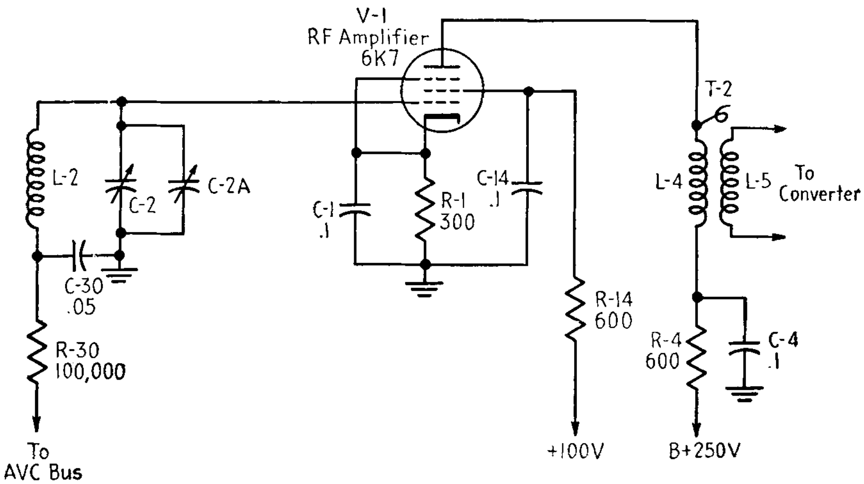


Fig. 16–4. Decoupling filters in the RF stage.

Tubes commonly used in the RF stage. Tubes of the 6K7 remote-cutoff pentode type are commonly used as RF amplifier tubes. When the 6K7G or 6K7GT tubes are used in this stage, they are usually covered with a closely fitting shield. The single-ended 6SK7 and the miniature 6BA6 remote-cutoff pentodes are more often used. All these tubes have characteristics similar to those of the 6K7. Multiband receivers generally use the 6SG7, which is also a triple-grid RF pentode with a higher gain and leads brought out in such a way as to provide for wiring with minimum coupling effects. Receivers with locking-base tubes use the 7A7 or the 7G7/1232. The 7A7 is similar to the 6SK7 and the 7G7/1232 is similar to the 6SG7. Older receivers use the 6D6 and 78 tubes, which are similar except for lower gain.

AC/DC receivers use any of the above tubes in circuits designed for 0.3-amp heaters. When the circuit is designed for 0.15-amp heaters, the RF tubes used are the 12BA6, the 12SK7, the 14A7, and the 6SS7.

NORMAL TEST DATA FOR THE RF STAGE

Normal signal check for the RF stage. The signal generator is connected to the antenna and ground through a 0.00025-mfd condenser, and adjusted for a modulated output at 1,500 kc, with the attenuator set for a very low output. The receiver is adjusted for maximum gain; that is, volume control full on, tone control at maximum high AF response, and fidelity control in the selective position. The receiver dial is set for a quiet point between 1,400 and 1,500 kc. If an output meter is connected to the receiver, it should be on a high-voltage range. The signal generator dial is then rotated through 1,400 to 1,500 kc.

When the receiver is operating normally, the signal generator modulation note will be heard in the speaker very strongly as the signal-generator dial passes the point at which the receiver is tuned. The RF stage is then known to be functioning. Usually, the output in the speaker will be greater than the standard output of 50 mw, even with both attenuation controls set at zero. In addition, with the receiver gain controls set at maximum, random noise pulses, picked up by the receiver, cause considerable output meter deflections, so that sensitivity measurements for the RF stage cannot be made to get the usual standard output.

However, if the signal check does not show some gain over a signal measurement from the RF grid, it may be assumed that there is trouble between the antenna and the RF grid.

Normal voltage data for the RF stage. Readings are taken from the indicated terminal to the chassis or common negative. Normal voltage data for the RF stage are given in the accompanying table.

Tube terminal	*6K7 pin No.*	*AC receiver, volts*	*AC/DC receiver, volts*
Plate	3	250	90
Screen	4	100	90
Cathode	8	3	3

Normal resistance data for the RF stage. Normal resistance data are given in the following table:

Antenna to ground, or across *L*-1 (primary)	30–50 ohms
Across *L*-2, secondary of the antenna transformer *T*-1	5 ohms
Cathode to chassis	300 ohms
Plate to *B* plus	40 ohms plus the resistance of a decoupling filter, if used
Control grid to chassis	1,600,000 ohms
Screen grid to chassis	30,600 ohms
Screen grid to *B* plus	30,600 ohms

The screen grid readings are for the standard receiver and will vary, depending on the screen grid circuit of the receiver being tested.

In receivers where the antenna transformer is replaced by a loop antenna, antenna to ground will measure less than 1 ohm and the grid coil of the loop will measure 1 to 3 ohms.

COMMON TROUBLES IN THE RF STAGE

Most of the parts used in the RF stage are similar to those used in other stages in the receiver. In this section, the common troubles and how they are found will be covered, but the reader will be referred to other parts of the text to avoid repetition of replacement notes.

Troubles common to the antenna transformer. Either winding of the antenna transformer *T*-1 is likely to open. An open secondary would cause weak, noisy reception, possibly accompanied by hum. The trouble would be localized on a signal check since there would be no gain between the RF grid and the antenna. An ohmmeter check would then confirm the difficulty.

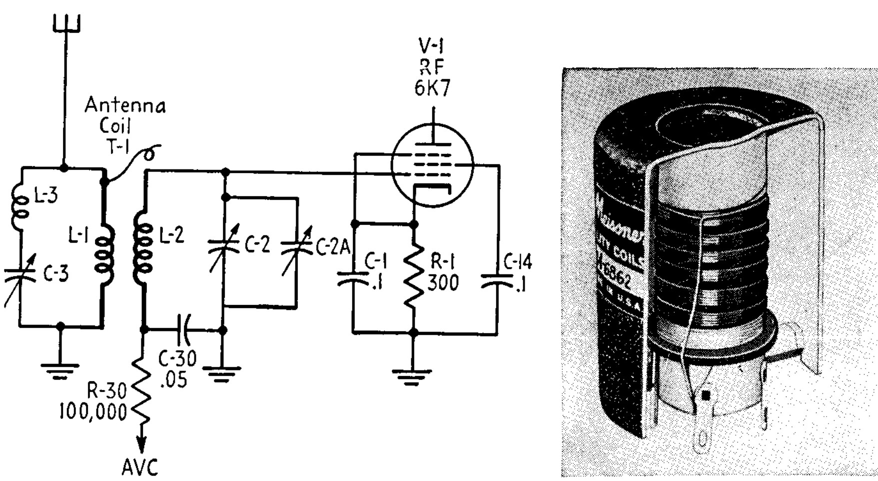


FIG. 16–5. An antenna coil and its position in the RF circuit.

An open primary winding might not be so easily found, owing to the fact that the capacitive gimmick winding may transfer sufficient energy to the secondary for fair operation of the receiver. The nature of the open in the winding will affect the type of trouble experienced with the radio. Usually it will be noisy, and a noisy receiver always calls for a routine check of coils that will locate the trouble.

Replacement notes on antenna transformers will be found in Chap 14.

Troubles common to the antenna tuning condenser. The antenna tuning condenser develops troubles in common with any section of the gang tuning condenser. The plates may touch and cause a short and no operation or very noisy operation over parts of the tuning range. Also the plates and the associated trimmer condenser collect dust and cause noisy operation and a partial short. Sometimes the wipers make poor contact, again causing noisy operation or weak reception over parts of the tuning range.

A shorted tuning condenser or trimmer would be found on signal check. When the converter stage is checked from the RF grid, the defective condenser would short the signal-generator output and cause no signal. An ohmmeter check would then disclose the short. Since this might be in the trimmer or the plates of the tuning condenser, the serviceman must determine which unit is defective. An easy way of doing this is to rotate the tuning condenser to the full open position and check again. If the short remains, it is probably due to cracked mica in the trimmer condenser.

When the tuning condenser is causing noisy reception over part of

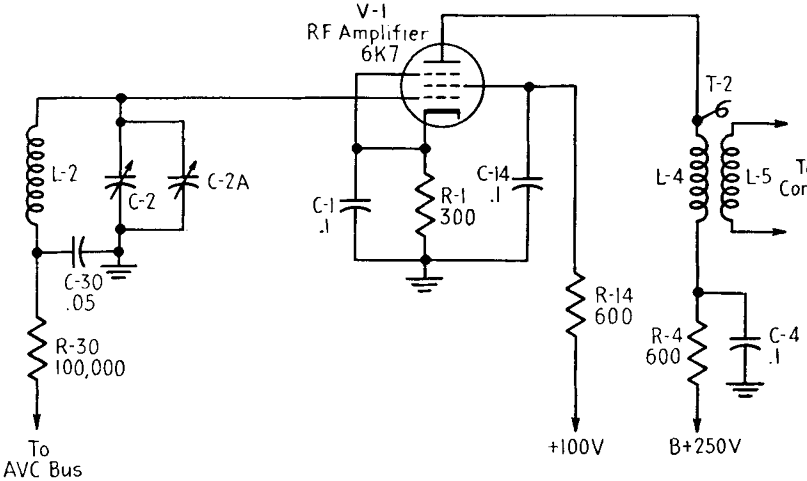


FIG. 16–6. Decoupling filters in the RF stage.

the range, a thorough overhaul of the tuning-condenser gang will be necessary. A procedure for doing this is given in Chap 14.

Troubles common to the RF-stage decoupling filters. The resistors in decoupling filters usually give no service troubles unless the associated condenser shorts. If *C*-14 or *C*-4 should short, there would be an overload of current through *R*-14 or *R*-4 which might damage them. When this happens, the resistors are usually replaced. Condenser *C*-30 in the AVC circuit rarely shorts and, if it should, there is insufficient current in this circuit to harm resistor *R*-30.

If condenser *C*-4 shorts, the stage becomes inoperative owing to lack of plate voltage. The condition would be found much earlier in the test procedure, however, since the short would reduce the total *B* voltage and affect the operation of stages previously tested. Similarly, a short in condenser *C*-14 would affect the operation of any later stage whose screen supply came from the same source. The shorted condensers would be found by voltage and resistance checking.

If condenser *C*-30 shorts, the AVC voltage applied to the stage would be shorted out. This would cause the stage to be operating at maximum volume with consequent overloading of itself or succeeding stages. The overload would cause poor tone on all but weak signals, a symptom of defective AVC operation, which would focus attention on this circuit.

If any of these condensers open, the trouble would be found by checking for the symptom that ensues. If plate condenser *C*-4 opens, the gain of the stage would be reduced with possible oscillation also resulting. Signal check and sensitivity measurements would show normal response from the converter grid and insufficient gain from the RF grid. This could be caused by a weak RF tube, improper operating potentials, a defective interstage RF transformer, or an open plate by-pass condenser *C*-4, all of which would have to be investigated. The condition would be found when a test condenser, bridged across *C*-4, restores normal operation.

If the screen by-pass condenser *C*-14 opens, the receiver will oscillate. The oscillation will be tunable; that is, as the receiver is tuned, each station will come in with a squeal. This should not be confused with image-frequency interference. The latter causes a whistle on only one or two stations. Standard servicing procedure for oscillation includes bridging all by-pass condensers with a test condenser. This will disclose the open screen condenser.

If AVC by-pass condenser *C*-30 opens, the tuning circuit in the RF stage becomes ineffective. This causes a weakening of the received signal, which in turn causes the AVC to step up the gain of the controlled tubes. The net result is that strong locals come in like weak stations, that is, with a high noise level, and weak ones do not come in at all. The trouble would be found on signal check, since operation would be normal from the RF grid and show no gain or a loss when checking from the antenna. An open antenna coil primary may give the same results. The trouble would be confirmed when a test condenser bridged across *C*-30 restores normal operation. A second check that may be used for confirmation is that the trimmer condenser across the antenna section of the gang tuning condenser is ineffective.

Troubles common to the wave-trap circuit. The wave-trap circuit composed of *L*-3 and *C*-3 rarely causes service difficulties. Figure 16–7 shows the two common connections for the wave trap. In either circuit, even if the wave-trap coil *L*-3 should open, the receiver would continue to operate normally. There may, of course, be a tendency for the receiver to have "code" interference, a heterodyne effect, but this would occur only if the receiver is located near a station transmitting at or near the intermediate frequency.

If the complaint is code interference all over the tuning range, the wave-trap circuit would naturally be suspected and checked. Then, when the trap is found to be defective, it is repaired or replaced. Using an exact replacement is desirable, but not essential. Any wave trap that is tunable to the intermediate frequency of the receiver will do.

Correct alignment procedure for the wave trap is first to have the receiver in perfect alignment, then to tune the receiver to 1,000 kc, feed a strong modulated signal at 455 kc (or the intermediate frequency of the receiver) into the antenna, and adjust the trap trimmer condenser

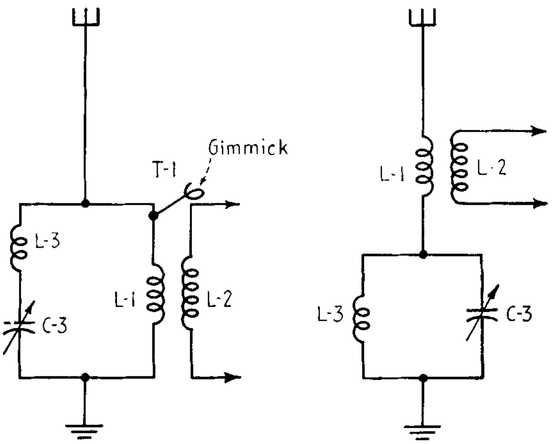


FIG. 16–7. Common wave-trap circuits.

or permeability-tuned coil for minimum response. In some cases, the interference is more completely eliminated if the trap is adjusted for minimum response at the frequency of the interfering signal.

Reduction of image-frequency interference. Interference caused by the normal response of superheterodyne receivers to stations operating at the image frequency causes service difficulties in relatively few instances. Receivers that incorporate a tuned RF stage are not troubled. Loop-operated receivers are likewise little affected, since the tunable loop antenna is less responsive to a station 910 kc off resonance than are the ordinary antenna and antenna coil which respond to a very large band of frequencies. The usual offenders, as regards image-frequency interference, are the types of receivers that employ an antenna and no RF stage, or an RF stage followed by an untuned converter stage. Also, the trouble is a local one, since another requirement is the presence of a strong image-frequency signal at the high-frequency end of the broadcast band (twice the intermediate frequency above the frequency of the desired station).

Image-frequency interference can be recognized as a whistle, or "birdie," which mars reception on one station at the low-frequency end of the broadcast band while reception is normal for all other stations. In the metropolitan New York area, the stations affected are either WMCA –570 kc, or WRCA–660 kc. In the case of station WMCA, the interference will be prevalent in the vicinity of station WHOM operating at 1,480 kc ($570 + 910 = 1{,}480$). Station WRCA may be troubled with image-frequency whistles caused by the presence of a signal from WQXR operating at 1,560 kc ($660 + 910 = 1{,}570$). In addition, reception at many points in the tuning range may on occasion experience image-frequency interference, if the receiver should be in the vicinity of police or amateur stations operating on frequencies ranging from 1,700 to 2,400 kc.

When the service job is to reduce image-frequency interference, various methods can be employed by the serviceman. A simple yet sometimes effective method is to reduce the signal input to the receiver. Modern superheterodyne receivers are usually more sensitive than needed for normal requirements of local reception, and may perform satisfactorily with very little antenna pickup. When this is the case, a reduced antenna may receive so much less signal from the interfering station that the whistle disappears. It is always worth while, therefore, to try the effect of a short indoor antenna on the interference. If it is effective, the serviceman should then check carefully to see that reception from all desired stations is satisfactory with regard to both signal strength and freedom from noise.

Another expedient is the installation of a wave trap tuned to the frequency of the interfering station. This frequency may be determined by adding twice the receiver intermediate frequency to the frequency of the station experiencing the interference. The wave trap chosen should have a range which includes the frequency of the interfering station. If such a wave trap is not obtainable, it may be made by adding a series mica condenser of approximately 0.0001-mfd capacity to a standard IF wave trap. The circuit is shown in Fig. 16–8. Several capacities from 0.00005 to 0.0002 mfd should be tried for the series condenser, in order to extend the range of the wave trap so that it covers the frequency of the interfering station.

Still another method of reducing image-frequency interference is to change the intermediate frequency of the receiver. The operation of a receiver is not greatly altered in respect to sensitivity, selectivity, tracking, etc., if the intermediate frequency is shifted about 10 kc, provided the receiver is completely re-aligned. The change, however, may reduce image-frequency interference. For example, assume a receiver with an IF amplifier tuned to 455 kc and experiencing an image whistle when tuned to a station at 570 kc. The whistle is caused by a station operating at 1,480 kc (1,480 — 910 = 570). Suppose now that the IF amplifier is retuned to 465 kc, and the entire receiver is realigned to operate at this intermediate frequency. The station at 1,480 kc will still be present and will cause image-frequency interference when a station at 550 kc is tuned in (1,480 — 930 = 550). But there is no local station at 550 kc and the image-frequency interference that marred reception from the station at 570 kc will be greatly reduced or entirely eliminated.

Variations in the RF stage. Multiband receivers will, of course, cause changes in the RF stage. These will be in the tuning circuit, switching arrangements, etc. The servicing of these components has been dealt with in connection with multiband circuits in the converter stage, and it is felt that the serviceman will be able to apply the same techniques to similar situations in the RF stage.

However, a few points should be mentioned. One is that the RF stage is used only on the broadcast band in some receivers. Another is that some provision must be made for a loop antenna to operate on more than one band. The Motorola 103K1 receiver of Fig. 16–9 illustrates both of these points.

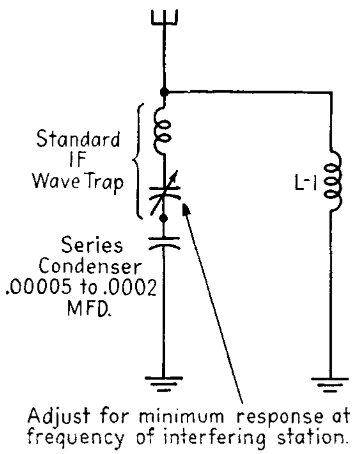


FIG. 16–8. Using a standard IF wave trap to reduce image-frequency interference.

The antenna winding of the loop feeds the arm of the range switch section marked "58–1." This arm is open in the broadcast position, and the grid winding of the loop feeds the control grid circuit of the RF tube. In the police and short-wave positions of the range switch, the antenna winding of the loop feeds the appropriate antenna coil through this same switch arm. The secondary of either antenna coil feeds the signal grid circuit of the converter tube through the arm of range switch section 58–2, thereby dispensing with the RF tube in these positions. In the broadcast position of switch 58–2, the converter signal grid is fed by the interstage RF transformer which is marked BC-RF COIL in the diagram. Note also that the push-button arrangement for this receiver makes use of a motor-driven tuning condenser gang.

RF stage followed by an untuned converter. Many receivers employ an RF stage that is resistance-coupled to the converter signal grid. This arrangement gives the receiver some of the advantages of an RF stage

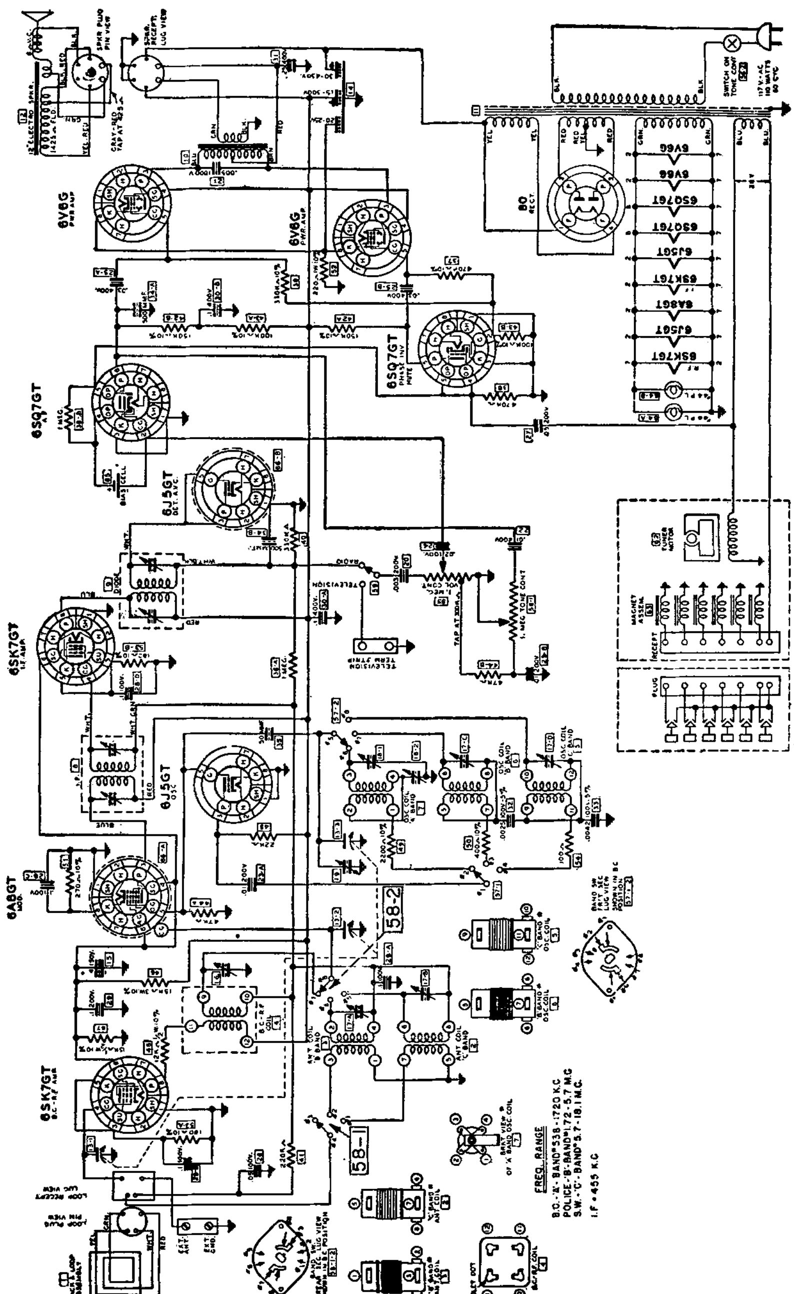


FIG. 16-9. Schematic diagram of the Motorola 103K1 receiver.

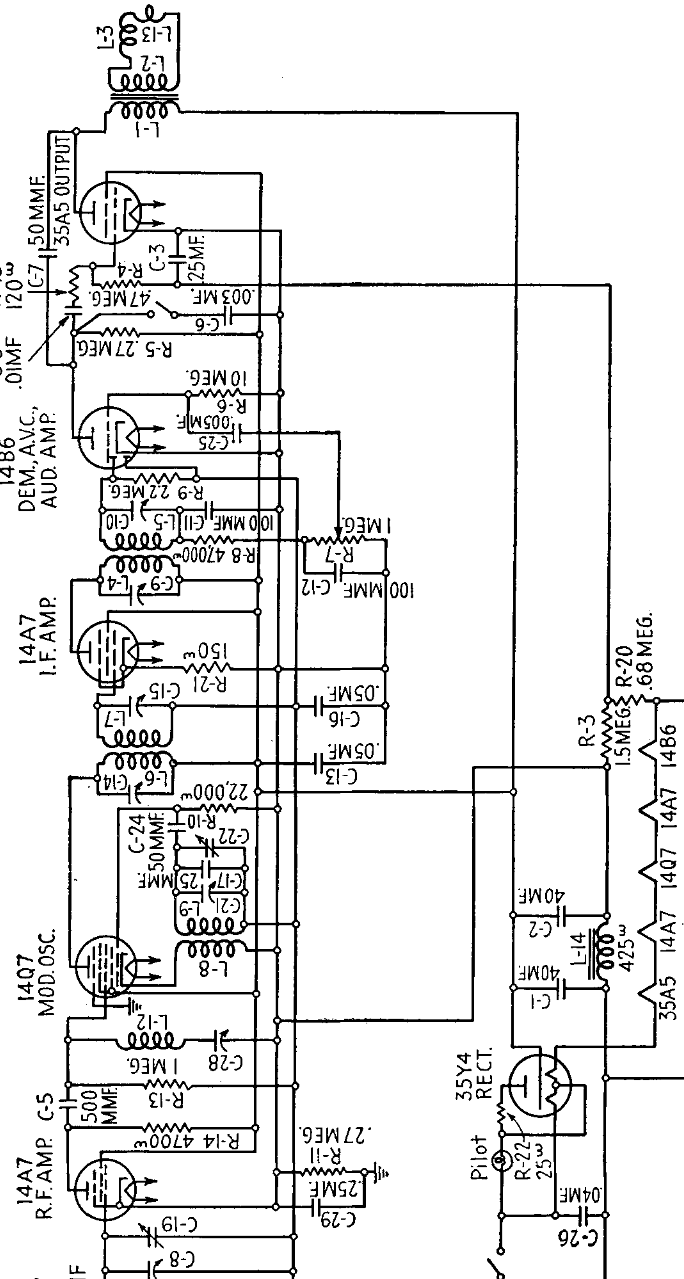


FIG. 16–10. Schematic diagram of the Stromberg-Carlson No. 1000 receiver.

while using only two tuned circuits: the RF grid and the oscillator. The Stromberg-Carlson No. 1000 receiver shown in Fig. 16–10 uses this type of circuit.

The coupling between the RF and the converter tubes consists of RF plate load *R*-14, coupling condenser *C*-5, and converter signal grid load *R*-13. The circuit composed of *L*-12 and *C*-28 in the converter signal grid is a wave trap tuned to the intermediate frequency of the receiver. Similar circuits in other receivers use different values for the components in the resistance-coupling circuit. The plate load varies from 5,000 to 10,000 ohms. The coupling condenser varies from 0.0001 to 0.0005 mfd. The grid-load resistor is often smaller than the one shown in the diagram, 25,000 to 100,000 ohms being more usual. Another circuit difference is that some receivers bring the grid-load resistor to ground or common negative rather than to the AVC bus, as shown in Fig. 16–10.

From a servicing point of view, receivers of this type are checked in the same manner as the standard receiver. There would be only two differences noted. In a voltage check, the RF plate voltage would measure lower than usual, owing to the voltage drop across the plate load resistor. And also, in sensitivity measurements, when checking from the RF grid, there would be a lower gain found than for the tuned coupling. A tuned coupling produces an average gain of 20 between the RF and converter grids. Checking between the same two points will show an average gain of approximately 7 for an untuned coupling.

The components of the resistance coupling circuit rarely give any service difficulties. The coupling condenser is usually a mica type which is comparatively trouble-free. An open plate-load resistor would be readily found on signal and voltage checks. The grid-load resistor is also trouble-free.

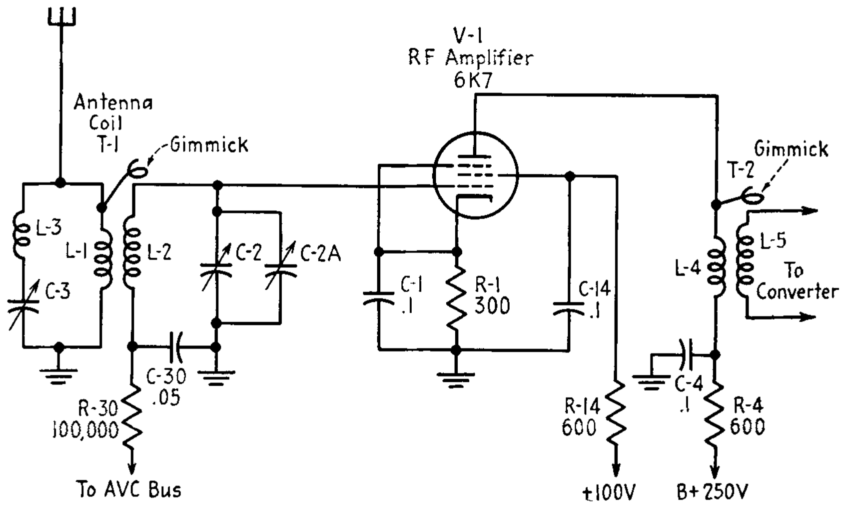
SUMMARY

Quick check for normal operation of the RF stage

If all previous stages checked showed a normal response, the trouble must be in the RF stage.

Standard RF stage diagram

The accompanying figure shows the standard RF stage.



Normal voltage data for the RF stage

Readings are taken from the indicated terminal to the chassis or common negative. Normal voltage data are given in the accompanying table.

Tube terminal	*6K7 pin No.*	*AC receivers, volts*	*AC/DC receivers, volts*
Plate	3	250	90
Screen	4	100	90
Cathode	8	3	3

Normal resistance data for the RF stage

Across *L*-1	30–50 ohms
Across secondary of the antenna transformer	5 ohms
Cathode to chassis	300 ohms
Across primary of interstage RF transformer	30–50 ohms
Control grid to chassis	1,600,000 ohms
Screen grid to chassis	30,600 ohms
Screen grid to *B* plus	30,600 ohms

SERVICE DATA CHART

Symptom	*Abnormal reading*	*Look for*
No signal from the speaker	Plate voltage = 0. Other voltages normal	Open primary of interstage RF transformer *T*-2. Open plate decoupling resistor *R*-4
	Plate voltage = 0. Other voltages low	Plate-chassis short circuit in the RF circuit. Short-circuited decoupling condenser C-4
	Cathode voltage high. Other voltages normal	Open cathode resistor *R*-1
	Screen voltage = 0. Other voltages normal	Short-circuited screen by-pass condenser C-14. Open decoupling resistor *R*-14
	Cathode voltage = 0. Other voltages normal	Dead RF tube *V*-1
	All voltages normal	Short circuit in gang tuning condenser C-2
Weak signal	All voltages normal	Weak RF tube *V*-1. Open antenna transformer *T*-1. Open cathode by-pass condenser C-1. Open plate by-pass condenser C-4. Open AVC by-pass condenser C-30. Misalignment
Oscillation	All voltages normal	Open screen by-pass condenser C-14. Shielding improperly grounded. Incorrect lead dress

SERVICE DATA CHART—(*Continued*)

Symptom	*Abnormal reading*	*Look for*
Noisy operation	All voltages normal	Open or cor oded antenna transformer *T*-1. Open AVC by-pass condenser C-30. Corrosion in the interstage RF transformer *T*-2. Defective RF tube *V*-1. Defective gang tuning condenser
Code interference	All voltages normal	Open wave-trap circuit. Mistuned wave trap
Poor tone quality	All voltages normal	Short-circuited AVC by-pass condenser C-30
Whistles on one or two stations	All voltages normal	Image-frequency interference

QUESTIONS

1. Outline a procedure for checking the source of trouble in a receiver that has a defective RF stage.

2. A weak AC superheterodyne receiver gives a normal response when the proper test signal is applied to the RF grid and a weaker response when the same test signal is applied to the antenna. What are the likely sources of the trouble, and how would you check for each?

3. A dead AC superheterodyne receiver gives a normal response when the proper RF test signal is applied to the converter signal grid and no response when the same test signal is shifted to the RF grid. Use the standard circuit of Fig. 1–1 and list the possible causes of the trouble. How would you check for each?

4. The receiver of Fig. 16–10 gives poor reception in the customer's home although it operates normally on the service bench. A long outdoor antenna was suggested and installed. The reception was greatly improved but the receiver is now troubled with code interference all over the tuning range. What is likely to be wrong and how should it be checked?

5. A superheterodyne receiver gets a station operating at 570 kc all over the dial. What is likely to be wrong? How can you check for this condition?

6. The receiver of Fig. 18–19 operates normally on all local stations except one at 660 kc. On this station, there is a persistent whistle that cannot be tuned out. What is the most likely cause of the difficulty? Outline a procedure to be followed in an attempt to minimize the condition.

7. The receiver of Fig. 16–9 is inoperative. Signal check shows that the trouble is in the RF stage. A voltage check of the RF stage gives the following results:

Plate	250 volts
Screen	100 volts
Cathode	50 volts

What is likely to be wrong? How would you confirm your assumption?

8. Assume the receiver of question 7 gave the following voltage readings:

Plate	250 volts
Screen	100 volts
Cathode	0 volt

What is likely to be wrong in this case? How would you confirm your assumption?

9. The receiver of Fig. 16–9 has poor tone quality on local stations. Removing the RF tube and connecting the antenna to the plate terminal of the RF tube clear up the tone. What in the RF stage can cause this trouble? How would the serviceman confirm the cause?

10. A receiver with an RF stage like the standard circuit of Fig. 1–1 picks up local stations but the reception is below normal in strength and is coupled with considerable noise. A signal check shows normal response when the proper test signal is applied to the RF grid, and a loss when the same test signal is applied to the antenna. Name the parts that may cause this condition. How would each one be tested?

17 ANTENNAS

Function of the antenna. The antenna is the first link in the receiver signal channel. Radio waves from all stations sweep across the antenna. Radio waves are one of the variety known as "electro-magnetic" waves. When such waves sweep across a wire conductor like an antenna, they generate a voltage in the wire, which in turn drives a feeble current through the antenna-ground system in the receiver. The current produced has the same frequency as that of the current in the broadcasting-station antenna and possesses the same modulation that represents the desired intelligence.

Types of antennas commonly used. Almost any wire connected to the antenna post of the receiver will function to some degree as an antenna.

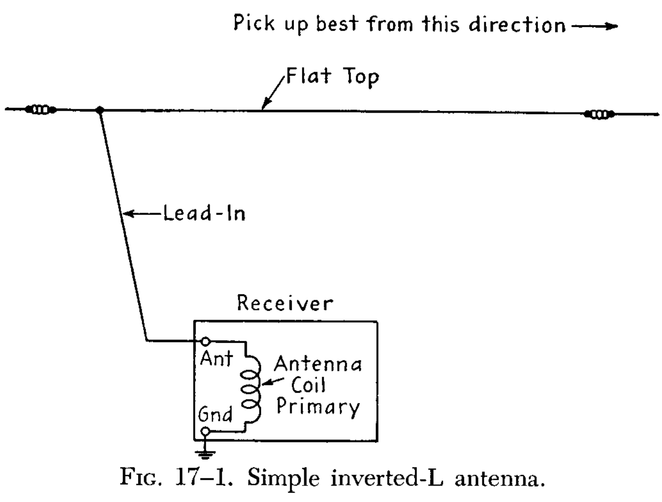


FIG. 17–1. Simple inverted-L antenna.

However, an antenna that is properly installed will result in far superior receiver performance to that of a makeshift one. It is wisest to install the type recommended by the receiver manufacturer. For cases where none is recommended, a standard antenna is described below. Other types will be presented under antenna variations.

The old standby most frequently recommended is the Marconi antenna, in which the ground is an important part. The most common variety of these grounded antennas is the inverted L. Here a wire is suspended horizontally between two insulators and is known as the "flat-top." Another wire, known as the "leadin," is connected to the flat-top—near one end—and brought down to the antenna post of the receiver. The ground post of the receiver is then connected to a well-grounded object. Within the receiver, the antenna and ground posts are connected to the terminals of the antenna-coil primary (see Fig. 17–1).

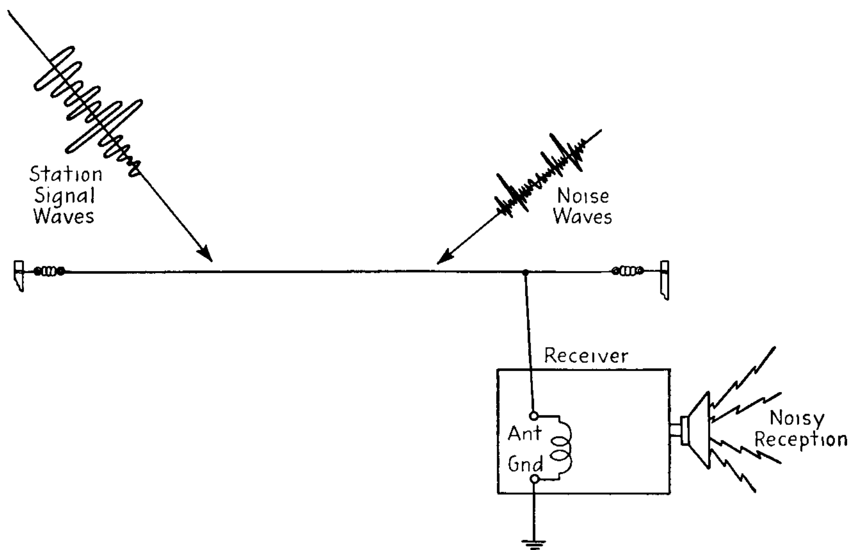


FIG. 17–2. Noise and signal pickup by an antenna.

The inverted-L antenna is a fairly efficient one for most surrounding stations. However, if not blocked by surrounding objects, it will have a little greater pickup from the direction in which the longer part of the flat-top points. This condition is shown by the arrow in Fig. 17–1.

Signal-to-noise ratio. The purpose of the antenna is to pick up signals from the various broadcasting stations, and to conduct them to the receiver. Unfortunately, the antenna cannot differentiate between desired signals and undesirable radio waves that result in noise in the loudspeaker. Both signals come in simultaneously with disturbing effects for the listener, as indicated in Fig. 17–2.

What is the origin of these undesirable noise waves? The explanation is simple. Any electrical machinery, especially rotary equipment, that emits a spark is a noise producer. A spark is an oscillatory discharge across a gap that produces radio waves of many frequencies. These latter waves chop up the desired signal and give the noisy effect. All motor-driven devices, such as elevators, refrigerators, vacuum cleaners, and fans, are noise producers. Pressing irons and diathermy and X-ray equipment are stationary devices that produce sparks and radiate undesired noise waves. Power lines will also pick up noise due to sparking devices along them and will act as an antenna for such noise.

It has become common usage to compare the pickup of the antenna with respect to desired signal and undesired noise. The relationship is referred to as the signal-to-noise ratio. A high signal-to-noise ratio pro-

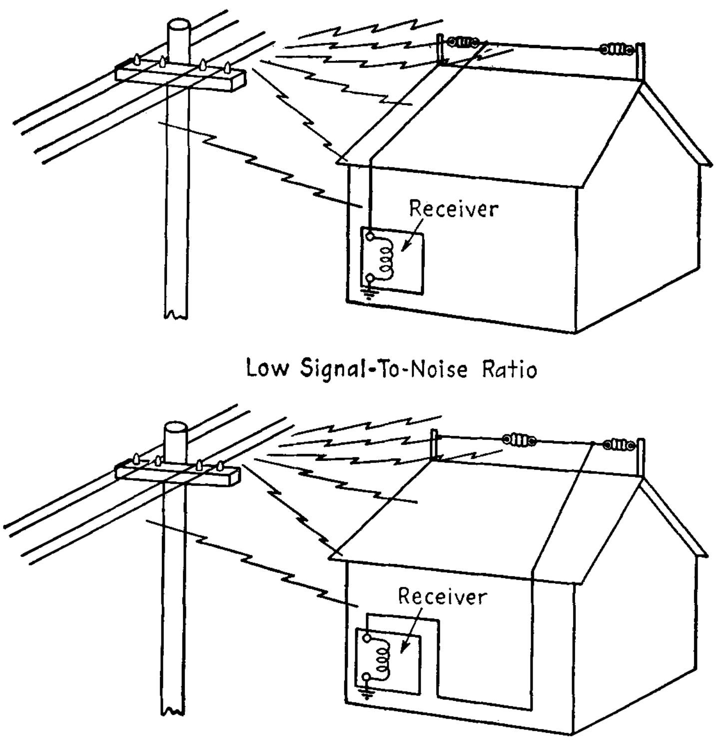


FIG. 17–3. Low and high signal-to-noise ratios.

duces relatively noise-free reception from the receiver, since signal pickup is large while noise pickup is small. A low signal-to-noise ratio produces noisy reception from the receiver, since signal pickup may be large or small, but noise pickup is relatively great in comparison. Figure 17–3 shows a high and a low signal-to-noise ratio pickup by the antenna and leadin. The associated noise producer is the nearby power lines.

The antenna should be so designed that noise pickup is at a minimum. As stated previously, any wire will serve to some extent as an antenna, but its noise pickup may be high. A properly installed antenna attempts to reduce noise to a minimum.

Because of the conditions stated above, indoor antennas, especially in city apartment houses, have low signal-to-noise ratios. This is because of the presence of many noise-producing electric machines within the building and nearby power lines. For the same reason, the leadin close to the building will also pick up much noise, unless special types of leadins are used. This condition is not so bad in rural areas.

So far, the antenna has been discussed only from the point of view of reducing noise pickup to give a higher signal-to-noise ratio. The ratio may also be increased by designing the antenna more efficiently so that its signal pickup will be greater. The factors entering into antenna efficiency will therefore be discussed in the following section.

Efficiency of the antenna. A highly efficient antenna has a maximum signal pickup with a minimum noise pickup. Many factors enter into the over-all efficiency of the antenna.

One factor is its length. A long outdoor antenna, about 25 to 75 ft in length including the length of the leadin, is recommended by many manufacturers. Such a long antenna will usually carry the wire away from the vicinity of near-by noise producers.

A second factor in antenna efficiency is its height. The greater the height of the antenna, the greater the signal voltage generated in it by the radio wave from any particular station, and the less the noise voltage generated in it.

Another efficiency factor is the placement of the flat-top of the antenna and the leadin. Wherever possible, the antenna should not be close to metal objects that absorb radio waves and block the antenna from the signal. Many a receiver with an indoor hank antenna has been dead in a steel-frame building.

Further, the antenna should be as far as possible from devices likely to produce noise. In this regard, nearby power lines and house elevators are troublesome noise producers. Antennas should be far from power lines and at right angles to them for minimum noise pickup. It is well to point out that at no time should an antenna wire cross over or under a power line, because of the danger of contact. Elevator shafts usually terminate in a small housing on the roof covering the elevator motor which may radiate noise waves. Antennas should be located as far from the motor housing as possible. The serviceman should remember that the leadin is an integral part of the antenna system and may pick up noise signals if near noise producers.

A fourth efficiency factor is the directional characteristic of the inverted-L antenna. For any one station, the antenna may be turned so that it obtains the greatest signal pickup. However, since all stations do not transmit from the same direction, the placement of the receiver antenna will at best be a compromise for all stations.

A fifth efficiency factor is the associated antenna resistance. The feeble voltage generated in the antenna will be quickly dissipated if resistances along it are too great. All connections must be carefully soldered. Twisted mechanical connections should be avoided.

A sixth efficiency factor is the antenna installation itself. Leakage from it will tend to weaken the signal current delivered by the antenna to the receiver. Therefore, supporting insulators should be made of such materials as pyrex glass or glazed porcelain, which do not absorb moisture and thereby do not provide a leakage path. Further, the flat-top must be taut. If it swings, two defects may appear. One is regular fading of the receiver signal. The other, if the swinging antenna touches grounded objects, is the production of noise in the receiver. Since the leadin usually lies close to the grounded building, a rubber-covered leadin should be used.

The final efficiency factor is the ground connection. The ground lead is an integral part of the antenna system. As such, it may pick up noise. Therefore, it should be as short as possible and away from noise-producing devices. It, too, is made of wire, size No. 14, in rubber insulation. It should be attached to a grounded object, like a radiator or cold-water pipe; never a gas pipe. Good contact with the grounded object must be made. Paint or rust on the pipe should be scraped off, and use should be made of a good ground clamp for firm contact. A good ground connection may improve receiver reception, although many operate well without it.

Installing a receiver antenna. The discussion of the antenna installation will be confined to the inverted-L type. Before actual construction, the serviceman must size up the situation. He must consider all the factors of antenna efficiency and then proceed to erect the antenna. Typical installations are shown in Fig. 17–4. Two rigid supports, sufficiently far apart and properly located, are chosen. Attach one antenna insulator firmly to one support, using a piece of the antenna wire. Then attach one end of the antenna wire by means of a nonslipping knot to the other end of the same insulator, as shown in Fig. 17–5. Antenna wire most commonly used is bare No. 14 copper wire, or standard wire of an equivalent size. Then attach the other end of the antenna wire firmly to the other insulator. Before proceeding with the mounting, solder the leadin near one end of the flat-top. This gives an L type of antenna. If the antenna wire used is of the enameled type, scrape the enamel away carefully before making this connection.

Now attach a pulley to the other rigid support. Tie a rope firmly to the other end of the second insulator and pass it over the pulley wheel. Draw hard on the rope until the flat-top becomes taut, and tie down the end of the rope to maintain the tautness. The result is shown in Fig.

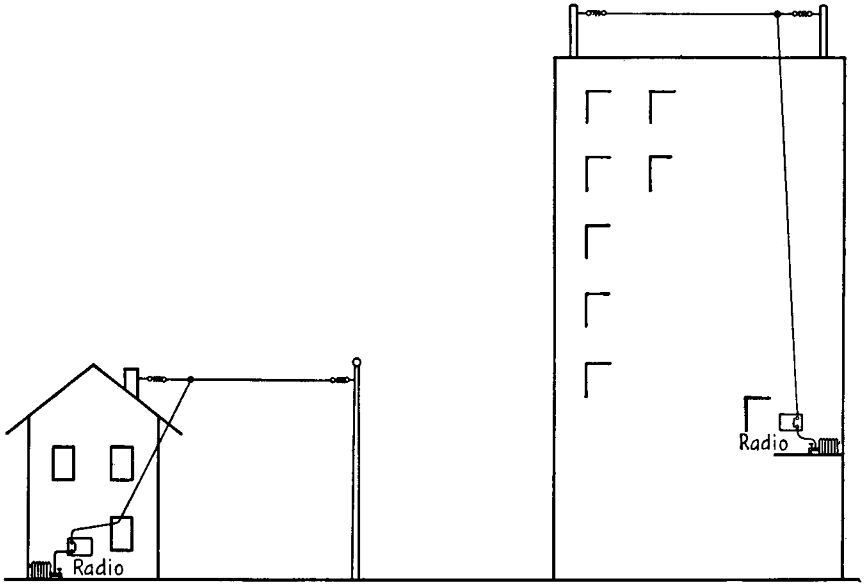


FIG. 17–4. Typical receiver antenna installations.

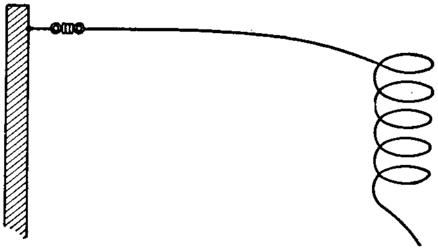


FIG. 17–5. Attaching one end of the antenna.

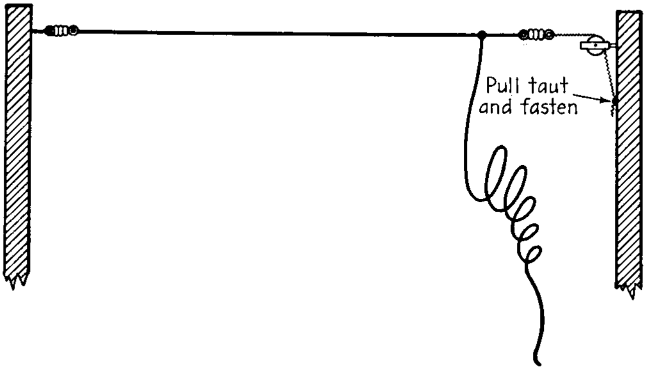


FIG. 17–6. Attaching the second end of the antenna.

17–6. Bring the leadin down the side of the building, guided by means of insulated nail knobs.

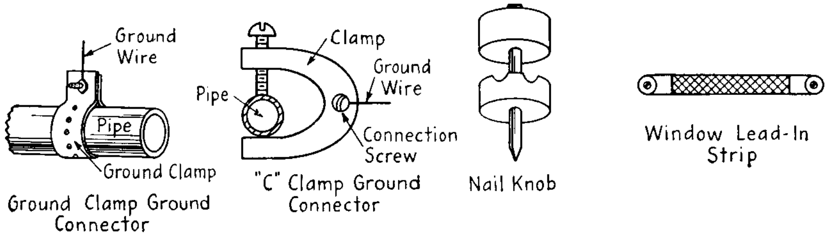


FIG. 17–7. Antenna accessories.

At the window for entry, there is danger of breaking the lead-in wire because of the window pressure. To avoid this possibility, the leadin is connected to an insulated flat copper mesh, called a "window lead-in

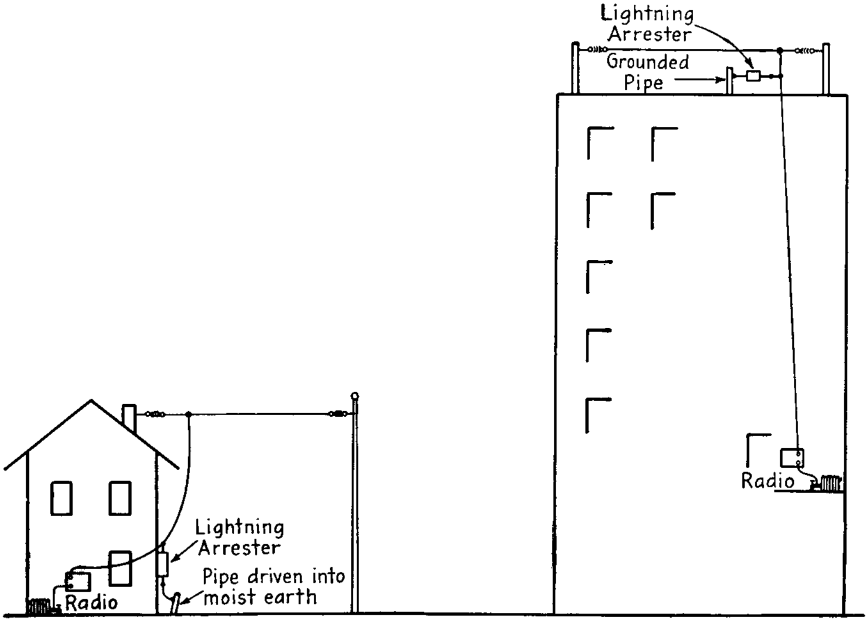


FIG. 17–8. The installation of lightning arresters.

strip," which can take more flexing and pressure. The window strip is in turn connected to a lead that goes to the antenna terminal of the receiver. All connections should be soldered, including those at the window strip, even if the latter is supplied with Fahnestock clips. The ground terminal of the receiver is then connected to the ground clamp and fastened firmly around a grounded pipe, as shown in Fig. 17–7.

The last requirement is one made by the National Board of Fire Underwriters; namely, the use of a lightning arrester, designed to pass any heavy currents due to lightning to ground, rather than into the receiver. The arrester is merely connected directly from the antenna lead-in wire to a good ground connection, as shown in Fig. 17–8.

TROUBLES COMMON TO THE ANTENNA

Complaints related to the operation of the antenna may be divided into two main groups: weak signals delivered to the receiver, and noise pickup. Weak signal and its associated phenomenon, fading, will be considered as a servicing problem rather than an installation problem; that is, it will be considered as a problem arising after the antenna has been functioning properly for some time. Noise will be considered both as an installation and as a servicing problem and will be taken as the effect producing a low signal-to-noise ratio.

Weak signal and fading. To check whether a condition of weak signal or fading is due to the antenna system, remove the connection of the antenna to the antenna post of the receiver. Then connect a length of wire to the post and see if the condition improves. If the receiver operates normally, making allowance for the short antenna of course, the trouble is in the antenna installation. If the condition does not improve, the receiver should be checked for the cause.

If this check shows a faulty antenna, a careful inspection of the entire antenna system must be made. Wires must be carefully checked for breaks. Corrosion at soldered connections is a common trouble. The antenna insulators must be checked to see if accumulated dirt has provided a leakage path across them for the signal current. The lightning arrester, in parallel with the leadin, must be checked to see that dirt has not provided a shunt path to ground for the desired signal.

Where fading occurs, the antenna should be inspected to see that it is not loose and swinging. Drawing the antenna taut and refastening it to the support will help the condition. Intermittent breaks, which make and break the contact, will also cause fading. These are often found in window strips where constant opening and shutting of a window has broken the metal strap under the insulation. Another intermittent break may result from a poor connection at the junction of the flat-top and lead-in wire.

Noise pickup. Noise produced in a receiver may be traced to many sources, which may be grouped as follows:

1. Antenna pickup of noise—from natural electrical phenomena like lightning (called "static"), or from a noisy area produced by man-made electrical machinery

2. Noise from the power lines
3. Noise pickup by the receiver leads
4. A noisy receiver

For this section, the first source is of prime importance. But the others may not be dismissed, since the serviceman must know how to limit noisy reception to that source.

Lightning is simply a giant oscillatory spark from a cloud to ground, or from cloud to cloud. This spark produces a splash of radio waves of many frequencies, which produce noise voltages in nearby antennas. Nothing can be done about this situation. However, the serviceman need not be concerned about this fact because the noise will be infrequent, and this is generally recognized and understood by the average customer.

Much more significant is man-made noise picked up by the antenna or the receiver power lines. It is likely to be more or less constant and annoying to the listener, and therefore a valid servicing problem. The first question that must be answered by the serviceman is that of determining the source of the noise. To do this, the serviceman should remove the antenna and ground connections to the receiver, and short the antenna post to the ground post. Then the receiver is turned on. If the noise still persists, the noise originates either through the power lines or in the receiver itself. If the noise is eliminated, the antenna is probably at fault.

If the antenna is found to be at fault, a thorough visual check of the mechanical construction of the antenna system itself should be made. Possible mechanical trouble sources are tabulated below:

1. A grounding flat-top or leadin. This may be due to swinging of the wires against some grounded object like a drain duct.
2. A break or poor connection in the system: flat-top to lead-in wire, ground lead to ground post, ground and antenna connections to the receiver, the window strip, etc.
3. Conductive dirt across the antenna insulators or the lightning arrester.

Noise produced by the antenna system by the above defects will usually be of the type that produces irregular crackles. A simple check for breaks in the leadin is to pull on the lead-in wire while listening to the radio. Increased noise indicates a break in the wire.

If the noise is more or less regular as picked up by the antenna, the trouble is that the antenna is in an area of noise. In modern apartment houses with elevator motors and other rotary or sparking electric machinery, there is likely to be a region of noise-producing radio waves of sufficient intensity to affect radio reception. This condition is shown in Fig. 17–9. If the antenna is a fairly short one, the remedy is simply to lengthen it in a direction such as to bring a major part of it in a relatively noise-free area, as shown in Fig. 17–10. Or the antenna might be elevated into a similar noise-free zone. A good rule is simply to avoid installation of the antenna near elevator shafts, power lines, and similar noise producers.

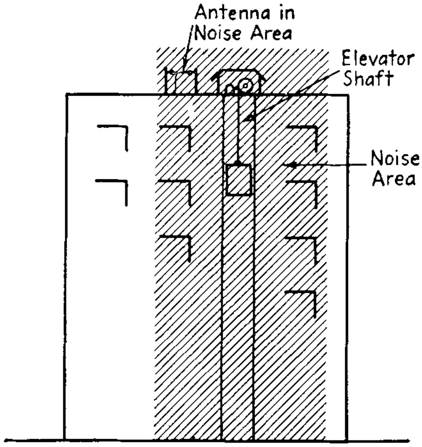


FIG. 17–9. An antenna installed in a noise area.

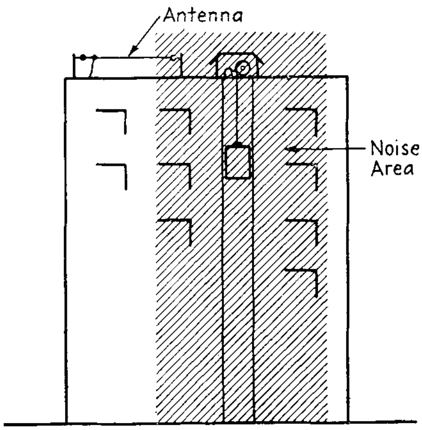


FIG. 17–10. Moving antenna out of the noise area.

A timesaving servicing instrument to aid in locating noise-free areas for antenna location is a portable battery-operated receiver. Tune it to a nonstation spot on the dial and listen for the presence of noise. The loop antenna of the portable test receiver is quite directional. The source of the noise will always be at right angles to the broad side of the loop. When the test receiver is moved into an area of minimum noise, a good location for the permanent antenna installation is located.

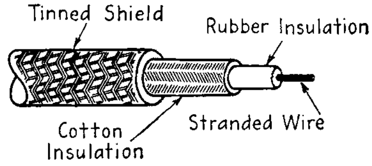


FIG. 17–11. Structure of shielded lead-in wire.

Even after the antenna flat-top has been placed in a noise-free area, the trouble may not be completely eliminated. The antenna leadin, passing through the noise area and being vertical, is especially prone to pick up noise voltages.

Several methods have been designed to isolate the leadin so that it does not pick up any signals whatsoever, but merely brings the signal from the flat-top to the receiver. One method uses a completely shielded lead-in wire of the type shown in Fig. 17–11. It must have low capacity between the lead wire and shield and must be weatherproof. The outside tinned shield must be connected to a good ground. This type of leadin will be good for the broadcast band if the flat-top is long, but will be inefficient for short-wave reception because of the losses resulting

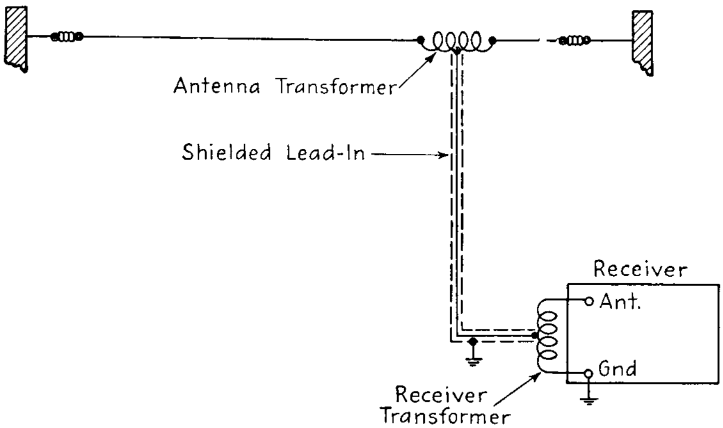


FIG. 17–12. Noise reduction by the installation of coupling transformers and a shielded leadin.

from the fairly high shield-to-conductor capacity. By the use of coupling transformers at the antenna and receiver, this loss may be reduced. Such a setup is shown in Fig. 17–12.

Another method uses a standard twisted-pair leadin, of special weatherproof wire. The connections are shown in Fig. 17–13.

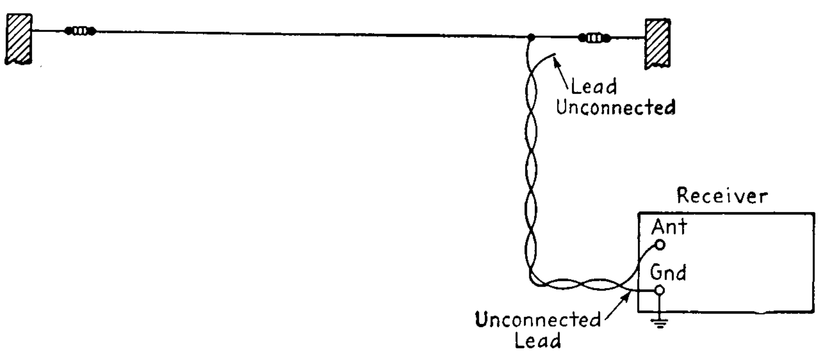


FIG. 17–13. Noise reduction by means of a twisted-pair leadin.

Complete kits of noise-reducing antennas of various types are purchasable.

If the check, in which the antenna and ground leads were disconnected and their respective receiver posts shorted together, indicates that the noise is not due to antenna pickup, the other possible sources are noise from the power lines, noise pickup by the receiver leads, and a noisy condition within the receiver.

If the serviceman suspects that noise is originating from the power lines, he should take the receiver to his shop where he knows the normal level of noise from the lines. If the noise disappears on the shop bench, it must originate in the customer's power lines.

To reduce noise pickup form the power lines, many receivers use a line filtering condenser, as shown in Fig. 17–14, which is internally connected. A special consideration with respect to this filter, which by-passes

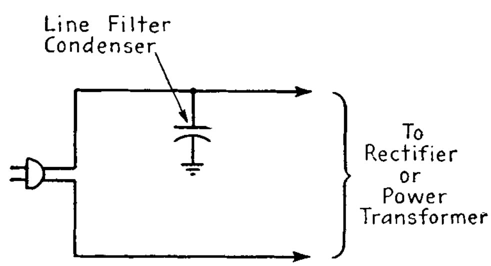


FIG. 17–14. Line filter condenser in a receiver.

noise frequencies to ground, comes up. In modern power lines, one line is "hot," and the other is grounded. To be effective, the condenser must be connected to the hot side. This condition is shown in Fig. 17–15. Sometimes, therefore, reversing the line plug will reduce noise. Further, this line filtering condenser should be checked to see that it is not open.

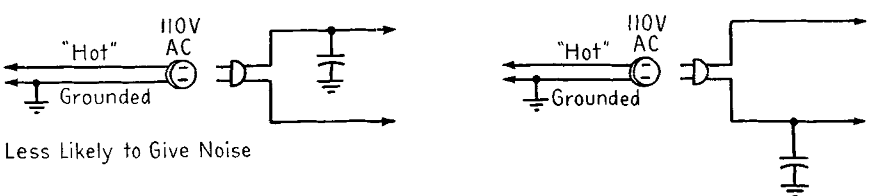


FIG. 17–15. Noise reduction by reversing the receiver line plug.

If a receiver has both lines of the power cord grounded through condensers, reversal of the line cord will, of course, make no difference.

Where possible, placing a filter across the offending equipment right at the source will help to reduce noise. A typical filter for the noise producer is shown in Fig. 17–16. Unfortunately, installation of such source filters is not always feasible.

When the checks show that the noise pickup is from neither the antenna nor the power lines, another possibility is noise pickup by the leads within the receiver. To check this possible source, the serviceman should try the operation of the receiver in another room, on the theory that the regular installation spot is a noisy area. The serviceman should also check that a bottom metal shield, if provided, is on and has not been removed. In some cases, such a bottom shield may be added, even though it has not been originally supplied.

When all other sources of noise have been eliminated, there remains a noisy receiver as a possible cause. The causative factor here may be broken connections, noisy tubes, grounded leads, corroded joints, etc.

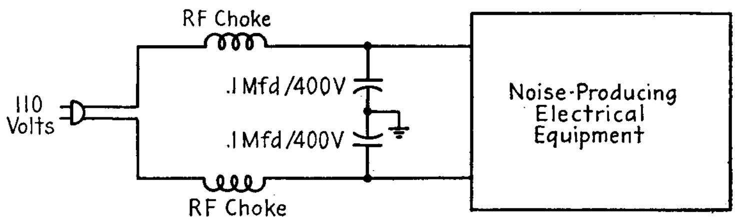


FIG. 17–16. Filtering line noise at the source.

If, while the receiver is operating, the serviceman gives it a sharp slap and the noise becomes worse, then something within the receiver is probably the cause. The hunt for the cause of noise within the receiver is fully described in Chap. 27.

ANTENNA VARIATIONS

There are several variations from the inverted-L type of antenna just described. Most of them present the same servicing problems as for the standard antennas.

Indoor antennas. Several types of antenna have been designed for indoor use to avoid the nuisance of an outdoor antenna. They are primarily for use with portable, table-model radios. One type is the hank antenna, so called because it is merely a hank of wire. It may be stretched out along the floor of a room or mounted on the molding, as shown in Fig. 17–17. Both give good reception for local broadcast stations but are rarely effective for good short-wave reception. They are prone to be noisy, especially in large apartment houses. Little can be done to improve that condition, except the construction of a large outdoor antenna.

Flagpole antennas. Many apartment-house owners forbid the construction of roof antennas. As an alternative, they furnish some sort of wall antenna connection. Unfortunately, most of these are poor. Of course, an indoor hank may be used. But a commercial flagpole antenna, similar to an auto-radio whip antenna, will produce better results. It is mounted like a flagpole from the window, as shown in Fig. 17–18.

Loop antennas. Many receivers use a loop antenna. It consists of several turns of wire and is connected directly across the tuning condenser, as shown in Fig. 17–19.

Loop antennas have small pickup, but modern superheterodynes are so sensitive that this is no weakness. However, the receiver may be in a noisy area. Provision is made to overcome this defect. A smaller primary

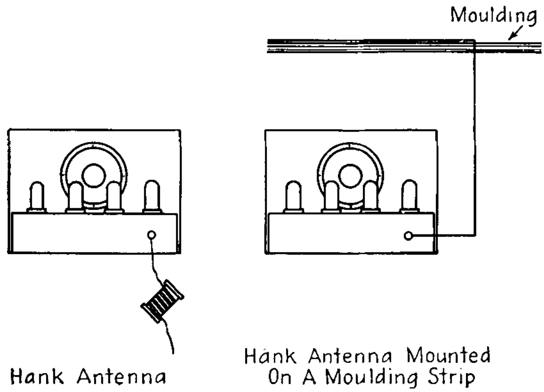


FIG. 17–17. The hank antenna.

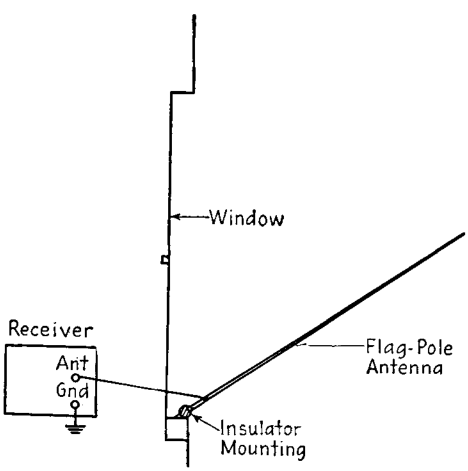


FIG. 17–18. The flagpole antenna.

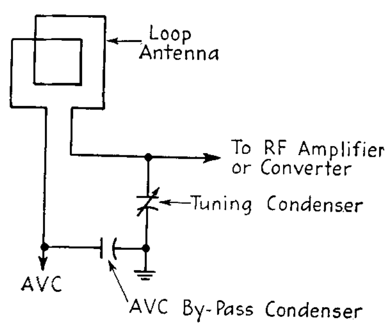


FIG. 17–19. The loop antenna.

is wound near the main loop, and this primary may be connected to a standard outdoor antenna. Energy is then inductively coupled from the primary to the main loop. As a result, the signal-to-noise ratio is increased. The circuit is shown in Fig. 17–20.

If the receiver is installed in a very noisy area, the addition of the outdoor antenna may not be sufficient to give satisfactory reception, since the loop may still pick up much noise. In such a case, it is necessary to remove the loop and replace it with a standard antenna coil, a shielded one being preferred. Of course, re-alignment of the receiver will be necessary after such a substitution.

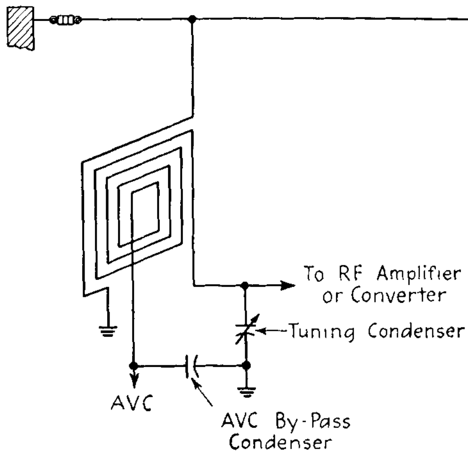


FIG. 17–20. A loop with an antenna winding.

A loop is quite directional. Rotating the receiver will increase the signal pickup and increase the volume in the receiver. This condition is illustrated in Fig. 17–21, showing the top view of the loop. Service notes for loop antennas are given in Chap. 14 .

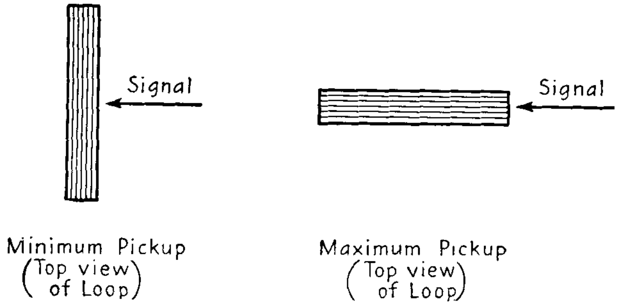


FIG. 17–21. Directional characteristic of a loop antenna.

A variation of the loop consists of a small coil with an iron core. This type, better known as a "ferrite" antenna, is usually mounted on the frame of the tuning condenser, as shown in Fig. 17–22. In operation, it is similar to the flat pancake loop, being connected across the tuning condenser. In servicing, test signals are fed to it by means of an injection loop, and an open in the antenna will be found by the procedure described for loop antennas.

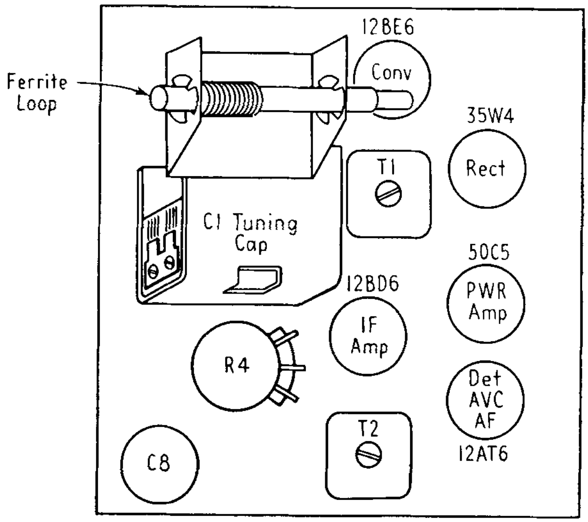


FIG. 17–22. The ferrite antenna mounted in position in a receiver.

Hertzian ungrounded antenna. Where a receiver is designed for broadcast and short-wave reception, the antenna design is made partial to short-wave efficiency rather than broadcast efficiency. This is because the former signals are usually weaker and more subject to instability.

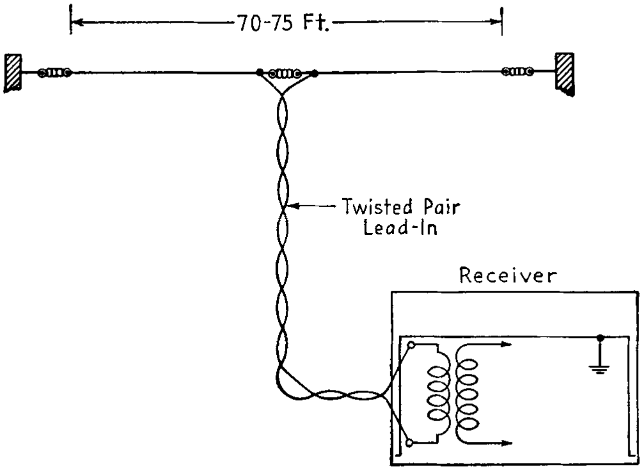


FIG. 17–23. The hertzian dipole antenna.

A good antenna for such purposes is the Hertzian ungrounded antenna, shown in Fig. 17–23. It is also known as the simple doublet or dipole. The flat-top should be about 70 to 75 ft and with both sections of equal length, making reception especially good around the 49-meter short-wave band. In this antenna, reception for a particular frequency may be made highly efficient by making the flat-top about one-half the wave length of the particular station desired. It will be fairly efficient also for broadcast stations. The leadin is a twisted-pair transmission line.

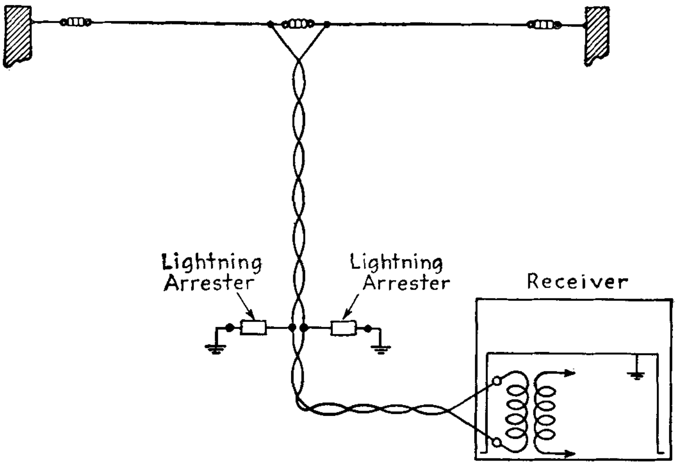


FIG. 17–24. Connected lightning arresters to a twisted-pair leadin.

Although no ground is associated with the dipole antenna system, the receiver itself should have a good ground to prevent chassis pickup, etc.

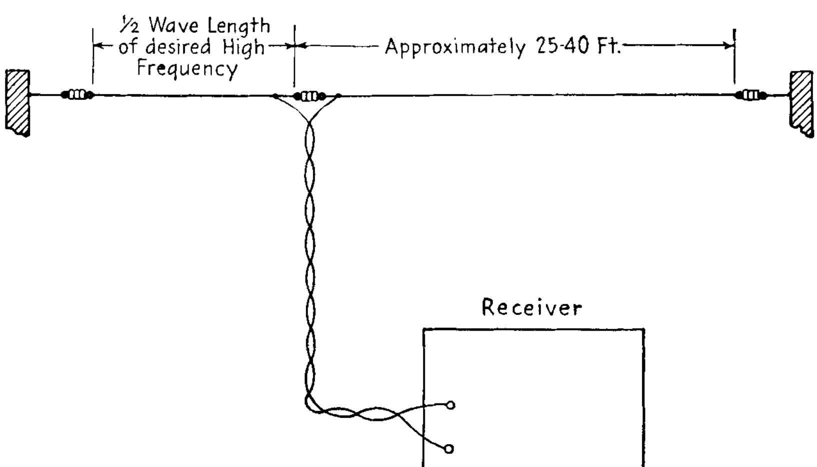


FIG. 17–25. The asymmetrical dipole antenna.

The doublet is quite directional, receiving maximum signal when the broad side is in the direction of the desired station.

The servicing procedure for the doublet antenna is the same in other respects as that for the standard antenna. It should be high and in a

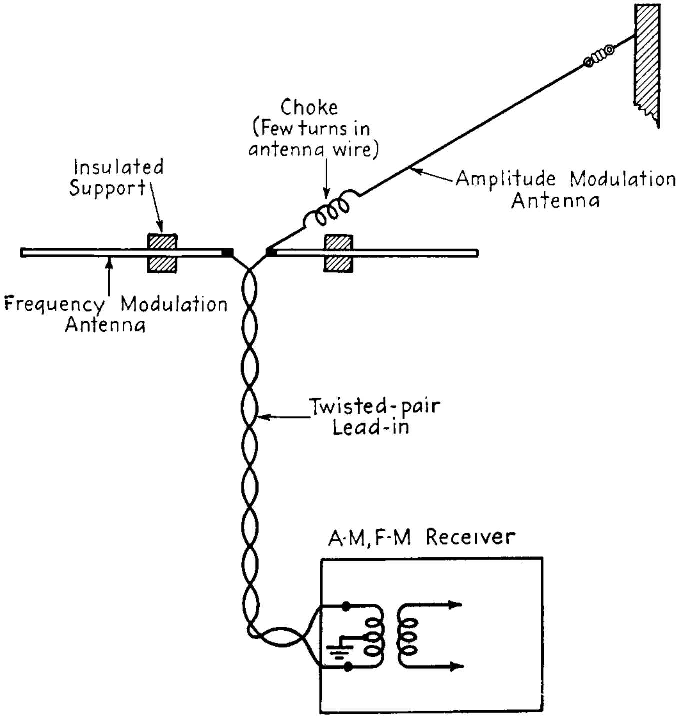


FIG. 17–26. A-M and F-M antenna.

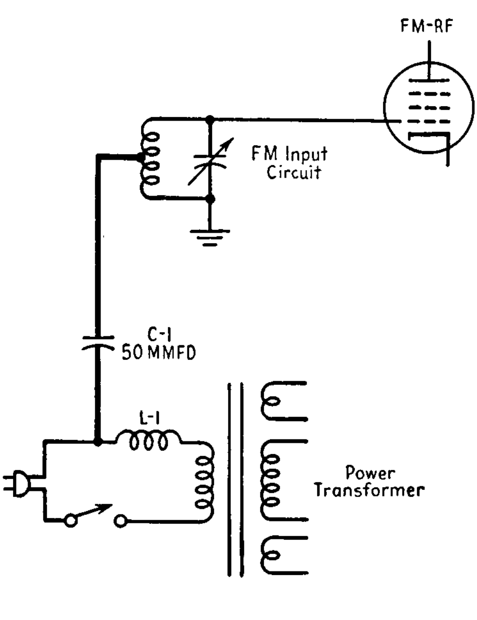


FIG. 17–27. Line-cord antenna for F-M reception.

noise-free area. Broken leads and connections will produce crackling noise. Shorts and breaks in the conducting wire may result and produce noise if the weatherproof insulation corrodes. A good check is to yank the leadin from the window and listen for noise in the receiver. Increased noise indicates such defects.

In connecting lightning arresters to a doublet antenna, Fig. 17–24 will serve as a guide.

Asymmetrical dipole antenna for all-wave reception. A system often used for all-wave receivers is that in which one section of the flat-top is made responsive to a particular short-wave frequency, and the other section is made considerably longer for a better pickup on the broadcast band. Matching transformers at the antenna and receiver ends of the leadin are also common. The short section is usually one-half the wave length of the desired short-wave frequency. Such an antenna is shown in Fig. 17–25.

A-M/F-M receiver antenna. Figure 17–26 shows an antenna used for a combination F-M and A-M receiver. The F-M antenna is a dipole whose size is about one-half the wave length of the center of the F-M band. The A-M antenna is a long lead connected at one end to one of the twisted-pair lead-in wires. A choke, made by coiling a few turns in the long A-M lead, prevents interaction between the two antennas.

Some A-M/F-M receivers use a loop antenna for the A-M section of the receiver, and a line-cord antenna for operation on F-M. The line-cord antenna circuit is shown in Fig. 17–27. The power cord acts as the antenna. RF choke L-1 and condenser C-1 couple the signal into the F-M input circuit. At the same time, the capacitance of condenser C-1 is small enough to block the 60-cycle line current from the F-M input circuit. Sometimes condenser C-1 is omitted, and a third wire in the power cable performs its function. The third wire is unconnected at the plug end.

QUESTIONS

1. What considerations must the serviceman keep in mind when installing an outdoor inverted-L antenna?

2. List several possible sources of noise pickup by an antenna and leadin.

3. A receiver is reported as suffering from fading. A check of the receiver shows it is perfect. What might be the cause?

4. A receiver, after perfect operation for a long time, begins to produce crackling sounds. If it checks perfect, outline the procedure for tracking down the cause.

5. An antenna is to be installed near several power lines. What precautions should be taken to reduce noise pickup?

6. A receiver picks up noise from its power mains. What can be done to reduce the interference?

7. A receiver with a loop antenna is in a noisy area. Use of an outdoor antenna fails to reduce noise sufficiently. What can be done to reduce the noise further?

18 AC/DC POWER SUPPLY

The wide popularity of the AC/DC type of receiver is due not so much to its ability to operate on either AC or DC lighting mains as to the fact that it makes possible an efficient inexpensive power supply for small receivers. The percentage of AC/DC receivers in use is very large as compared with the percentage of homes supplied by 110-volt DC lighting mains. The power transformer is an expensive unit, and its elimination in the AC/DC receiver accounts for its wide prevalence.

The signal circuits of the AC/DC receiver are the same as in an AC receiver, with minor differences. The signal checks and stage-gain data are approximately the same for both. The main difference between the two lies in the power supply. Throughout the text, in the voltage data for each stage, for example, reference was made to comparable operation in AC/DC receivers. This chapter will discuss the operation and service problems connected with the AC/DC power supply and will also cover points pertinent to AC/DC receivers not previously covered in the description of the various stages.

Quick check for proper operation of the AC/DC power supply. If all the tubes in the receiver light, the hum level is normal, and the *B* plus voltage measures approximately 90 volts, the AC/DC power supply is probably functioning normally.

Function of the AC/DC power supply. The function of the AC/DC power supply is like that of any other type: to furnish the necessary *A*, *B*, and *C* voltages to the filament, plate, and grid circuits of the rest of the receiver. In this case, the power source is the 110-volt lighting mains, to be used regardless of whether it is alternating or direct current.

THEORY OF OPERATION OF THE AC/DC POWER SUPPLY

RF and push-pull second AF stages are rarely found in AC/DC receivers. These are common adjuncts of large receivers where expense is not the main factor. Large receivers, therefore, are AC-operated. There are some AC/DC receivers incorporating RF and push-pull output stages, but these are the exceptions that were actually designed to give large-receiver qualities in districts powered by DC mains.

The most common type of AC/DC receiver uses a 5-tube superheterodyne circuit. The stages employed are a converter, IF, detector and AVC, first AF, second AF, and power supply. The detector and first AF stage functions are combined in one tube. A receiver of this type should be kept in mind while studying the power supply stage.

The power supply can be easily subdivided into a study of the *A* or heater circuit and the *B* or plate circuit.

Heater circuits in AC/DC power supplies. The heater circuit in the AC/DC power supply is so designed as to use tubes for the receiver which draw the same heater current. The heaters are connected in series, a dropping resistor is added if necessary, and then the circuit is connected directly across the power line.

Figure 18–1 shows an AC/DC heater circuit commonly used in early receivers of this type. The heaters will light equally well on alternating or direct current in the same way that an ordinary lamp will. The tubes

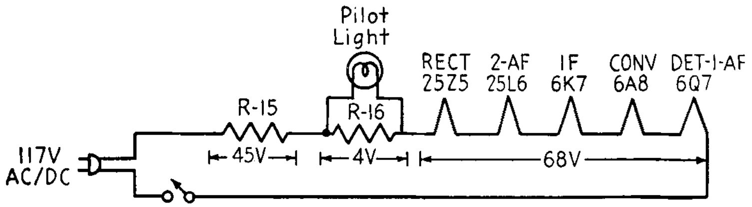


FIG. 18–1. A typical AC/DC heater circuit for 0.3-amp tubes.

shown all draw a heater current of 0.3 amp. The pilot lamp draws 0.15 or 0.25 amp depending on type, the excess current being taken by the shunt resistor *R*-16. As shown in the diagram, the voltage drop across the tube heaters is 68 volts and the drop across the pilot light is 4 volts, leaving 45 volts across the dropping resistor *R*-15 to make a total voltage drop of 117 volts.

Pilot-lamp shunt resistor *R*-16 is usually a wire-wound 5-watt resistor whose value ranges from 20 to 30 ohms. Calculations usually allow 4 volts across the pilot lamp because, although the lamp is rated at 6 to 8 volts, it is normally operated at reduced brightness owing to the heavy initial current drawn by this type of circuit. The cold resistance of the tube heaters is low. This causes a heavy current when first the receiver is turned on; the heavy current would burn out the pilot lamp. In addition to shunting excess current from the pilot lamp, resistor *R*-16 has the added function of allowing the receiver to operate if the pilot-lamp filament should open.

Dropping resistor *R*-15 is found in many forms. Sometimes it is a heavy-duty wire-wound resistor of approximately 150 ohms; sometimes it is a ballast tube; sometimes it is in the form of a wire resistor included with the other wires in the line cord. The last type is known as a "resistor-type line cord." All three types are pictured in Fig. 18–2.

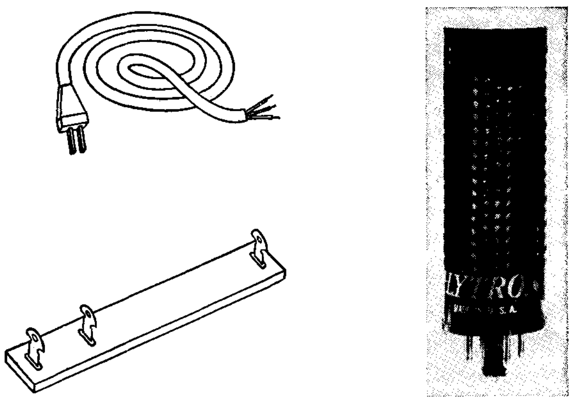
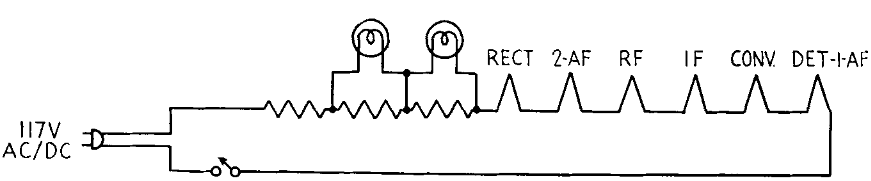


FIG. 18–2. Types of voltage-dropping resistors for 0.3-amp heater circuits.

Very often, resistors R-15 and R-16 are included in one tapped unit, the tap being used for the pilot-lamp wire.

In wiring up the tube heaters, it is usual practice to place the detector and first AF heater nearest B minus or ground potential, which is the position of minimum hum. The converter is usually next, to avoid hum modulation in the oscillator section. The sensitivity of the other tubes to hum places RF and IF amplifiers next, followed by the second AF tube and finally the rectifier. This order is shown in Fig. 18–3.

FIG. 18–3. Heater circuit for a receiver using an RF tube and two pilot lights.



With minor modifications, the typical circuit of Fig. 18–1 is capable of a large number of possible combinations. Figure 18–3 shows a variation of the same circuit to supply an RF tube and an extra pilot light.

Modern AC/DC receivers use tubes that have a heater drain of 0.15 amp. These tubes are very similar in all characteristics to the corresponding tubes with a heater drain of 0.3 amp. In order to maintain an equivalent heating effect on the cathode, that is, to dissipate the same wattage, the heater voltage is increased. Possibly an example will help clear up this point.

	Pentagrid converter	
	6SA7	*12SA7*
Heater voltage, volts	6	12
Heater current, amp	0.3	0.15
Heater wattage, watts	1.8	1.8

The net result of using tubes with heaters that require higher voltage and lower amperage is to eliminate the line dropping resistor. Figure 18–4 shows a modern AC/DC heater circuit.

The total voltage drop required by the tube heaters adds up to 121 volts. This is slightly higher than the line voltage, which is considered to be 117 volts for all calculations. However, actual line voltage is usually 120 volts. Operation of the receiver will be very little affected if the applied voltage is somewhat larger or smaller than the rated voltage. Receivers with a circuit and tube complement similar to that shown in

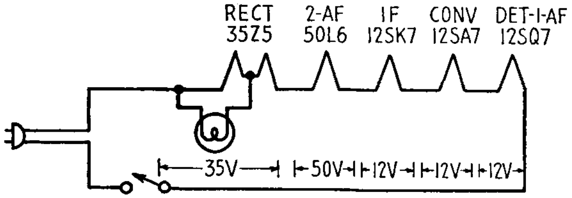


FIG. 18–4. A typical AC/DC heater circuit for 0.15-amp tubes.

Fig. 18–4 are considered suitable for operation on line-voltage ratings between 105 and 125 volts.

Note that the pilot-light shunt resistor has been eliminated also. It is replaced by part of the heater of the 35Z5-GT rectifier tube, which is provided with a special tap for the purpose.

In order to use more tubes in a receiver and still take advantage of the simplicity of the heater circuit of Fig. 18–4, some special tubes were designed. These include the 35L6-GT beam-power tube, the 6SS7 RF and IF pentode, and the 6AF6-G electron-ray tube. The heater requirements for these tubes are given in the accompanying table.

Tube	*Heater voltage, volts*	*Heater current, amp*
35L6-GT	35	0.15
6SS7	6	0.15
6AF6-G	6	0.15

An example of a 6-tube AC/DC heater circuit is given in Fig. 18–5.

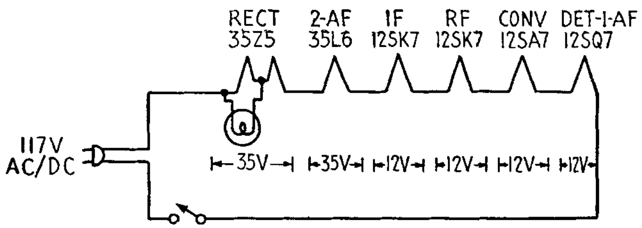


FIG. 18–5. Heater circuit for a six-tube receiver using 0.15-amp tubes.

B power supplies in AC/DC receivers. The *B* power supply in AC/DC receivers consists of a half-wave rectifier and filter circuit. Figure 18–6 shows a typical circuit.

Condenser *C*-17 acts as a line filter to keep RF disturbances like those caused by refrigerator motors, electric shavers, etc., from affecting the receiver. In addition, since one side of the line is grounded, it acts to ground the receiver, no other ground connection being used with AC/DC receivers. It is usually a 200-volt condenser, capacity ranging from 0.006 to 0.25 mfd.

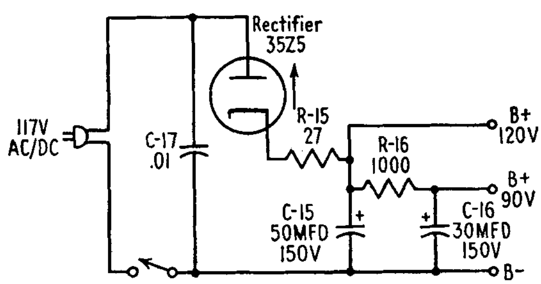


FIG. 18–6. Typical AC/DC *B* power supply.

The rectifier tube is a 25Z5 or 25Z6-GT in receivers with a 0.3-amp heater line. Receivers with a 0.15-amp heater line use a 35Z5-GT. The 35W4 and the 35Y4 are the miniature and lock-in equivalents of the 35Z5-GT. Some receivers which have a large number of tubes omit the rectifier heater from the series heater chain, since the other tubes require the full 117 volts of the line. These sets will use a 117Z3, a 117Z6-GT, or a dry-plate selenium rectifier. These tube rectifiers have a 117-volt heater, which may be connected directly across the line. The selenium rectifier has no heater.

In the half-wave rectifier circuit of Fig. 18–6, current flows from cathode to plate on the half cycle of line current when the plate is positive with respect to common negative. The selenium rectifier, when used, is hooked up in the same way and performs the same function. When the receiver is operated on a DC line, the rectifier simply acts as a series resistor. However, in this case, polarity of the line plug is important, since the rectifier will act as a series open circuit if the plate is connected to the negative side of the DC line. This explains the tag found near the plug on many AC/DC receivers which says, "If the receiver does not work on a DC line, reverse the line plug." This connects the rectifier plate to the positive side of the DC line.

On DC operation, the filter circuit is not so important, since the rectifier output is already DC. It acts mainly as a decoupling filter for the *B* circuits in the receiver. On AC operation, the rectifier output is 60 pulses of current per second, which requires the smoothing action of the filter circuit. This consists of resistors *R*-15 and *R*-16 and condensers *C*-15 and *C*-16. Input filter condenser *C*-15 is most effective in

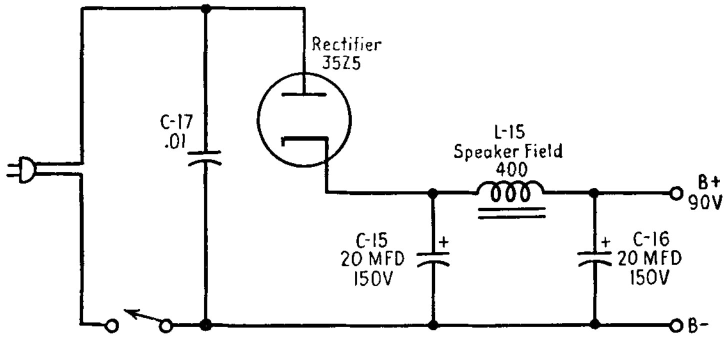


FIG. 18–7. An AC/DC *B* power supply using an electrodynamic speaker.

reducing hum and maintaining output voltage. It is a large condenser, 50 mfd/150 volts being the usual size. The initial charge current of a 50-mfd condenser is high enough to harm the rectifier, so resistor *R*-15 is connected in series with the rectifier and input filter condenser. This resistor, known as a "surge" resistor, is usually 27 or 33 ohms, and serves to keep down the charge current of the condenser.

The output voltage of the AC/DC power supply is limited to the line voltage, or a little higher, since the input filter condenser acts to bring the voltage up to the peak value of the AC line. The *B* supply for the second AF tube should be high to realize a large output signal. Hum introduced at this point is not so important, since there is no amplification in the receiver beyond the second AF plate. For these reasons, the *B* supply for the second AF plate circuit is taken from the input filter condenser. The voltage measured from common negative to this point is approximately 120 volts.

Filter resistor *R*-16 and output filter condenser *C*-16 supply *B* voltage to the rest of the receiver. This R-C filter produces a further reduction in hum and also acts as the decoupling filter circuit for the receiver. The resistor is usually a 1-watt size, varying from 1,000 to 2,000 ohms in different receivers. The output filter condenser is usually a 30-mfd or higher electrolytic type, also rated at 150 volts. Both filter condensers are usually enclosed in the same container.

The speakers used in AC/DC receivers are usually 4-, 5-, or 6-in. P-M dynamic units, depending on the size of the cabinet in which the receiver is housed. Some receivers use an electrodynamic loudspeaker. In this case, the field coil is used as a filter choke, and the *B* power supply circuit is as shown in Fig. 18–7. These speakers have a field winding of approximately 400 ohms, which drops the *B* voltage to about 90 volts for use on all tubes, including the second AF power tube. Filtering is more efficient than in the R-C filter circuit of Fig. 18–6, and so the filter con-

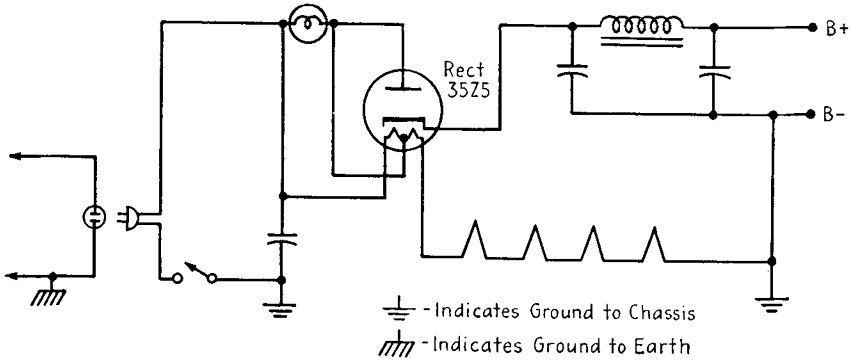


FIG. 18–8. An AC/DC power supply with *B* minus connected to chassis.

densers have a lower rating. A condenser of 20-20mfd/150 volts is common for this circuit. The surge resistor is usually omitted because the rectifier can handle the charge current of a 20-mfd condenser.

A voltage divider is not often found in an AC/DC power supply since the full *B* plus voltage is usually applied to the plate and screen circuits of all tubes. In some few exceptions, the screen of the converter and IF tubes, and sometimes even their plate circuits, are supplied through suitable by-passed dropping resistors.

Floating chassis circuits in AC/DC receivers. Early AC/DC receivers connected *B* minus to the receiver chassis, as shown in Fig. 18–8. Since one side of the lighting mains is always grounded, it is desirable that *B* minus be connected to that grounded main. However, if the plug is reversed, *B* minus (and therefore the chassis) would be connected to the "hot" side of the line. Various disadvantages would result.

First, the antenna may become grounded. An outdoor antenna or lead-in wire may ground on some grounded object. Some installations use a steam radiator antenna which is grounded through the water mains. All AC/DC receivers use a small condenser in series with the antenna circuit to isolate the antenna and to avoid possible short circuits resulting from a grounded antenna. However, if the condenser were to short, then the grounded antenna would be connected to the hot side of the line and would short-circuit the power mains. Or, if the insulation of the antenna wire were to become frayed as it goes through the chassis and make contact between the wire and chassis, it would connect the chassis ground to the grounded antenna, again resulting in a short across the mains. The dotted line in Fig. 18–9 traces the path of the short circuit under these conditions.

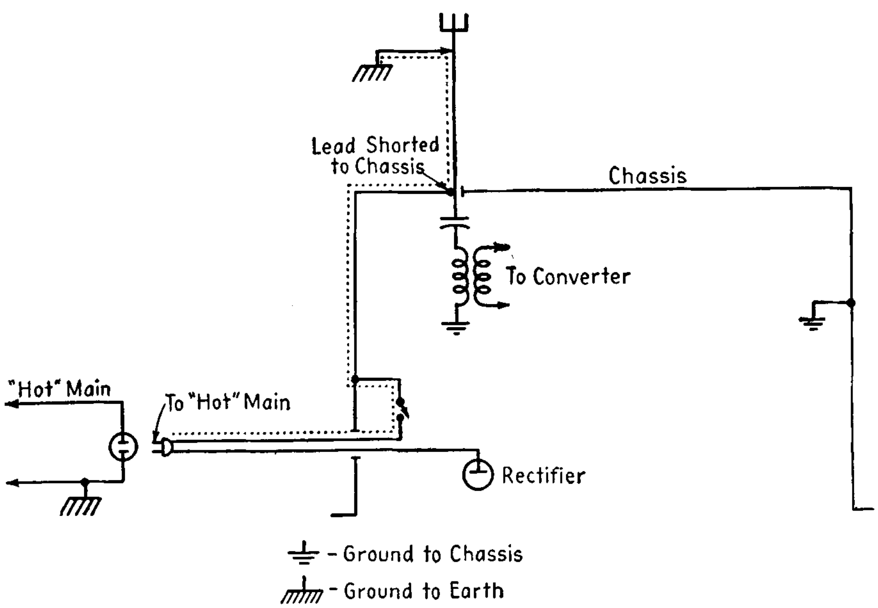
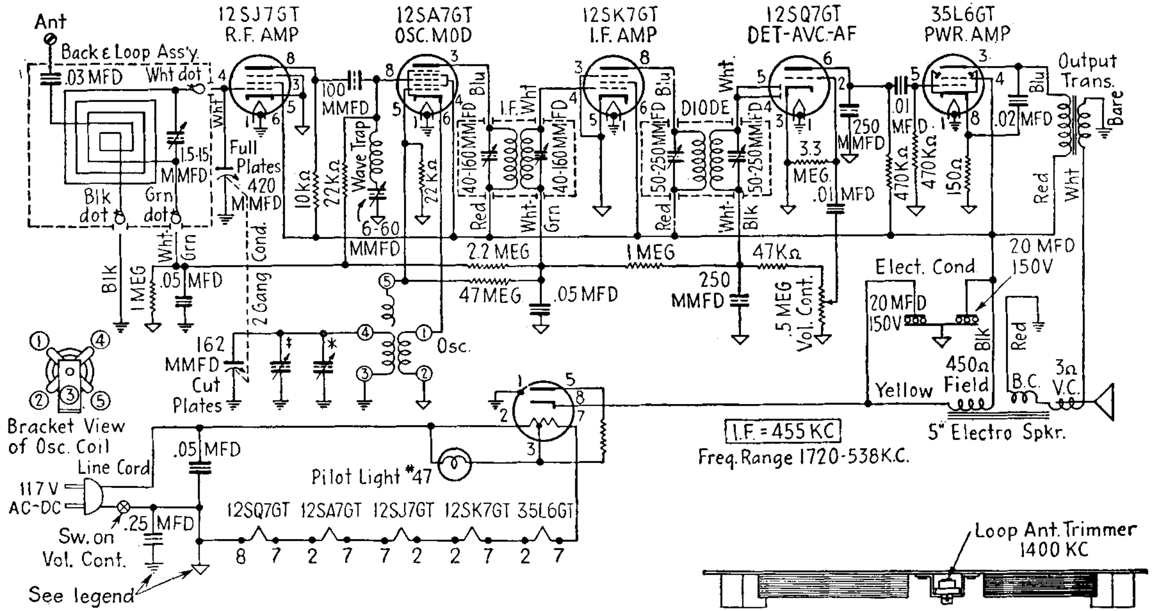


FIG. 18–9. Possible short circuit when *B* minus is connected to chassis.

Another way in which the chassis may become grounded is connected with the portability of small AC/DC receivers. People carry receivers of this type from room to room in their homes, set them down on any convenient spot, plug in, and enjoy their favorite programs. If the convenient spot turns out to be a steam radiator, there is likelihood of a short circuit through the chassis holding bolts which extend through the bottom of the cabinet.

This problem of possible short circuits of the lighting mains through the chassis does not occur with AC receivers, since the power transformer automatically insulates *B* minus and the chassis from any direct contact with the line. In AC/DC receivers, *B* minus must be connected to one side of the line.

Many modern AC/DC receivers avoid the possibility of short-circuit-



VOLTAGE CHART				
Tube		Plate to B-	Screen to B-	Cath. to B-
12SJ7GT	R.F. AMP.	40V	85V	0
12SA7GT	OSC. MOD	85V	85V	0
12SK7GT	I.F. AMP.	85V	85V	0
12SQ7GT	DET-AVC-AF	30V	–	0
35L6GT	PWR. AMP.	80V	85V	4.5V
35Z5GT	RECT.	A.C.	–	105V

LEGEND

⏚ Ground to chassis
▽ Ground to B-
* Trimmer on gang (top)
‡ Trimmer on gang (bottom, do not adjust)
Input: 117V A.C.
Output: Max. power 1.75 watts
Note: All voltages measurered on a 1000 Ohms per volt voltmeter

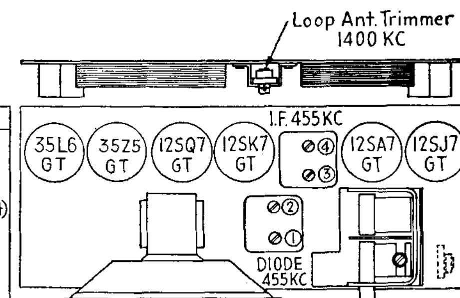


Fig. 18–10. Schematic circuit of the Motorola 61X11 receiver.

ing the line through the chassis by "floating" it, that is, insulating the chassis from *B* minus and consequently the line. A receiver of this type is the Motorola 61X11 series shown in Fig. 18–10.

The line switch connects to *B* minus. Note the use of the special symbol to denote *B* minus. This makes the diagram easier to read, since so many circuits are connected to *B* minus that connecting them with a line would complicate the drawing. The chassis is connected to *B* minus through the 0.25-mfd condenser near the line switch. Since this condenser offers practically no impedance to RF currents, it permits many components to be connected to the chassis and still act as if they are grounded. These components are the rotor of the gang-tuning condenser, the tube and coil shields, and the antenna coil primary. Its impedance is high with regard to low frequencies and therefore serves to isolate *B* minus from chassis for them.

NORMAL TEST DATA FOR THE AC/DC POWER SUPPLY STAGE

Quick check. The AC/DC power supply stage is probably functioning properly when

All tubes light or heat.

The hum level is normal.

There are no bad squeals or motorboating.

The *B* plus voltage measures approximately 90 volts to the common negative terminal.

This is the quick check for the stage.

The serviceman should familiarize himself with the normal brightness of tube heaters, since any marked variation is indicative of trouble in the heater circuit. Another aid to determining trouble in this regard is the length of time it takes for the tubes to reach their proper operating temperature. Tube brightness is not of great importance when AC receivers are serviced, since variations in applied heater voltage are infrequent.

If the quick check indicates trouble in the power supply, disconnect the plug and discharge the filter condensers by shorting them before proceeding to further checks. The filter condensers may retain a charge with subsequent danger of shock or damage to test equipment. This precaution is especially necessary in AC/DC receivers because there is usually no bleeder to discharge the filter condensers automatically.

Normal resistance data. Normal resistance data are given in the following table:

Line plug, prong to prong (switch closed)	100–200 ohms
Rectifier cathode to *B* plus	1000 ohms
Rectifier cathode to common negative	Condenser action
B plus to common negative	Condenser action

The reading from plug prong to prong takes in the heater circuit. There will be considerable variation in this reading depending on whether the tubes are still warm or not. Resistance of tube heaters, as of most conductors, varies with temperature. At the time of testing, the tube heaters may be anywhere from room temperature to several hundred degrees with a consequent difference in the resistance reading.

Readings in all AC/DC receivers should be taken from the common negative terminal rather than from the chassis. The common negative terminal is found either at the line switch or at the negative terminal of the filter condenser, both of these being easily identified parts.

The readings from the common negative to *B* plus or rectifier cathode are called "condenser action" because the electrolytic filter condensers are connected across these points. Since there is usually no bleeder in an AC/DC power supply, the point at which the ohmmeter needle comes to rest will indicate the leakage of the electrolytic condensers. Reverse the test prods and take the higher reading as the leakage resistance.

Standard circuit. The standard circuit is shown in Fig. 18–11.

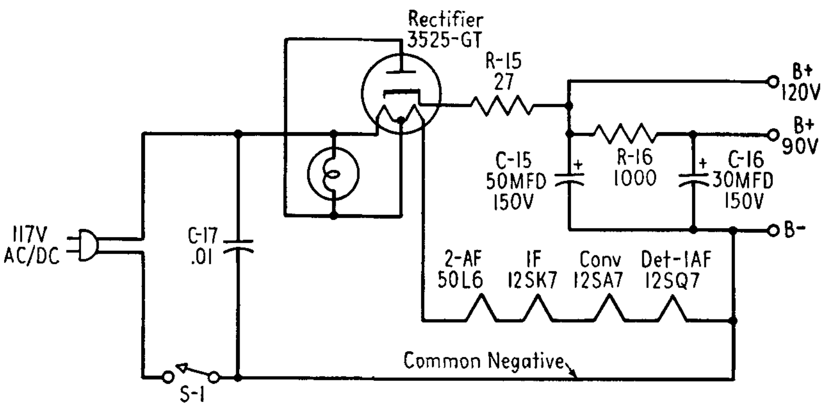


FIG. 18–11. Schematic diagram of a typical AC/DC power supply.

Normal voltage data. Normal voltage data are shown in the following table:

Common negative to rectifier plate	117 volts AC (line)
Common negative to rectifier cathode	110–120 volts DC
Common negative to *B* plus	85–95 volts DC

Heater voltages should be measured across each tube heater. The normal heater voltage for each tube is the rated voltage as found in the tube manual. An easy way of knowing the normal heater voltage is the first number in the tube designation. For example, the heater of the 50L6-GT is rated at 50 volts, 25Z5 at 25 volts, etc. Loctal tubes, an exception to this, can be recognized by the numbers 14 and 7. The 14B6 and the 7C6 are locking-base detector and first AF tubes. Their heaters are normally operated at the same 12 and 6 volts, respectively, as the corresponding 12SQ7 and 6SQ7 octal base tubes.

COMMON TROUBLES IN THE AC/DC POWER SUPPLY

Troubles common to 0.3-amp heater circuits. Since the heater circuit in an AC/DC receiver is a series chain, any open in any part of the circuit will cause the entire circuit to be open and the tubes will not light. The series chain includes the line cord, the dropping resistor, the pilot-light circuit, the tube heaters, and the switch. A break in any one of these can cause failure of the tubes to light, and all of them are common troubles. The serviceman must be able to find the break quickly and efficiently.

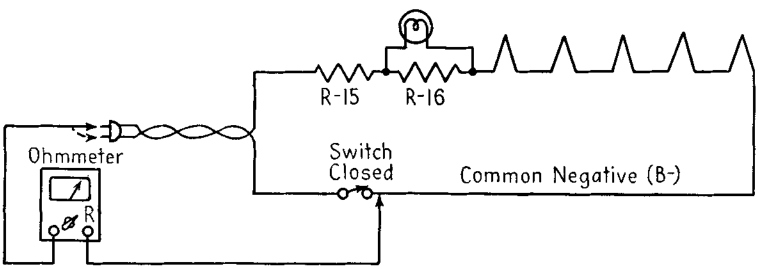


FIG. 18–12. Checking the line cord and switch in an AC/DC heater circuit.

When the tubes in an AC/DC receiver do not light, a good way of determining the cause is to make a continuity check of the heater circuit with an ohmmeter. Checking across the two prongs of the line plug with the switch turned to the ON position should, of course, show an open circuit. If it shows the normal reading of 100 to 200 ohms, the receiver had been plugged in to a defective or dead line outlet.

The next check should be from the common negative side of the switch to each of the line-plug prongs, as shown in Fig. 18–12. One of the line-plug prongs should show continuity (zero resistance) to the common negative wiring. If neither prong shows continuity, the trouble is in the line cord connected to the switch or in the switch itself. Which of these two is at fault is determined by further checking across the switch terminals.

If the check from common negative to the line plug shows continuity to one of the line-plug prongs, the test prod is shifted to the other prong that connects to the heater wiring, and this circuit is checked.

The heater circuit of a receiver whose tubes draw 0.3 amp is shown in Fig. 18–13, *R*-15 and *R*-16 being a ballast tube, a heavy-duty resistor, or a resistor in the line cord. The checks will be the same for all three.

The plug prong that connects to the heater circuit has already been determined. Checking from this prong to the rectifier heater shows whether the dropping resistor is open. Checking from the plug prong to the rectifier plate shows whether the line cord to the plate is open. If these show continuity, the open is in one of the tube heaters. The tubes are then checked in a tube checker or by an ohmmeter check across each pair of heater terminals. Of the tubes commonly used in receivers of this type, all heater pins are terminals 2 and 7 except the 6SQ7 detector and first AF tube, the heater pins of which are 7 and 8.

A word of caution might be mentioned at this point. When any defective condition in an AC/DC power supply is found and repaired, the

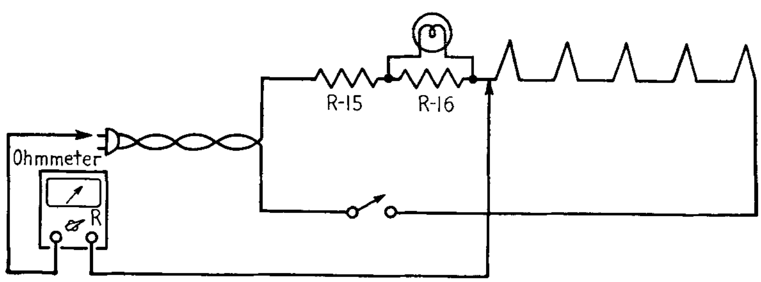


FIG. 18–13. Checking the voltage-dropping resistor in an AC/DC heater circuit.

filter circuit should be checked from rectifier cathode to the common negative, before plugging in. A shorted filter condenser will ruin a rectifier tube.

Repairing breaks in resistor-type line cords. If the continuity check shows an open line-dropping resistor in a resistor-type line cord, it may be an easily repaired break. As was mentioned before, AC/DC receivers are often carried from room to room, thereby giving the line cord and plug a greater than normal amount of handling. The resistance wire is attached to one of the plug prongs or to its associated wire, and, being a solid wire, it is much more easily broken by handling at this point than the other stranded line cord wires.

The plug should be taken apart and inspected. If a break in the resistance wire is found at this point, a repair is easily effected, since a slightly shorter length will not make much difference. When making the repair, the serviceman should, of course, be careful to connect the resistance wire to the proper lead. This is the one that shows continuity to the rectifier plate, as shown in Fig. 18–14. Taping the asbestos-covered resistance wire to its associated plate wire adds strength against future breakage.

Breaks in other parts of the line cord are not easily found and call for replacement of the entire cord.

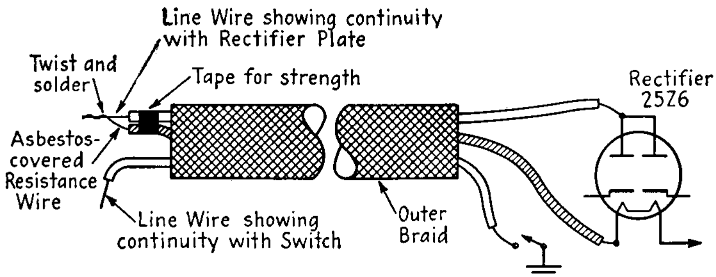


FIG. 18–14. Repairing a break at the line plug in a resistor-type line cord.

Replacement notes on resistor-type line cords. Replacement resistor-type line cords have various values of resistance, usually 135, 160, 180, 200, 220, 250, and 290 ohms. Some larger sizes are also available as well as various tapped units. The taps are for purposes of a pilot-lamp connection as well as to make the line cords more universally adaptable.

The proper resistance value is calculated as follows. The tube heater voltages are added. In the receiver of Fig. 18–15, this would come to 68

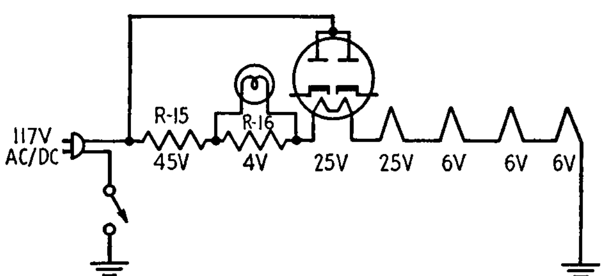


FIG. 18–15. An AC/DC heater circuit using a resistor-type line cord.

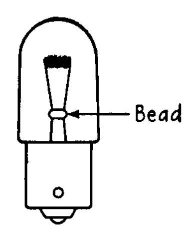


FIG. 18–16. A pilot lamp showing position of bead.

volts. Adding 4 volts for the pilot lamp makes a total of 72 volts for the heaters and pilot lamp. Subtracting from 117 volts leaves 45 volts to be dropped in the line cord resistor. The resistance value can then be found by substituting in Ohm's law, knowing that the tubes, and therefore the circuit, draw 0.3 amp.

$$R = \frac{E}{I} = \frac{45}{0.3} = 150 \text{ ohms}$$

The standard resistance-type line cord nearest in value is 160 ohms. The serviceman should always choose the value just higher than the calculated value in order to conserve the life of the tubes in the receiver. A 180-ohm line cord, tapped at 160 ohms, could also be used, 20 ohms being the correct shunt for a 150-ma brown-bead pilot lamp.

If separate pilot-lamp shunt resistors are employed, 5-watt/20-ohm resistors should be used for the 150-ma brown-bead pilot lamps, and 5-watt/30-ohm resistors for the 250-ma blue-bead pilot lamps. The bead mentioned is the glass bead that supports the filament in the pilot lamp, as shown in Fig. 18–16.

How to identify leads in a resistor-type line cord. The leads of a resistor-type line cord are usually color-coded for identification, but the coding has not been standardized. It is usually possible to recognize the resistor lead by its asbestos covering, but sometimes even this is replaced by an ordinary lead.

The following procedure identifies the leads in a tapped resistor-type line cord. It can be applied even more easily to an untapped resistor.

Connect one prod of the ohmmeter to either prong of the line plug. Connect the other test prod to each lead coming out of the line cord. As can be seen by referring to the diagram of Fig. 18–17, it will show continuity to either three leads or one, depending on the prong used.

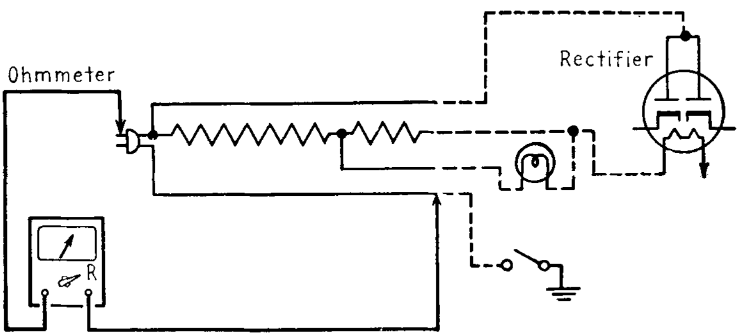


Fig. 18–17. Identifying leads of a resistor-type line cord.

This identifies the single lead, which is usually coded red and connects to the switch in the receiver.

Connect one test prod to the plug prong that shows continuity to the three leads. Check resistance to each of these three leads on the R or $R \times 10$ scale of the ohmmeter. One will show a resistance of zero ohms or short. This lead, which is usually colored black, connects to the plate of the rectifier tube.

Then carefully check the resistance from the same plug prong to each of the other leads. The one showing the higher value of resistance is the end of the resistor. This lead, usually white (asbestos), connects to the heater of the rectifier tube. The last lead is the tap that connects to the pilot lamp.

Sometimes the braided covering of the resistor-type line cord is brought to a tie-cord finish at the lead end. Do not mistake this for a lead. After the line cord has been installed in the receiver chassis, fasten the tie cord to a convenient point. Its purpose is to take the strain from the other leads.

Replacement notes on ballast tubes. When a ballast tube is replaced, the serviceman should be careful to use the proper replacement. Failure to do so may cause inefficient operation of the receiver, or a shortened life for the other tubes in the receiver. The R.T.M.A. coding for ballast-tubes is given for ease in determining the proper ballast tube to be used.

Standard R.T.M.A. designation code for ballast tubes. Ballast tubes are designated by a letter, followed by a number, and followed by a second letter as in the following example: K-55-B.

The first letter designates the type of pilot lamp:

K = 6- to 8-volt/150-ma lamp (brown bead).

L = 6- to 8-volt/250-ma lamp (blue bead).

The numbers designate the total voltage drop produced by the ballast including the pilot-lamp voltage.

The last letter designates the type of base wiring, as shown in Fig. 18–18.

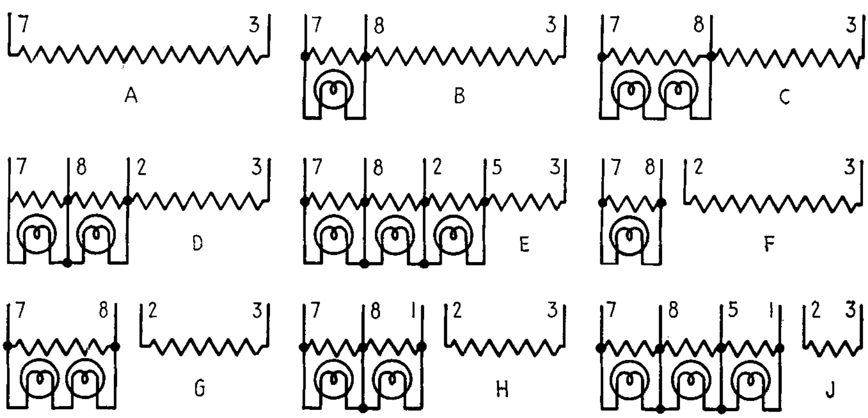


FIG. 18–18. Standard base wiring for ballast tubes.

Some manufacturers use the letters BK for the first or pilot-lamp designation. This denotes a special pilot-lamp shunt section which limits the current delivered to the lamp when the receiver is first turned on.

The table on page 333 lists the usual voltage drops (including pilot-lamp voltages) provided by the manufacturers of ballast tubes and the receiver tube complements for which they are intended.

As an example of how the R.T.M.A. listing can be used, assume that the receiver of Fig. 18–19 has an open ballast tube on which the markings cannot be read.

Inspection of the pilot lamp shows a blue bead supporting the filament. This makes the first letter L. Adding up the heater voltages brings

Dropping voltage	Rectifier	Second AF	No. of 6-volt tubes
67	12Z3	43	2
61	12Z3	43	3
55	25Z5	25L6	2
49	25Z5	25L6	3
42	25Z5	25L6	4
36	25Z5	25L6	5
30	25Z5	25L6	6

the total heater voltage to 68 volts. Subtracting 68 volts from 117 volts (the nominal line voltage) gives a voltage drop of 49 volts for the dropping resistor and pilot lamp. This makes our ballast L-49. Next the wiring is examined to determine the pins connected to the pilot lamp. This

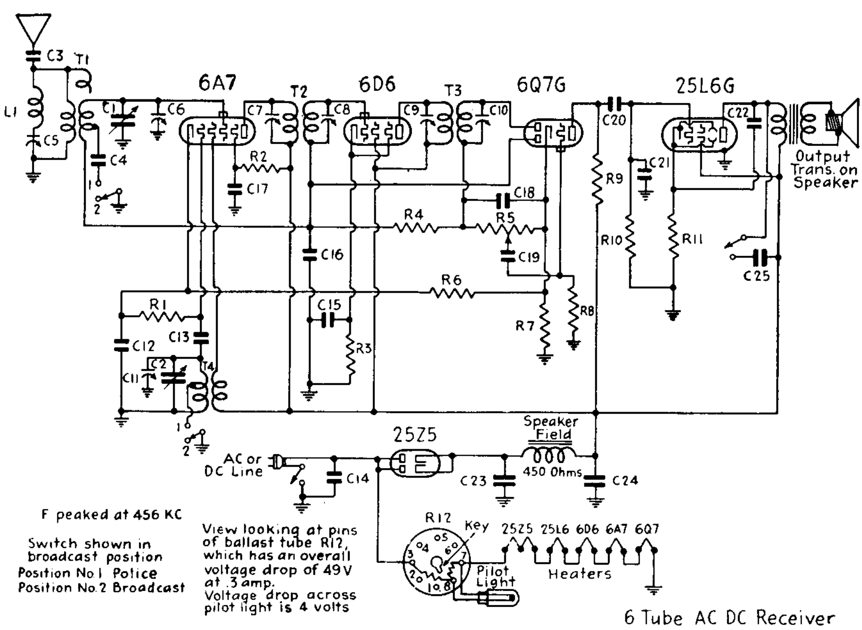


FIG. 18–19. Schematic diagram of the Emerson Model BH-203 receiver.

is compared with the type of base wiring shown in Fig. 18–18 and found to be type *B*. The correct replacement ballast is a type L-49-B.

Replacement notes on line dropping resistors. When a line dropping resistor of the type pictured in Fig. 18–20 is replaced, the serviceman should try to get an exact replacement. When this is not obtainable, mounting and space requirements and the possibility of harming nearby parts by heat dissipation make it advisable to replace the unit with a resistor-type line cord rather than a resistor of proper resistance and wattage specifications. Calculating the resistance value and making provision for the pilot-lamp shunt is considered under the replacement notes for resistor-type line cords.

When an exact replacement is used, examine and replace the connecting leads if the insulation has deteriorated because of heat.

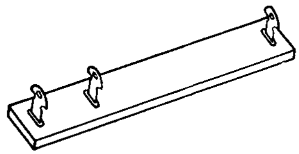


FIG. 18–20. A line voltage-dropping resistor.

Troubles common to 0.15-amp heater circuits. The 0.15-amp heater circuit of the more modern AC/DC receivers is the same series chain as the 0.3-amp circuit, uncomplicated by a line dropping resistor. The same procedure described on page 328 can be used to determine an open line cord, pilot-lamp circuit, tube, or switch.

The pilot-lamp circuit is somewhat different and deserves special attention. The pilot-lamp shunt resistor is part of the heater of the 35Z5-

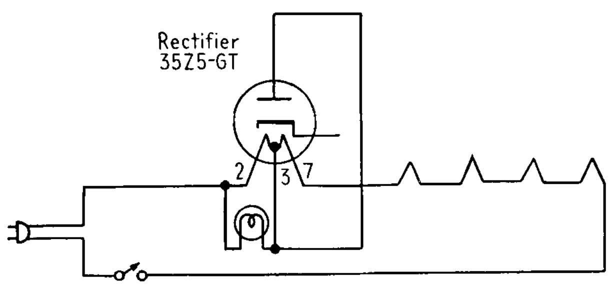


FIG. 18–21. Pilot-lamp circuit for a 0.15-amp heater line.

GT rectifier tube. In addition, the plate of the rectifier tube is usually fed from the pilot-lamp tap as shown in Fig. 18–21.

If the pilot-lamp shunt section of the rectifier tube opens, the pilot lamp burns out owing to the overload, and the heater circuit opens. When making a continuity check, the serviceman, in finding the open circuit, should remember that this is a shunt circuit and that both branches are open, requiring replacement of both the pilot-lamp and rectifier tube.

Blinking AC/DC receivers. A fairly common complaint with AC/DC receivers is that, when the radio is turned on, it seems to operate normally for a short time but then stops and the pilot lamp goes out. A few seconds later, the lamp lights up again, reception may or may not be resumed only to go off again, and blink on and off intermittently.

This condition is caused by an intermittent thermal open in one of the tube heaters. When the tube heats up, the circuit opens; when it cools down sufficiently, it heals again. The offending tube may or may not act the same way in a tube checker where the conditions of applied heater voltage are likely to be different from those in the receiver.

When servicing a blinking AC/DC receiver, if the tube checker gives no indication, the serviceman may use either one of two methods. He can replace the tubes one at a time and observe receiver operation after each replacement. In doing so, it is best to start with the rectifier and second AF tubes since these turn out to be at fault more often than the other tubes in the receiver.

The other method is to operate the receiver with the AC voltmeter (150-volt scale) hooked across individual tube heaters in turn. A good tube will show normal heater voltage when the receiver is on. This will drop to zero voltage when the receiver blinks off. The offending tube will also show normal heater voltage while the receiver is on, but this will rise to line voltage, 117 volts, when the receiver blinks off.

Troubles due to a short between heater and cathode. Heater-type tubes are so constructed that the heater is inside a closely fitted cathode, and shorts between the two are fairly common. In an AC receiver, both heater and cathode are near ground potential so that a short between them will affect a bias potential or introduce a hum, confining the

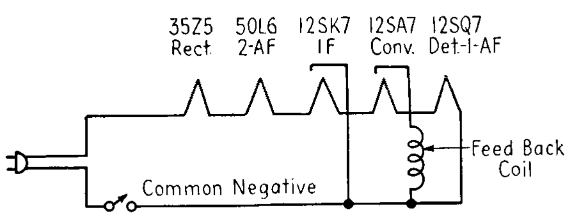


FIG. 18–22. How a cathode-to-heater short affects other tubes.

trouble to one stage. In an AC/DC receiver, a similar trouble will have more widespread effects.

Consider the circuit of Fig. 18–22 and assume a short between the cathode and heater of the 12SA7 converter tube. Since the converter cathode is connected to the common negative through the low resistance of the feedback coil, a short between its heater and cathode will short out the detector first AF tube heater.

With glass tubes, the situation would be sufficiently obvious as trouble somewhere in the heater circuit; when metal tubes are used, the trouble would be more obscure. Signal check would show a normal second AF stage and a dead first AF stage, and the serviceman would lose time checking a perfectly good first AF stage until he reaches the point of replacing the tube, when he would notice that it is not even warm.

Similarly, a short between heater and cathode of the 12SK7 IF tube would short out the converter and detector first AF tubes. In either of the above cases, the line voltage would divide itself among the remaining tubes and make them much brighter than normal.

The fastest way of recognizing troubles of this sort is for the serviceman to be on the alert for troubles in the heater circuit. These constitute a large proportion of all the service difficulties experienced with AC/DC receivers. Even if the tubes in the IF, converter, and detector first AF stages are metal tubes, the rectifier and second AF tubes are usually glass. When the heaters in these tubes appear to be too bright, a heater-cathode short should be suspected and checked for.

The tubes can be tested in a tube checker which disclose cathode-heater shorts. Possibly a faster method of finding the offending tube is to remove the detector first AF tube, fully expecting the others to remain lighted. When this happens, the cathode-heater short is confirmed and the converter tube is also removed. If the other tube heaters start to dim down, the short is in the converter tube; if they remain bright, the shorted tube is still in the receiver. It is probably in the IF tube, which is then removed for confirmation.

Troubles in the B power supply in AC/DC receivers. The *B* power supply in AC/DC receivers is similar to the *B* power supply in AC receivers except for the lower voltages involved. The unit is subject to the same troubles which were described in detail in Chap. 8. To avoid repetition, the trouble and service procedures will be briefly outlined here except for those circumstances which apply to AC/DC receivers only.

When the quick check discloses normal heater operation, coupled with hum, motorboating, low or no *B* plus voltage, the trouble is probably in the *B* power-supply section of the receiver.

Troubles common to the rectifier tube. Aside from trouble in the heater, the rectifier tube may become weak or entirely inactive, resulting in low or no *B* plus voltage. When this is the case, a tube checker will confirm the condition. Before replacing the tube, the serviceman should first check the filter circuit. This should be done because rectifier tubes used in AC/DC receivers have an easily fused cathode lead inside the tube. This internal cathode lead will melt on any overload, such as that caused by a shorted filter condenser, thereby ruining the new tube.

Troubles common to the input filter condenser. The input filter condenser commonly opens and occasionally shorts. When the condenser is open, the receiver hums and the *B* plus voltage is low—approximately 30 volts. The receiver may still operate weakly at the low voltage, but the quality of the reception will be badly garbled by hum.

The low voltage is due to the use of a half-wave rectifier, the output of which is half of the average of the applied voltage, when the rectifier is not followed by a condenser input filter. This is the condition when the input filter condenser is open. The rectifier output drops to approximately 50 volts, which is reduced to 30 volts on the *B* plus end of the filter. The best check for this condition is to substitute a test condenser.

When the condenser shorts, it will short the rectifier output, giving zero *B* voltage. The condition will be found on resistance check, the resistance from the rectifier cathode to *B* minus checking short instead of the charge reading of the condenser. The condenser should be replaced with one of the same capacity and voltage rating as the original. The rectifier tube and surge resistor will also have to be replaced since the short will have ruined them.

When replacing either filter condenser in an AC/DC power supply, the serviceman should be careful to use the correct capacity and voltage rating. Using condensers with higher voltage rating is not advisable,

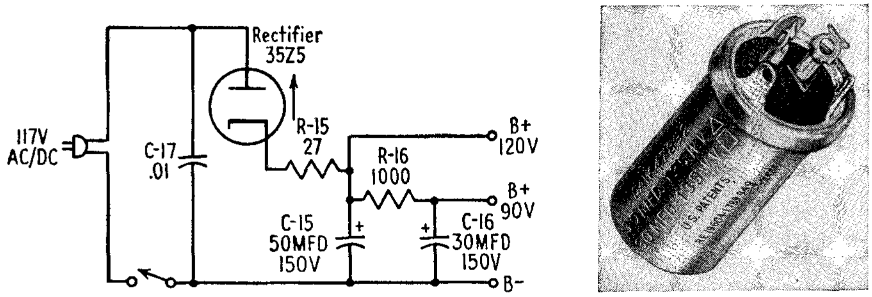


FIG. 18–23. Typical filter block and its position in the circuit.

since experience has shown that electrolytic condensers rated at 450 volts used for replacement purposes in AC/DC receivers deteriorate rapidly.

Troubles common to the output filter condenser. The output filter condenser C-16 also opens and rarely shorts. When it is open, the receiver operates, *B* plus voltage is normal, the receiver may hum slightly but it surely will squeal or motorboat, or both. This effect is much more apparent in AC/DC receivers than a similar condition in AC receivers, since the output filter condenser is usually the sole by-pass agent for all screen and plate circuits.

The best check for this condition is to bridge the condenser with a test condenser.

The output filter condenser may also short. This condition will be found by no voltage at *B* plus and almost normal voltage at the rectifier cathode. The rectifier tube may not be harmed owing to the intervening resistance of the filter resistor. Since a short at this point may be due to other agencies—for example, the IF plate trimmer shorting to its shielding—Fig. 18–24 shows a complete *B* circuit of a typical receiver, for analysis of the likely locations of the short.

The diagram will help solve another short which may be confusing. Suppose condenser *C*-12 in the plate circuit of the second AF tube were to short-circuit. The receiver would not play, and there would be a heavy current drain through the short. Surge resistor *R*-15 would overheat, as would cathode resistor *R*-13. A voltage check would give the clue. The voltage at rectifier cathode would be low—about 70 volts, indicating a heavy drain, or a weak rectifier. The overheating resistors point to the heavy drain. The voltage at *B* plus would measure about 60 volts—low, to be sure, but normally lower than the voltage at the rectifier cathode. This places the short in the second AF stage. Con-

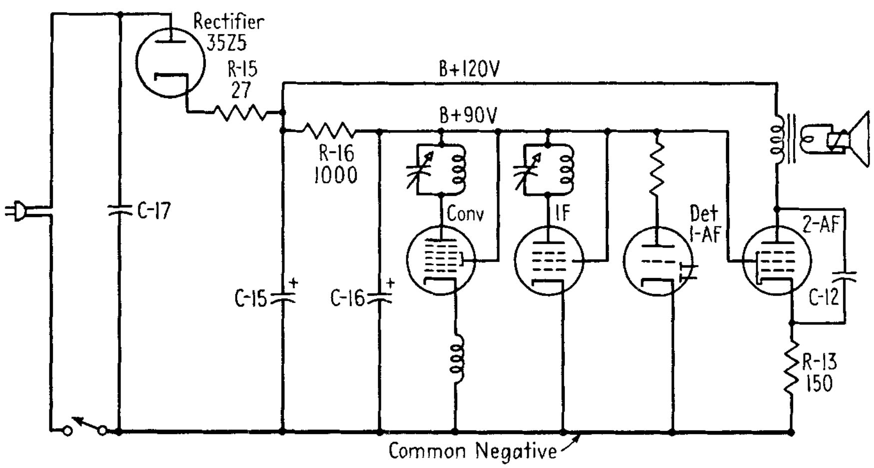


FIG. 18–24. Skeleton *B* circuit of a typical AC/DC receiver.

tinued voltage checking shows approximately 30 volts at the second AF plate, and the same 30 volts at the second AF cathode. An ohmmeter now confirms the short in plate condenser *C*-12.

Troubles common to the filter resistor. As can be seen in Fig. 18–24, filter resistor *R*-16 carries the *B* current of the converter, IF, and detector-first AF tubes. Normally, it carries this load without difficulty. However, any short in the *B* plus line puts an overload on the resistor, causing it to overheat. This may cause it to change in value. Therefore, whenever a short in the *B* plus line is corrected, filter resistor *R*-16 and surge resistor *R*-15 should be carefully checked and replaced if there is any sign of harm caused by the overload.

Sometimes filter resistor *R*-16 burns open. In this case, voltage at *B* plus drops to zero, while the voltage at the rectifier cathode remains normal or goes up slightly. The condition is readily found by voltage and resistance checks, and the resistor is replaced. If the size of the original cannot be ascertained, a 1,000-ohm/1-watt resistor will work satisfactorily in most receivers.

Troubles common to the speaker field. In those receivers that use an electrodynamic loudspeaker, the speaker field is the filter choke for the entire receiver. Refer to Fig. 18–7. The common difficulty encountered is an open field winding. This would cause no reception and no voltage at *B* plus. Voltage at the rectifier cathode would be high—150 volts or more, the peak voltage of the line.

When this condition is found, the receiver plug is removed from the outlet, and the filter condensers discharged by shorting them before making a resistance check to confirm the condition.

An open field winding usually necessitates replacing the entire speaker. The replacement chosen should be exactly like the original or match it as closely as possible in physical and electric details.

General service notes pertaining to AC/DC receivers. The circuit of an AC/DC receiver causes some problems in service procedure and techniques. For example, when a signal generator is connected for signal check or alignment, a bad hum may be experienced. This is especially prevalent in the floating-chassis type of receiver. It can usually be avoided by connecting the shielded lead from the signal generator to the common negative rather than to the chassis. Another expedient that sometimes gives good results is to connect the shielded ground lead through a 0.1-mfd condenser. The isolating condenser will still be used in the "hot" lead.

Another difficulty often experienced is when the test bench is ringed with a grounded metal trim. This will cause shocks to the serviceman and danger of short circuits if the chassis should touch the metal trim. Another danger of short circuits exists when the signal generator test lead is connected. If this has exposed shielding, it is likely to touch any grounded object such as the plate of an electrical outlet, thereby causing a short circuit.

VARIATIONS IN AC/DC POWER SUPPLIES

Fixed bias in AC/DC receivers. Some AC/DC receivers develop a voltage in the *B* minus lead for use in fixed-bias circuits. Figure 18–25 shows the schematic diagram of the Pilot B-3 receiver. The two resistors in the upper right corner of the diagram marked "47 ohms, part No. 30–352" are connected from *B* minus to ground. The negative end feeds *C* voltage to the grid of the 35L6 tube, the cathode of which is grounded. The tap between the two resistors is brought to the AVC bus to furnish the delay voltage for the AVC system.

From the servicing point of view, the power supply should be checked with the *B* minus end of the switch as the reference point, rather than the chassis. Then all checks would be the same as for the standard

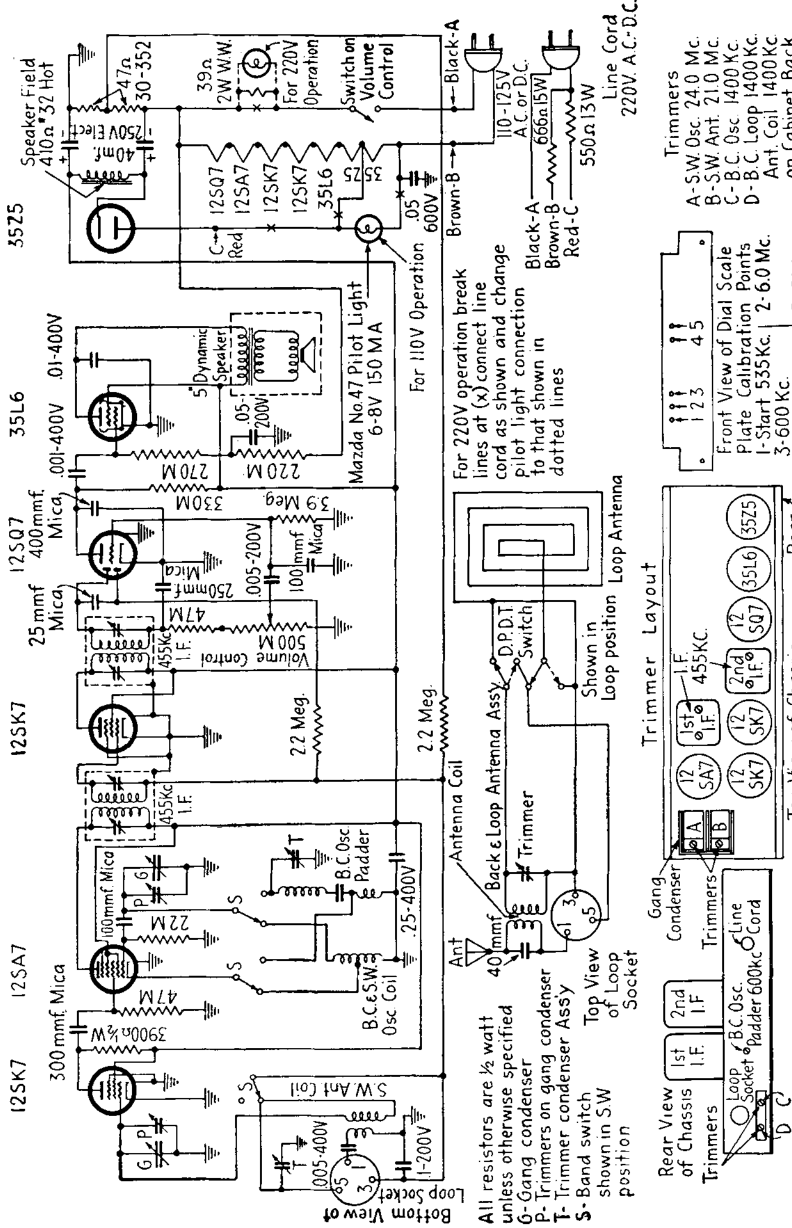


FIG. 18–25. Schematic diagram of the Pilot Model B-3 receiver.

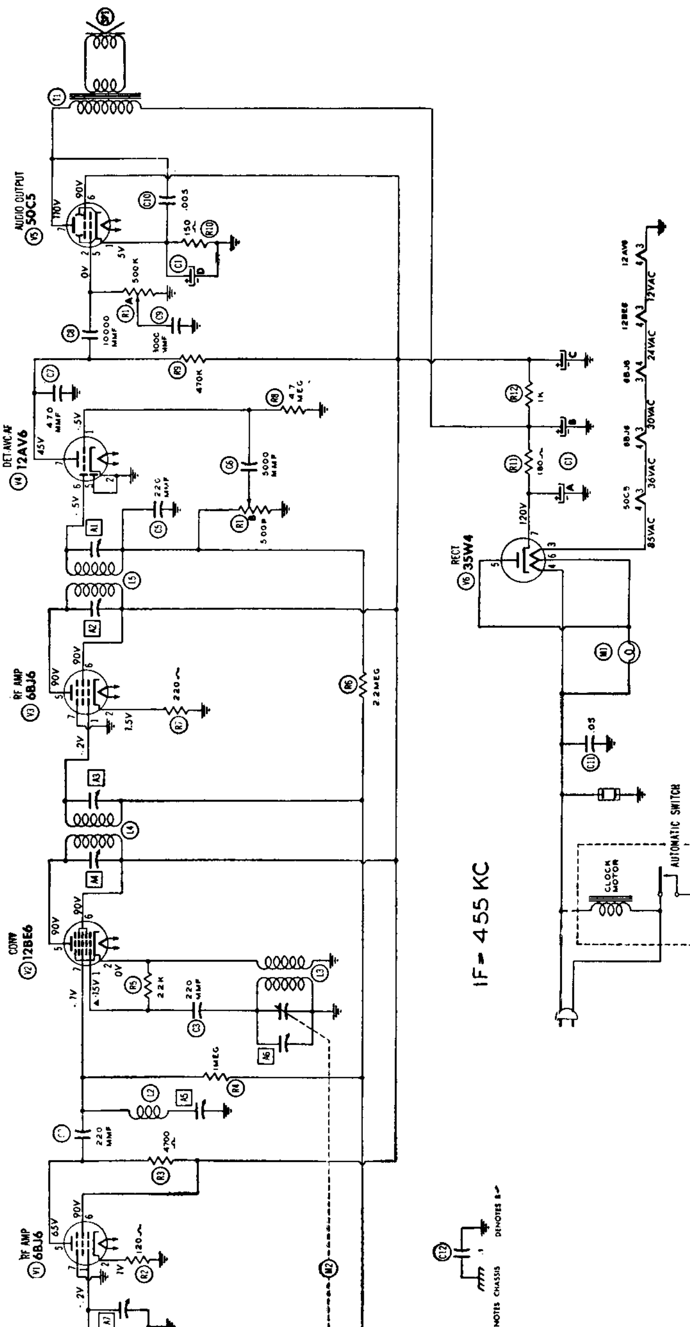


Fig. 18-26. Schematic diagram of the Packard Bell Model 621 clock radio.

circuit with the exception of the output filter condenser and the bias circuit. These should be checked by referring to the diagram.

Two-section R-C filters. Some receivers use a two-section R-C filter for improved hum elimination. The Packard-Bell Model 621 clock radio of Fig. 18–26 is an example. Note the automatic switch in the clock motor section which turns the radio on and off at preset times.

The *B* power circuit has been redrawn in Fig. 18–27. The first section of the filter system consists of resistor *R*-11 and condensers *C*-1*A* and *C*-1*B*. This feeds the second AF plate circuit. Filter resistor *R*-11 has a low ohmic value so that the voltage drop to the second AF plate circuit is low. The second section of the filter system, consisting of resistor *R*-12 and condensers *C*-1*B* and *C*-1*C*, feeds *B* plus to the rest of the receiver. This is like the conventional single-section R-C filter of the standard circuit. Both filter resistors are 1-watt units.

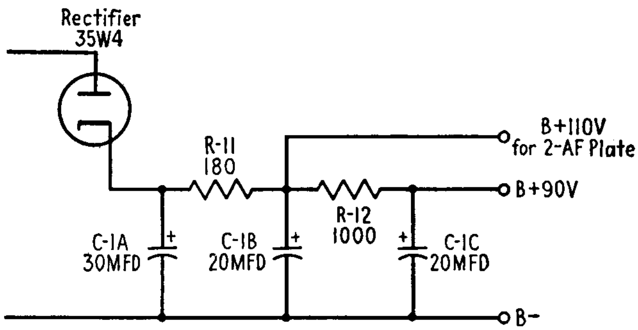


FIG. 18–27. Two-section R-C filter used in the receiver shown in Fig. 18-26.

Servicing the power supply in a receiver of this type offers no new problems beyond the extra parts to be checked. Service notes previously given for filter resistors and condensers may be applied to the two-sections circuit. An open input filter condenser will cause low *B* voltages and hum. An open mid-section filter condenser will cause hum. An open output filter condenser will cause squealing, motorboating, or a combination of both. The filter resistors will stand up unless overloaded by a short elsewhere in the receiver.

Tapped output-transformer filter systems. Some receivers make use of a tap on the output transformer to introduce a humbucking voltage to cancel the hum that would otherwise appear in the speaker. Figure 18–28 shows an RCA 16X-1 receiver which uses a filter circuit of this type.

The cathode of the rectifier connects to the input filter condenser *C*-24 and the tap on the output transformer. The lower section of the output transformer is in series with the filter resistor *R*-16 which furnishes the *B*-plus voltage to the rest of the receiver. Condenser *C*-25 is the output filter condenser. The location of the tap on the output transformer is

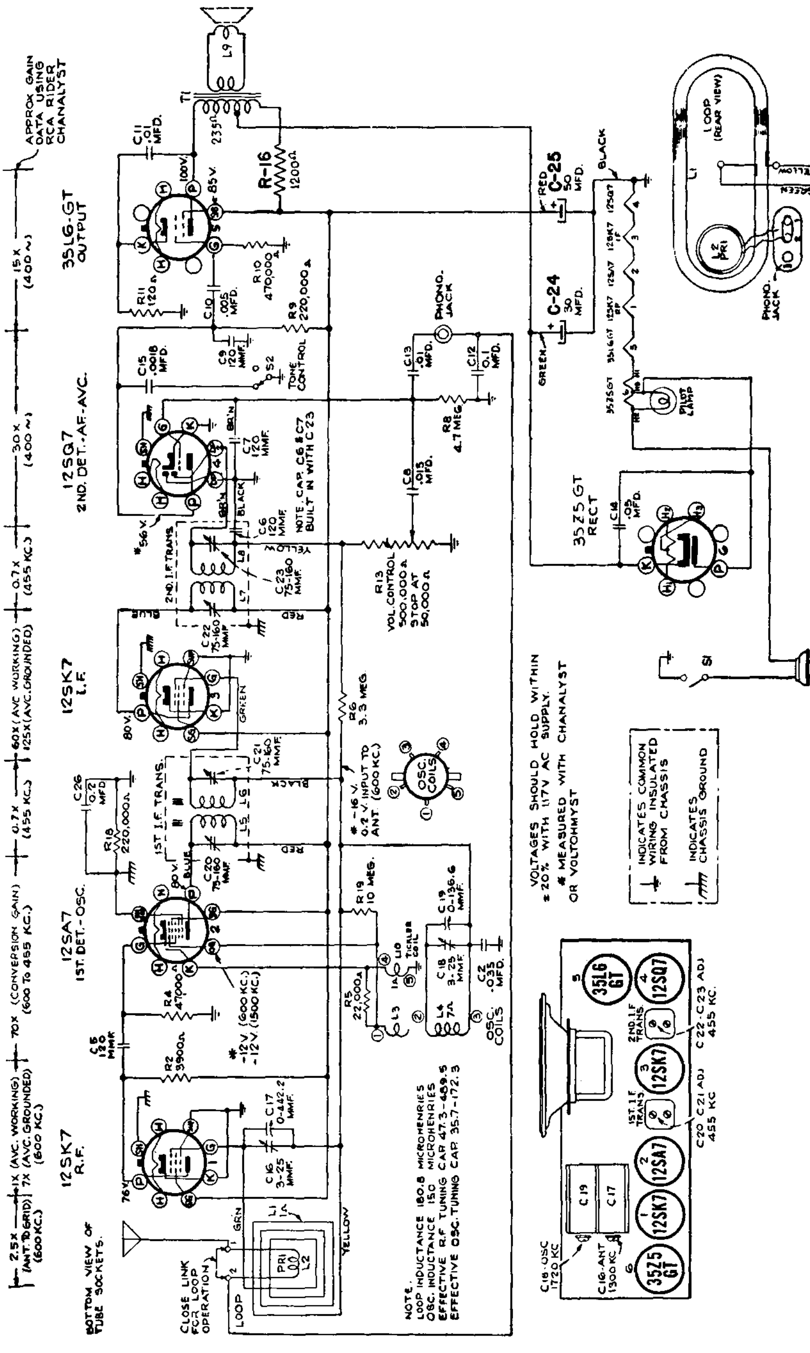


FIG. 18–28. Schematic diagram of the RCA Victor Model 16X-1 receiver.

designed so that just the right amount of humbucking voltage is introduced.

From the servicing point of view, all checks are the same as for the usual AC/DC receiver. If the output transformer should become defective, it would be necessary to obtain an exact replacement. An ordinary center-tapped output transformer could not be used since this would introduce too much hum. In replacing the transformer, the serviceman should be careful to connect the leads properly since any reversal would cause hum, weak output, or both.

If an exact replacement transformer cannot be obtained, an ordinary matching transformer can be used and the filter circuit revised in any one of the following ways.

1. Use the circuit of Fig. 18–29. In case the hum level is high, it may be reduced by adding a 20-mfd/150-volt condenser as shown by the dotted lines.

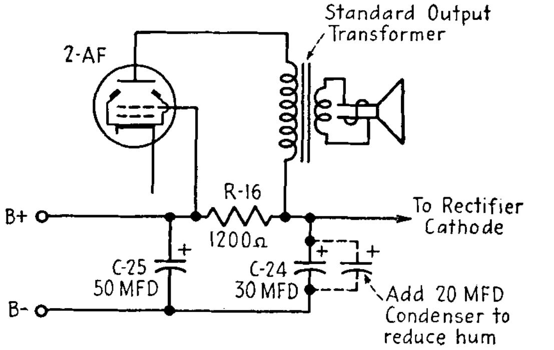


FIG. 18–29. Replacing a hum-bucking-type output transformer, method 1.

2. Use the circuit of Fig. 18–30. This filters the second AF plate voltage supply also and will decrease the *B* plus voltage. The filter resistor should be replaced by one of higher wattage.

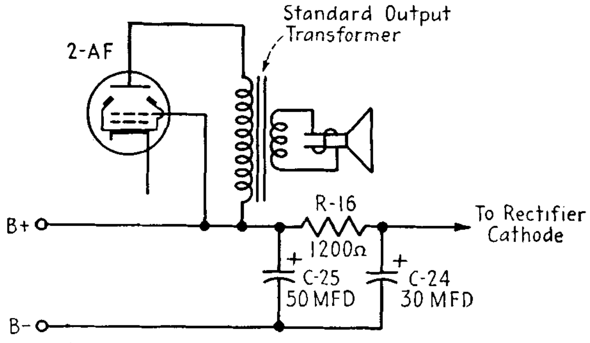


FIG. 18–30. Replacing a hum-bucking-type output transformer, method 2.

3. Use the circuit of Fig. 18–31. This replaces the filter resistor with a small choke. This method is satisfactory, provided that there is room in the receiver to mount the choke.

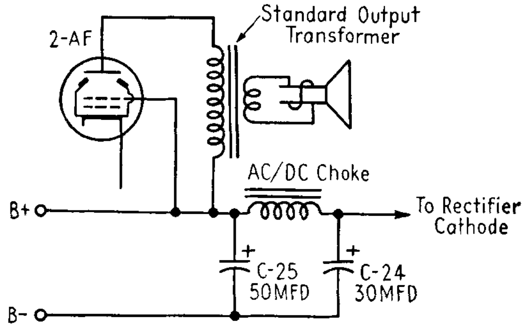


FIG. 18–31. Replacing a hum-bucking-type output transformer, method 3.

4. Use the circuit of Fig. 18–32. This provides a second section R-C filter.

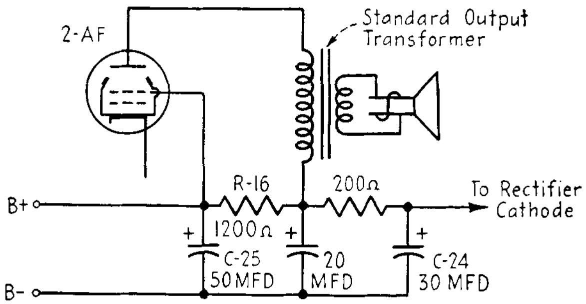


FIG. 18–32. Replacing a hum-bucking-type output transformer, method 4.

5. Use the circuit of Fig. 18–33. This replaces the P-M speaker with an electrodynamic unit.

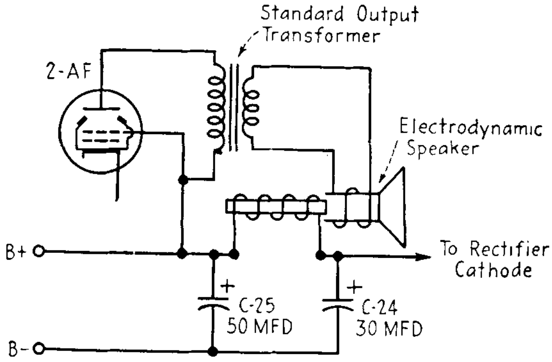


FIG. 18–33. Replacing a hum-bucking-type output transformer, method 5.

SUMMARY

Quick check for normal operation of the AC/DC power supply

All tubes light at normal brightness.

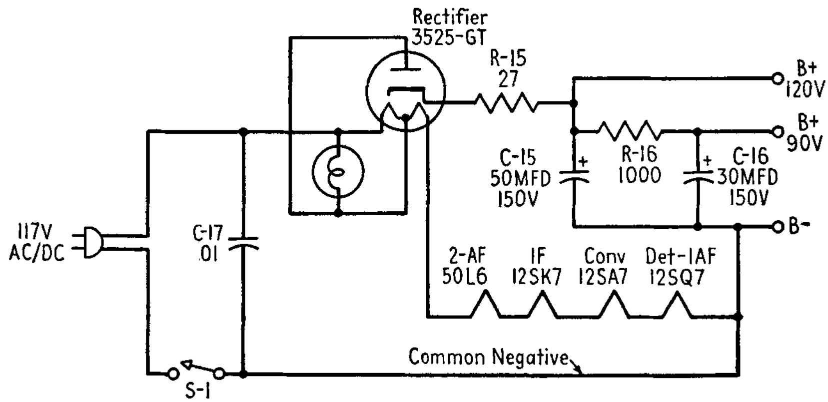
The hum level is normal.

There are no bad squeals or motorboating.

The *B* plus voltage measures approximately 90 volts to the common negative terminal.

Standard circuit

This circuit is shown in the accompanying figure.



Normal resistance data

Plug, prong to prong (switch on)	100–200 ohms
Rectifier cathode to *B* plus	1000 ohms
Rectifier cathode to common negative	Condenser action
B plus to common negative	Condenser action

Normal voltage data

Common negative to rectifier plate	117 volts AC (line)
Common negative to rectifier cathode	110–120 volts DC
Common negative to *B* plus	85–95 volts DC

SERVICE DATA SHEET

Symptom	*Abnormal reading*	*Look for*
Tubes do not light	Plug prong to prong checks open	Open line cord. Open switch. Open dropping resistor (resistor, resistor-line cord, or ballast). Open pilot light and pilot-light shunt resistor. Open heater in one of the tubes
Pilot lamps keep burning out		Open pilot-lamp shunt resistor
Pilot lamp blinks on and off		Intermittent thermal open in the heater of one of the tubes
Some tubes are overly bright, others do not light or warm up		Cathode-heater short circuit in one of the tubes
Tubes light—no reception	No *B* plus voltage	Dead rectifier tube, short-circuited input filter condenser, or both
Tubes light—no reception	No *B* plus voltage. Low voltage from common negative to rectifier cathode	Short-circuited output filter condenser. Short in the *B* plus wiring
Tubes light—no reception	No *B* plus voltage. Voltage from common negative to rectifier cathode measures 150 volts	Open filter choke (speaker field). (Discharge filter condenser before checking)
Tubes light—bad hum	*B* plus voltage measures 30 volts	Open input filter condenser
Tubes light and receiver motorboats, squeals, or both	*B* plus voltage normal but jumps with the motorboat	Open output filter condenser
Modulation hum	All tests normal	Open line filter condenser C-17

QUESTIONS

1. The tubes in an AC/DC receiver do not light. List the possible causes and explain how you would check for each.

2. A dead AC/DC receiver is brought in for repair. All the tubes light, there is no hum or squeal, and the *B* plus voltage measures zero. List the likely causes of trouble and outline how you would check for each.

3. An AC/DC receiver continues to burn out pilot lamps. What is likely to be wrong and how would you check for it?

4. The receiver of Fig. 18–19 needs a new ballast tube. The necessary L-49-B ballast tube is not in stock, but a K-49-F and an L-42-B are on hand. Draw a wiring diagram of the heater circuit indicating the necessary changes needed so that the K-49-F ballast tube could be used. Repeat for the L-42-B.

5. When an AC/DC receiver hums, what is likely to be wrong and how would you check for it?

6. It is desired to add a 6AF6-G electron-ray tube to the receiver of Fig. 15–2. It is proposed to accommodate the extra heater by changing the 50L6-GT tube in the second AF stage to a 35L6-GT. Redesign the heater circuit to accomplish these changes. Give the value of the needed resistor in ohms and watts.

7. What precautions should be taken before replacing a dead rectifier tube in an AC/DC receiver?

8. In an AC/DC receiver, the 35Z5-GT and the 50L6-GT tubes light up very brightly. The receiver does not play. What is likely to be wrong and how would you check for it?

9. What is the most probable cause of a tunable hum (modulation hum) in an AC/DC receiver?

10. Calculate the values of the line-dropping resistor and pilot-lamp shunts needed for the circuit of Fig. 18–1. Assume 150-ma pilot lamps and a voltage drop of 4 volts across each. Give the values in resistance and wattage rating.

11. When an AC/DC receiver squeals badly, which unit in the power supply can cause this condition? How would you check to determine whether or not this unit is at fault?

12. In the *B* circuit breakdown of Fig. 18–24, assume that an ohmmeter check from common negative to *B* plus gives a reading of 40 ohms.

List some of the likely locations of the short. Outline a procedure that could be used in tracking down the short.

13. The receiver of Fig. 18–10 chirps at a staccato rate. A voltmeter connected from the common negative to *B* plus reads about 80 volts, but the meter pointer fluctuates with each beat of the motorboat. What is the probable cause of the trouble and how would you check for it?

14. List the bench provisions and techniques that should be observed when working with AC/DC receivers relative to the use of grounds, accidental grounding, and connections to a signal generator.

15. What is the most probable cause of a blinking pilot light in an AC/DC receiver? Outline a test procedure that will determine the exact cause.

16. The receiver of Fig. 18–28 has an open output transformer. An exact replacement is unobtainable. What method would you use to repair it?

19 PORTABLE RECEIVERS

Portable receivers may be subdivided into two general groups: those that work only on battery power, and those that can be switched from battery operation to line operation. Receivers in the first group are known as "battery" portables, while those in the second are usually called "three-way" portables, since they may be operated from batteries, the AC line, or the DC line. The switch-over, therefore, is from a battery power supply to an AC/DC type of power supply.

Both types of portable receivers employ the standard superheterodyne lineup of converter, IF amplifier, detector, and audio stages. The standard signal checks of the AC receiver may therefore be applied to these receivers as well. Again, the main difference between the standard AC receiver and the portable types lies in the power supply. This chapter will discuss the operation and servicing of portable power supplies as well as any differences in servicing the stages that arise from the minor differences in the circuits.

Tubes used in portable receivers. The tubes most commonly found in both the battery and three-way portable receivers are the miniature types listed in the chart of Fig. 19–1. Because of their small size, the miniature tubes are particularly adaptable to the compact construction desirable in portable receivers. The octal and lock-in base types will be found in older and in larger receivers.

The converter, IF, and detector-first AF tubes use directly heated cathodes rated at 1.5 volts and 0.05 amp. In spite of this very low filament power consumption, these tubes give approximately the same performance as the much heavier cathode-heater types operating in the same stages in AC or AC/DC receivers. The second AF tubes also use directly heated cathodes, rated at 3 volts and 0.05 amp. The filament is center-tapped to permit operation from a 1.5-volt dry cell, as shown in Fig. 19–2. The portable-type second AF tubes, however, do not produce as much signal as do the equivalent tubes in AC or AC/DC sets. The 3S4, for example, at operating potentials usual in the portable set, delivers ¼ watt of signal to the loudspeaker, as against 2 watts for the

	Converter	IF	Det-1st AF	2nd AF
Miniature	1R5 1L6	1U4 1T4	1U5	3S4 3V4 1S4
Lock-in	1LC6	1LC5	1LD5	1LB4
Octal	1A7-GT	1N5-GT	1H5-GT	3Q5-GT

FIG. 19–1. Tubes commonly used in portable receivers.

50L6-GT in AC/DC sets, and 4 watts for the 6V6 in AC sets. This explains why the portable set is the equal of the others in its ability to pick up stations but is somewhat lacking in volume and tone quality.

Filament or A circuit in battery portables. Whereas the signal circuits in battery portables and three-way portables are essentially the same, the filament and plate supply circuits differ. These will be described separately. The filament circuit commonly used in battery portables is shown in Fig. 19–2. The filaments are connected in parallel. Note that

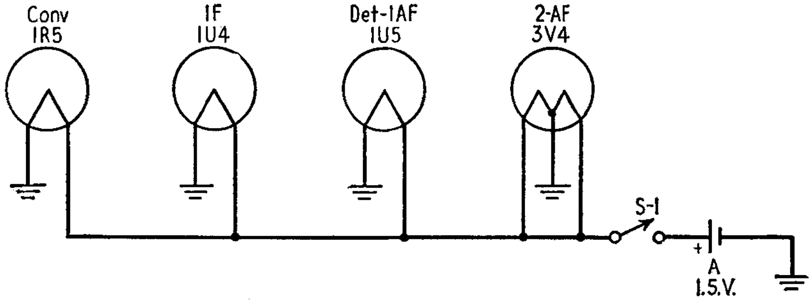


FIG. 19–2. Filament circuit commonly used in battery portables.

the center tap on the 3V4 filament permits the two halves to be connected in parallel and fed from the same source.

The *A* battery used to light the filaments is generally two ordinary flashlight cells connected in parallel. In some of the more compact receivers, a single cell is used. In most cases, the negative terminal of the battery is connected to the ground, as shown in the diagram. In these directly heated cathode tubes, the cathode connection is conventionally considered to be the negative lead of the filament. All cathodes are therefore at ground potential in these receivers. Switch S-1 breaks the filament line and is the on-off switch for the receiver.

Plate or B circuit in battery portables. The skeleton *B* circuit of a typical battery portable is shown in Fig. 19–3. The *B* battery shown is a 67-volt size. Some of the larger portables use a 90-volt battery, but the circuit is the same. The positive end of the battery is connected to the plate and screen circuits of all the tubes in the receiver. This is the *B* plus line. The tube cathodes are connected to ground through the *A* circuit. This is the common negative line. The negative end of the *B* battery is connected to common negative through switch S-2 and bias resistor *R*-1. The plate and screen currents of all tubes, therefore, flow through resistor *R*-1 and establish a voltage across it, with polarity as indicated in the diagram. The value of resistor *R*-1 (470 ohms) is chosen so that the voltage across it will be correct for the bias of the second AF tube. Note that grid-load resistor *R*-2 of the 3V4 tube is connected to the negative end of bias re-

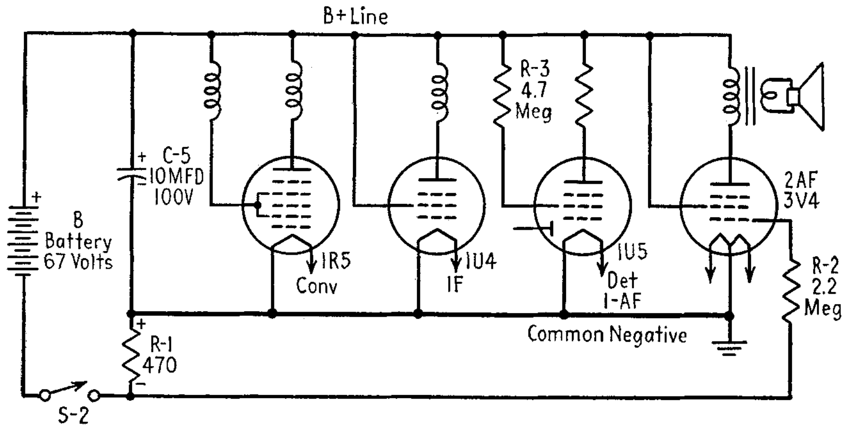


FIG. 19–3. Skeleton *B* circuit in battery portables.

sistor *R*-1. When the 3S4 is used as the power amplifier tube, bias resistor *R*-1 has a value of approximately 700 ohms, since this tube requires a higher bias voltage. The use of switch S-2 to break the *B*-battery circuit is common practice in portable receivers. It is ganged with switch S-1 in the *A* circuit.

Condenser *C*-5 is connected from *B* plus to common negative and serves as a decoupling filter for the plate circuits of the various tubes. Note that the 1U5 detector-first AF tube is a diode-pentode, rather than the diode-triode 6SQ7 of the AC receiver. Screen voltage for the 1U5 tube is supplied through dropping resistor *R*-3, of 4.7 megohms. In some receivers, resistor or *R*-3 may be 3.3 megohms. The value of grid load resistor *R*-2 is fairly standard at 2.2 megohms for most portable sets.

Complete schematic diagram of a typical battery portable. The Olympic model 489 battery portable receiver is pictured in Fig. 19–4. Its complete schematic diagram is given in Fig. 19–5 as an example of a typical set of this type.

The set is about the size and shape of a flat camera. The hinged cover has a snap to hold it closed. The cover holds the on-off switch in the open position. When the cover is opened, the switch springs to the closed position, thereby starting the set. The cover also contains the loop antenna. Similar switch-loop-cover arrangements are quite common with this type of receiver. The front panel is loosened from the case to expose the receiver for servicing.

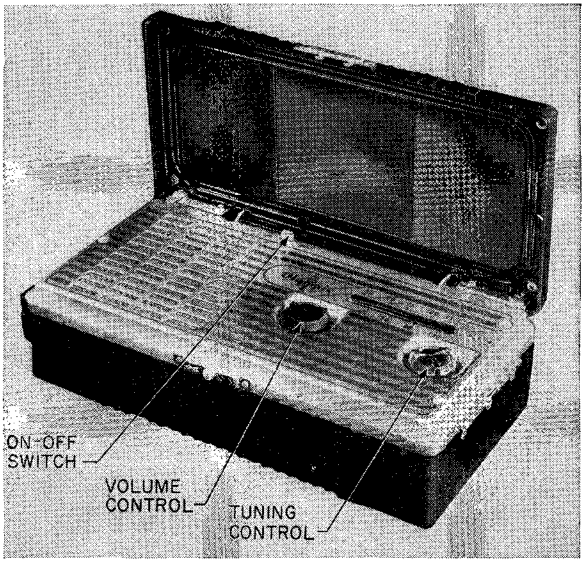


FIG. 19–4. Olympic Model 489 battery portable receiver.

In the schematic diagram, observe first the standard superheterodyne lineup of stages. Then note that the power supply stage consists simply of the two batteries *M*-1 and *M*-2, the dual switch *M*-3, bias resistor *R*-6, and decoupling filter *C*-1. The filament circuit is drawn in the power-supply section. Trace the leads to see how both halves of the 3V4 are powered from the same 1.5-volt *A* battery. Follow grid load resistor *R*-7 from the 3V4 control grid to the negative end of the *B* battery. This is the bias connection for this tube. The bias voltage is developed across resistor *R*-6 in the negative *B* lead. The grid voltage is negative when measured from the chassis. Bias for the other tubes is very simple. The converter grid is operated from the AVC line; the IF tubes work at full sensitivity at zero bias; and the first AF tube is biased in the usual way by contact-bias resistor *R*-4. Finally, observe dropping resistor *R*-5 in the screen circuit of the 1U5 detector-first AF tube.

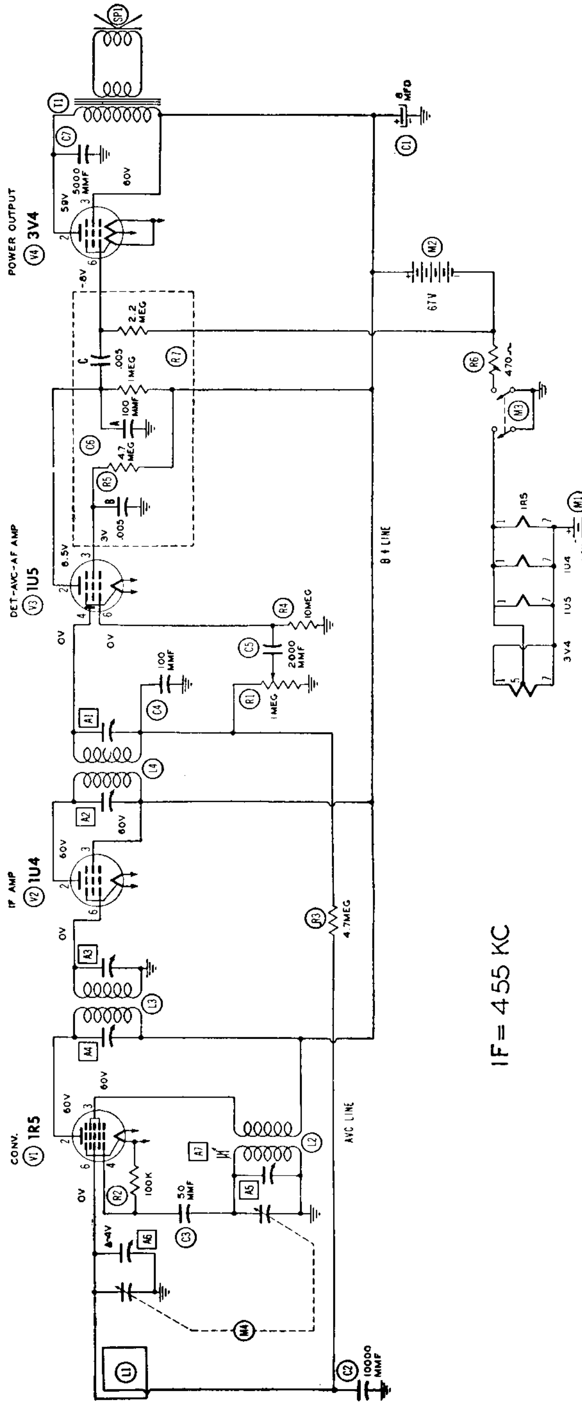


FIG. 19–5. Schematic diagram of the Olympic Model 489 battery portable receiver.

Servicing procedure for battery portables. The battery portable is subject to all the ills of the standard superheterodyne, and, in addition, some new troubles are introduced by the battery-type power supply. Batteries wear down, and as they do, reception weakens and finally dies. Battery life is comparatively short, and frequent renewal is necessary. The filaments in the portable tubes are fragile, and these tubes also require frequent replacement. Service work on battery portable sets should therefore be done in the following sequence:

1. Check batteries.
2. Check tubes.
3. Apply signal, voltage, and resistance checks according to the standard servicing procedure.

Test data on batteries used in portable receivers. As batteries wear down, the voltages they deliver decrease. A new dry cell has a terminal voltage of slightly more than 1.5 volts. As it is used, the voltage drops

Battery	*Normal reading*	*Replace at*
1.5-volt *A*	1.3–1.5 volts	1.3 volts or lower
7.5-volt *A*	6.5–7.7 volts	6.5 volts or lower
9-volt *A*	7.8–9.3 volts	7.8 volts or lower
67-volt *B*	58–70 volts	54 volts or lower
90-volt *B*	78–93 volts	72 volts or lower

FIG. 19–6. Replacement data on batteries used in portable receivers.

slowly to 1.4 volts, and then to 1.3. Below this point, deterioration is rapid. A voltmeter check is therefore a reliable indication of the condition of the cell. Since a *B* battery is a collection of dry cells connected in series, the same voltage ratio, multiplied by the number of cells in the battery, tells the condition of the *B* battery. Test and replacement data for *A* and *B* batteries commonly used in portable receivers are found in Fig. 19–6.

The batteries must be tested in the receiver, with the switch turned on. In this way they are tested under normal load conditions. If tested out of the receiver, the voltmeter is the only load, and the reading may be erroneously high.

In general, the *A* and *B* batteries run down together and are replaced simultaneously. In some cases, either the *A* or the *B* outlasts the other, and they may be replaced separately. Note that the replacement data in the chart of Fig. 19–6 show that *B* batteries may be allowed to reach a proportionately lower value than *A* batteries.

How to test tubes in portable receivers. The directly heated cathode of the tubes used in portable receivers consists of a hair-fine filament which glows a very dim red when it is working. Do not look for the tubes to light up, since this may be difficult to tell. If there is any doubt as to whether a tube is working, check it in a tube tester. Do not test the tubes for filament continuity on the $R \times 1$ ohmmeter range of your multimeter. Your meter may be equipped with a 3-volt self-contained battery which may burn out the filament on the low-ohmage range. It is safe to use the $R \times 100$ range for this purpose, since there is more resistance in the ohmmeter circuits on the high-resistance ranges.

Service hints for battery portables. Weak or dead batteries and weak or dead tubes account for most of the troubles with battery portables. After

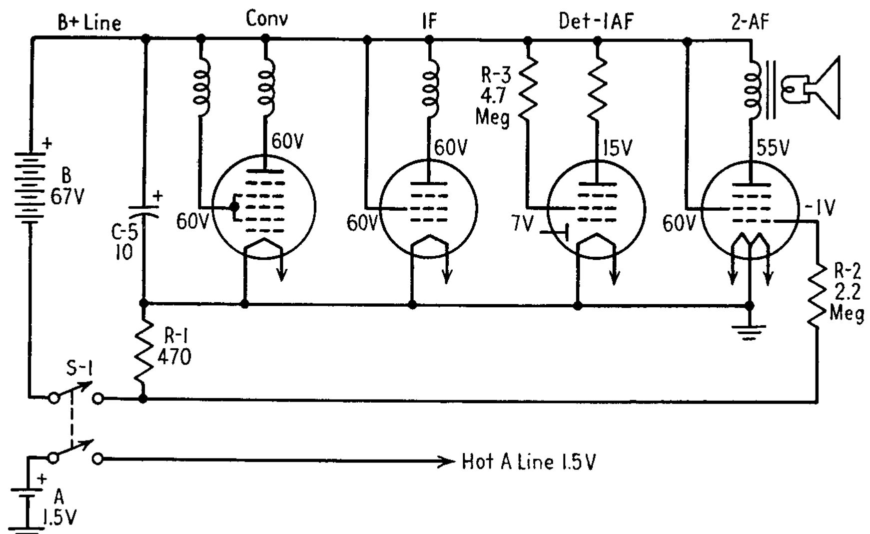


FIG. 19–7. *A* and *B* circuit of a battery portable receiver.

these have been ruled out, the set is tackled like an ordinary superheterodyne with signal and voltage checks. Normal voltages at strategic test points are given in the skeleton *A* and *B* circuit diagram of Fig. 19–7. An audio signal fed to the hot end of the volume control will tell whether the audio stages and speaker are working. If not, a voltage check on the AF tubes is next in order. Do not neglect the screen voltage on the first AF tube, since an open voltage-dropping resistor (*R*-3 in Fig. 19–7) at this point is a common cause of trouble.

Portable receivers usually employ a loop antenna or a loop-stick antenna and seldom have an external antenna connection. Test signals at RF or IF may be fed in by an injection loop. This consists of two turns of hookup wire. The signal-generator output is connected to the ends of the loop, which is then placed near the loop or loop stick of the receiver.

Sufficient signal can then be fed in to check the operation of the IF and converter stages.

When the complaint on a battery portable is squeals or motorboating, the most common cause of the trouble is an open plate decoupling filter condenser (*C*-5 in Fig. 19–7). Bridge the suspected condenser with a test filter condenser, and if the trouble clears up, replace it. A condenser rated at 10-mfd/100 volts will make a satisfactory replacement in most cases.

Block diagram description of the power supply in three-way portable receivers. Three-way portable receivers use the same tubes as battery portables, but since the power supply must make provision for operation from the line as well as from batteries, the circuit is much different. A

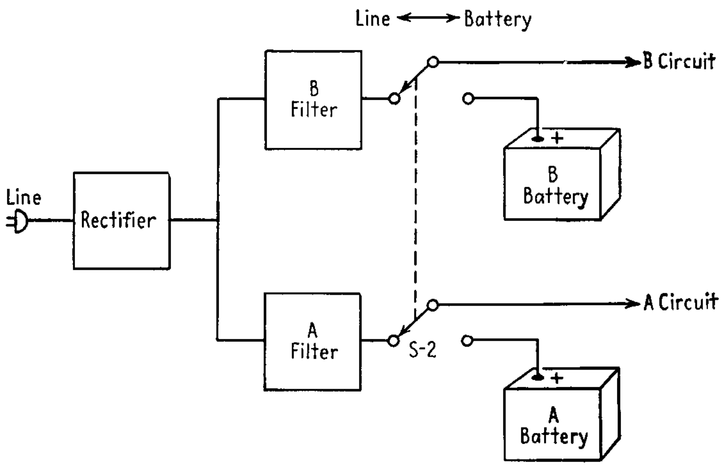


Fig. 19–8. Block diagram of the power supply in a three-way portable receiver.

block diagram of the power supply is shown in Fig. 19–8. The line feeds a rectifier which changes alternating current into pulsating DC. The rectifier feeds two filter circuits. The upper or *B* filter is a standard *B* filter circuit like the one in AC/DC receivers. This feeds the *B* or plate circuits of the receiver. The lower filter circuit provides smooth DC for the *A* or filament circuit. In the latter, the tubes are connected in series and require 0.05 amp of filament current. A current of 0.05 amp is the same as 50 ma. When the *B* circuit requirements of 15 or 20 ma are added, the total current for the portable receiver is within the scope of a simple rectifier. Some sets use the familiar 35W4 rectifier of AC/DC receivers. The dry-plate selenium rectifier, however, is found most often.

Switch S-2 is the changeover switch which changes the receiver from line to battery operation. In some receivers, the switch is manually operated, but more often its operation is made automatic. The receiver provides a space to stow the line cord when it is on battery operation. The space includes a receptacle for the line plug which covers the changeover switch. The insertion of the plug in this receptacle switches the receiver to battery operation. When the plug is removed, the switch is sprung to make the connections for line operation.

Most three-way portables use the floating-chassis type of construction to reduce shock hazard. As a result, the serviceman must remember to use the common negative connection, rather than the chassis, for the common test point. Common negative is most easily found at the common negative lead of the filter condenser. In those receivers where the line is connected to the chassis, chassis bolts, knobs, and dials are either recessed or insulated so that the user cannot come in contact with the live chassis. In working on sets of this type, the serviceman should be careful to leave such insulation intact so as to maintain the shockproofing.

The filament circuit in three-way portables. As was mentioned previously, the tube filaments in three-way portables are connected in series,

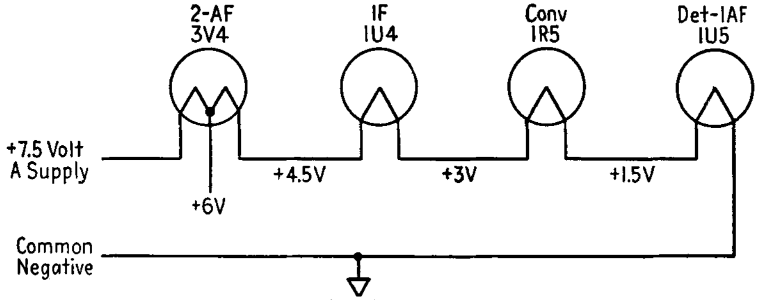


FIG. 19–9. Series arrangement of tube filaments in three-way portable receivers.

as shown in Fig. 19–9. In the series arrangement, the detector, converter, and IF tubes require 1.5 volts each, and the 3V4 or 3S4 second AF tube requires 3 volts, making 7.5 volts for all. On battery operation, a 7.5-volt *A* battery is needed. Some receivers use an extra 1U4 tube as an RF or added IF amplifier. This is added to the series chain, and a 9-volt *A* battery is used.

In the diagram of Fig. 19–9, the voltage at each tube filament is indicated, as measured from the negative end of the *A* battery, or common negative. Note that the center tap or cathode of the 3V4 filament is plus 6 volts with respect to common negative. If the grid of this tube is returned to common negative, a 6-volt bias is established on the tube. This is the biasing arrangement used in most three-way portables for the second AF tube.

The series-filament arrangement introduces a complication. Refer to Fig. 19–10. The 3V4 second AF tube has a normal plate current of 7.7 ma. This current must flow through any conductor connected between its cathode and the negative end of the *B* battery. The conductor in this case is the other tube filaments. But these are already carrying 0.05 amp

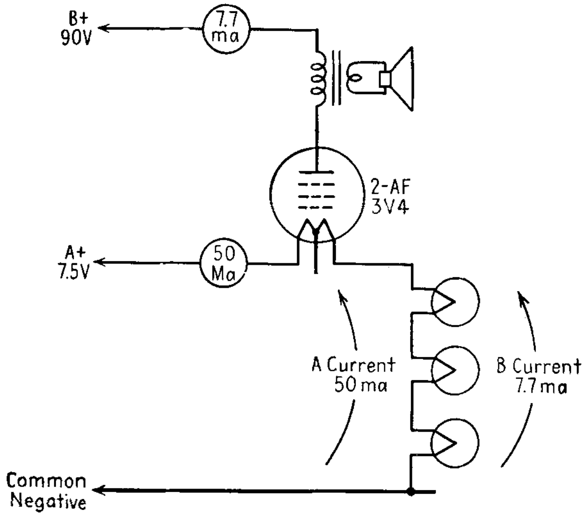


Fig. 19–10. Plate and filament currents of the 3V4 second AF tube.

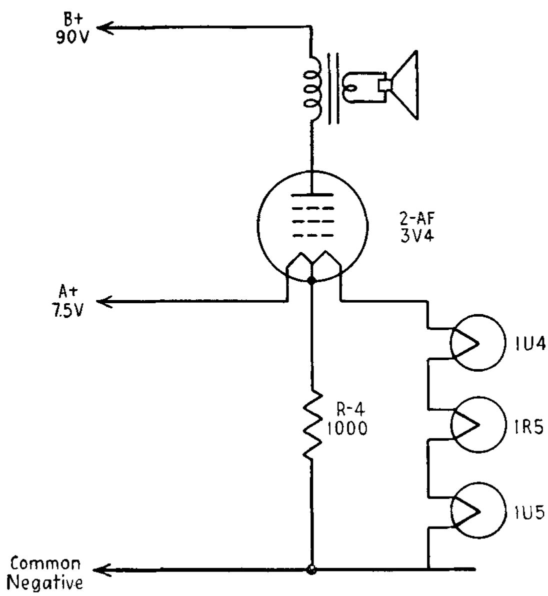


Fig. 19–11. Resistor compensating for the *B* current of the 3V4 tube.

or 50 ma of current from the *A* battery. The two currents are additive, and the *B* current adds 15 per cent overload, a serious consideration in the case of these fragile filaments.

The problem is solved by shunting part of the current out of the filaments by resistor *R*-4, as shown in Fig. 19–11. The resistor is connected from the 3V4 cathode to common negative, where it will carry both *A* and *B* currents. Its value is calculated to compensate for the added *B* current of the 3V4 tube. It may be called a bypass resistor, since it serves to bypass plate current out of the filament chain. The resistor is usually ½-watt size with a value of approximately 1,000 ohms.

Similarly, the plate current of the 1U4 IF tube must pass through the filaments of the last two tubes in the chain, etc. These currents should be bypassed also, and some receivers connect similar resistors from each filament to common negative. However, the plate current of some of the tubes is small, and in some receivers, one or more of the bypass resistors may be omitted.

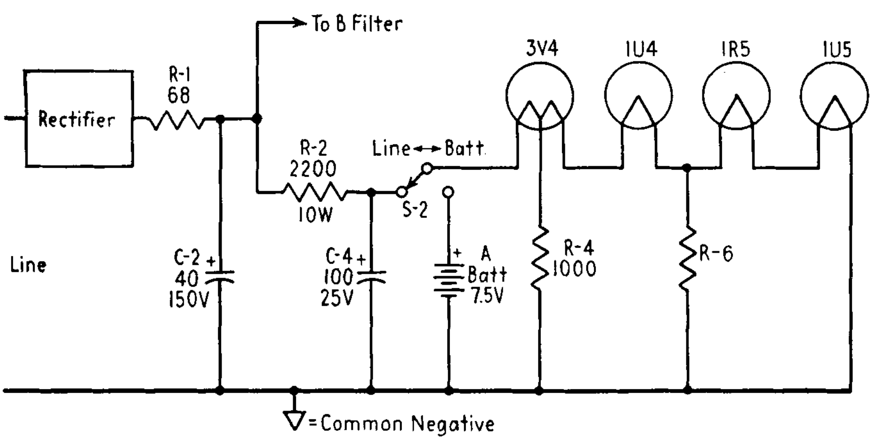


FIG. 19–12. The *A* circuit in three-way portable receivers.

The A circuit in three-way portables. A basic complete *A* circuit of a three-way portable is shown in Fig. 19–12. The filament circuit is on the right, and when changeover switch *S*-2 is in the battery position, a 7.5-volt *A* battery supplies the filament current. Bypass resistor *R*-4 is in the cathode circuit of the 3V4 tube. This resistor is present in all three-way portables. Resistor *R*-6 represents the other bypass resistor used. Its position and value vary with different receivers.

When the switch is in the line position, as shown in Fig. 19–12, the filament chain is fed from the line. Resistor *R*-1 is a surge resistor which prevents the initial charge current of filter condenser *C*-2 from overloading the rectifier. Condenser *C*-2 is the input filter, and is common to both the *A* and *B* circuits. The value 40 mfd/150 volts is usual in most receivers. The value of *A* filter resistor *R*-2 is calculated to drop the 120-volt rectifier output to 7.5 volts for the *A* line. It carries 50 ma of *A* current and is subject to heating. A resistor rated at 10 watts, 2,000 or 2,200 ohms, is the usual size. Output *A* filter condenser *C*-4 has a large capacity. The rating 100 mfd/25 volts shown in the diagram is usual. Some manufacturers use a 200 mfd/25-volt condenser as the output *A* filter. The condenser is often connected further down the filament string across bypass resistor *R*-4.

The rectifier and B circuit in three-way portables. A typical *B* circuit used in three-way portables is shown in Fig. 19–13. The rectifier in most common use is the dry-plate selenium type pictured in the diagram. The usual size has a 75-ma rating, although some receivers use a 65-ma recti-

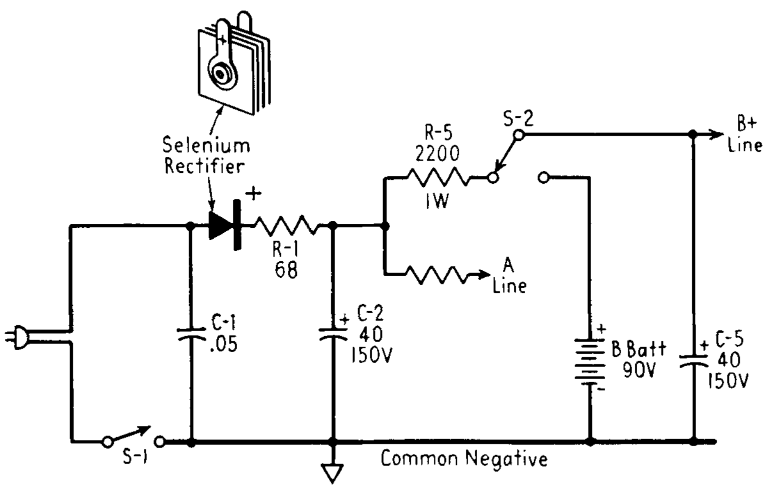


FIG. 19–13. A selenium rectifier and its position in the power supply of a three-way portable receiver.

fier. As shown in the diagram, the rectifier feeds the 50-ma *A* line as well as the *B* line. Since the latter draws approximately 15 ma, a 65-ma rectifier will be working at full capacity. Input filter condenser *C*-2 works in both the *A* and *B* circuits. The *B* filter is a standard R-C circuit as used in the usual AC/DC set. Besides input filter condenser *C*-2, it consists of *B* filter resistor *R*-5 and output filter condenser *C*-5. The values shown in the diagram are conventional. Output filter condenser *C*-5 is on the receiver side of the changeover switch, so that it can act as the decoupling filter when the receiver is switched to battery operation. Condenser *C*-1 is the conventional line filter condenser.

Other rectifiers are also used in three-way portables. Some receivers use a 35W4 rectifier tube in the circuit shown in Fig. 19–14. Resistor *R*-3 is incorporated in a 560-ohm resistor-type line cord. It drops the line to 35 volts for the rectifier filament. Service hints and replacement notes on resistor-type line cords are given in Chap. 18 on the AC/DC Power Supply.

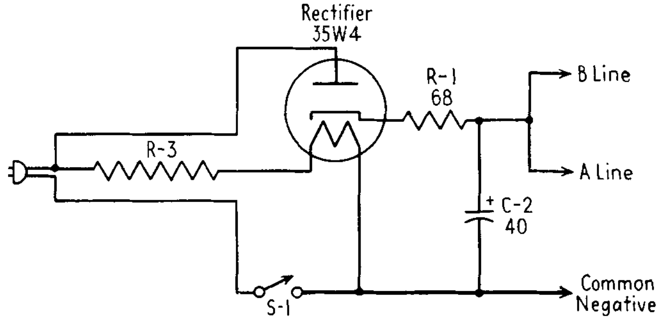


FIG. 19–14. The 35W4 tube used as the rectifier in a three-way portable receiver.

Another rectifier sometimes used in three-way portables is the 117Z3 rectifier tube. Here the full line voltage is applied to the rectifier filament, and the line dropping resistor is not used. In other respects, the circuit is the same.

TEST DATA FOR THREE-WAY PORTABLE RECEIVERS

Basic power supply diagram. A basic power-supply diagram, useful in diagnosing service problems in three-way portables, is given in Fig. 19–15. Replacement data on batteries and hints on checking tubes were given earlier in the chapter. See Fig. 19–6.

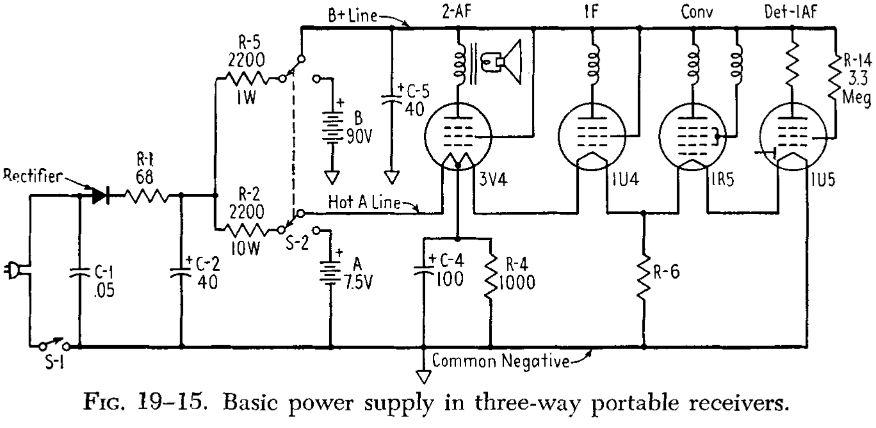


FIG. 19–15. Basic power supply in three-way portable receivers.

Normal voltage data for three-way portable receivers. Normal voltages for the line power supply are given in Fig. 19–16. Unless the complaint specifies trouble when on battery operation, service work on three-way portables is carried out in the line mode of operation. The voltage chart is given for line operation and refers to the basic circuit of Fig. 19–15. The rectifier output voltage is measured from common negative to the cathode pin of a 35W4 or 117Z3 tube rectifier. In the case of a selenium rectifier, the voltage is measured at the soldering lug marked with a plus sign. Voltage on the *B* plus line is measured at the usual test point, the screen pin of the second AF tube (pin number 3 for a 3V4 tube). The *A* plus test point is most easily found at one end of the *A* filter resistor. This is easily recognized as a 10-watt unit, the only large resistor in the receiver. Refer to the diagram of Fig. 19–15 and observe that one end of this resistor will be at a potential close to 120 volts and the other will

Voltage—	
At rectifier output	120
On the *B* plus line	90
On the *A* plus line	7.5
Across 3V4 filament	3
Across other filaments	1.5
At the first AF Screen	10

FIG. 19–16. Voltage chart for a three-way portable receiver.

measure the *A* potential of 7.5 volts. This will, of course, be 9 volts for a five-tube receiver. The screen voltage for the first AF tube is included in the voltage chart simply to make sure that it is not overlooked in a routine voltage check of the receiver. In three-way portables, voltages reading lower than 10 per cent below normal are likely to cause trouble in the receiver. This point will be discussed in more detail later.

Common troubles in three-way portables. The common troubles that develop in three-way portables are weak or dead batteries, weak or dead tubes, weak or dead rectifiers, and weak filter condensers. In addition, there are some special troubles like the open screen-dropping resistor to the first AF tube, open *A* filter resistors, and a special type of intermittent reception on line operation but normal response on battery operation. Tube considerations and replacement data for batteries were given earlier in this chapter. Replacement notes on rectifier tubes, resistor-type line cords and filter condensers were given in Chap. 18, on AC/DC receivers, and are applicable to the three-way portable receiver. Also, the open screen-dropping resistor is quickly found in a routine voltage check. The troubles peculiar to the three-way portable will now be described.

A precaution must be given for working on three-way portables. If a tube is removed from a socket, before reinstalling it or replacing it with another tube, discharge the filter condensers by shorting them. The reason for this is that the filter condensers, especially *A* filter *C*-4, become charged with a high voltage when the filament line is open. If the filament line is closed by the reinsertion of the tube before the charge is removed, the high voltage may damage one or more of the fragile filaments.

Troubles common to the selenium rectifier. The dry-plate selenium rectifier is composed of stacks of a material which shows good conductivity to current flow in one direction and high resistance to current flow in the opposite direction. This characteristic is what makes it a rectifier. It de-

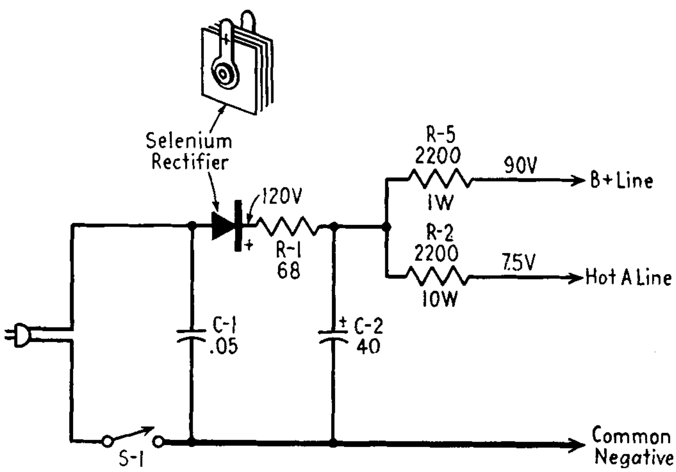


Fig. 19–17. The selenium rectifier and normal voltage measurements at test points in the power supply of three-way portable receivers.

velops troubles common to all rectifiers—it weakens with age. In addition, it sometimes allows too large a current flow in the opposite direction. In either case, the DC output voltage drops.

It would seem that a selenium rectifier is easily checked with an ohmmeter. Connect the test prods to the two terminals and find a low reading; then reverse the test prods and find a high reading for a good rectifier. A weak rectifier shows a high reading both ways. A rectifier conducting in the back direction shows a low reading both ways. All of this is true. The trouble is that for test purposes, the words "low reading" and "high reading" are relative. Actual readings will vary even in good rectifiers and will also depend on the ohmmeter circuit. The serviceman's check, therefore, is based on the DC output voltage. Refer to Figs. 19–16 and 19–17.

If the output voltage is lower than the normal 120 volts given in the voltage chart, the condition may be due to a weak rectifier, an open input filter condenser, *C*-2, or an overload in the *B* circuit. The input-condenser situation is investigated by connecting a test condenser across it and observing the effect on the rectifier output voltage. An overload will be accompanied by overheating of surge resistor *R*-1 and *B* filter resistor *R*-5. Discount heating of *A* filter resistor *R*-2, since this normally dissipates a large amount of heat. If surge resistor *R*-1 is the only one that overheats, the trouble is probably due to leakage in filter condenser *C*-2. If these checks show all else is good, the rectifier is replaced.

When replacing the rectifier, a unit rated at 75 ma will be satisfactory for most three-way portables. Be sure to observe polarity when soldering in the replacement. The lug marked with a plus sign is connected toward the filter circuits.

Troubles common to the A filter resistor. A common fault in three-way portables is caused by an open *A* filter resistor *R*-2. When this is the case,

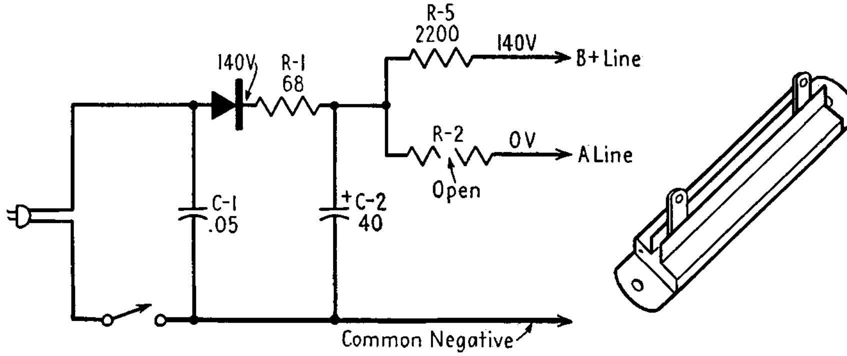


FIG. 19–18. A typical *A* filter resistor and the effect when it is open.

there is no current in the *A* line, and the receiver will not play on line operation. It will still function on battery operation.

The trouble is readily found on voltage analysis. Refer to Fig. 19–18. Voltage readings at the rectifier cathode and *B* plus will be abnormally high, since there are no *A* current drain and no *B* current drain with the filaments cold. Voltage on the hot *A* line will measure zero. Observe the precaution of discharging the filter condensers by shorting them before making an ohmmeter check to confirm the open circuit.

Any 10-watt/2,000-ohm resistor may be used as the replacement, but do not change the location, since the resistor heats; the heat in a different position may harm nearby components.

Oscillator failure in three-way portables. A fairly common complaint with three-way portables is that reception is intermittent on line operation but normal on battery operation. The set plays for a minute or so, and then cuts off. Or it continues to play until a nearby light is snapped on.

Investigation on the bench, with the set in its faded nonplaying condition, may reveal slightly lowered voltages in the power-supply section. This is likely to be ignored, however, since the set's response is apparently normal to an audio or IF test signal. Its failure to respond to an RF test signal focuses attention on the oscillator circuit. The fault is most likely to be a critical oscillator tube. When a new tube restores operation, the repair is considered completed.

The repair may be short-lived, however. The clue to the real trouble lies in the slightly lowered voltages in the power supply. Assume a small drop in the power-supply output voltage. This reduces the *B* supply and also the *A* supply. Plate circuits work with almost equal efficiency at slightly reduced voltages. The reduction in the *A* voltage reduces electron flow in the individual tubes. But in most cases, this lowers the efficiency of the tube rather than stops operation. The first circuit to feel the pinch of lowered electron flow is the oscillator. Here operation is stopped. A new tube may restore operation, since the different filament may draw more heat from the series line, or function by virtue of its slightly higher electron emission. The repair is short-lived because conditions soon equalize or the output voltage continues to drop a little lower. The correct repair is to find and correct the cause of the lowered output voltage. This will usually turn out to be a weak rectifier or a weak input filter condenser or both.

This failure of the oscillator is the reason why voltages in three-way portables should not be allowed to drop more than 10 per cent below normal, whereas *B* voltages as much as 20 per cent below normal are often disregarded in other receivers.

The sure check on the oscillator failure in a three-way portable is to measure the filament voltage across the oscillator tube. If this measures 1.3 volts or better, try operation with a new tube. If the voltage measures below 1.3 volts, look for the cause of low voltage even though a new tube may restore operation.

Changeover switches in three-way portables. Changeover switches vary considerably in different receivers in appearance and wiring details. The function, however, is the same. In addition to switching the *A* and *B* circuits of the receiver to line or battery operation, the changeover switch also throws the on-off switch into the battery circuit or the line circuit. The changeover switch circuit of the receiver in Fig. 19–21 has been redrawn in Fig. 19–19 as a typical example. Note how the lower section of on-off switch S-1 is changed from the common negative of the line to the common negatives of the batteries by the lower section of changeover switch S-2.

Fortunately, changeover switches give very little service difficulty. Occasionally, the contacts may need a cleaning. A wash with alcohol or carbon tetrachloride, supplemented by snapping the switch a few times, is usually all that is required. The snapping is done by inserting and removing the line cord from the special receptacle.

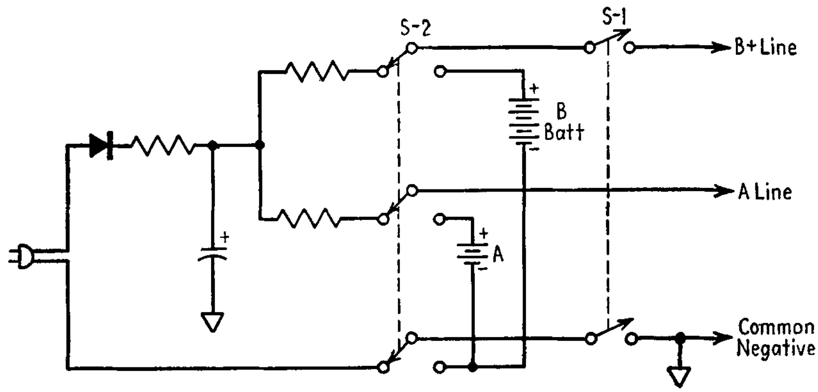


FIG. 19–19. Change-over-switch circuit in the receiver shown in Fig. 19–21.

Typical circuits. The complete schematic of the RCA Model 9BX56 receiver is given in Fig. 19–20 as an example of a four-tube three-way portable. The five-tube Truetone Model D3265A is given in Fig. 19–21.

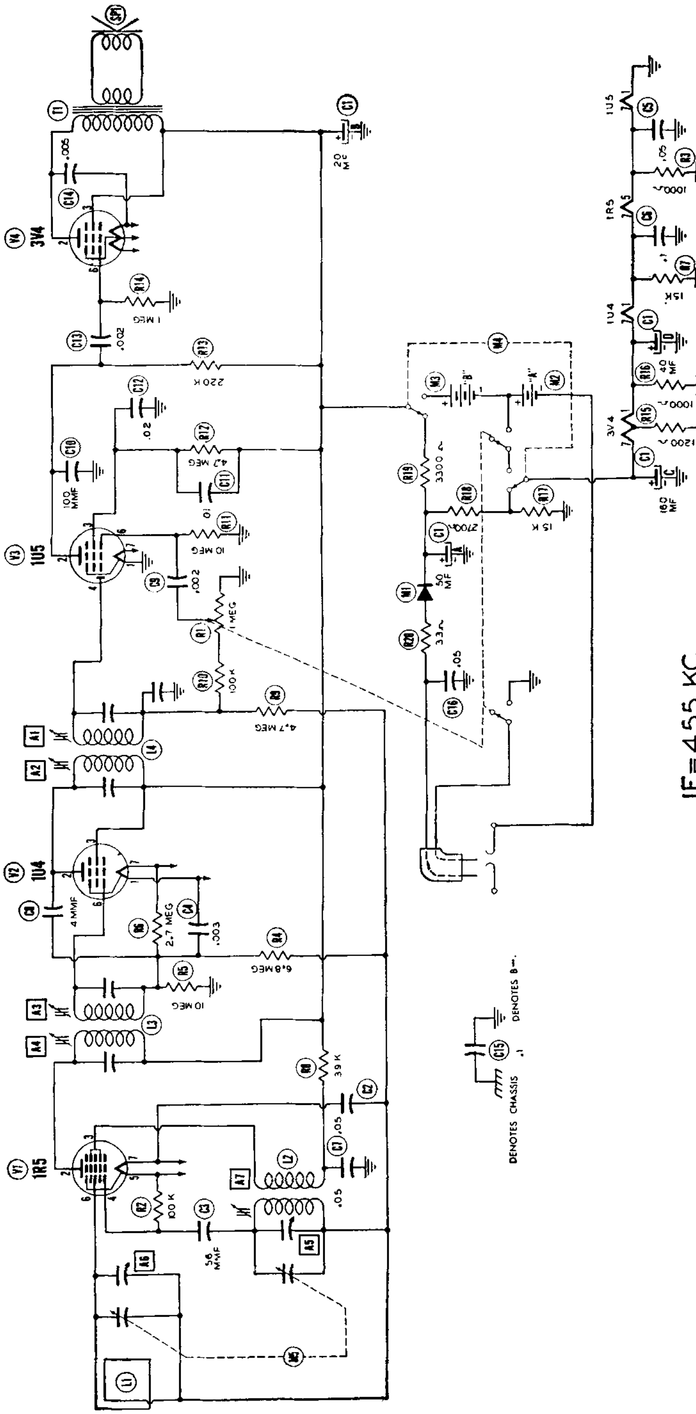


FIG. 19–20. Schematic diagram of the RCA Model 9BX56 receiver.

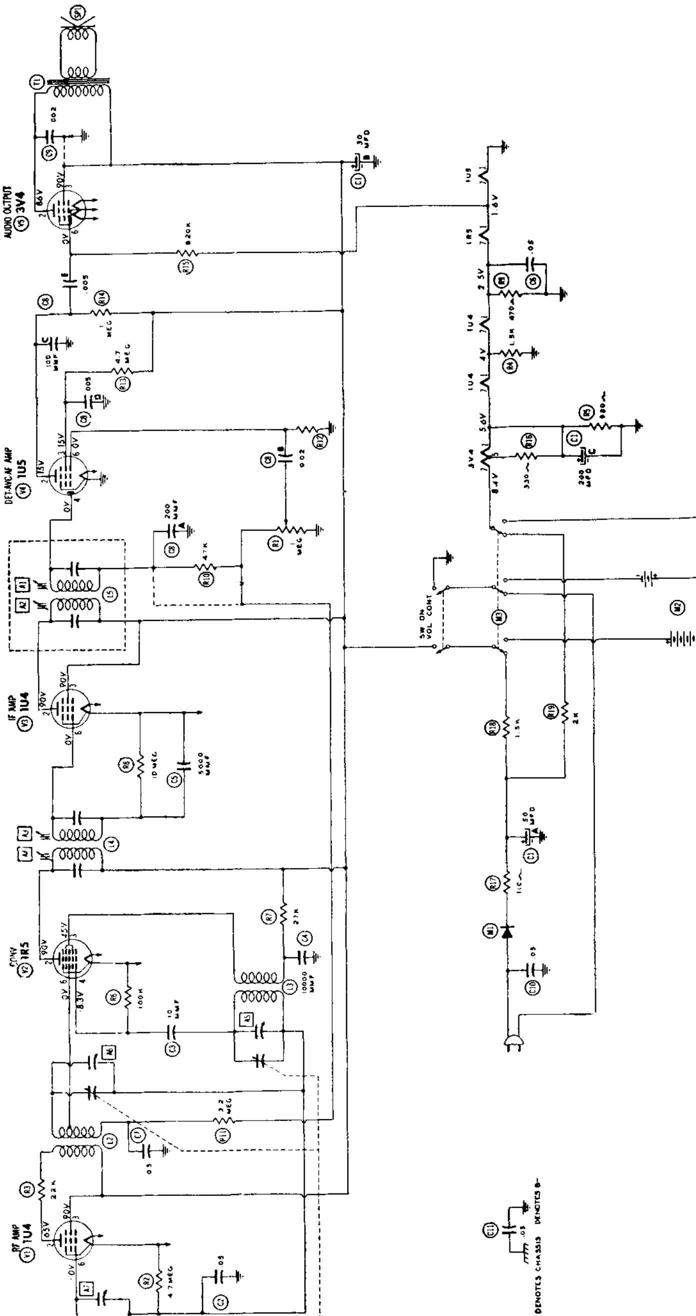


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FIG. 19–21. Schematic diagram of the Truetone Model D3265A receiver.

SUMMARY

Standard circuits

A standard diagram of the *A* and *B* circuits of a battery portable receiver is given in Fig. 19–22. A basic power supply circuit of a three-way portable receiver is given in Fig. 19–23.

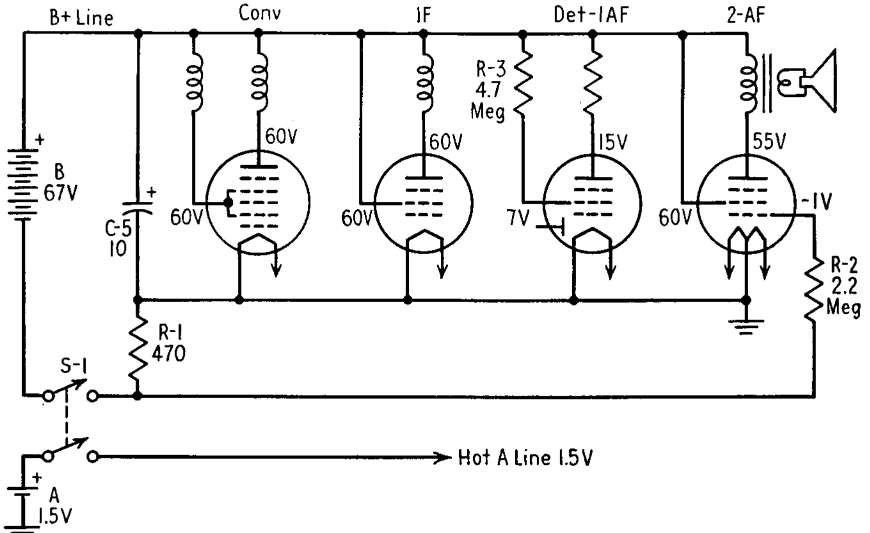


FIG. 19–22. Basic *A* and *B* circuits of a battery portable receiver.

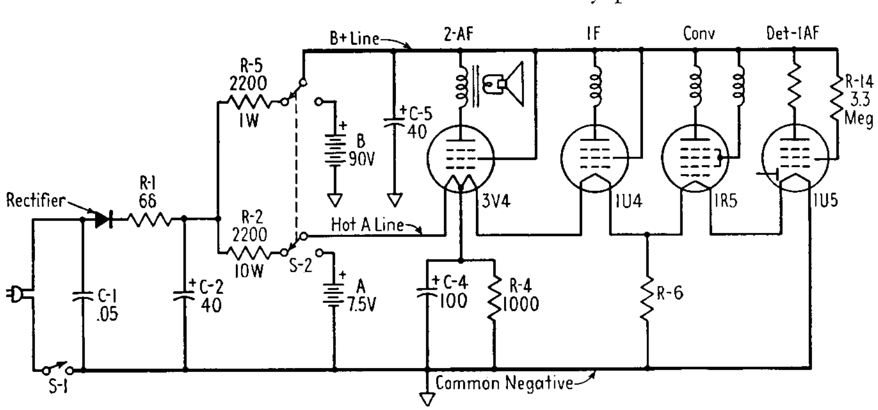


FIG. 19–23. Basic *A* and *B* circuits of a three-way portable receiver.

Battery voltage table

Batteries in portable and three-way receivers should be tested with a voltmeter under normal load conditions. Test them in the set, with the switch turned on, and the set in the battery mode of operation. Normal readings are given in the accompanying table.

Battery	*Normal Reading*	*Replace*
1.5-volt *A*	1.3–1.5 volts	Below 1.3 volts
7.5-volt *A*	6.5–7.7 volts	Below 6.5 volts
9.0-volt *A*	7.8–9.3 volts	Below 7.8 volts
67-volt *B*	58–70 volts	Below 54 volts
90-volt *B*	78–93 volts	Below 72 volts

Precautions and service hints for portable receivers

Do not look for tubes to light. Test them in a tube checker. Filament continuity may be checked on the R $\times$ 100 ohmmeter range. Do not use the low-ohm range, which may burn out tube filaments. Unplug batteries when making resistance checks. Look for full voltage in the power supply of three-way portables. Allow a tolerance of no more than 10 per cent below voltage readings. When a tube is removed from a three-way portable for test purposes, remove the receiver plug and momentarily short each filter condenser before replacing the tube in the set.

Chart of normal voltages

Normal voltage readings at strategic points in battery portables are given in the diagram of Fig. 19–22. Normal voltages in the power supply of the three-way portables are based on the diagram of Fig. 19–23, and are given in the accompanying chart:

Voltage at rectifier output	120 volts
Voltage on the *B* plus line	90 volts
Voltage on the *A* plus line	7.5 volts
Voltage across the 3V4 filament	3.0 volts
Voltage across other filaments	1.5 volts
Voltage at the first AF screen	10 volts

Servicing procedure for common troubles in battery portables

1. Check batteries.
2. Check tubes.
3. Check decoupling filter condenser *C*-5 of Fig. 19–22 for squealing or motorboating.

4. Check screen-dropping resistor *R*-3 for an inoperative audio amplifier.

For all other trouble use the standard servicing procedure.

SERVICE DATA CHART OF COMMON TROUBLES IN THREE-WAY PORTABLES

The following chart refers to the basic diagram of Fig. 19-23.

Symptom	*Abnormal test condition*	*Look for*
Set does not play	Voltage at *A* plus line is 30 volts instead of its normal 7 volts	Open filament in 1R5, 1U4' or 1U5
Set does not play	Voltage at *A* plus is 120 volts or more	Open filament in 3V4
Set does not play	Voltage at *B* plus is high; voltage at *A* plus is zero	Open filament resistor R-2
Set does not play	Voltage at *B* plus is low	Open input filter condenser C-2. Short or leakage in *B* plus line. Weak rectifier
Set squeals or motorboats	Voltage check is normal	Open output *B* filter condenser C-5
Intermittent operation	Power supply voltages are normal	Inoperative oscillator section of converter tube. Replace 1R5
Intermittent operation	Power supply voltages are low. Voltage across 1R5 filament is below 1.3 volts	Low line voltage. Weak rectifier. Weak input filter condenser C-2
Set does not play	Power supply voltages are normal. Voltage at 1U5 screen is zero	Open screen resistor *R*-14

QUESTIONS

1. List the precautions to be observed when working on battery and three-way portable receivers.

2. A battery portable receiver does not play. The batteries are tested in the set with the switch on. The flashlight-cell *A* battery reads 0.9

volt; the 67-volt *B* battery reads 65 volts. Which battery should be replaced?

3. A battery portable receiver motorboats. What is likely to be wrong?

4. The battery portable receiver of Fig. 19–5 comes in with a complaint of poor tone. Outline a procedure you would use to find the trouble.

5. A three-way portable receiver does not play on battery or line operation. The batteries are tested first, and the 7.5-volt *A* battery reads 7.2 volts regardless of whether the set switch is turned on or off. What is likely to be wrong?

6. The receiver of Fig. 19–20 does not play on line operation. A voltage check of the power supply, taken at the filter condenser leads, gives the following readings:

At condenser *C*-1A	140 volts
At condenser *C*-1B	135 volts
At condenser *C*-1C	0 volt
At condenser *C*-1D	0 volt

What is likely to be wrong? How would you confirm this suspicion?

7. A three-way portable does not play on battery or line operation. All tubes test good in a tube checker. The *A* battery is good; the *B* battery is dead. Voltage check on line operation gives the following results:

Voltage at rectifier output	80 volts
Voltage at *B* plus	0 volt
Voltage on the *A* plus line	5 volts

What is likely to be wrong? How would you go about finding the trouble?

8. A three-way portable does not play on battery or line operation. The batteries are dead. The tubes check good in a tube checker. A voltage check on line operation shows normal results. The audio section responds to a test signal at the volume control. The signal generator drives a 455-kc test signal through the receiver when fed through an injection loop. An RF test signal gives no response. A voltmeter across the 1R5 filament prongs reads 1.4 volts. What is likely to be wrong? How would you confirm the suspicion?

9. In the receiver of Fig. 19–21, the grid load of the 3V4 tube is returned to the hot side of the 1U5 filament, rather than to common negative. What is the bias voltage that this connection establishes on the power tube?

20 AUTOMOBILE RADIO INSTALLATION

Radios designed to operate in automobiles are, for the most part, superheterodyne receivers incorporating radio frequency, converter, intermediate frequency, detector, two audio stages, and a power supply. This chain makes the auto receiver very similar to the standard home receiver. The differences lie in the special provisions made for operation under the conditions found in an automobile. These include reception with a small antenna, operation in a field of considerable radio noise disturbance due to the electrical system of the car, and utilization of the power source available—the 6-volt storage battery.

The same servicing procedures which locate a defective IF transformer, for example, in a home receiver, will locate a similar fault in an auto receiver. This chapter and the next, therefore, will deal with the special servicing problems which relate to auto receivers alone—to repeat, operation with a short antenna, electrical noise, and the auto radio power supply.

The first two are primarily design and installation problems rather than service problems. However, since the radio serviceman is often called upon to install auto radios, change them from one car to another, or check for motor noise, these items will be covered in some detail in this chapter. The next chapter deals with the auto radio power supply.

Typical auto radio installation. Figure 20–1 shows a typical auto radio installation. The receiver itself is usually mounted to the dash of the car behind or below the instrument panel. The antenna shown is the one in most common use, the side-cowl antenna, sometimes called the "buggy whip." It is insulated from the car and is connected to the radio receiver by a length of low-capacity, shielded lead-in wire. Power for the receiver is usually obtained through a lead connected to the ammeter on the instrument panel, and the ammeter is in turn connected to the "hot" side of the storage battery. The car frame or chassis acts as the common return lead. The receiver picks up a ground connection through its mounting bolts to the dash, and the ground side of the battery is connected to the car frame by a heavy bonding strap. The radio controls, dial, volume, etc., are usually mounted in a cutout designed for the purpose on the instrument panel of the car.

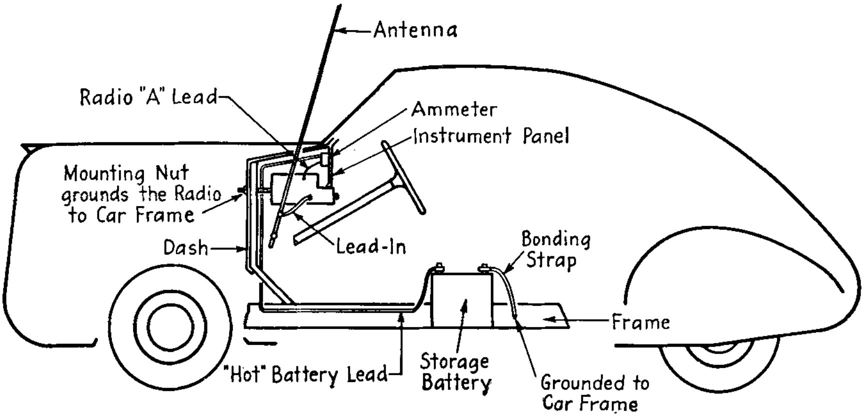


FIG. 20–1. Typical automobile radio installation.

Antennas for auto radios. The auto radio antenna most often used is one of the types that mount on the cowl of the car. This is a vertical telescopic antenna, the maximum length of which averages about 4 ft.

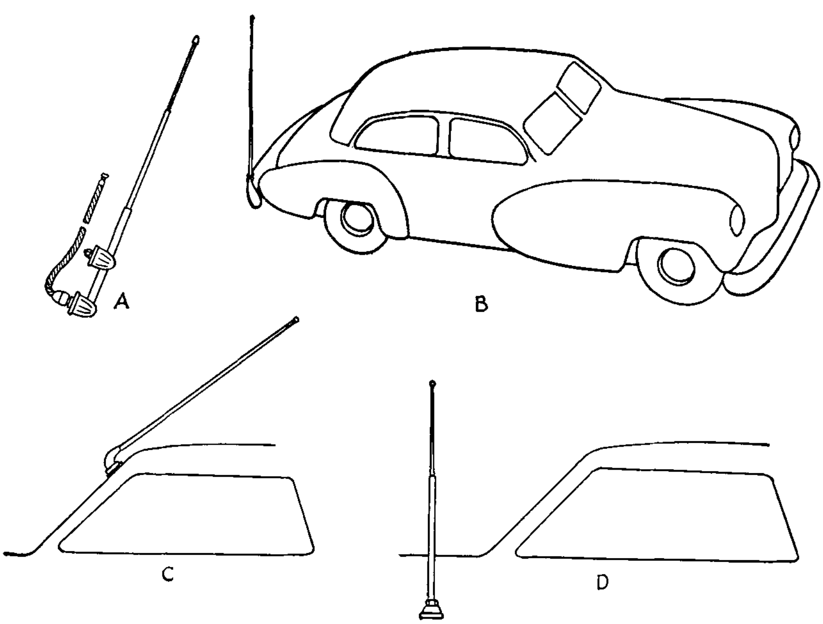


FIG. 20–2. Common automobile radio antennas. (*A*) Side cowl; (*B*) rear-bumper mount; (*C*) topper; (*D*) disappearing cowl.

The telescopic sections are plated for appearance and freedom from corrosion. The type illustrated in Fig. 20–2*D* is adjustable in length from inside the car. These antennas are extended to full length to permit maximum signal pickup. The topper antenna illustrated in Fig. 20–2*C* is a similar type and is mounted over the roof of the car. The topper is usually not adjustable. The rear-bumper type of antenna, shown in Fig. 20–2*B*, has an extended length of 8 ft or more. It is particularly useful in areas where signal strength is low, since the longer antenna has greater signal pickup capabilities.

Auto radio antenna coupling circuits. The coupling between the antenna and the RF amplifier grid is somewhat different in auto radios than in home radios, in that provision is made to tune the input circuit so as to match it with the antenna being used. This allows for maximum transfer

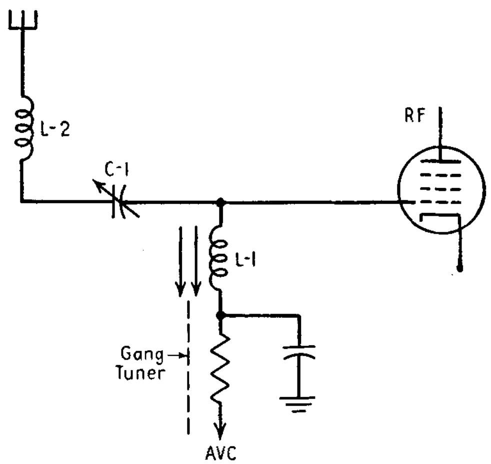


FIG. 20–3. Typical automobile radio antenna coupling circuit.

of energy of the small signal pickup of the short antenna to the receiver. A typical auto radio antenna-coupling circuit is shown in Fig. 20–3.

The antenna signal is impressed across the tuning circuit, consisting primarily of antenna condenser *C*-1 and permeability-tuned coil *L*-1. Coil *L*-1 is ganged with similar permeability-tuned coils in the oscillator and mixer stages. The junction of condenser *C*-1 and coil *L*-1 feeds the signal grid of the RF amplifier tube. Coil *L*-2 is a loading coil to compensate for the low inductance of the short antenna.

For installation purposes, it is important to know that trimmer condenser *C*-1 is accessible for adjustment through a hole in the metal-shielded cabinet of the receiver. This provision is made so that the receiver may be matched to the antenna being used. After the set has been installed in the car, the usual procedure is to extend the antenna to full length, tune to a weak station around 1400 kc, and to peak the antenna trimmer *C*-1 to maximum volume.

Motor interference. From the point of view of the generation of RF interference, the ignition system of an automobile is really a spark transmitter. The sparks at the distributor and the spark plugs feed RF energy to the ignition wiring, which may be looked upon as the transmitting antenna or source of the ignition interference. The radiations feed energy to the entire electric system of the car and to any ungrounded metal parts in or near the motor compartment. The diagram of Fig. 20–4 represents the ignition system as a transmitter.

The signal generated by the ignition system is very broadly tuned and will cover the entire broadcast band. Its strength in the near vicinity of the motor compartment is about equal to that of a strong local broadcast station. As a result, if no provisions were made to reduce the ignition signal, it would be received by an automobile radio all over the tuning range equally as strong as a strong local station, thereby interfering with all reception. Interference from this source is called "ignition" interference and can be identified as a series of ticks in the speaker at the same rate of speed as the spark plugs are firing in the motor.

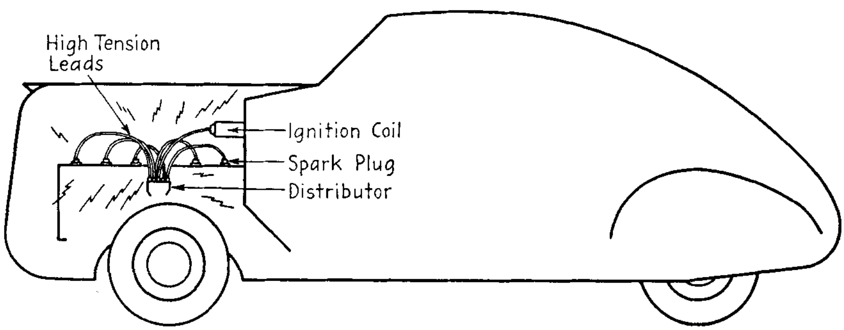


FIG. 20–4. RF interference from the ignition wiring.

The generator is an additional source of disturbance because of the sparking at the brushes. The generator noise is distinguishable because its pitch is higher than that of ignition noise. Still another source of noise is a static electricity charge, generated by the rotating wheels, discharging periodically to the axle.

General notes on reduction of motor interference. The reduction of motor interference to a point where it will not disturb broadcast reception takes in three main factors. The RF radiation is reduced at the source by means of suppression, shielding, etc. The antenna is placed in a position where it will receive a minimum of signal from the motor. The radio itself is thoroughly shielded, so that the only signal applied to it comes from the antenna.

Reduction of ignition interference. Radiation from the ignition system can be reduced by installing a suppressor resistor in series with the high tension lead, which connects the ignition coil and the center connection of the distributor. Figure 20–5 shows a typical distributor-suppressor installation. The suppressor should be installed close to the distributor connection.

The resistor in the distributor lead reduces oscillations produced by the spark and, therefore, radiation. In the case of early automobile radios, suppressor resistors were also installed in each sparkplug lead. This procedure would affect the motor performance by reducing the intensity of the spark and is not recommended. Fortunately, a careful installation makes it unnecessary to use more than the one suppressor resistor in the distributor lead. This does not materially affect motor performance.

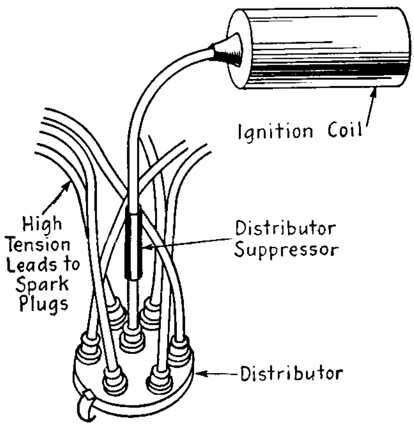


FIG. 20–5. Distributor-suppressor installation.

In the case of some cars, the high-tension wiring to the distributor is inaccessible. On these cars, a distributor suppressor cannot be used.

In modern motors, the distributor is usually centrally located with respect to the cylinders, and the ignition coil is close by, thereby making for short high-tension leads with a consequent reduction in radiation from these leads. In addition, some car manufacturers route the high-tension leads through metal conduits or spreaders that are grounded to the motor block, thereby partly shielding the leads and further reducing radiation.

The metal hood that covers the motor compartment is an important point in the reduction of ignition noise. When the hood is well grounded, a shield is interposed between the motor compartment and a roof or side antenna. The hood hinges and its holding clamps may not make good electric contact with the car frame. A hood bond is usually employed to ensure the effectiveness of the shield.

Figure 20–6 shows a typical hood-bond installation. The bond is a piece of brass one surface of which has been serrated to give an effect like the teeth of a rasp. The bond is attached to the cowl panel by means of a self-tapping screw in such a way that the teeth are on top of the hood weather stripping. The self-tapping screw gives a good contact to the cowl panel while the teeth of the hood bond make good contact to the hood when it is closed.

In the above discussion, the importance of shielding the motor compartment has been stressed. However, the serviceman should be warned against making any attempt to shield the high-tension wires themselves. Although this may be effective in reducing ignition noise, it must be remembered that the shielding would constitute a nearby ground to leads which are carrying current at extremely high voltage, and excessive leakage would result. Since the high-tension wiring is the main source of ignition noise, and the dash, hood, and car chassis form a shielded

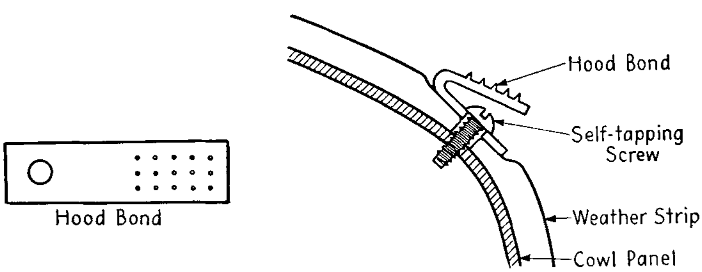


FIG. 20–6. Hood-bond installation.

compartment around the source, any antenna installed outside of this compartment will be relatively free of ignition noise.

Reduction of chassis pickup. The radio itself is thoroughly shielded by its container so that there will be no pickup of signal (motor noise or otherwise) from any source but the antenna. Figure 20–7 shows a top view of a typical installation. The mounting nut that holds the radio to the dash provides the ground for the radio. The installation man should carefully remove paint from under the nut so as to make sure of this ground contact. Another good ground contact is established at the antenna end of the shielded lead-in wire. The cup that encloses this contact usually has a serrated surface, which makes good contact to the body cowl when the antenna assembly is tightened in place.

In spite of the shielding, motor interference sometimes gets through to the radio owing to its position in a relatively noisy field. Interference of this type is known as "chassis pickup." It can be identified by its presence even after the antenna is disconnected from the radio.

Interference of this type is usually carried to the radio by the steering column, temperature and oil-line tubing, and brake, throttle, and speedometer cables that lead through the dash to the motor compartment. It can be removed by bond-grounding the cables where they enter the

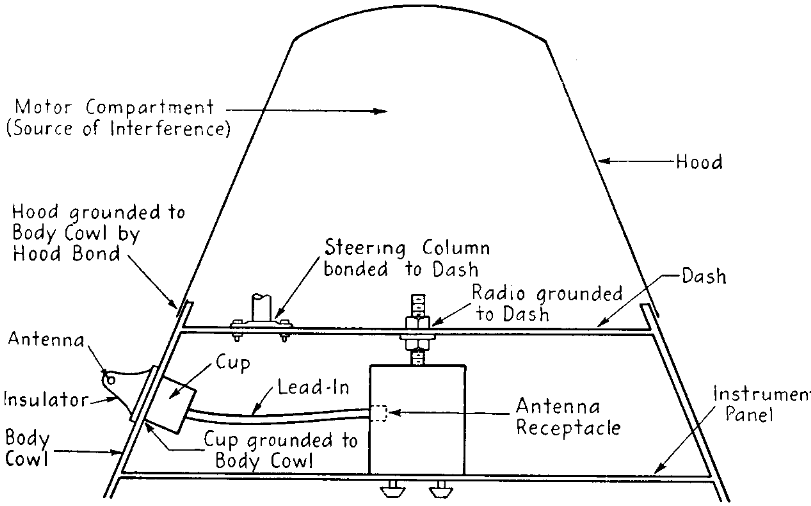


FIG. 20–7. Top view of automobile radio installation.

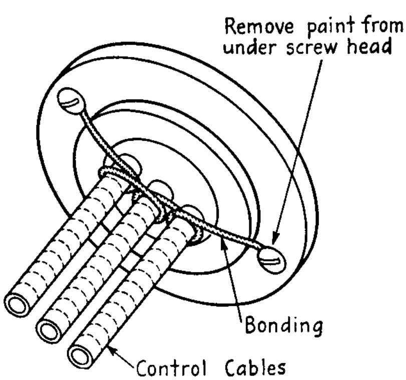


FIG. 20–8. Control-cable bonding installation.

dash from the motor compartment. Figure 20–8 shows a method of connecting the ground. The cables, tubing, and steering column are cleaned with fine emery or sandpaper. The bonding braid is wrapped and connected under the holding screws as shown. Paint is removed from under the screw head. The connection can be made permanent by spot-soldering the braid to the cable.

Any wiring, other than the antenna, entering the radio, like the battery lead or the leads to an external speaker, is also a possible source of noise. However, the original design of the radio places filters at the entrance point for this wiring inside the radio, to bypass any motor interference. These filters are in a low-voltage circuit and do not break down. From the servicing point of view they may be neglected.

Reduction of generator interference. Sparking at the commutator of the car generator will also cause interference. This type will be recognized as a high-pitched whine which increases in pitch and intensity as the motor speed is increased.

Generator interference is reduced by installing a condenser on the generator. The latter usually has two terminals: one marked *A* for the armature, and the other *F* for the field winding. The generator condenser is connected from ground to the armature terminal as shown in Fig. 20–9. The installation man should remember the usual precaution of removing paint from under the ground connection.

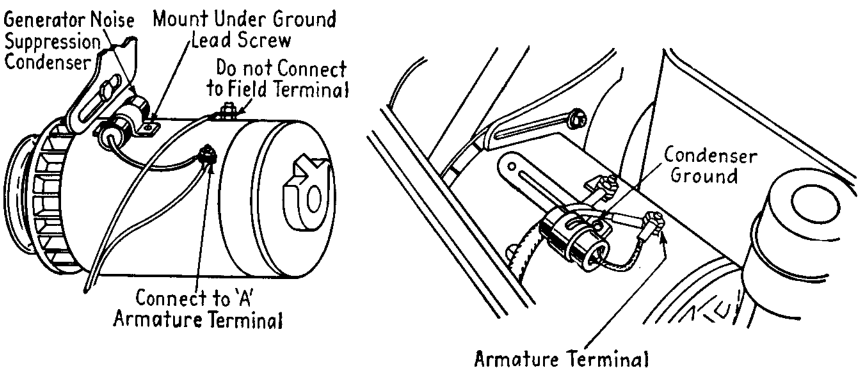


FIG. 20–9. Generator-condenser installation.

Reduction of wheel static interference. The wheels, in turning, generate static electricity which discharges to the axle, thereby radiating some RF interference. Sometimes a cowl antenna will pick up some disturbance from this source. The front wheels are the greater offenders, since they usually are weighted for wheel-balancing purposes. In addition, the rear wheels are usually grounded more effectively, thereby preventing the generation of static charges.

Wheel-static interference usually starts when the car is traveling at a fair speed on a smooth, dry road. It can be recognized by driving until the interference starts and then turning off the ignition key and coasting. If the interference persists with the motor turned off and gradually disappears as the car loses speed, it is caused by wheel static.

This type of interference can be reduced by installing static-collector springs. The latter are spring contacts that ground the wheel to the axle, thereby eliminating the static. Various types of collector springs are available to fit the various makes of automobiles. Figure 20–10 shows the installation of two typical static-collector springs. Wheel weights should be cleaned for good contact to the tire rims.

Checking for motor interference. Motor interference need not be entirely eliminated. Like hum in a home radio receiver, a certain amount of motor interference is permissible. Good judgment should be used as to just how much interference is objectionable. The car owner, of course, is the final judge in this regard, but the serviceman should have some idea of a normal degree of motor interference.

In general, reception from local stations should be completely free of motor interference. A slight amount of it may be tolerated when listening

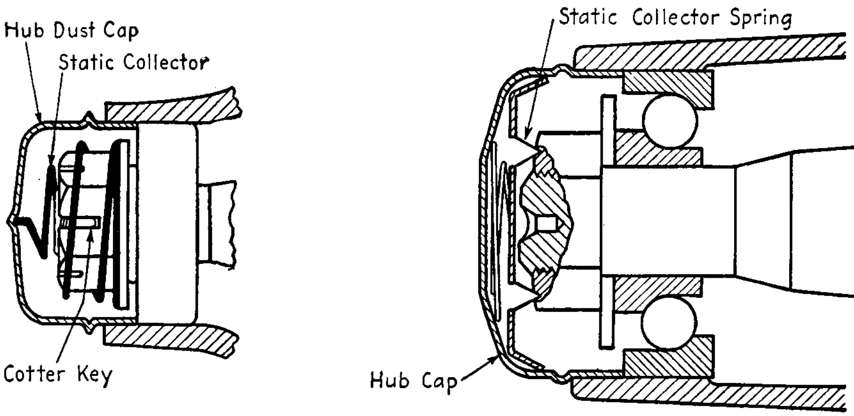


FIG. 20–10. Front-wheel static-collector-spring installation.

to weak distant stations, since a high noise level is the general expectation in this case. When the radio is tuned to a position between stations, the AVC circuit brings the receiver to a condition of maximum sensitivity, and some motor interference can be expected. Some automobile radios have noise-reducing squelch circuits. When this is the case, the receiver is prevented from reaching maximum sensitivity, and there should be no motor interference, regardless of the position of the receiver dial.

After the receiver has been competently installed and the motor interference is eliminated, there is usually very little service work needed in connection with motor interference. The interference condensers operate in low-voltage circuits and rarely break down. Occasionally, a condenser or bonding strap is removed in connection with general repair work on the automobile and is not replaced. A bonding strap may break, or grounding nuts may become loose. Any of these will cause complaints of motor interference. Usually, a visual inspection of the installation will locate the faulty condition.

The motor compartment should include a properly installed generator condenser and distributor resistor. Further inspection takes in the mounting nut for the radio and the ground connection at the antenna end of the shielded lead-in wire. The hood bond comes next.

If the inspection does not reveal the trouble, the source of the motor interference may be more quickly localized by disconnecting the antenna plug from its receptacle and substituting a specially prepared antenna plug which grounds the antenna wire to the plug casing. If the motor noise stops, the antenna installation should be rechecked more carefully. If the motor noise continues, it is caused by chassis pickup, and the

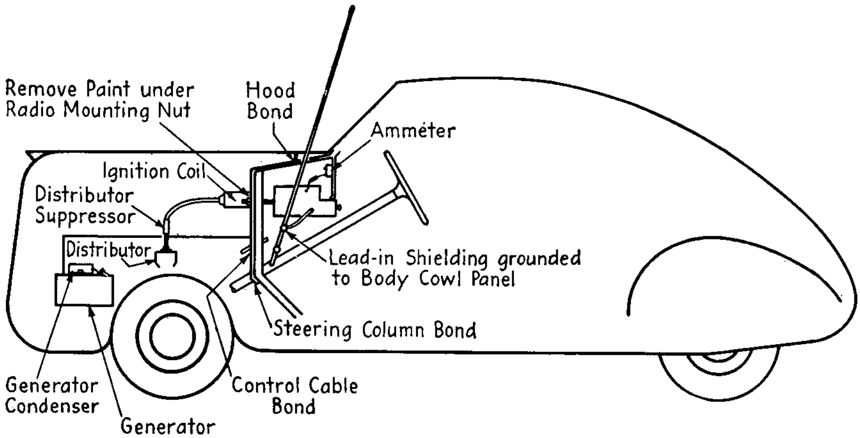


FIG. 20–11. Standard automobile radio installation for side-cowl antennas.

receiver ground and bonding of the tubing, which leads through the dash, should be more carefully checked. As an aid in locating check points, Fig. 20–11 shows a standard installation for cars with cowl antennas.

GLOSSARY OF AUTOMOBILE RADIO TERMS

Bond. A lead used for grounding to the car chassis. It is usually a short, heavy, flat, flexible piece of tinned and braided copper, provided with connection lugs.

Buggy-whip antenna. Same as the side-cowl antenna.

Cowl. The section of the body that is between the motor section and the front doors.

Dash. The wall between the motor compartment and the driver's compartment. The dash is sometimes called the "fire wall."

Distributor. The part of the ignition system that operates like a rotary switch to transfer the ignition current from the ignition coil to the various spark plugs in rotation.

Generator. The part of the automobile electric system that charges the storage battery. It is operated by the motor, usually by means of the fan belt. A generator is shown in Fig. 20–9.

Hinge antenna. An antenna similar to the side-cowl type, but with a one-point mount designed to be fitted to the pin of the door hinge.

Hood. The hinged cover of the motor compartment.

Ignition coil. The part of the ignition system that supplies the high voltage required for firing at the spark plugs. It is cylindrical in shape and is usually mounted in the motor compartment.

Ignition wiring. The varnished high-tension leads that carry the ignition current from the ignition coil to the distributor, and from the distributor to the spark plugs. The distributor, ignition coil, and ignition wiring are shown in Fig. 20–5.

Instrument panel. The panel directly below the windshield on which is mounted the ammeter, speedometer, gas gauge, etc. It is sometimes called the "dashboard."

Side-cowl antenna. An antenna mounted on the cowl.

Topper antenna. An antenna designed to be mounted over the roof of the car.

Turret top. An all-metal body construction, which includes the roof of the car and prevents the use of any antenna inside the car.

SUMMARY OF GENERALIZED INSTALLATION NOTES

The installation of radios in automobiles offers individual problems depending on the type of car and the type of radio. The serviceman is referred to the instruction sheets that come with the radio for dealing with specific cases. Certain recommendations will apply to all installations, and these are tabulated below.

1. Clean the area around the holes for mounting the radio so as to establish a good chassis ground contact.
2. Establish a good ground connection for the antenna end of the lead-in wire.
3. Connect the antenna and "hot" battery lead, and adjust the antenna compensating condenser.
4. Install the generator condenser and distributor suppressor.
5. Install hood bonds if needed.
6. Bond steering column and control cables as they enter the dash.
7. Check for motor interference.
8. Check for wheel static.

QUESTIONS

1. An automobile radio has the following motor interference complaint: a high-pitched whine which gets louder and higher pitched as the car speed is increased. What is likely to be wrong? How would you correct it?

2. An automobile radio is troubled with motor interference only while the car is in motion. What is likely to be the cause of the trouble, and what is the remedy?

3. An automobile radio operating with a cowl antenna is troubled with motor interference, which stops when the antenna is disconnected. Outline your check procedure in servicing this complaint.

4. What is the check for chassis pickup? How is interference from this source reduced?

5. A side-cowl antenna is removed from an auto, and a topper antenna is installed. The radio then shows low sensitivity. What readjustment should be made?

21 AUTO RADIO POWER SUPPLIES

Quick check. If all the tubes in the receiver light, the vibrator is buzzing, the hum and hash level are normal, and the *B* plus voltage measures approximately 200 volts, the auto radio power supply is probably functioning normally.

Function of the auto radio power supply. The function of the auto radio power supply is like that of any other type: to furnish the necessary *A*, *B*, and *C* voltages to the filament, plate, and grid circuits of the rest of the receiver. In this case, the power source is the 6-volt storage battery, which is standard equipment for the electric system in the automobile.

THEORY OF OPERATION OF THE AUTO RADIO POWER SUPPLY

The *A* power or heater circuit of the auto radio is quite simple. All tubes are of the 6-volt heater type, and are connected in parallel and fed

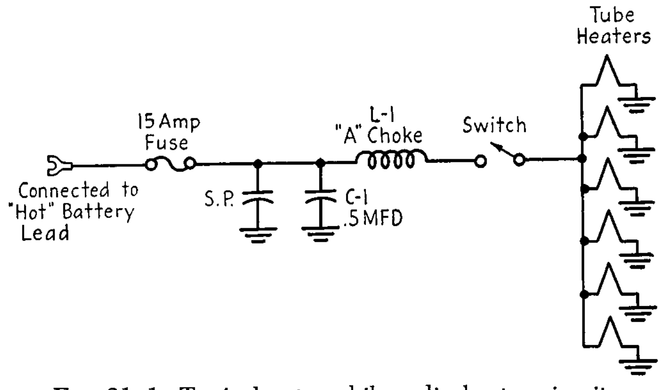


FIG. 21–1. Typical automobile radio heater circuit.

directly from the battery. The only special provision made is the installation of a filter circuit designed to prevent motor noise from entering the radio through the "hot" battery lead. Figure 21–1 shows a typical *A* power-supply circuit.

The condenser marked S.P. is connected to the "hot" battery lead at the point where it enters the receiver. It consists of a metal plate insulated from the chassis by a thin sheet of mica. The piece of metal is one plate of the condenser, and the chassis is the other. Condensers of this type are called "spark plates." Figure 21–2 shows such a spark plate connected in the circuit. They have a very small capacity but are effective in filtering RF currents. The rest of the filter consists of the 0.5-mfd condenser *C*-1 and the RF *A* choke *L*-1. The latter is about 30 to 50 turns of heavy wire wrapped in the form of a flat coil, the diameter of which is approximately 1½ in. The choke offers opposition to any current at radio frequency, while the two condensers offer an easy path to ground, thereby keeping radio frequency out of the receiver from this source. The choke is wound with heavy wire in order to carry the heavy current of the receiver (5 to 8 amp).

Auto radio B power supplies. Early auto radios were entirely battery-operated. The car battery was used for the *A* supply and a set of *B*

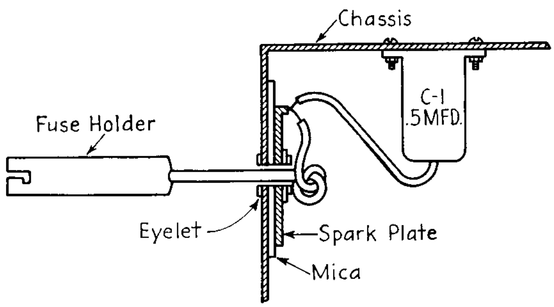


FIG. 21–2. Spark-plate filter connected to the "hot" battery lead at the point of entry to the receiver.

batteries took care of the plate requirements of the receiver. The next step was replacing the *B* batteries with a dynamotor powered by the car battery. The dynamotor combines motor and generator in one unit, the motor operating from the 6-volt battery, and the generator delivering an average DC output of 180 volts at 50 ma. Dynamotors are still used as the source of high potentials suitable for *B* power in a large number of mobile electronic devices. However, in automobile radios, a vibrator type of *B* power unit was developed and has been universally adopted. This chapter, therefore, will confine the discussion entirely to the vibrator type of *B* power supply.

Vibrator-type B power supplies. Vibrator-type *B* power supplies operate by changing the magnetic field that results from a direct current in the primary of a step-up transformer. The changing field induces high alternating voltage in the secondary of the transformer. The secondary voltage is then fed through a rectifier and a filter in the usual way to supply the high-voltage direct current necessary to operate the plate circuits of the receiver. This sequence can be illustrated by the block diagram of Fig. 21–3. Grid bias voltage or C power supply is obtained in the usual way by self-bias or voltage divider circuits.

Some receivers use a mechanical rectifier consisting of an extra pair of points on the vibrator. Such a system is known as a "synchronous-

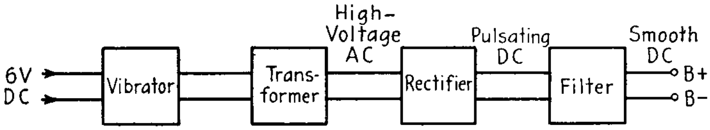


Fig. 21–3. Block diagram of a vibrator-type B power supply.

vibrator" type of power supply and is described in the variations section of this chapter.

How the vibrator works. To understand vibrator operation consider first the circuit of Fig. 21–4. The battery sets up a steady magnetic field in the core of the transformer. A steady magnetic field does not induce voltage in the secondary. If the battery terminals are reversed, the magnetic field goes through a reversal, which is a change that induces voltage in the secondary winding.

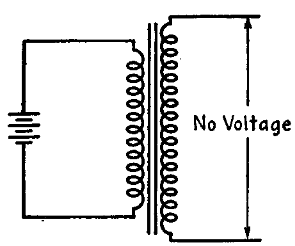


Fig. 21–4. Transformer fed with direct current.

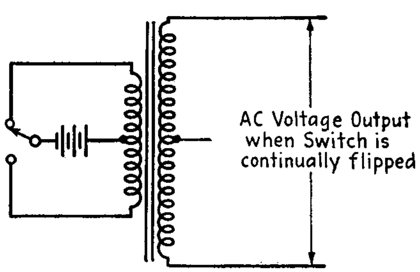


Fig. 21–5. Reversing direct current through a transformer primary.

The reversal of the magnetic field could be accomplished by using a single-pole, double-throw switch and the circuit of Fig. 21–5. The primary winding is center-tapped, and the battery connected to the tap. When the switch is in the position shown, current flows through the top half of the primary winding and sets up a magnetic field. When the switch is thrown and makes contact with the bottom terminal, current flows through the bottom half of the primary winding and sets up the opposite magnetic field. The changing field induces voltage in the secondary winding. When the switch is thrown again, the magnetic field is reversed, inducing a secondary voltage in the opposite direction. If the switch is thrown rapidly, an alternating voltage is set up in the secondary winding.

If the switch of Fig. 21–5 is replaced by a pair of contacts on a magnetically vibrating reed, we have the basic circuit of all vibrator type *B* power supplies. This is shown in Fig. 21–6. At the starting position, current flows through the top half of the transformer primary winding and the vibrator coil, which are in series. The vibrator coil becomes an electromagnet which attracts the reed upward, making the top contact. The top contact shorts out the vibrator coil, and a heavy current flows through the top half of the primary winding. The deenergized vibrator coil allows the reed to break the top contact, swing through the starting position, and make the bottom contact. This drives a heavy

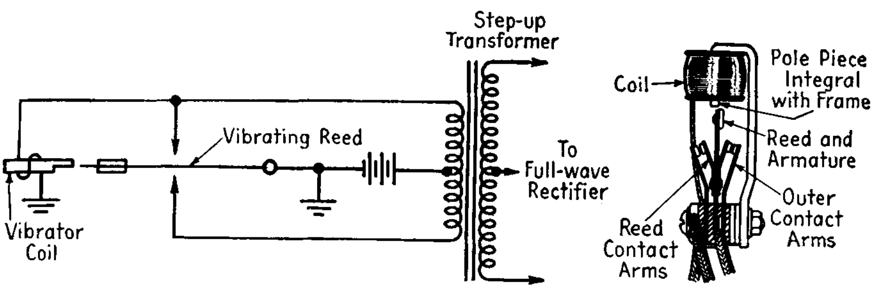


FIG. 21–6. A typical vibrator used in automobile radio power supplies and a basic vibrator circuit.

current through the bottom half of the transformer primary reversing the magnetic field. The broken top contact removes the short across the vibrator coil, and it is energized once again, attracting the reed upward. This cycle of events repeats itself continuously. The constant reversal of the magnetic field in the core of the transformer induces an alternating voltage in the secondary winding. The frequency of this alternating voltage is determined by the mechanical structure of the vibrator. This is adjusted by vibrator manufacturers to be approximately 115 cycles per second.

Vibrator hash. The making and breaking of current at the vibrator contacts are accompanied by sparking. The sparking decreases the life of the vibrator points and causes RF interference in the receiver. This interference is known as "hash." Practical vibrator circuits include provision for spark suppression and hash filters. A typical circuit is shown in Fig. 21–7.

Condenser *C*-3 is known as the "buffer" condenser. It takes up the high-voltage surges that would otherwise result from the rapid magnetic changes taking place during the time the reed is traveling between contacts. It also is effective in reducing sparking at the contacts. The condenser stores energy during high-voltage periods. The discharge circuit is the transformer, and the inductance of the transformer forms an oscillating circuit with the capacity of the condenser. For this reason, the capacity of the buffer condenser is an important factor in the design of the power supply, and its value should not be changed in service work. The buffer condenser is sometimes called a "surge condenser" or a "timing capacitor." Common values for the buffer condenser vary from

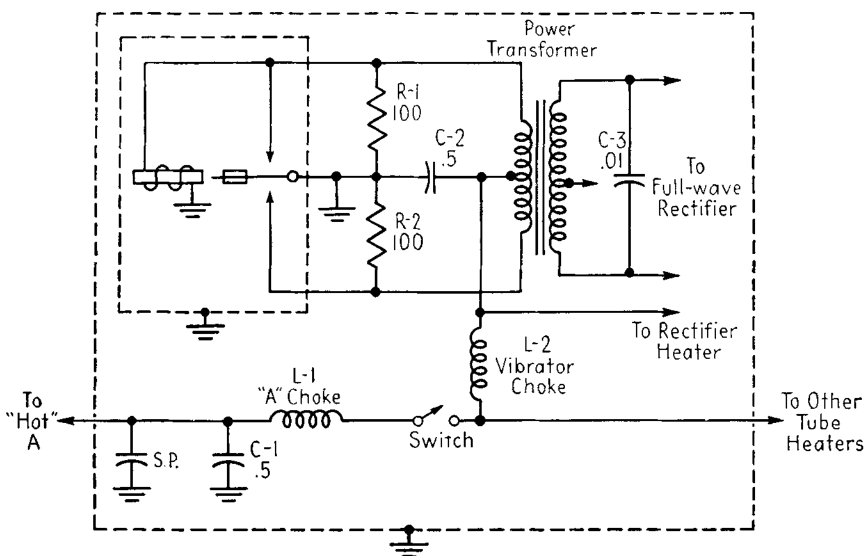


FIG. 21–7. Typical vibrator circuit including provision for hash suppression.

0.005 to 0.03 mfd. The condensers used are of the oil-filled type with a rating of 1,600 volts.

Resistors *R*-1 and *R*-2 are connected across the vibrator contact points and are also effective in reducing sparking and hash. These resistors vary in different circuits from 50 to 200 ohms. They form a discharge path for back electromotive force in the primary which would otherwise cause a heavier spark at the contact break. These resistors rarely cause any service difficulty. Sometimes condensers are used in the same circuit instead of resistors *R*-1 and *R*-2.

The vibrator choke and condenser *C*-2 form a hash filter. The choke acts to keep RF current from the vibrator out of the receiver heater lead, while the condenser offers a short path to ground for the same currents. A similar hash filter is sometimes also connected to the *B* plus output lead.

Other methods used for hash suppression are the total shielding of the vibrator, and sometimes of the power supply itself. The vibrator is shielded by being enclosed in a metal can. The entire power supply is often shielded by being enclosed in a metal compartment of the receiver assembly, as shown in Fig. 21–8.

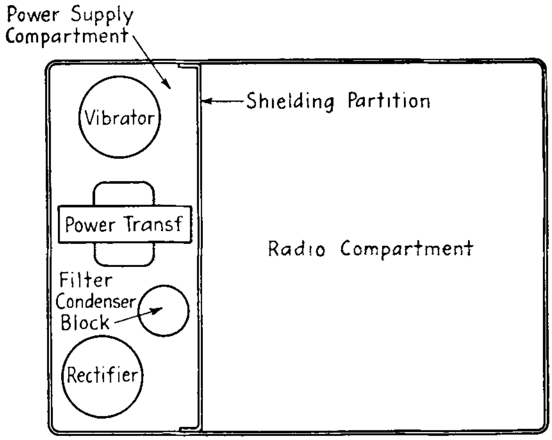


FIG. 21–8. Top view of an automobile radio, showing separate shielded compartments for the receiver and power supply.

Rectifiers used in auto radio power supplies. The vibrator and transformer convert 6 volts DC to a high-voltage alternating current. This is fed to a conventional full-wave rectifier and filter circuit.

The rectifier in most common use is a full-wave, high-vacuum rectifier of the heater-cathode type. The circuit is shown in Fig. 21–9. The heater-cathode type of construction is necessary because the heater is fed by

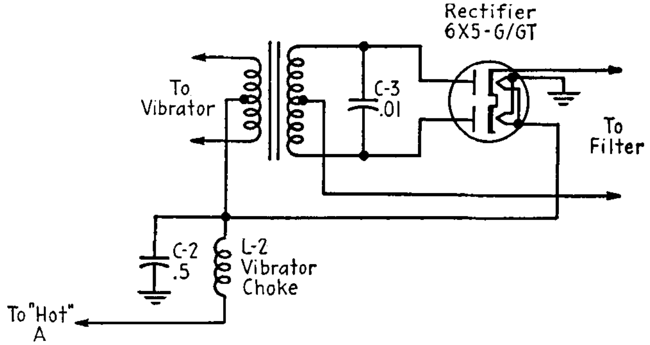


FIG. 21–9. Full-wave rectifier in the vibrator-type power supply.

the battery and is therefore at ground potential. The rectifier cathode in a full-wave circuit, on the other hand, is at the highest DC potential.

The 6X5-G and 6X5-GT tubes are widely used rectifier tubes in auto radio receivers. The 6X4 is the miniature equivalent of the 6X5 tube. Receivers that feature locking-base tubes use the 7Y4 type. Older auto radio receivers use the 6Z4 and 84 types. All these types have about the same ratings and characteristics.

Cold-cathode rectifiers. Some receivers use a cold-cathode type of rectifier tube, like the OZ4 and OZ4G, which do not use a filament or heater to obtain electron emission from the cathode. Instead, they contain a gas which ionizes when the AC potential is applied. The cathode of the tube is bombarded by gas ions until it emits electrons, after which the tube rectifies in the usual way. Figure 21–10 shows the circuit of the cold-cathode type of rectifier tube. The tube emits a purplish glow when it is operating.

Gas-filled rectifiers introduce an RF disturbance or hash of their own. Circuits of this type, therefore, require an extra hash filter. Condensers *C*-4 and *C*-5 serve this purpose in the circuit of Fig. 21–10. The condensers function as RF bypass units. Their usual value is 0.0008 mfd.

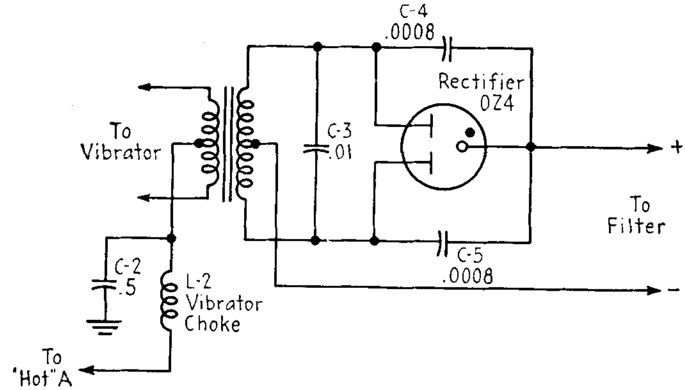


FIG. 21–10. Cold-cathode type of rectifier circuit.

Some receivers are wired so that either a 6X5-G heater-cathode type or an OZ4 cold-cathode type rectifier may be used. This is very easily arranged, since the plate and cathode pin numbers of both types of tubes are the same.

Auto radio B filter circuits. Some auto radio power supplies use a standard L-C filter circuit to smooth the rectifier output. It consists of a small *B* choke and two electrolytic condensers, as shown in Fig. 21–11. The input and output filter condensers are usually rated at 10 mfd/300 volts. The choke usually has an inductance of 10 to 20 henrys. Auto radio receivers do not use the field of an electrodynamic speaker as a *B* choke. The speakers in these radios are either of the P-M dynamic type or, when electrodynamic units are used, the field winding is a 4- to 6-ohm coil, which is fed by 6 volts DC from the heater line.

Some receivers use an R-C filter circuit. In this case, the *B* choke is replaced by a resistor, the value of which is 1,000 to 2,000 ohms. The filter condensers may also be increased in capacity to 20 mfd to maintain efficient filtering. It must be remembered that filtering in auto radios is more efficient than is the case in home receivers, because of the higher hum frequency, resulting from the vibrator frequency of approximately 115 cycles per second.

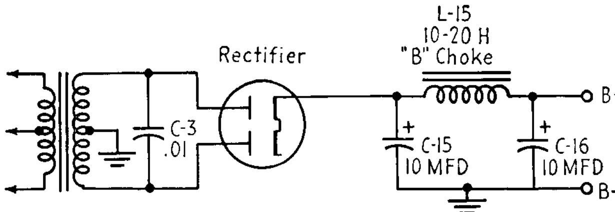


Fig. 21–11. Filter circuit in the vibrator-type power supply.

Finally, some auto receivers include an RF filter in the *B* plus lead for hash suppression. A typical circuit is shown in Fig. 21–12. Condenser *C*-6 is a 0.01-mfd RF bypass unit rated at 400 or 600 volts. The RF choke is wound with fine wire and has an average inductance of 20 mh.

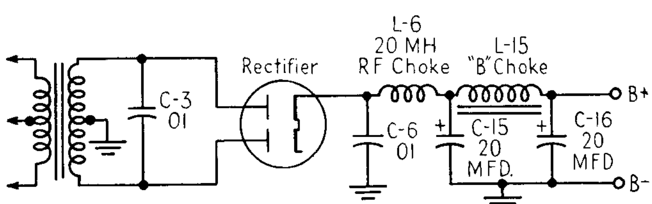


Fig. 21–12. An RF filter in the *B* plus circuit for hash suppression.

Auto radio receivers rarely use a voltage divider. Screen voltages are usually obtained from *B* plus by suitably bypassed dropping resistors.

A typical auto radio power supply. Figure 21–13 shows the schematic diagram of the Motorola Model 401 auto radio. Note the following points of interest in the power supply. The "hot" battery lead filter is composed of the *A* choke, part (10), the 0.25-mfd condenser (37), and the two spark plate condensers labeled S.P. The hot lead then goes through the switch on the volume control, from which point it branches off to feed the dial lamp, speaker field, tube heaters, and power supply. RF choke (11) feeds the tube heaters, and vibrator choke (9) feeds the power supply. Note the spark plate condenser as the lead enters the power supply. The vibrator choke feeds the vibrator and also the 6X5-GT rectifier tube heater, the latter being separated from the other tube heaters for reasons of hash suppression. Condenser (45), connected

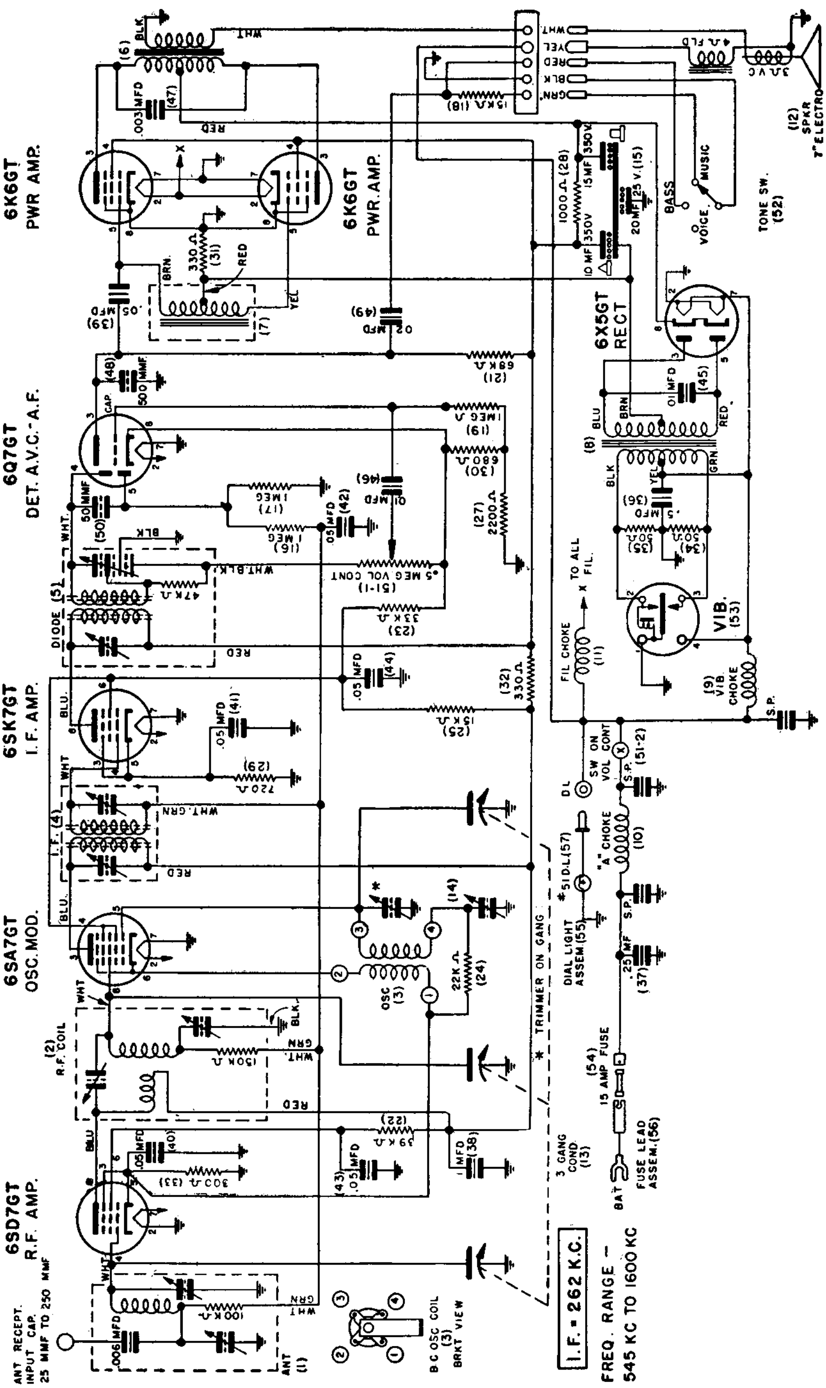


FIG. 21–13. Schematic diagram of the Motorola Model 401 receiver.

across the high-voltage winding of the power transformer, is the buffer condenser. Resistors (34) and (35) are connected across the vibrator points for reduced sparking and hash. The *B* filter is an R-C filter composed of resistor (28) and condenser block (15).

In this circuit, the common condenser connection in the block is not grounded, indicating a resistor in the negative *B* lead for bias. The *C* bias resistor is part number (31) near the second AF tubes. The 20-mfd/25-volt condenser in the power supply bypasses the bias voltage.

NORMAL TEST DATA

Quick check for normal operation of the auto radio power supply

Vibrator is buzzing.

Hum and hash level are normal.

All tubes in the receiver light.

B plus voltage measures 150 to 250 volts.

The mechanical noise or buzz made by the vibrator is well damped by rubber cushions, etc., but is still discernible as soon as an auto radio is turned on. When he works on an auto radio, the serviceman's first check is to turn on the receiver and listen for this buzz. Its absence is an indication of a blown fuse or a defective vibrator, both of which are common troubles in auto radios.

Then, as the tubes warm up, the hum and hash become noticeable. A normal level for these may be established as an amount that is just discernible when the receiver is turned to an off-station position. Hum is higher pitched than for a home receiver, owing to the higher frequency of the vibrator. Hash is a steady tearing sound. Too high a hum or hash level indicates trouble in the filter or hash-suppression circuits.

To check that the tubes light or warm up in the case of metal tubes, the receiver cover must be removed. *B* plus can be measured at the screen pin of the second AF tube or any other convenient *B* plus point. The wide variation (150 to 250 volts) given for the *B* plus measurement is not because vibrator power supplies operate over wide limits, but rather that the receivers have been designed for this wide variation. As a general rule, small receivers are designed to operate at the low voltages.

Normal voltage data for the auto radio power supply. Normal voltage data for the auto radio power supply are given in the table on page 396. It is assumed that the test battery is in good condition and the charger is not operating.

In actual operation in the car, the battery voltage varies considerably, depending on the condition of the battery, the operation of the charger, and the charging rate. The normal *B* voltage shown has wide limits,

Point to point	0Z4 and 6X5 pin No.	Voltage
Chassis to "hot" battery lead		6
Chassis to center tap of transformer primary		5.5
Chassis to rectifier plates	3 and 5	150–250 AC
Chassis to rectifier cathode	8	160–260
Chassis to *B* plus		150–250
Current drain		5–8 amp

which depend on the design of the receiver. The actual normal *B* voltage may be ascertained by reference to the receiver schematic or to the voltage rating stamped on the filter condenser block. When the filter block is stamped "200 volts," the serviceman will know that the receiver has been designed to work at a low *B* voltage.

An ammeter check of the current drawn from the battery, if convenient, is indicative of trouble in the power supply. The normal current drain of auto receivers is 5 to 8 amp, depending on the number of tubes in the receiver, the maximum *B* voltage, and the type of speaker used—P-M or electrodynamic. Trouble in the form of shorts in the *B* circuits of the receiver would cause a current drain increase of approximately 1 to 2 amp. A shorted buffer condenser would cause an even heavier increase in battery current. When vibrator points stick, the current drain exceeds 15 amp.

The ammeter check can be made in the automobile by connecting the "hot" battery lead to the proper terminal of the charge-discharge ammeter on the instrument panel. To make this check on the test bench, an ammeter could be connected in series with the test battery. It is not advisable to use the ammeter range of the bench multimeter for this purpose. A shorted vibrator could draw sufficient current to damage the instrument. Instead, a single-unit ammeter with a range of 20 amp and of a rugged construction should be used. Ammeters designed for the instrument panel of an automobile are satisfactory.

Standard Diagram. The standard diagram is shown in Fig. 21–14.

Normal resistance data for the auto radio power supply. Normal resistance data for the auto radio power supply is given in the following table:

Chassis to rectifier plate	150–300 ohms
Rectifier plate to plate	300–600 ohms
Chassis to *B* plus	Condenser action
Transformer primary winding	Less than 1 ohm

The rectifier plate readings measure the resistance of the high-voltage winding of the transformer. Large receivers with heavy *B* current drain will give the lower readings. When half the winding (chassis to rectifier plate) reads as high as or higher than the full winding, the *B* circuit is of the type that obtains *C* bias by means of a resistor in the *B* minus lead.

The reading from chassis to *B* plus shows the charging current of the electrolytic filter condenser, since there is usually no bleeder in an auto radio receiver. The reading after the charging current has subsided is

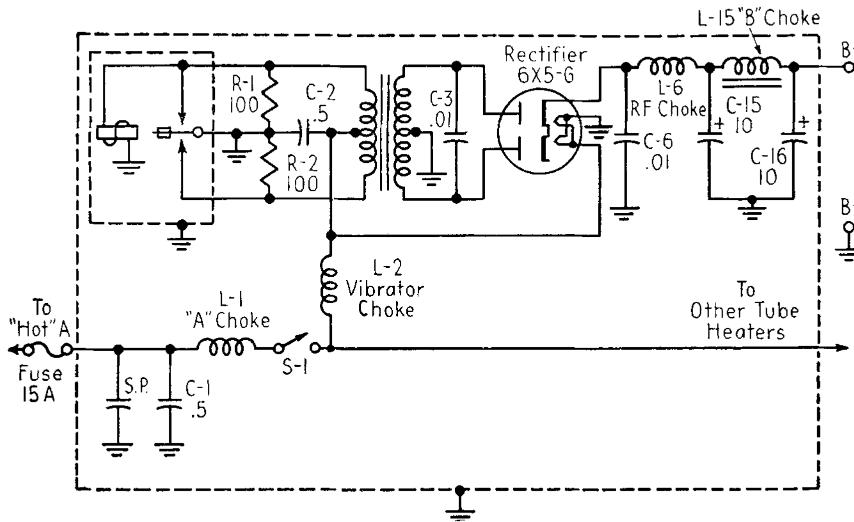


FIG. 21–14. Typical automobile radio vibrator-type power supply.

indicative of the leakage of the electrolytic condensers. Reverse the test prods and take the higher reading as the leakage resistance.

COMMON TROUBLES IN THE AUTO RADIO POWER SUPPLY

The troubles that commonly develop in auto radio power supplies are in the vibrator, rectifier tube, buffer condenser, filter condensers, and switch. The power transformer and the *B* choke rarely cause a defective receiver. The other components operate in low-voltage circuits and breakdowns are also rare.

On occasion, however, normal vibration in an automobile causes a grounding lug or screw to work its way loose. The resulting open circuit would most probably affect hash suppression. A servicing procedure for complaints of excessive hash includes checking for loose shielding and grounding screws.

Troubles common to vibrators. Vibrators are subject to many ills. Shorts and overloads in the *B* circuit of the receiver place an abnormally heavy load on the vibrator. In addition, it is a component that is normally in constant motion, and deterioration due to wear may be expected. The spring loses its tension, the contact points wear, and sometimes the points become pitted and stick. A defective vibrator can sometimes be repaired by filing the points and adjusting the spring tension and contact break distance. This, however, requires special techniques and equipment, and the repair effected may not be lasting. It is best to replace a defective vibrator with a new unit similar to the old one.

As the vibrator points wear or the spring weakens, the unit will sometimes fail to start. The car owner soon discovers that, if he flips his switch rapidly two or three times or hits a bump that gives his entire car some extra vibration, the receiver starts to play. The radio then seems to operate normally until the next time it is turned on.

When a receiver is brought in with a complaint describing the above symptoms, the serviceman may be reasonably certain that the vibrator is at fault. To check, he verifies the condition by turning on the radio and listening for the vibrator buzz. If it is not heard, he gives the corner of the radio a sharp slap. When this starts the vibrator and normal operation, the condition is confirmed. If the vibrator does start buzzing immediately after turning on the switch, the intermittent operation must be checked by other means.

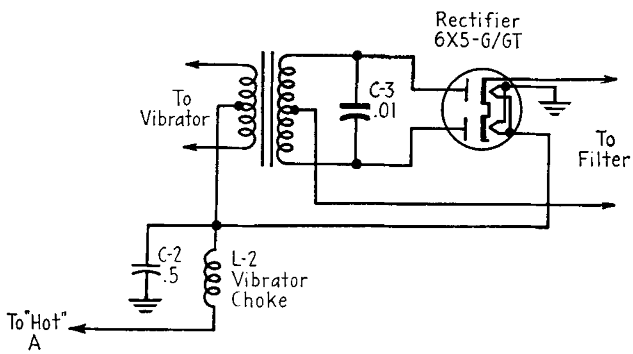
A good check for vibrator starting is to operate the receiver at a lower battery voltage. The "hot" battery lead is clipped to the 4-volt intercell connection strap on the storage battery. A vibrator that gives intermittent service, owing to the widened space between the worn points, will not start on a 4-volt input source, unless it is jarred. Even then, it will probably stop soon after having been started. A good vibrator will start without being jarred and will continue to operate when the input supply is 4 volts.

When pitted vibrator points stick, there is a heavy current drain through the half of the transformer primary winding that is fed by that point. The heavy current blows the fuse in the "hot" battery lead. Again, it sometimes happens that the car owner finds the blown fuse and replaces it himself. This may restore normal operation, but it will be short-lived, since the pitted points will stick and blow the fuse again. Continued blowing of fuses and checking with an ammeter comprise the method for determining sticking vibrator points.

As mentioned before, when the symptoms and checks indicate that the trouble is definitely in the vibrator, replacement with a new unit is the best service procedure. There is considerable variation among vibrators, not only in the method of making connections but also in the construction and operating characteristics. For this reason, the replacement should be made with an exact duplicate of the original or, at least, with one that is specified by its manufacturer as being correct for the receiver being repaired. In the latter case, the replacement is not always the same size as the original, and the serviceman should be sure that provision is made for properly grounding the vibrator shield can and for holding it in place when sponge-rubber vibration-damping devices are provided.

Troubles common to the buffer condenser. The buffer condenser often breaks down owing to voltage overload. When this happens, the radio is inoperative because of the absence of *B* voltage. The receiver draws heavier than normal current from the battery to feed the short across the secondary of the power transformer.

The shorted buffer condenser will be found when a voltage check shows no *B* plus voltage and no AC plate voltage being fed to the rectifier plates. Then a resistance check shows the short from plate to



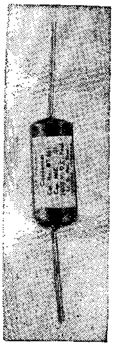


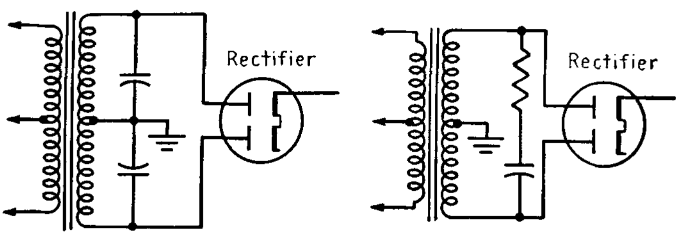
FIG. 21–15. A typical buffer condenser and its position in the circuit.

plate of the rectifier tube instead of the normal 300- to 600-ohm reading of the power transformer secondary winding.

The condenser should be replaced by one of the same capacity rating as the original, and the same or a higher voltage rating. Any change in the capacity of the buffer condenser may cause a shortened life for the vibrator, increased hash, or both. The replacement condenser should be of the oil-filled type, with a rating of 1,600 volts.

In replacing the buffer condenser or any unit in an automobile radio, the serviceman should remember that mobile equipment is subject to a considerable amount of vibration, and parts should be installed with this point in view. With improper installation, normal vibration may break the connection leads of the replacement unit. Most of the parts in an automobile radio are strapped down to take the vibration strain off the leads. The serviceman should be careful to use the original, or a similar, secure fastening to hold down the replacement unit. Also, connections should be well wrapped and soldered.

Variations in the buffer condenser circuit. The buffer condenser is sometimes connected in circuits like those shown in Fig. 21–16. The function of the buffer circuits shown is the same as the single condenser connected directly across the high-voltage winding. The common trouble is also the same; that is, the condenser is likely to become shorted. The effect on the receiver, however, may be different. If either condenser in Fig. 21–16*A* should become shorted, there would be a heavy load on the transformer and vibrator, but there may be some *B* plus voltage from the half of the transformer connected across the good condenser. If the buffer condenser of Fig. 21–16*B* should become shorted, *B* plus would not be shorted out. The voltage would be lower, however, depending on the size of the series resistor and the decreased efficiency of the vibrator



(A) (B)

FIG. 21–16. Variations in the buffer-condenser circuit.

without its timing capacitor. The receiver may play, but the hash content would be high.

A shorted buffer condenser in either of the two examples of Fig. 21–16 would be found in a routine voltage and resistance check of the power supply. They would both give incorrect readings for *B* plus voltage, and AC plate voltage. A resistance check would readily show the short in the circuit of Fig. 21–16*A*, and the hash level would focus attention on the buffer condenser of Fig. 21–16*B*.

Troubles common to the rectifier tube. The rectifier tube in an automobile receiver has the usual ills of any rectifier tube: weak or no electron emission. In addition, cathode-to-heater leakage causes trouble, since any leakage here acts like a short on the *B* power supply. The heater is at chassis potential, and the cathode is the point of highest voltage in the receiver.

When the rectifier tube is weak or entirely inactive, low or no *B* plus voltage will result. The same condition can also result from other causes. Low battery voltage, a weak vibrator, an open or shorted filter condenser, or a heavy drain in the *B* plus line can cause the same effects. Checking the tube in a tube tester will eliminate the tube as the cause of the trouble. Before a poor tube is replaced, the *B* circuit should be checked for shorts and overloads, since a short here may harm the new tube as well as be the cause of failure of the old one. Figure 21–18 is a skeleton diagram of the *B* circuit of a typical auto radio and should be an aid in locating shorts in the *B* plus circuit.

When the trouble is due to a cathode-heater short, *B* plus will be shorted out and the receiver will not operate. This condition may or may not be indicated by the tube checker, depending on its design. A resistance check may not reveal the trouble either, since the short may not be present except when the tube is functioning, and the expanded heater touches the cathode.

In this set of circumstances, the cathode-heater short would be found by a process of elimination. The vibrator is working. A heavier than normal battery drain indicates a shorted condition. A voltage check shows a reading of AC voltage at the rectifier plates. This reading would be lower than usual, but any reading at all clears the transformer and buffer condenser of suspicion. The voltage check also shows a condition of no voltage in the *B* plus line, placing the short in this circuit. A resistance check then shows no apparent short in the *B* plus line, a contradiction that is possible only when the short appears under operating conditions. This makes the rectifier tube a likely suspect, since cathode-heater shorts that appear only when the heater is expanded by normal operation are quite common. Replacing the tube with one known to be good is the final confirmation.

Cold-cathode rectifier tubes have the same failings as the thermionic types, with the exception, of course, of cathode-heater leakage. Not all tube checkers are equipped to test this type of tube, however. If this is the case and the serviceman suspects the rectifier because of low or no *B* voltage, and no sign of a short, the tube is checked by replacing it with one known to be good.

Troubles common to the filter circuit. The chokes in the filter circuit rarely cause any service troubles. The electrolytic condensers *C*-15 and *C*-16, however, open and sometimes short. When input filter condenser *C*-15 opens, the receiver will hum. The serviceman is again reminded that hum in an auto radio is higher pitched than hum in the usual AC home radio. The condition will be found when a test condenser of approximately the same capacity is bridged across the input filter condenser. When the output filter condenser *C*-16 opens, the receiver will hum and oscillate. Again, the condition is found by bridging a test condenser across condenser *C*-16. If RF bypass condenser *C*-6 should open, the hash level may increase. The condition would be found in a routine check for hash.

If any of the three condensers should become shorted, there would be no voltage at *B* plus and the receiver would be inoperative. The shorted condenser would be found by an ohmmeter check. It must be remembered that a short at any point in the *B* plus line may be difficult to find, because of the many parallel branches in which it may be located. Figure 21–18 shows the complete *B* circuit of the typical receiver of Fig. 21–13, to serve as an aid in locating shorts in the *B* supply.

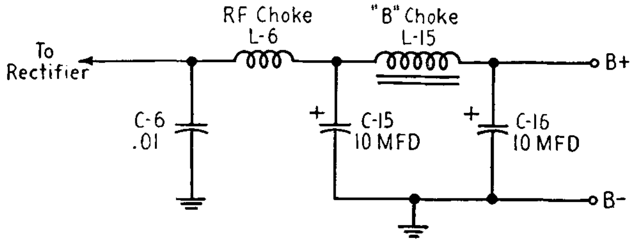


FIG. 21–17. The automobile radio *B* filter circuit.

When a filter condenser is replaced, it would be advisable to use an exact replacement unit. If this is not obtainable, the unit chosen should have the same or higher capacity rating, the same or higher voltage rating, and in addition, should have some mounting provision to ensure against lead breakage by vibration.

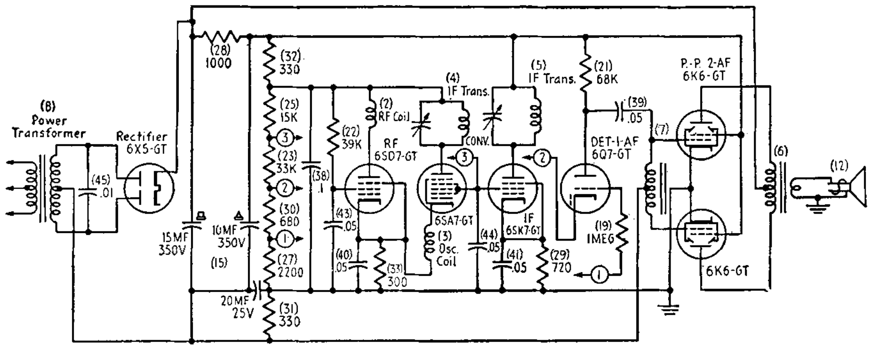


FIG. 21–18. Skeleton *B* circuit of the automobile radio receiver in Fig. 21–13.

When the filter circuit includes an R-C filter, the filter resistor rarely gives any service trouble unless it has been overloaded by a short in the *B* plus line. When this is the case, the resistor should be replaced with one of the same resistance and wattage rating as the original.

Troubles common to the power switch and battery lead. On-off switches in automobile receivers give more trouble than similar switches in home receivers. This is because the switch must break 5 to 8 amp, whereas the AC receiver switch breaks only 0.3 to 1 amp. In addition, although a 110-volt supply will override the slight resistance caused by a poor contact in a switch without overheating, the same circumstance in the low-voltage, high-amperage circuit of the auto radio switch will cause considerable loss of power, heating, and finally burning of the switch.

Poor operation of an auto radio, due to switch contact resistance, would be found in a voltage check. The reading at the "hot" battery lead would show the normal 6 volts, but the reading at the center tap of the transformer primary would be considerably lower than the 5.5 volts given as the normal reading in the voltage chart. Reference to Fig. 21–19 shows that the voltage loss may be due to poor contact in the fuse receptacle, or switch, or possibly to a rosin joint at one of the connections. Which item is at fault could be determined by inspection, overheating, or a voltage check across the individual units. If the switch or fuse shows 1 volt across its terminal points, there is no doubt as to where the contact resistance is located.

When replacing a defective switch, or volume control and switch, in an auto radio, the serviceman should make sure that the replacement

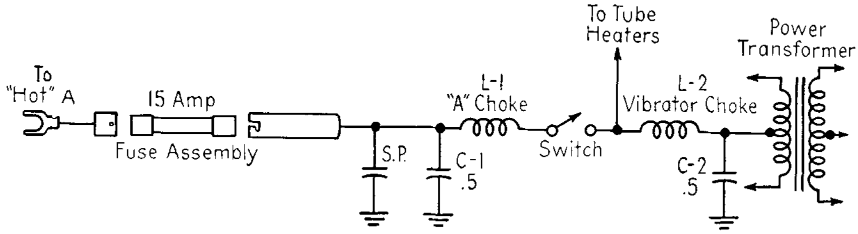


FIG. 21–19. Partial automobile radio *A* circuit.

unit has been designed for auto radio use. Auto radio switches usually have double contacts connected together either internally or externally, and are marked with their rating specifications. The replacement switch should be labeled at least "10A–12V," indicating that it has been designed to break a 12-volt/10-amp circuit.

Hash suppression. Hash suppression is a design problem, and for an individual type of receiver has been solved in its original design. Subsequent complaints of excessive hash in the receiver are caused by the breakdown of one or more of the hash-suppression components. Different types of receivers use various methods of hash suppression, and, as a result, the generalized service procedure for curing excessive hash may include the checking of items that are not incorporated in the receiver being serviced.

Service procedure for excessive hash

1. Tighten all chassis screws. This procedure is particularly important in the power-supply compartment.

2. *Check all ground connections.* Most of the ground connections are established by the chassis screws; some may be soldered directly to the chassis. These should be resoldered with a heavy-duty soldering iron. Occasionally, a chassis rivet may be used for a grounding connection. These should be carefully cleaned and spot-soldered to the chassis.

Spring contacts of various types are used for grounding purposes in various parts of the receiver. The ground connection for the vibrator-shield can is usually of this type. Spring contacts are also used between the metal cabinet and the chassis and the top and bottom covers. These spring contacts should be cleaned and resprung.

3. *Try replacing the vibrator.*

4. *Try replacing the rectifier tube.* If the receiver is wired for either an OZ4 or 6X5, the 6X5 is less likely to cause hash.

5. *Replace the RF by-pass condenser in the B plus lead.*

6. *Check the resistors or condensers across the vibrator contact points for opens or poor connections.*

7. *Check the buffer condenser for correct capacity rating.*

VARIATIONS OF AUTO RADIO POWER SUPPLIES

The synchronous vibrator. Some receivers use an extra pair of points in the vibrator to act as a mechanical rectifier, which replaces the rectifier tube. The circuit used is that of Fig. 21–20. When the contact at *A* is

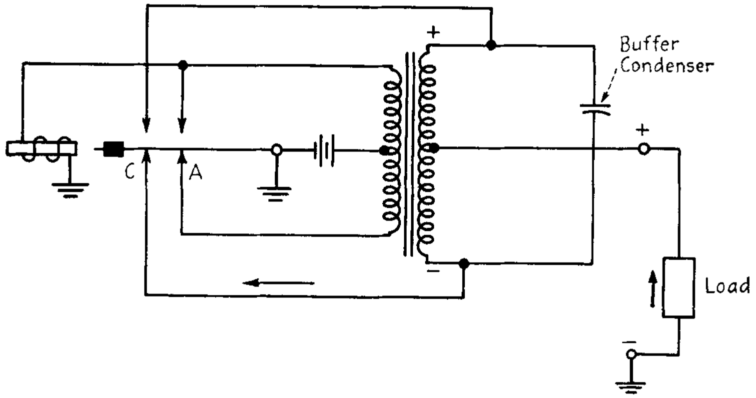


FIG. 21–20. The synchronous vibrator: operation position 1.

made, the magnetic field in the core caused by the flow of primary current induces a voltage in the secondary, the polarity of which we shall assume to be as marked in the diagram. The voltage, in the lower half of the secondary, drives a current through the load in the direction of the arrow through the contact at *C*, which is also closed when the *A* contact is closed.

As the contact at *A* is broken by the vibrator action, the contact at *C* also opens.

When the vibrator swings up, the contact at *B* reverses the magnetic field in the core, reversing the polarity of the voltage induced in the secondary, as shown in Fig. 21–21. But current still flows through the load in the same direction as previously, because it is now being furnished by the top half of the secondary through the closed contact at *D*.

In this manner, the contacts at *C* and *D* serve as a full-wave rectifier for the load which, of course, is the *B* circuit of the receiver.

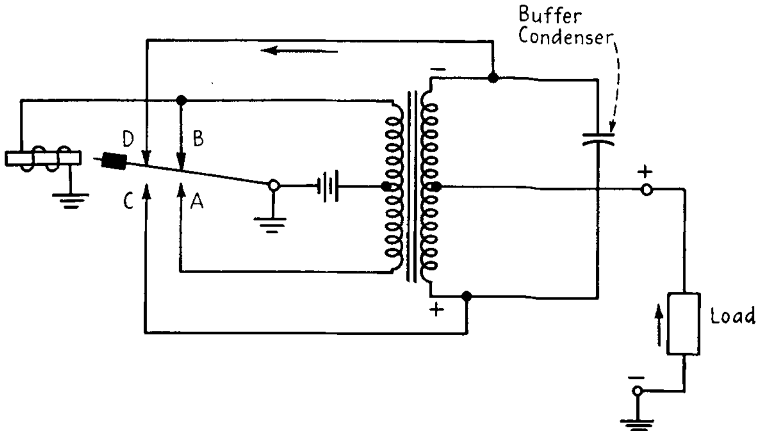


FIG. 21–21. The synchronous vibrator: operation position 2.

Battery polarity when synchronous vibrators are used. In discussing automobile radio up to this point, we never mentioned the polarity of the car battery. The only distinction made was reference to the "hot" lead and the grounded lead. However, some automobile manufacturers ground the negative terminal of the car storage battery; others ground the positive terminal. Furthermore, the same manufacturer may change the polarity of the grounded lead in his models from one year to the next. As a result, the "hot" battery lead may be either the positive or the negative terminal, depending on the make and year of the car.

In the case of a radio with a nonsynchronous vibrator and a rectifier tube, this is a matter of no importance, since this type of power supply will function regardless of the polarity of the source battery. However, in the case of a radio that uses a synchronous vibrator, the polarity of the "hot" battery lead is an important factor, since it will determine the polarity of the rectified output. Since the *B* supply must connect *B* minus to the chassis and *B* plus to the plate circuits of the receiver tubes, reversed polarity of the car battery will cause nonoperation of the receiver.

A radio with a synchronous vibrator must, therefore, include some provision for reversing the output *B* polarity, since the radio may be installed in any automobile, and either the positive or the negative battery terminal is the hot lead. Either one of two methods is commonly employed to reverse the *B* output when necessary. In one, the two ends of the high-voltage winding are brought to a screw-terminal strip and equipped with spade lugs to permit a convenient reversal. In the other, the vibrator and its socket are so constructed that the vibrator may be installed in either one of two positions. In one position, the receiver will operate properly with the negative terminal of the battery grounded, and the other position accommodates a grounded positive. Figure 21–22 shows a receiver of this type.

A typical auto radio using a synchronous vibrator. Figure 21–22 shows the schematic diagram of the RCA Model 67M1 auto radio receiver, which uses a synchronous vibrator. Note the following items of interest. The power supply is enclosed in a shielded compartment, as indicated by the dotted line surrounding it. There is no filter on the pilot-lamp lead. This is unnecessary since the pilot lamp is installed in a remote-control head and therefore cannot bring hash or ignition interference into the radio receiver. There is a spark plate condenser *C*-40 connected to the hot battery lead as it enters the receiver. Condenser *C*-43 and RF choke *L*-12 make up the hash filter for the transformer primary and vibrator. Condenser *C*-41 and RF choke *L*-10 form an additional hash and ignition noise filter to feed the heater line.

The vibrator socket has six prong holes and a center-pin hole. Prongs 2 and 3 are thicker than the others so that the vibrator can be inserted in only two positions. In either position, pin No. 1 is grounded and pins 4 and 5 remain unchanged because of the reversing connections of the two unmarked pins. The location of the rectifier contacts, however, with respect to the ends of the high-voltage winding, will be reversed as the vibrator is shifted from one position to the other.

Resistors *R*-18 and *R*-19 and condensers *C*-45 and *C*-46 function as the buffer circuit. Condenser *C*-47 is an RF by-pass which functions as a hash filter in the *B* plus lead. The *B* filter circuit consisting of *L*-13, *C*-48, and *C*-49 is conventional.

Servicing synchronous vibrator-type power supplies. From the serviceman's point of view, the synchronous vibrator type of automobile radio includes some problems of its own. First, he must observe polarity when connecting the radio for operation on his test bench. To do this he must connect the "hot" battery lead to the same terminal on his test battery as the "hot" lead in the car from which the receiver was taken.

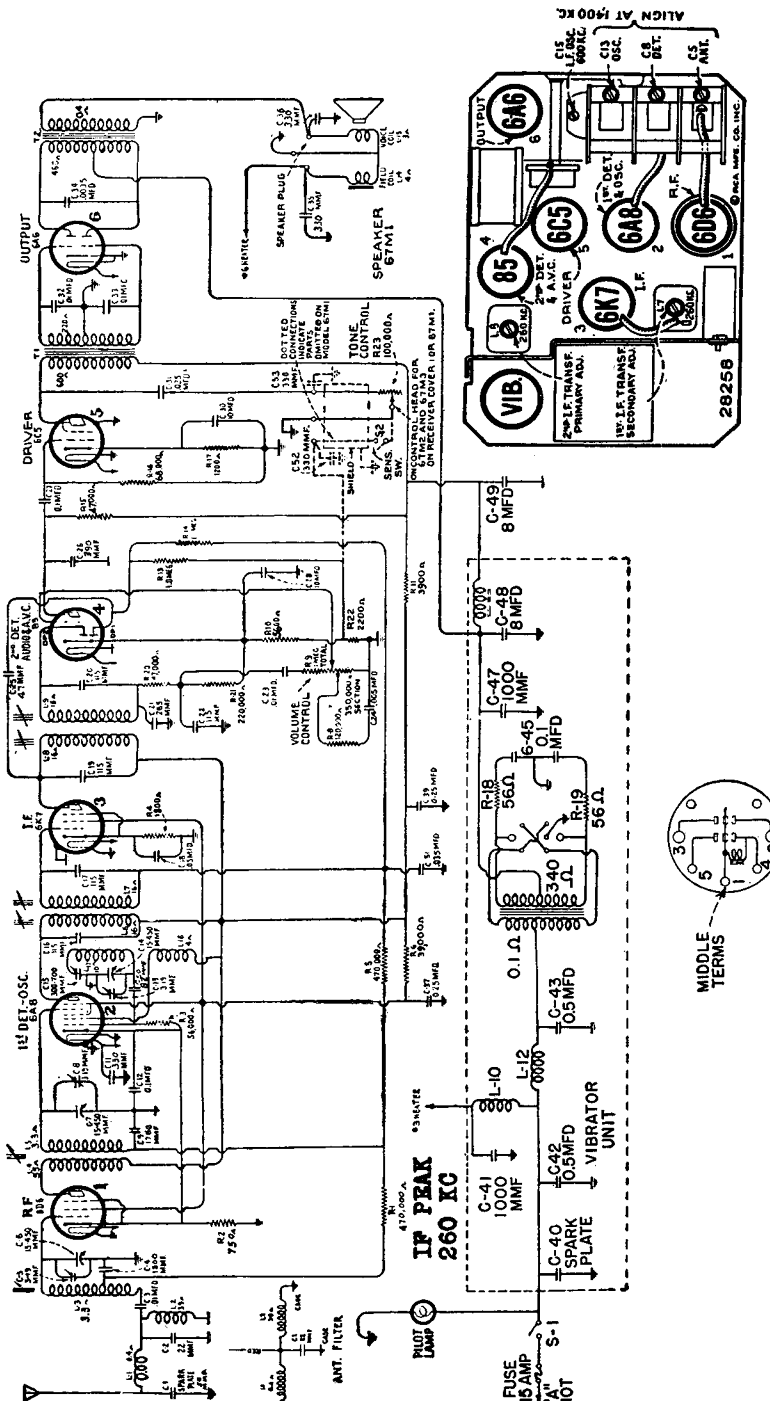


FIG. 21–22. Schematic diagram of the RCA Model 67M1 receiver.

If the automobile is available, polarity is easily determined with a voltmeter. Simply clip the negative lead of the multimeter to the instrument panel or other convenient ground. Adjust the meter for the 10-volt DC range. Touch the positive voltmeter lead to either terminal of the ammeter on the instrument panel. If the meter reads 6 volts, the negative terminal of the car battery is grounded. If the meter pointer swings backward, the positive terminal of the car battery is grounded. If the car is not available but known as to model and year, the grounded battery terminal can be ascertained by reference to charts that list this information. These charts are obtainable from the publishers of the various automobile trade periodicals. One such chart is included in the Appendix. If the car is unknown, the receiver may be connected with either battery terminal connected to the hot lead, and the voltmeter test prods are connected to chassis and *B* plus. A reversed reading of the voltmeter indicates incorrect battery polarity. No harm is done if the receiver is operated for a short time with the battery reversed.

Another instance where battery polarity becomes of importance in the synchronous vibrator type of radio is when such a radio is removed from one car and reinstalled in another. In this case, the polarity of the grounded lead is checked with the voltmeter in both the old car and the new. If there is any change, the appropriate switch must be made in the receiver.

When servicing a receiver, like the one of Fig. 21–22, where the polarity change-over is accomplished by the position of the vibrator in its socket, if the vibrator is removed for test or replacement, it is important to note the position identification. Then the vibrator may be replaced with the correct polarity setting.

The quick check for a synchronous-type power supply is the same as for the more common nonsynchronous type. The voltage and resistance data are the same, if due allowance is made for the difference in test points. The AC voltage readings are taken from the proper vibrator socket terminals, rather than from the plate pins of the rectifier tube. *B* plus would be checked at the filter condenser terminals. Common troubles and service notes are also the same for both types of power supply.

Note the IF of 260 kc for the receiver in Fig. 21–22. This intermediate frequency is commonly found in many auto radios.

SUMMARY

Quick check of the auto radio power supply

Vibrator is buzzing.

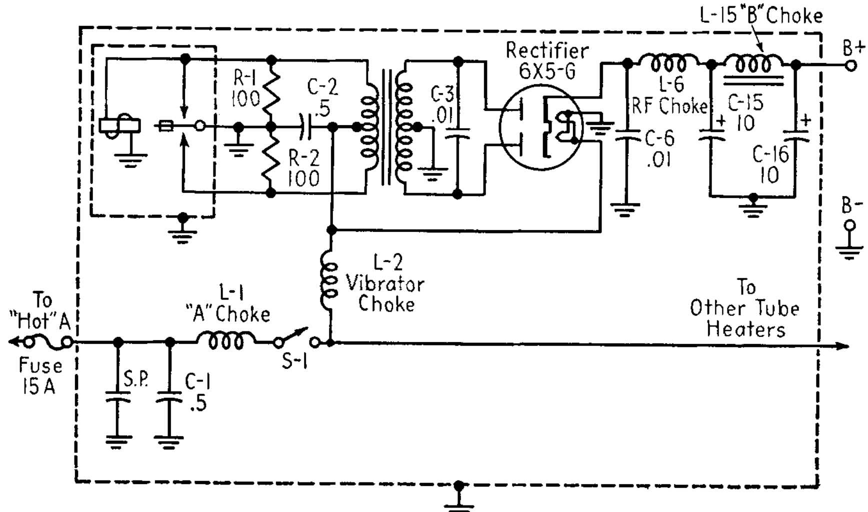
Hum and hash level are normal.

All tubes in the receiver light.

B plus measures 150 to 250 volts.

Standard circuit

The accompanying figure shows the standard circuit.



Normal voltage data for the auto radio power supply

Normal voltage data for the auto radio power supply are given in the accompanying table.

Point to point	*0Z4 and 6X5 pin No.*	*Voltage*
Chassis to hot battery lead		6
Chassis to center tap of transformer primary		5.5
Chassis to rectifier plates	3 and 5	150–250 AC
Chassis to rectifier cathode	8	160–260
Chassis to *B* plus		150–250
Current drain		5–8 amp

Normal resistance data for the auto radio power supply

Chassis to rectifier plate	150–300 ohms
Rectifier plate to plate	300–600 ohms
Chassis to *B* plus	Condenser action
Transformer primary winding	Less than 1 ohm

SERVICE DATA CHART

Symptom	*Incorrect check results*	*Look for*
Receiver does not operate	No buzz from vibrator	Disconnected "hot" battery lead. Blown or defective fuse. Burnt or inoperative switch. Defective or worn vibrator
	One or more tubes do not light	Defective tubes. Defective heater wiring
	B plus measures low or zero	Shorted buffer condenser. Worn-out vibrator. Defective rectifier tube (weak —or cathode-heater short circuit). Short-circuited RF hash by-pass condenser in *B* plus lead. Short-circuited filter condenser. Short circuit in receiver portion of the *B* plus line
	Power-supply checks give normal results	Trouble in the receiver. Make a stage-by-stage signal check
Receiver operation is weak	Low or erratic *B* voltage	Worn-out vibrator. Weak rectifier tube. Resistance in fuse. Resistance in switch. Incorrect capacity of buffer condenser. Component in the receiver drawing too much *B* current. Make a voltage check of the receiver
	Power-supply checks give normal results	Trouble in the receiver. Make a stage-gain signal check

SERVICE DATA CHART—*(Continued)*

Symptom	*Incorrect check results*	*Look for*
Excessive hum		Open filter condensers. Defective tubes. Poor ground connections in the receiver
Excessive hash		Poor ground connections in the receiver and power supply. Defective vibrator. Defective rectifier tube. Open hash filter. Incorrect buffer condenser capacity
Intermittent operation	Power-supply checks give normal results	Worn-out vibrator which sometimes fails to start. (Check at 4 volts.) Trouble in the receiver. Check tubes, condensers, etc.
Fuse blows repeatedly	Power-supply checks give normal results	Vibrator with sticking points. Intermittent cathode-heater short circuit in rectifier tube

QUESTIONS

1. The vibrator in an inoperative auto radio fails to start. List the possible causes and explain how you would check for each.

2. An auto radio is brought in with a complaint of intermittent operation. What unit in the power supply can cause this condition? How would you check to make sure?

3. An auto radio blows fuses repeatedly. What are the possible causes and how would you check for each?

4. An auto radio is brought in with a complaint of weak operation. A voltage check gives the following results.

Chassis to "hot" battery lead	6 volts (normal)
Chassis to center tap of transformer primary	4 volts (low)
Chassis to rectifier plate	120 volts AC (low)
Chassis to rectifier cathode	120 volts (low)
Chassis to *B* plus	110 volts (low)
Current drain	4 amp (low)

What is the most probable cause of the trouble? How would you make sure?

5. An inoperative auto radio gives the following results in a voltage check:

Chassis to "hot" battery lead	6 volts (normal)
Chassis to center tap of transformer primary	5.4 volts (normal)
Chassis to rectifier plate	120 volts AC (low)
Chassis to rectifier cathode	100 volts (low)
Chassis to *B* plus	0 volt
Current drain	9 amp (high)

What are the most probable causes of the trouble? How would you check for each?

6. If the receiver of question 5 gives a reading of 0 volt at the rectifier cathode and all other readings remain the same, what are the likely causes of the trouble? How would you check for each?

7. An auto radio that does not use a rectifier tube is to be transferred from a car with the negative battery terminal grounded to one with a grounded positive. What change should be made in the receiver?

8. An inoperative auto radio draws a heavier current than normal. The *B* plus check shows a reading of zero volts. There is no AC voltage at the rectifier plates, and there is no apparent short from *B* plus to chassis. What is likely to be wrong? How would you check to make sure?

9. List the causes for excessive hum in an auto radio and indicate how you would check for each.

10. Outline a procedure for removing excessive hash in an auto radio.

11. An inoperative auto radio draws a heavier current than normal. The *B* plus voltage checks zero, AC rectifier plate voltage checks low, and there is no apparent short from *B* plus to chassis. What is likely to be wrong? How would you check to make sure?

22 PUSH-PULL OUTPUT STAGE

Quick check. Place the tip of a plugged-in soldering iron on the control grids of each tube in a push-pull stage. A low growl should be heard from the speaker each time.

Function of the push-pull amplifier. The push-pull amplifier is generally used as the last audio or power stage in a high-fidelity receiver. It receives its signal voltage from the first AF stage, amplifies it, and drives the loudspeaker. This function is similar to that of the second AF stage in the standard receiver.

In addition, the push-pull stage serves in other functions. It makes it possible to deliver large amounts of power to the speaker with low distortion, while using small tubes and low *B* voltages. Another characteristic of the circuit is the reduction of hum. To summarize, the push-pull stage amplifies at audio frequencies with a large power output and with little distortion and hum.

Basic requirements of a push-pull amplifier. The theory underlying the operation of the push-pull amplifier can best be explained by means of

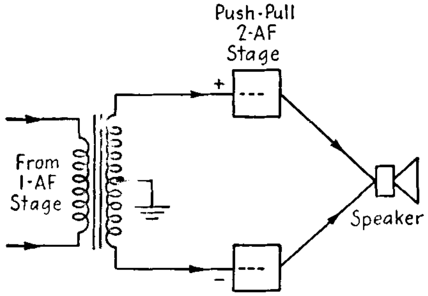


FIG. 22–1. Block diagram of a push-pull amplifier.

a step-by-step development. Figure 22–1 is a block diagram showing the requirements of a typical push-pull second AF amplifier. The audio signal from the first AF amplifier is broken up into two voltages of equal magnitude but opposite phase, and they are then fed to the two grids in the push-pull stage. The output from the two tubes is coupled to the speaker.

A simple method of obtaining the 180-deg phase difference for the two grids, as well as equal voltages, is by means of a center-tapped transformer. Such a circuit is shown in Fig. 22–2. At any one instant, the signal voltage at one end of the secondary will be positive, and at the other end negative in polarity. Since the center tap is grounded, one end of the secondary will be as much above ground in the positive direction as the other will be below ground in the negative direction.

Each of the terminals of the transformer is connected to the grids of the tubes as shown in Fig. 22–3. As a result, the grids are 180 deg out of phase. When one grid is being driven positive with respect to ground by the signal, the other grid is driven equally negative with respect to ground. In the first tube, as a result, plate current will increase; in the second tube, plate current will decrease to the same extent.

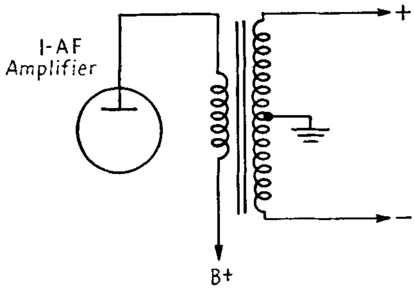


FIG. 22–2. The center-tapped transformer for obtaining input voltages for a push-pull stage.

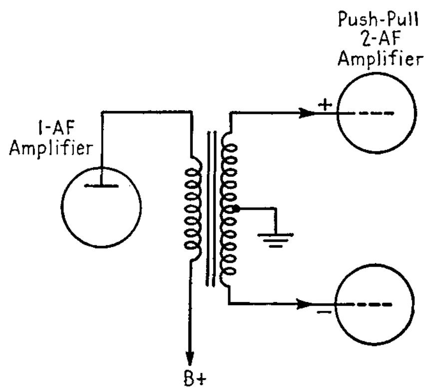


FIG. 22–3. Applying the signal-input voltages to the push-pull grids.

A negative bias voltage is obtained in the usual manner, as shown in Fig. 22–4, by connecting resistor *R*-7 in the directly heated cathode circuit of both push-pull tubes. The plate currents of both tubes flow through this resistor and establish the bias voltage across it. The grids of both tubes are connected to the negative end of this bias resistor, thereby establishing the same no-signal bias voltage on each tube. Condenser *C*-7 bypasses the bias voltage. In some circuits, it may be omitted, since its function is not so important in push-pull operation as it is in a single-tube second AF stage.

The output from both tubes is fed into a push-pull output transformer with center tap connected to *B* plus, as shown in Fig. 22–5. It should be noted that the flow of plate current through the two halves of the primary is in opposite directions. But coupled with this condition is another factor. Because one grid is driven more negative while the other

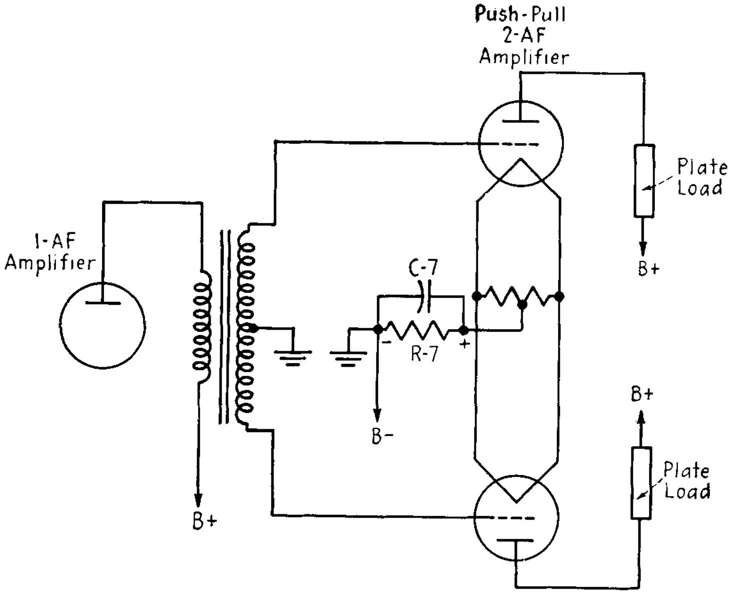


FIG. 22–4. A method of obtaining bias voltage for a push-pull stage.

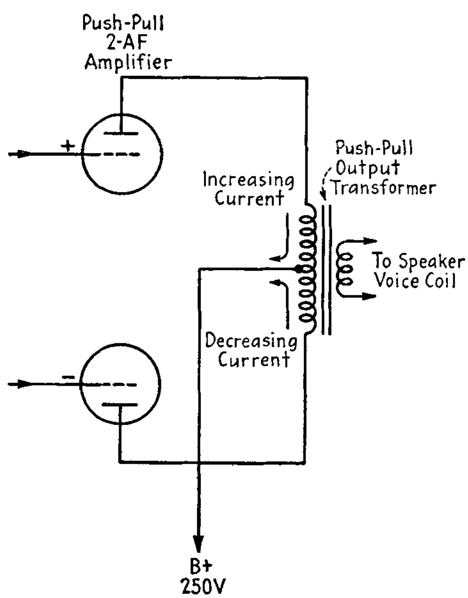


FIG. 22–5. The output circuit of a push-pull amplifier.

is being driven less negative, we have a decreasing current through the first tube and an increasing current through the second one. The combined effect is to add the outputs from the two tubes in the secondary of the output transformer where a considerable voltage is induced. The outputs from the two tubes then drive the speaker.

A splendid characteristic of the push-pull stage is that it reduces or eliminates even-harmonic (primarily second-harmonic) distortion, a characteristic of single-tube operation. For sine-wave input, by way of illustration, even harmonics have a tendency to flatten one-half the

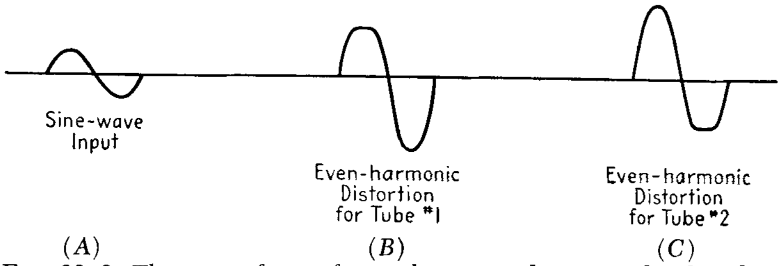


FIG. 22–6. The wave form of even-harmonic distortion developed in single-tube amplifiers.

cycle, as shown in Fig 22–6*A* and *B*. In the second tube of the push-pull amplifier, since the signal is 180 deg out of phase, the distorted curve would look like Fig. 22–6*C*. These two distorted signals are combined in the output transformer, with a canceling out of the even harmonics, as shown in Fig. 22–7.

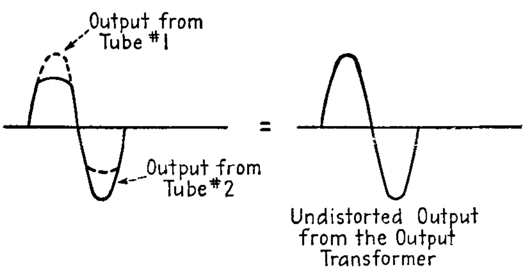


FIG. 22–7. Wave form showing cancellation of even-harmonic distortion in the output circuit of a push-pull amplifier.

Because even-harmonic distortion is reduced or eliminated in a push-pull stage, the tubes may be overloaded somewhat without distortion. This accounts for the great power output from such a stage. For example, maximum undistorted output for a single 6A3 will be 3.2 watts, while a pair of push-pull 6A3 tubes will deliver a maximum undistorted output of 10 watts.

A push-pull amplifier will also reduce or eliminate any hum due to hum ripple fed to its plates. The reason is obvious. Hum ripple from the power supply will be fed to the center tap of the primary of the output transformer. Here it will move in opposite directions through the primary, but (in contrast with signal plate currents through it) will be rising or decreasing at the same time in the primary halves. As a result, the hum ripple cancels out.

An important point should also be considered. Since each tube requires the same signal-driving voltage, practically, as if it were operating alone, the total signal voltage delivered from the first AF stage must be twice as great as for a single tube.

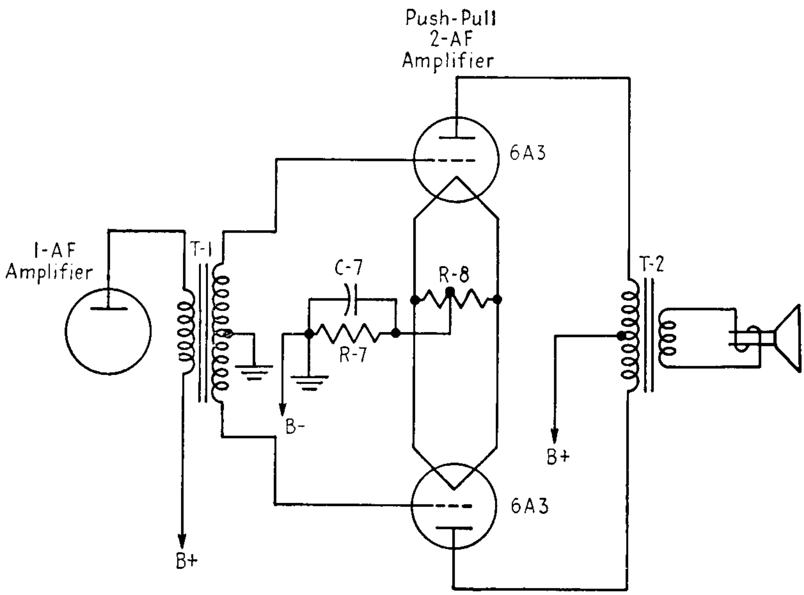


FIG. 22–8. Schematic diagram of a transformer-coupled push-pull stage.

Figure 22–8 now shows the complete transformer-coupled push-pull stage. Transformer *T*-1 is the push-pull input transformer, which couples the output from the first AF amplifier to the grids of the two tubes in the push-pull second AF stage. For high-fidelity reproduction, the push-pull stage is usually operated in class *A* or AB_1, where the grids are always negative and the tubes always or nearly always pass plate current. Resistor *R*-7 and condenser *C*-7 make up the common self-bias system for the push-pull tubes. Transformer *T*-2 is the push-pull output transformer. It combines the output from the two tubes and couples them to the speaker. Resistor *R*-8 is a center-tapped filament resistor, which gives a stable grid return point.

Transformer-coupled push-pull amplifiers are very common in older receivers and are still used to a minor extent in some modern ones. However, most modern receivers replace the input push-pull transformer with a resistance-capacitive type of coupling in conjunction with a phase-inverter tube.

Push-pull amplifier with phase inverter. Transformers are costly, and it is desirable to substitute for them where possible. Thus, resistance-ca-

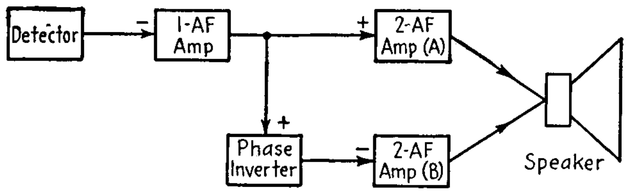


FIG. 22–9. Block diagram of a phase-inverter type of push-pull amplifier.

pacitance coupling between the first AF stage and the push-pull stage would be cheaper and more desirable. But it introduces a new problem. How can we get the 180-deg phase difference of signal voltage fed to

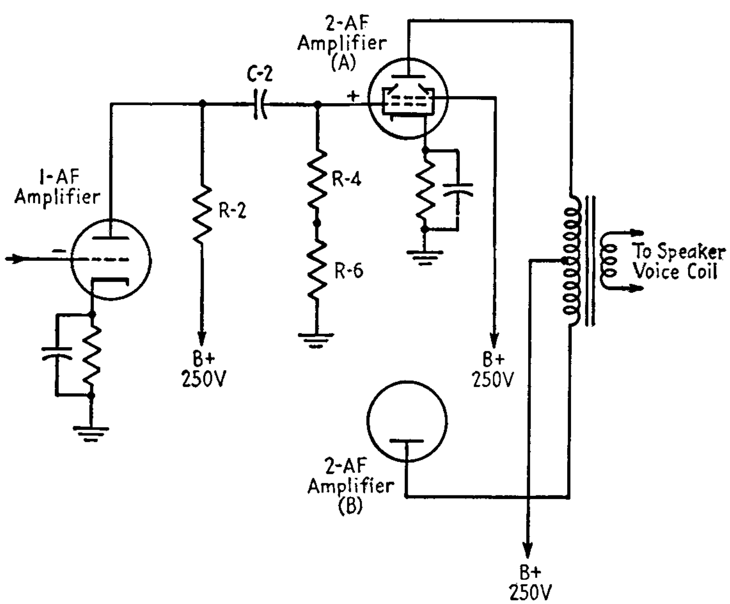


FIG. 22–10. Obtaining a positive signal on one push-pull tube grid from a negative signal on the first AF amplifier grid.

the push-pull grids? The practical solution requires the use of another tube, known as a "phase-inverter" tube.

Figure 22–9 is a block diagram of a push-pull stage with a phase inverter. The principle of the phase inverter is that, for any tube, the grid voltage variations are 180 deg out of phase with the plate voltage variations. Hence, the positive signal voltage going to one of the second AF grids is also directed to the inverter grid. The out-of-phase negative plate voltage pulse of the inverter is then fed to the grid of the other second AF amplifier.

Another job that must be performed by the inverter is that of delivering the same voltage to the second second AF grid as that which the first second AF grid receives directly from the first AF stage. With transformer coupling, a center tap to ground neatly takes care of this requirement. When using a phase-inverter tube, some provision must be made to compensate for the normal amplification of the added tube.

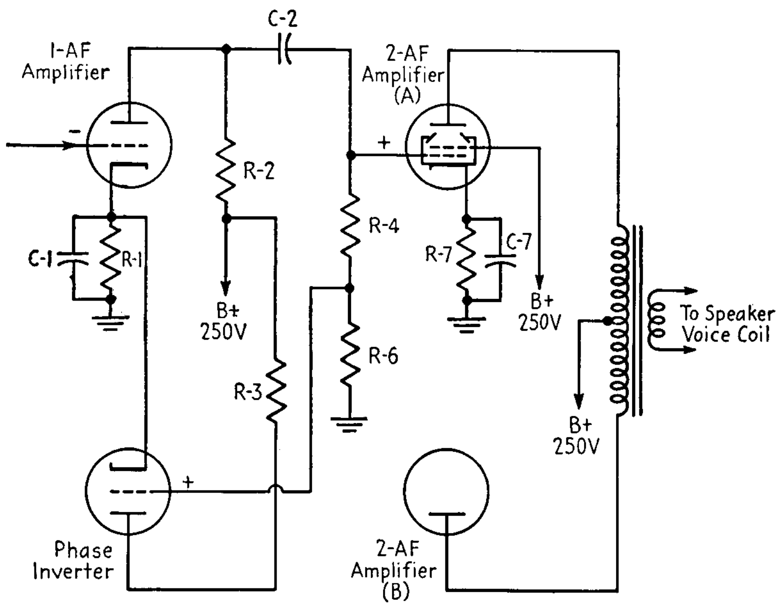


FIG. 22–11. Applying a portion of the positive output signal of the first AF amplifier to the phase-inverter grid.

Let us examine the development of such a circuit. Figure 22–10 shows one of the push-pull tubes coupled by normal resistance-capacitance coupling to the first AF amplifier. Note that a negative signal fed to the first AF grid produces a decrease in current through *R*-2. This results in a lowered voltage drop across the resistor and, as a result, a rise in positive voltage on the plate. This rise in positive voltage feeds a positive pulse through condenser *C*-2 to the control grid of the second AF (*A*) tube. The first AF tube has thus shifted the signal phase by 180 deg. The grid-leak resistor for the second AF (*A*) tube is shown as two separate resistors, *R*-4 and *R*-6.

To obtain an equal but opposite voltage on the control grid of the other second AF (*B*) tube, a portion of the positive output voltage pulse of the first AF tube is tapped off from the grid leak of the second AF (*A*) tube. Then this positive voltage is placed on the grid of a phase-inverter tube. Figure 22–11 shows the circuit described above. The self-bias circuit for the first AF tube, made up of *R*-1 and *C*-1, is common to the inverter tube.

The positive signal pulse on the inverter grid causes a rise of plate current through the plate load resistor *R*-3. The voltage drop across *R*-3 becomes greater and, as a result, the plate voltage of the inverter drops

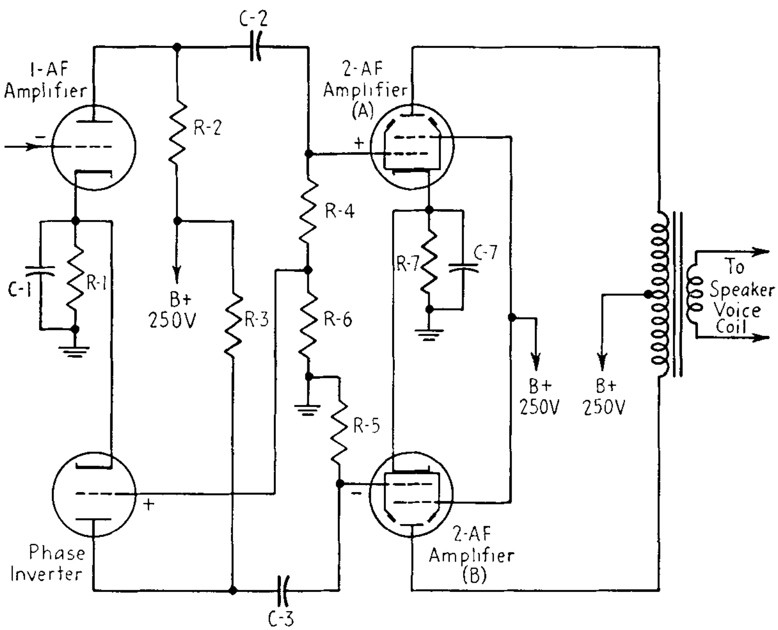


FIG. 22–12. Obtaining a negative signal on the other push-pull tube grid from the output of the phase-inverter tube.

and produces a negative pulse. This latter pulse is fed by resistance-capacitive coupling to the second AF (*B*) control grid, as shown in Fig. 22–12. Condenser *C*-7 and resistor *R*-7 make up the common self-bias system for both push-pull tubes.

Note that the over-all effect is to place opposite voltages on the control grids of the two output tubes, a condition that is desired. There still remains the problem of making these two voltages equal in magnitude. The output from the first AF tube is fed to the second AF (*A*) control grid. If this same output were fed to the inverter grid, the inverter gain would furnish a much larger voltage to the second AF (*B*) control grid. This is not desirable. Hence, if the gain of the inverter is 20, a tap on

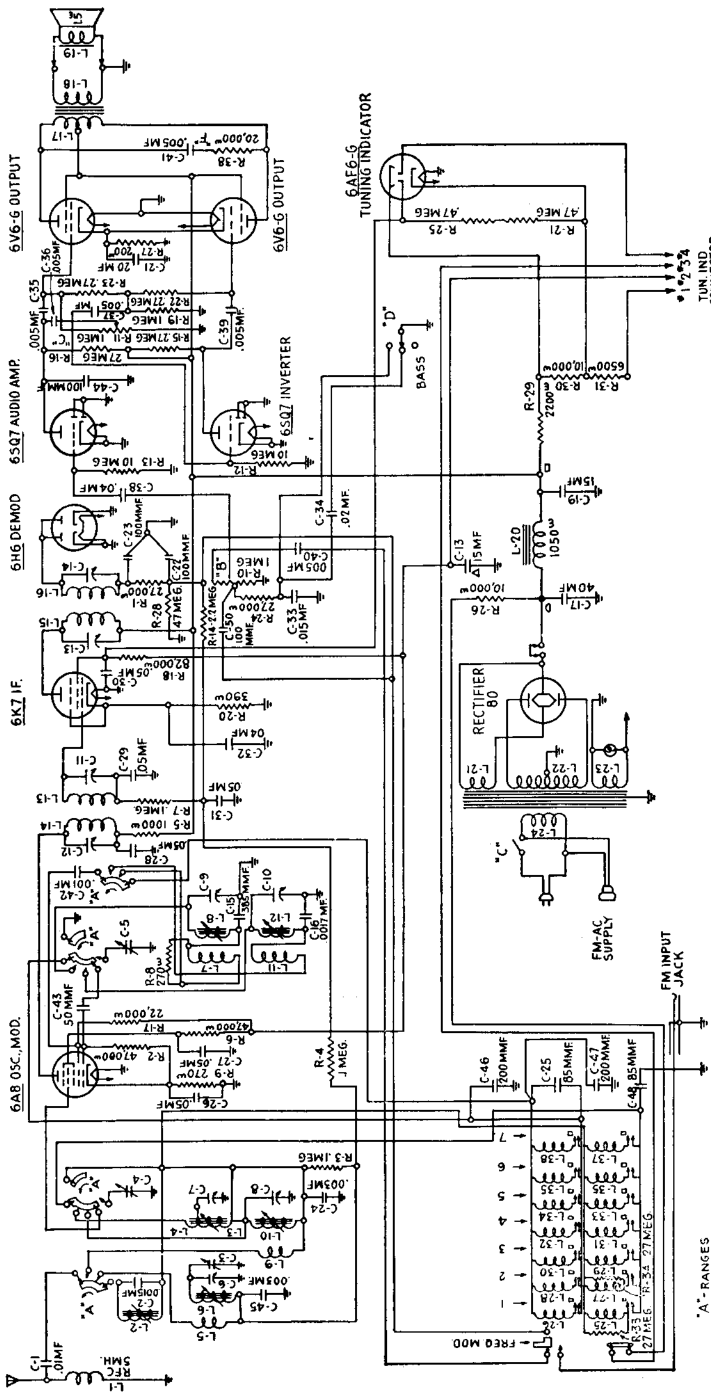
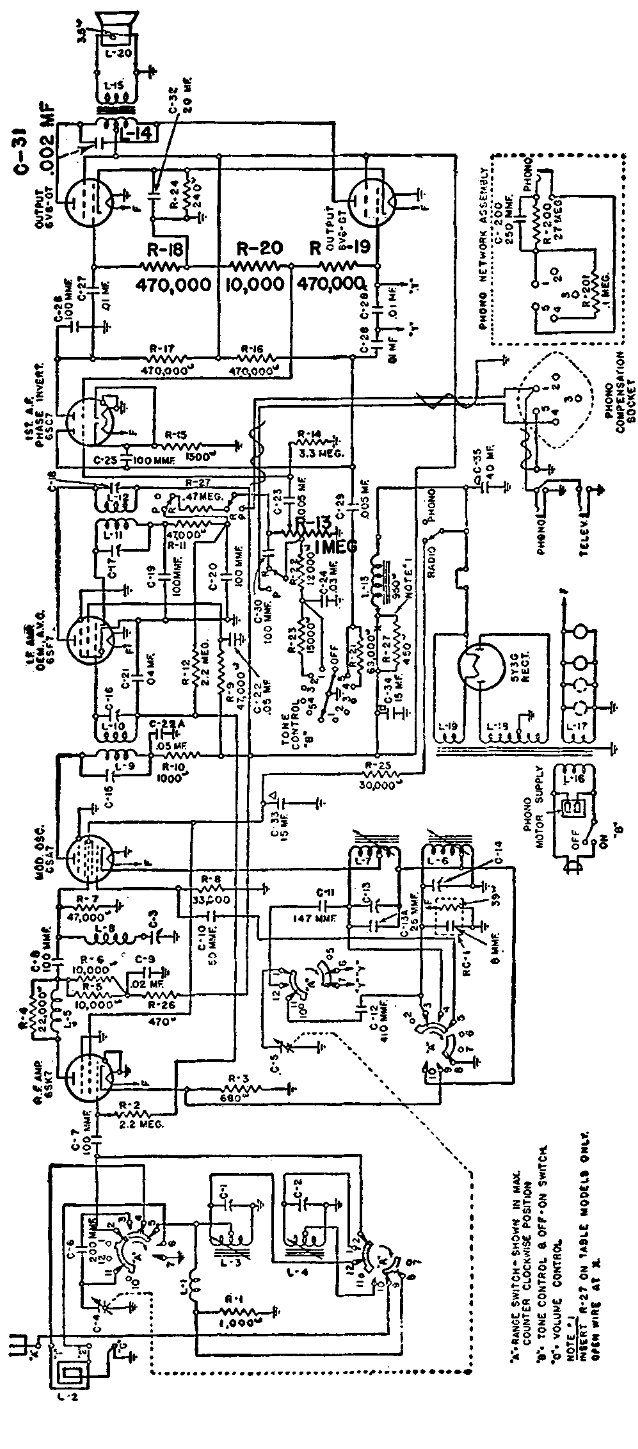


FIG. 22–13. Schematic diagram of the A-M receiver section of the Stromberg-Carlson No. 515 A-M/F-M receiver.



Schematic Circuit

FIG. 22–14. Schematic diagram of the Stromberg-Carlson No. 920 receiver.

the grid leak (R-4 and R-6) is taken so that only $\frac{1}{20}$ of the voltage across it is fed to the inverter grid. Then, the voltages fed to the grids of the two push-pull tubes will be equal. For example, if R-4 is 10,000 ohms and R-6 is 190,000 ohms, the total resistance in the grid circuit of the second AF (A) tube is 200,000 ohms. Then, since the voltage drop divides in direct proportion to the resistance,

$$\frac{10{,}000}{200{,}000} = \frac{1}{20}$$

and $\frac{1}{20}$ of the voltage fed to the second AF (A) tube is fed to the inverter grid. Here the voltage gain of 20 gives the same input voltage for both push-pull grids.

There are many other methods for obtaining the necessary phase inversion. In each, the principle is the same, but the tubes and circuit constants vary widely. Figure 22–13 shows a 6SQ7 functioning as the first AF driver tube and another 6SQ7 functioning as the phase inverter. In this case, the driver follows a 6H6 diode detector and AVC stage. The two 6SQ7 tubes might have been combined in a single twin triode 6SC7. A popular method often used is to employ a 6SQ7 diode detector, AVC, and first AF amplifier, as in the standard receiver, and then to use the triode section of another 6SQ7 as the phase inverter to feed the second push-pull grid.

Figure 22–14 shows a typical push-pull amplifier. Note that the IF amplifier, diode detector, and AVC circuit are combined in a single 6SF7 tube. The twin triode 6SC7 combines the functions of first AF amplifier and phase inverter. The signal from the detector is tapped from the volume control (R-13) and fed to the grid of the first AF section of the 6SC7 tube. The output from this driver is fed by resistive-capacitive coupling to the control grid of the lower 6V6-GT output tube. The grid leak for this latter tube is made up of resistors R-19 and R-20. The combined resistance of these two is 480,000 ohms. The tap between the two furnishes 10,000/480,000 or $\frac{1}{48}$ of the voltage to the grid of the inverter section of the 6SC7 tube, the gain of which is 48 under these operating conditions. The output of the inverter is then resistive-capacitive coupled to the control grid of the upper 6V6-GT output tube. In this way, equal but opposite signal voltages are obtained for the control grids of the two output tubes. Note condenser C-31 across the primary of the output transformer (L-14). Its function is to reduce the tendency of the push-pull stage to fall into oscillation.

NORMAL TEST DATA FOR THE PUSH-PULL AMPLIFIER

Signal check for normal stage operation. The signal check for the stage is shown in Fig. 22–15. The signal generator is adjusted to give an AF

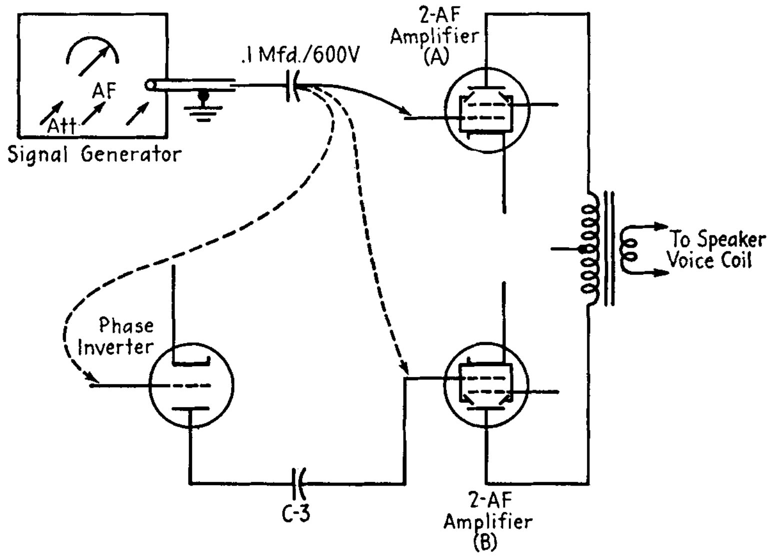


FIG. 22–15. Signal check of a push-pull amplifier.

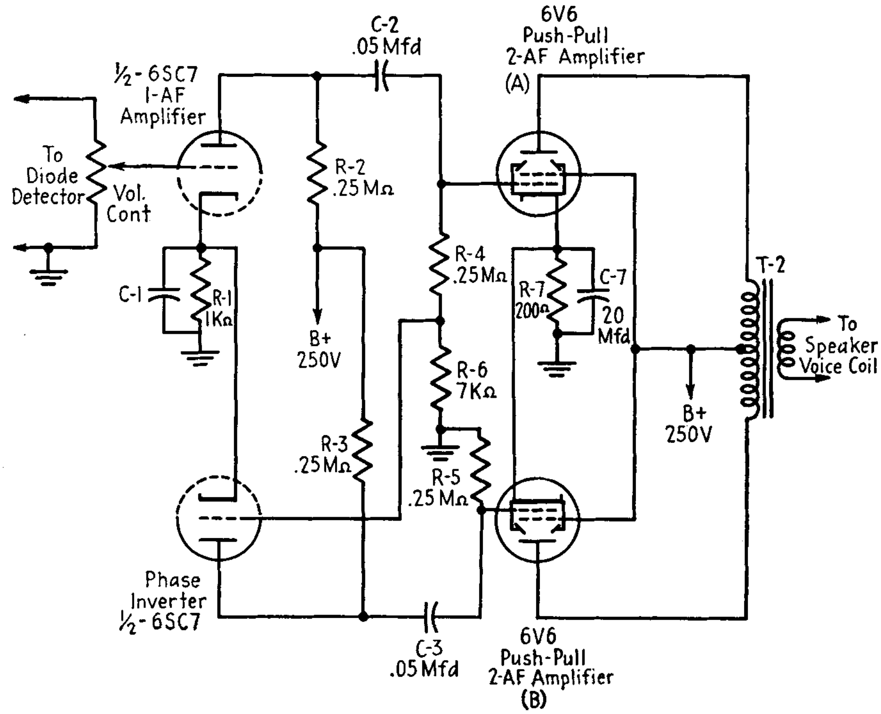


FIG. 22–16. Schematic diagram of a typical push-pull amplifier.

signal, and the attenuator is set for maximum output. The signal-generator ground lead is connected to the receiver chassis and the "hot" lead is connected through a 0.1-mfd/600-volt condenser in turn to the plate terminals of each second AF tube. If the signal generator has sufficient output, the audio note will be heard faintly each time in the speaker. The "hot" lead of the generator is then shifted to the control grid terminal of each tube. The signal-generator note should be heard in the speaker at a much greater volume, owing to the gain of each of the tubes.

For greater speed in checking, the quick check given at the beginning of this chapter may be reliably substituted.

To determine if the inverter is functioning, the "hot" lead of the signal generator is shifted to the inverter grid, and the attenuator is adjusted for less output. The signal-generator note should be heard clear and loud in the speaker.

Standard circuit. We shall consider the circuit shown in Fig. 22–16 as the standard circuit for a push-pull amplifier. Normal voltage and resistance data will refer to this circuit.

Normal voltage data. The normal voltage data given in the accompanying table refer to Fig. 22-16.

Either 6V6 control grid to ground	Pin 5	0 volts
Either 6V6 plate to ground	Pin 3	240 volts
Either 6V6 screen to ground	Pin 4	250 volts
Either 6V6 cathode to ground	Pin 8	19 volts
Inverter plate to ground		100–170 volts
Inverter grid to ground		0 volts
Inverter cathode to ground		2 volts

Normal resistance data. The normal resistance data in the following table refer to Fig. 22–16.

Second AF (*A*) plate to second AF (*B*) plate	300–500 ohms
6V6 cathodes to ground	200 ohms
Either 6V6 control grid to chassis	250,000 ohms
Inverter plate to *B* plus	250,000 ohms
Inverter grid to chassis	7,000 ohms
Inverter cathode to chassis	1,000 ohms

TROUBLES COMMON TO THE PUSH-PULL AMPLIFIER

The troubles common to a push-pull amplifier are similar in many ways to those of the single-tube second AF stage as described in Chap.

10. Only those troubles that apply to the push-pull amplifier will be discussed here.

Troubles common to the output transformer. The output transformer primary may open. As a result, one plate is open and no plate current flows from that second AF tube. The voltage drop across the common self-bias resistor becomes less, and the bias for the other second AF tube becomes too small. As a result, the operative second AF tube distorts the signal badly. The distorted signal will also be weak because only one tube is functioning. A voltage check will show no plate voltage on one second AF tube. Finally, an ohmmeter check will confirm the condition.

An open output transformer secondary is not usual. When it does occur, the output signal will produce no sound from the speaker. For a defective transformer, an exact replacement is recommended. Where such a replacement is not possible, a universal push-pull output transformer may be used. Care must be taken to obtain proper impedance match between the second AF tubes and the voice coil of the speaker. The transformer should be about the same size as the original in order to assure proper wattage dissipation. And the feedback connection, if present, must be properly connected. The reader is referred to the replacement notes on output transformers in Chap. 10 for a more detailed explanation.

Troubles common to the tubes. The second AF tubes may become weak or inoperative. The result would be very similar to that of an open output transformer primary. The operative second AF tube will be improperly biased. The sound from the loud-speaker would be weak and distorted. Replacement with a good second AF tube clears up the condition.

Troubles common to the coupling condensers. The coupling condensers *C*-2 and *C*-3 may become leaky. As a result, a positive voltage will be placed on the control grid of the second AF tube to which it is coupled, causing bad distortion. Replacement with a condenser of similar capacity will remedy the defect. Make sure that the voltage rating is as great as or greater than the original.

The inverter. The operation of the inverter is almost always foolproof. Only when its coupling condenser *C*-3 becomes leaky does trouble arise. This has been described in the preceding section.

Troubles in the inverter tube or its associated circuit will also affect the first AF tube and be found in a check of the first AF stage. When the inverter is a separate tube, it operates in a manner very similar to the first AF tube. A complete analysis of the first AF stage is given in Chap. 11.

CIRCUIT VARIATIONS OF THE PUSH-PULL OUTPUT STAGE

The transformer-coupled push-pull stage. In some receivers, the first AF stage is transformer-coupled to the push-pull output stage. No phase inverter tube is required, since phase inversion and equal-magnitude voltages are obtained by means of the input transformer whose secondary is center-tapped to ground. Figure 22–17 shows a typical circuit of this type.

Transformer *T*-1 is the push-pull input transformer. It couples the output from the first AF tube to the grids of the two tubes in the push-pull second AF stage. The secondary of the transformer is center-tapped, and the tap is connected to ground. This grounded tap makes the voltage fed to the grid equal but opposite in polarity with respect to ground.

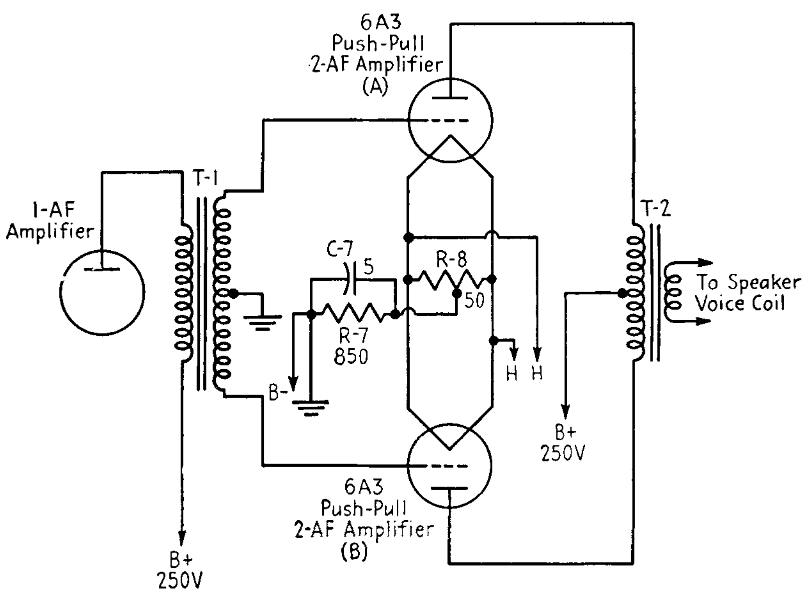


FIG. 22–17. Schematic diagram of a typical transformer-coupled push-pull amplifier.

Resistor *R*-7 and by-pass condenser *C*-7 make up the common self-bias system for both push-pull tubes. For a pair of 6A3 tubes, *R*-7 should be a 850-ohm, 5-watt resistor. Condenser *C*-7 is about 5 mfd/150 volts. In some cases, as described previously, this condenser may be omitted without harmful effects.

Resistor *R*-8 is a center-tapped filament resistor. Its purpose is to furnish a stable plate- and grid-return point. It is a wire-wound resistor of from 50 to 75 ohms. An alternative to this resistor is to bring the grid and plate returns to a center tap of the heater secondary of the power transformer.

The output transformer *T*-2 is similar to that of the phase-inverter type of push-pull stage. It differs only to the extent that the output tubes are triodes rather than beam-power tubes.

The troubles common to the circuit described above are similar, where applicable, to those for a resistance-coupled push-pull stage. Signal check for stage operation is also similar. Replacement notes for the output transformer are also applicable.

In addition, the input-transformer secondary may open. As a result, one of the grids will receive no signal voltage and have an open or zero bias. The tube will draw a heavy current and upset the bias for the other second AF tube. Hum and distortion of signal in the speaker will result. An ohmmeter check will confirm the condition. An exact replacement of the transformer is recommended.

The input-transformer primary may open. Both tubes will then give normal results on the signal check, but no note in the speaker when the 400-cycle signal is placed on the first AF plate. There will be no plate voltage on the first AF tube. An ohmmeter will confirm the open. Again an exact replacement transformer is recommended.

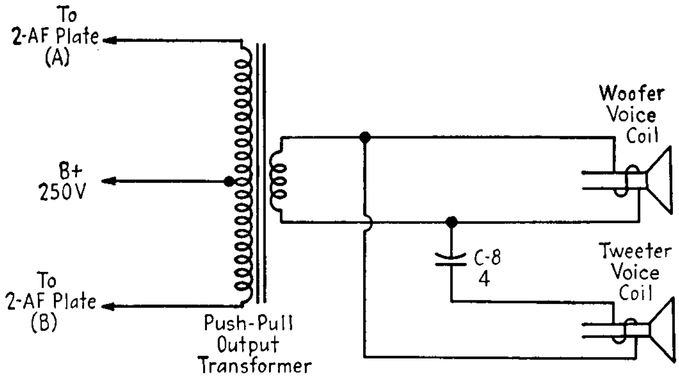


FIG. 22–18. A high-fidelity loudspeaker system.

Where an exact replacement is not obtainable, reference to a transformer catalogue will help to obtain a proper replacement transformer. The transformers are listed by the tubes that they couple.

Resistance data for the transformer-coupled push-pull circuit are as follows:

Each grid to ground	1,000–2,000 ohms
Each plate to *B* plus	150–250 ohms
Heater-resistor center tap to ground	850 ohms

Voltage data for the circuit are as follows:

Grid to heater-resistor center tap	68 volts
Each plate to ground	250 volts

High-fidelity loudspeakers. To obtain full advantage of the elimination of distortion in a receiver with push-pull output, many manufacturers use high-fidelity loudspeakers. This setup usually consists of two loudspeakers with different response characteristics. One responds especially to the high frequencies and is known as a "tweeter." The other responds especially well to the low frequencies and is known as a "woofer."

A typical circuit using this speaker system is shown in Fig. 22–18. The lower frequencies of audio signal are fed to the woofer voice coil and are blocked by the reactance of condenser *C*-8 from getting into the tweeter voice coil. On the other hand, higher audio frequencies meet little opposition from the condenser and feed through the tweeter voice coil.

Condenser *C*-8 has an approximate capacity of 4 mfd. It is a paper condenser and, since it is in a low-voltage circuit, rarely causes trouble.

The speakers in a woofer-tweeter system give the same troubles as those found with dual speaker systems, where both speakers are similar. Service notes on speakers are found in Chap. 9 on loudspeakers.

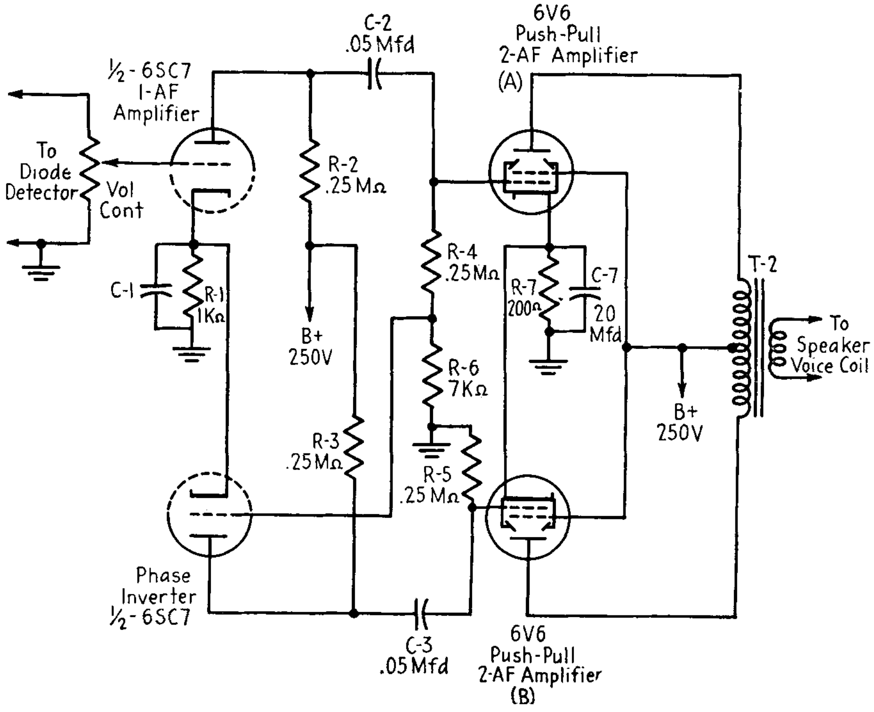
SUMMARY

Test for normal operation of the push-pull output stage

Place the tip of a plugged-in soldering iron on the control grids of each tube in the push-pull stage. A low growl should be heard from the speaker each time.

Diagram of a typical push-pull output stage

A diagram of the standard circuit for a push-pull amplifier is given in the accompanying figure.



Normal voltage data

The normal voltage data given in the accompanying table refer to the figure shown on page 430.

Either 6V6 control grid to ground	Pin 5	0 volts
Either 6V6 plate to ground	Pin 3	240 volts
Either 6V6 screen to ground	Pin 4	250 volts
Either 6V6 cathode to ground	Pin 8	19 volts
Inverter plate to ground		100–170 volts
Inverter grid to ground		0 volts
Inverter cathode to ground		2 volts

Normal resistance data

Second AF (A) plate to second AF (*B*) plate	300–500 ohms
6V6 cathodes to ground	200 ohms
Either 6V6 control grid to chassis	250,000 ohms
Inverter plate to *B* plus	250,000 ohms
Inverter grid to chassis	7,000 ohms
Inverter cathode to chassis	1,000 ohms

SERVICE DATA CHART FOR THE PUSH-PULL AMPLIFIER

Symptom	*Abnormal reading*	*Look for*
No signal from the speaker	Plate voltage of both tubes = 0. Screen voltage of both tubes = 0	Trouble in the power supply. See Chap. 8.
	Plate voltage of both tubes high	Open self-bias resistor *R-7*
Poor tone quality	Plate voltage of one tube = 0. Plate voltage of other tube normal	Open primary of output transformer
	Plate voltage of both tubes low. Screen voltage of both tubes normal	Shorted cathode by-pass condenser C-7. Shorted or leaky coupling condensers C-2 and C-3. Defective second AF tubes
	Voltages normal	Mismatched replacement output transformer
	Plate voltage of one tube is higher than the plate voltage of the other	Defective second AF tube. Open grid resistor in either tube
Motorboating		Open output filter condenser of power supply. Open grid load resistor of either second AF tube
For further defects refer to standard single-tube second AF stage in Chap. 10.		

QUESTIONS

1. A receiver is brought in for repairs, the complaint being "no reception." A voltage check shows that the plate voltages of both tubes in the push-pull amplifier are high. What is likely to be wrong? How would you check for it?

2. A receiver is brought in with the complaint, "The tone is not as good as it used to be, and the receiver seems weaker." In the push-pull amplifier, the voltage from plate to ground for one tube is normal, but is zero for the other tube. What is the defect? How would you confirm the condition?

3. A receiver is brought in for repairs with poor tone. The plate voltage of both push-pull tubes is low, although the screen voltages are normal. What are the likely troubles? How would you check for each?

4. The receiver of Fig. 22–14 requires a new output transformer and an exact replacement is not available. Use the universal output transformer chart of Fig. 10–11 for reference and choose (*a*) the type of transformer that should be used (wattage), (*b*) the secondary taps that should be used.

5. The receiver of Fig. 22–13 has poor tone quality. A voltage check shows a low plate voltage and a slight positive indication on the grid of one of the push-pull tubes. What is likely to be wrong? How would you check for it?

6. A receiver using a transformer-coupled push-pull stage is inoperative. A voltage check shows normal readings for the push-pull stage, but a plate voltage of zero for the first AF tube. What is likely to be wrong? How would you check for it?

23 ALIGNMENT OF A SUPERHETERODYNE RECEIVER

What is receiver alignment? The average superheterodyne receiver has seven or more tuned circuits, each of which has to be in resonance at its proper frequency for best operation of the receiver. When they are not in resonance, the receiver responds with a loss of sensitivity and selectivity to an extent depending on the degree to which the tuned circuits are out of resonance. The procedure for bringing these circuits to resonance at their operating frequencies is called "alignment."

Best alignment procedure for any particular receiver is an individual process. In each case, it is best to follow the exact method of alignment recommended by the receiver manufacturer in his service notes. Nevertheless, all methods are sufficiently similar to permit the presentation of a generalized procedure for use where specific service notes are not available. The purpose of this chapter is primarily to present such a generalized procedure.

The alignment procedure presented will be that to be used for a standard superheterodyne receiver operating in the broadcast band. Where special receiver variations occur, such as multiband receivers or broadband high-fidelity receivers, alignment notes have been given in the sections where such variations were described. They will not be repeated in this chapter.

In most receivers, alignment adjustment for tuned circuits is performed by varying small semivariable condensers in parallel or in series with the main tuning condensers of the tuned circuits. These condensers are known as "trimmers" when in parallel, and as "padders" when in series. They remove or add capacitance to the main tuning condenser, as the case may be. In some cases, as in wave traps or IF transformers, the trimmers are across the coils, and no other condenser is present.

In many modern receivers, the alignment adjustment is performed by varying the position of powdered-iron core plugs in the coils of the tuned circuits. This procedure varies the inductance and therefore the resonant frequency of the tuned circuit. These are known as "permeability-tuned coils." Regardless of whether the adjustment screw varies the capacitance or the inductance of the tuned circuit, the alignment procedure remains the same.

When does a receiver require realignment? The serviceman is often confronted with the question of whether or not to re-align the receiver. He must be guided by the symptoms of trouble, by his own purposes, and by a few general rules.

A receiver with a complaint of lack of sensitivity or selectivity, or oscillation, may be in need of re-alignment. However, other factors may cause the same complaint. These include weak tubes, open bypass condensers, etc., which must first be investigated. Be sure that the receiver is perfect in all other respects before resorting to re-alignment, which should not be performed unless it is necessary.

Alignment can be used as a service tool to find the cause of trouble in a receiver. For example, when the signal check shows a broad, weak response at an off-frequency setting, the circuit involved may be out of alignment. Then, when the associated trimmer is adjusted and fails to give a peak response, the indication is trouble in that circuit, rather than in alignment. Further investigation will show an open by-pass condenser, an open coil, or something similar. If adjusting the trimmer causes an improvement in response, the indication is that the alignment is at fault, and the receiver should be completely re-aligned.

As a general rule, when a coil or condenser, which is part of one of the many tuning circuits within the receiver, is replaced, re-alignment should become a routine step. This rule is important because the replacement will rarely have the same value as the original unit.

Alignment of a superheterodyne receiver involves the adjustment of the tuning circuits of three main units within the receiver. These are the IF stages, the local oscillator, and the RF stages. The order presented is the order in which the units should be re-aligned.

Equipment used for receiver alignment. When a receiver is aligned properly, it gives maximum output for any signal introduced at any point within the receiver. The equipment required, therefore, for alignment is that necessary to introduce a signal into the receiver and that necessary to measure the output for maximum.

To introduce a signal, the signal generator is a prime requirement. It furnishes any frequency needed at high or low magnitude. As indicated in Chap. 7, where RF signals are delivered to the receiver, as at the antenna, RF amplifier, mixer, and oscillator stages, a 0.00025-mfd/600-volt condenser should be connected in series with the "hot" lead of the signal generator. Where IF signals are delivered to the receiver, a 0.1-mfd/600-

volt condenser should be used. Since automobile radio receivers have a special antenna-input circuit for matching purposes with the short antenna used—a special coupling is needed between the signal generator and receiver for alignment of the RF stage. The circuit is shown in Fig. 23–1. When aligning the IF section of the auto receiver, the same 0.1-mfd/600-volt condenser may be used.

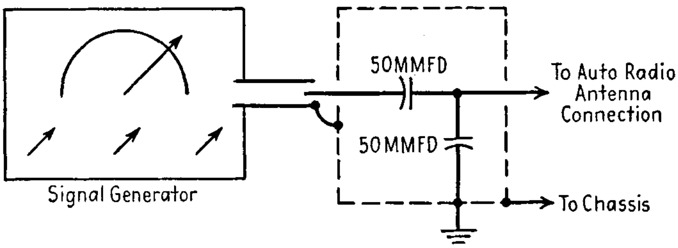


FIG. 23–1. Automobile radio coupling device.

When the receiver being aligned is of the loop-operated type and no antenna post is provided, the signal-generator output is fed into the loop of the receiver, as shown in Fig. 23–2. A two-turn loop, with a 6-in.

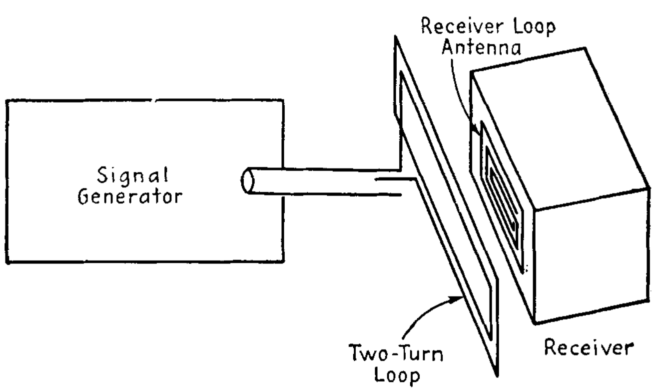


FIG. 23–2. Coupling the signal generator to a loop-operated receiver.

diameter, is constructed with hookup wire, and the ends are connected to the output terminals of the signal generator. This improvised loop is then placed in close proximity to the loop antenna of the receiver. The strength of the signal fed to the receiver can be adjusted by varying the distance between the two loops, or by adjusting the signal-generator attenuator.

The second requirement is a resonance or output indicator. The purpose of this device is to give not a numerical output value, but an indication of maximum output, regardless of its numerical value at that point. When a tuned circuit is at resonance, the output indicator will read maximum.

The resonance adjustment for most tuned circuits is screw-controlled. The head is usually slotted for screw-driver adjustment. Sometimes the head is hexagonal in shape, with or without a slot. Therefore, all that is required for adjustment is an aligning wrench or a screw driver. However, an ordinary screw driver should not be used. All resonant circuits in a receiver are quite sensitive. The capacity introduced by the metal shank of an ordinary screw driver throws off the true resonant point when the screw driver is removed. To overcome this difficulty, alignment screw drivers of polystyrene or bone fiber have been made which eliminate the capacity effect. Socket wrenches for adjusting hexagonal screw heads or nuts are also available in nonmetallic materials.

Another interesting alignment tool is the tuning wand. It consists of a fiber rod with a band of brass at one end and steel at the other. Insertion of the brass end into a coil reduces its inductance; insertion of the steel end increases its inductance. When a tuned circuit is in resonance to a signal from the signal generator, insertion of either end of a tuning wand into the coil should throw the circuit out of resonance. As a result, the output indication decreases. If one end of the wand increases and the other end decreases the output indication, then the tuned circuit is not in resonance and must be aligned.

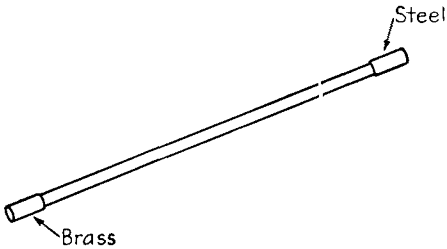


FIG. 23-3. A tuning wand.

Connecting an output indicator. If a receiver to be aligned is equipped with an electron-ray tuning-indicator tube, the tube gives a satisfactory

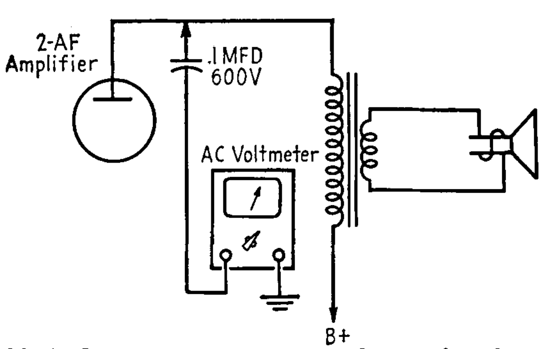


FIG. 23-4. Connecting an output indicator for alignment.

indication of when a circuit is tuned to resonance, and no other output meter is needed. Maximum output is indicated when the "eye" closes to the greatest extent. In this case, the signal-generator output need not be modulated.

Various other methods of obtaining an indication as to when resonance is reached may be used. Probably the most satisfactory method is to feed a modulated RF or modulated IF signal to the receiver, and to measure the output at the speaker with an AC voltmeter. The AC voltage range on the service multimeter may be connected as shown in Fig. 23–4.

The purpose of the condenser marked "0.1 mfd/600 volts" is to insulate the meter from the DC plate potential of the second AF tube. The condenser offers low impedance to the audio signal voltage. The latter is the modulation note of the signal generator—in most cases about 400 cycles per second. The relative output-signal strength is then obtained from the reading of the meter.

Strength of signal input. When the output indicator described above is used, it is extremely important to utilize as little output from the signal generator as is necessary to give a reading. The reason for this is the operation of the AVC circuit. When a large signal is introduced to the receiver and a tuned circuit is adjusted for resonance, as the circuit is detuned, the AVC voltage that is developed will drop. As a result, the controlled stages will have increased gain in an effort to keep the signal output of the receiver constant, and no drop in output at the output indicator will be seen. When a very small signal input is used, the AVC circuit will not become operative, and the controlled tubes will operate at maximum gain. As a result, with detuning, the output indicated on the indicator will drop, and the AVC circuit will not be functioning to raise the output to the constant level. The detuning will therefore be evident.

The standard output of 50 mw for receivers will require a signal input that is small enough to be below the level at which AVC action will interfere with alignment adjustments, and should therefore be used for this operation. Fifty milliwatts corresponds to an output-meter reading of 16 volts for the average receiver when the connections of Fig. 23–4 are used.

Receiver adjustments when aligning. When a receiver is aligned, its controls should be set in such positions as to give maximum gain. Below is a list of the positions for maximum gain. Of course, when a receiver does not have one or more of the listed controls, the serviceman will not make those settings.

Volume Control. Turned on full.

Tone Control. Set to the minimum bass position.

Fidelity Control. Set to low fidelity, or maximum selectivity position.

Sensitivity Control. Set to maximum sensitivity.

The tuning dial should be set up to the frequency required and indicated in the alignment procedure.

Location of IF trimmers in a receiver. Before attempting alignment, the serviceman would be wise to check service notes for diagrams showing the location of trimmers and padders. If such diagrams are not available, the following suggestions will be helpful. The IF trimmers are usually located in the IF cans. Figure 23–5 shows a common arrangement. Look for the detector, IF, and converter tubes, and visualize the block diagram of the superheterodyne receiver. The second IF can is between the detector and the IF tubes. The first IF can is between the IF and the converter tubes.

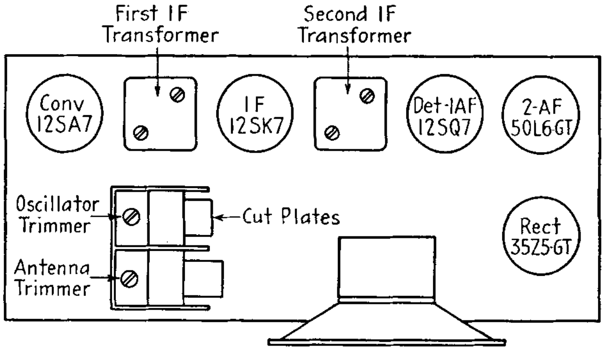


FIG. 23–5. Layout diagram of a typical small receiver showing trimmer locations.

Manufacturer's instructions always advise the adjustment of the trimmers of the secondaries of the IF transformers before those of the primaries of the IF transformers. The location of which is primary and which is secondary is not easily determined. However, it does not matter too much which we adjust first, since the alignment of them is repeated.

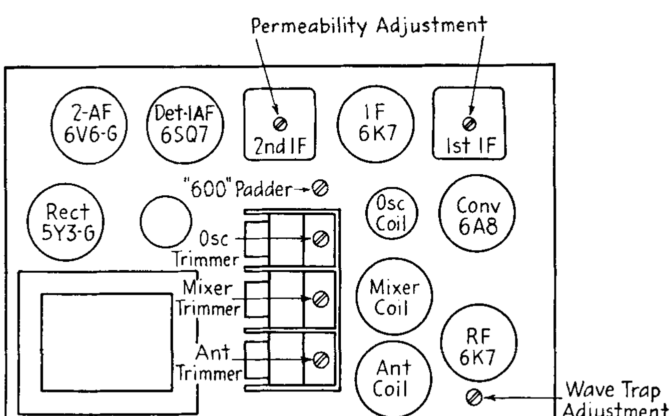


FIG. 23–6. Layout diagram of a six-tube superheterodyne receiver.

Sometimes the IF cans look like those in Fig. 23–6. Here, only one adjustment screw is visible from the top of each can. This arrangement is common for permeability-tuned IF transformers. The top adjustment screw will be for either the primary or secondary of the IF transformer. The adjustment screw for the other half of the transformer extends from the bottom end of the IF can and is adjusted from the underside of the chassis.

Location of oscillator trimmers and padders. The two controls for the oscillator-tuned circuit are the 600 or low-frequency padder, and the 1,500 or high-frequency trimmer. If the tuning gang condenser is of the variety with cut plates for the oscillator section, as in Fig. 23–5, the oscillator trimmer may be easily located. Receivers using this type of condenser usually are not equipped with a 600 padder.

When the condensers of the tuning gang all look alike, as in Fig. 23–6, the oscillator section can easily be found as follows: Tune in a station and touch the stator plates of each condenser section. When the antenna and RF sections are touched, reception will be little affected. But touching those of the oscillator section will detune the receiver. The trimmer mounted on this oscillator section is the high-frequency oscillator adjustment. The 600 padder will be located close to this oscillator section.

Some receivers do not use a padding condenser, but a permeability-tuned oscillator coil instead. The alignment procedure is the same in either case. The oscillator coil is usually close to the oscillator section of the gang tuning condenser. The permeability adjustment is usually located in the top of the coil, which is so mounted as to make the screw accessible from the top, side, or rear of the chassis.

Location of RF, antenna, and wave-trap adjustments. Trace the antenna wire to the antenna coil. The wave trap will be close to the antenna coil. The antenna coil will also lead to the antenna section of the condenser tuning gang. This locates the antenna trimmer. The RF trimmer is the only one to be located. It may be found by tracing the stator lead to the mixer coil.

When the receiver is of the multiband type, the IF trimmers are identified as before. The RF trimmers, however, are usually mounted on the coil assemblies rather than on the gang condenser. This makes the location of the trimmers somewhat more difficult, but it can be done.

Figure 23–7 shows the layout of a two-band superheterodyne receiver. All the coil cans, RF and IF, look alike. However, the second IF can is between the detector and the IF tubes. The first IF can is between the IF and the converter tubes. The oscillator coil can is in one line with the rear gang-condenser section and the converter tube. The 600 padder is between the gang condenser and the oscillator coil. The RF coil can lines up with the center section of the 3-gang condenser, and the antenna coil lines up with the front section of the gang condenser and the RF tube. Somewhat between the antenna lead and the RF coil can, the wave trap will be found. In Fig. 23–7, the wave-trap adjustment is the trimmer near the antenna post. It can be confirmed by tracing the antenna wiring. The only thing left is to determine which trimmer on each coil is for the broadcast band and which is for short wave. This is not too difficult. Start the alignment procedure with the adjustment of the

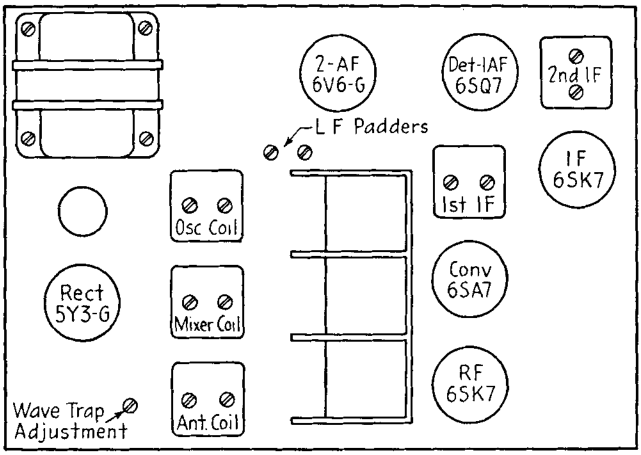


FIG. 23–7. Layout diagram of a six-tube, two-band receiver.

IF amplifier in the usual way. When the first coil trimmer adjustment is reached, set the receiver for broadcast reception and give either trimmer a half turn. If it has no effect, return it to its original position. The other trimmer is the broadcast coil trimmer. To verify, give it a half turn and note the effect.

Adjusting a trimmer to a peak response. When making a trimmer adjustment, turn the trimmer screw back and forth slowly on each side of

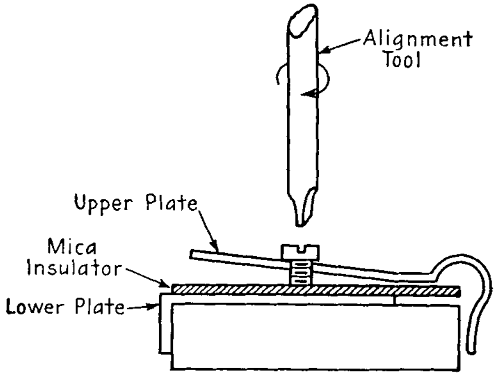


FIG. 23–8. Adjusting a trimmer condenser.

the peak output position. Note the peak position reading. The final adjustment is always one of tightening the screw, stopping at the peak response.

Sometimes, when the alignment tool is removed from the adjusting screw, the response falls below the peak obtained while the tool was in position. This effect occurs because the weight or capacity of the tool affects the trimmer capacity. When this happens, make the final tightening adjustment to the peak position, and tighten the screw an extra fraction of a turn. When this is done, the output meter reading will fall below the peak reading, but it should return to peak when the tool is removed.

In some receivers, peak response position occurs at the low-capacity setting of the trimmer condenser (when it is wide open), as shown in Fig. 23–9. A trimmer should not be left with this type of adjustment

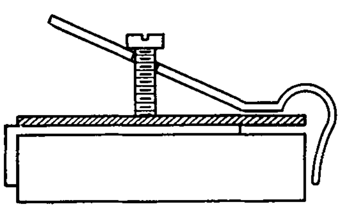


FIG. 23–9. A trimmer condenser at its low-capacity setting.

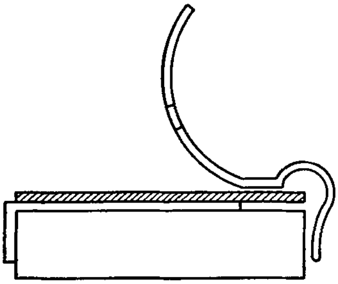


FIG. 23–10. Provision to avoid microphonics when the trimmer condenser peaks at the low-capacity setting.

since, in this position, the spring tension of the top plate is at its weakest. Any jar or vibration, like that from the speaker, will cause the upper plate of the trimmer to vibrate, with accompanying noise and microphonics. When peak response position is at minimum capacity, remove the adjustment screw and bend the top plate back, as shown in Fig. 23–10. Microphonics will thereby be eliminated.

Determination of the intermediate frequency of a receiver. Before attempting to align the IF trimmers, the serviceman must know the intermediate frequency for the particular receiver to be aligned. This information is always found in the manufacturer's service alignment notes, or on the schematic diagram.

Where the usual information is not available, the serviceman can assume that the intermediate frequency is probably 455 kc, if the receiver is of modern vintage. The IF amplifiers of the past few years have been designed to peak at some value between 440 and 480 kc. If, because of lack of information, a receiver designed to peak its IF amplifier at 465 kc is aligned at 455 kc instead, no great harm will have been done. The receiver will operate normally and satisfactorily, although the tracking of the tuning dial may be slightly off.

If the serviceman is entirely uncertain of the intermediate frequency, he can determine it approximately by connecting the "hot" lead of the signal generator to the mixer grid. Then, by rotating the signal-generator frequency control from 500 to 150 kc, he can see at what frequency a response is heard. Usually, a misaligned receiver is not too far from its correct setting and a broad response, with possibly two peaks, will be obtained. For example, if a receiver shows a broad response centering at approximately 270 kc, it may safely be assumed that the receiver was originally designed to operate at 260 kc, the nearest commonly used intermediate frequency. The most commonly used intermediate frequencies are 175, 260, 455, and 465 kc.

When the procedure just described is used, it is important to make sure that the oscillator of the receiver is made inoperative. If the receiver oscillator is operating, there will be many squeals and responses heard, depending on the position of the receiver tuning control. The oscillator is made inoperative by placing a short across the oscillator tuning condenser.

It is also important in the procedure to make sure that the receiver is not responding to a harmonic of the signal-generator output. This unwanted response can be avoided by starting the search for the intermediate frequency at the high-frequency end of the IF spectrum, that is, at 500 kc. Then, when a receiver shows a response at 460 kc, the serviceman should expect another weaker response at 230 kc, the second harmonic of which is 460 kc. Still another very weak response should occur at 153 kc, whose third harmonic is about 460 kc. Were the serviceman to make the check at random frequencies, he might stop at the 230-kc response, assume an intermediate frequency of 260 kc, and try to align the receiver at that frequency, with very poor results.

Aligning the IF amplifier. The receiver, signal generator, and output meter are hooked up as shown in Fig. 23–11. The output meter is adjusted for a high-voltage AC range, and connected through a 0.1-mfd/600-volt condenser to the plate pin of the second AF tube. The signal generator is adjusted for a modulated output at the intermediate frequency of the receiver. The signal-generator output is connected through a 0.1-mfd/600-volt condenser to the mixer grid of the receiver. The stator terminal of the oscillator condenser is shorted to the condenser frame. The receiver controls are set for maximum gain. Both the receiver and the signal generator are allowed a warm-up period of 15 min.

The signal-generator attenuator is adjusted to give an output as low as possible, with the modulation note heard faintly in the speaker of the receiver. Either trimmer in the output IF can is then adjusted for the loudest note from the speaker. The attenuator is then reduced until the note can just be heard again. Then the other trimmer in the second or output IF can is adjusted for the loudest note from the speaker. The procedure is repeated for the two trimmers in the input or first IF shield can—first reducing the output to a faint note and then adjusting the trimmer for a maximum note.

The alignment is then repeated for the four trimmers in turn, starting with either trimmer in the second IF can. This time the output meter setting is reduced to the 50-volt AC range. The attenuator is reduced to give a reading of about 5 volts, and each trimmer is adjusted for peak voltage reading. If the output meter shows a reading over 30 volts while any one trimmer is aligned, the attenuator setting of the signal generator is reduced again, and the adjustment continued.

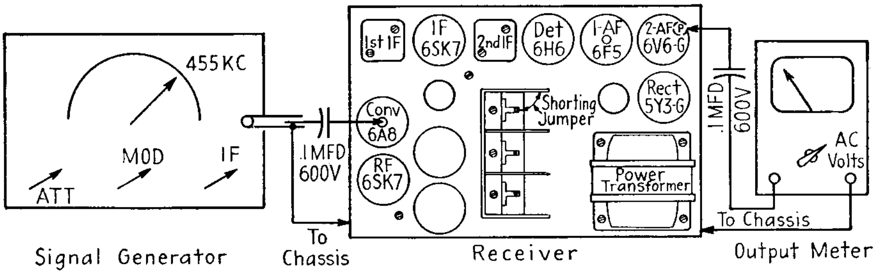


FIG. 23–11. Connections to a receiver for aligning the IF amplifier.

When all four trimmers have been readjusted to give peak response on the output meter, the IF alignment is complete.

Setting the receiver tuning-dial scale adjustment. The next step in the alignment procedure is to adjust the receiver tuning-dial pointer. The most common adjustment is to rotate the gang condenser to maximum capacity (plates fully engaged) position. Then set the dial pointer to the last calibration mark on the low-frequency end of the dial scale, as shown in Fig. 23–12.

Aligning the oscillator circuits. After the IF trimmers have been adjusted, there remain the oscillator and RF or antenna adjustments. Normally, the oscillator will have two adjustments: the high-frequency trimmer and the 600 padder. However, when a receiver uses cut plates in the oscillator section of the tuning gang condenser, and no 600 padder, the adjustment of the oscillator circuit is relatively simple. The remainder of this section will give the alignment procedure for such an oscillator circuit, and it will be followed by the RF and antenna circuit adjustments. The section after that will present the alignment procedure for an oscillator stage with a 600 padder.

The short (used in the IF alignment) is removed from the oscillator section of the gang tuning condenser. The signal-generator output lead is shifted to the antenna post of the receiver, and a 0.00025-mfd/600-volt mica condenser is added as the dummy antenna in series with the generator output lead. The output meter is switched to a high-voltage AC range. The receiver is tuned to a quiet point on the tuning range, between 1,500 and 1,700 kc. The receiver controls are kept at the maximum gain positions.

Now, the signal-generator frequency control is adjusted to deliver the same frequency as that shown on the receiver tuning dial, let us say 1,500 kc. The oscillator trimmer is then loosened all the way and tightened carefully until the signal is heard. This adjustment is very

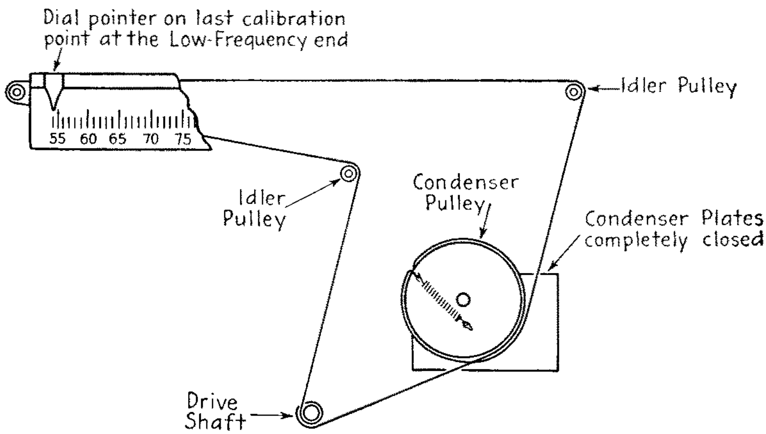


FIG. 23–12. Setting the dial pointer.

critical. When it is reached, the signal-generator output is reduced, and the output meter is switched to the 50-volt AC range. Then the trimmer adjustment is repeated for peak voltage output. If the reading goes down after removing the aligning tool, follow the procedure suggested in the section on adjusting a trimmer (page 441).

Adjusting the RF and antenna trimmers. There remain now only the RF and antenna trimmer adjustments. The signal-generator dial is turned to 1,400 kc. Then the receiver is tuned for maximum or peak response at or near 1,400 kc. The generator attenuator is reduced to give a low reading on the output meter, and the mixer trimmer is adjusted for peak response on the meter. If an antenna trimmer is present, it is then adjusted for peak response. Alignment of the receiver is now complete, except for the adjustment of a wave trap, if present.

Adjusting the oscillator and RF circuits when a 600 padder is present. The alignment procedure is somewhat different when a 600 padder or permeability adjustment is present for alignment at 600 kc. The signal-generator output is fed to the antenna of the receiver through a 0.00025-mfd mica condenser, acting as a dummy antenna. The generator is adjusted for a modulated output at 600 kc. Then the receiver is tuned to 600 kc, and the 600 padder is adjusted for peak response.

Next, the receiver is tuned to a quiet point near the high-frequency end of the dial. The signal generator frequency control is adjusted for the same frequency as that shown on the receiver tuning dial. The high-frequency trimmer on the oscillator section of the gang condenser is then carefully adjusted for peak response. This last adjustment is critical. In making it, the trimmer screw should first be loosened and then slowly tightened until the note is heard. The attenuator is then reduced for a low reading on the output meter, and the adjustment repeated for peak voltage on the output meter.

The next step comprises the RF and antenna trimmer adjustments. The oscillator is set to 1,400 kc. The receiver tuning knob is tuned back and forth near 1,400 kc and left at the position of greatest response. The RF and antenna trimmers are now adjusted for peak response, as described previously.

Alignment of the oscillator circuit is not yet complete. The gang tuning condenser must be rocked at 600 kc on the tuning dial, and the 600 padder adjusted for peak response. This rocking procedure is described in the next section.

Rocking the gang tuning condenser at 600 kc. In the rocking procedure, performed step by step, the receiver and signal generator are both tuned to 600 kc, and the 600 padder is readjusted for peak response. The attenuator is then set to give an output meter reading of 16 volts. The signal, of course, is being fed to the antenna.

The receiver is then tuned slightly higher than 600 kc, such as 605 kc. The signal generator, however, is left at 600 kc, and the 600 padder is readjusted for peak response. If the output meter reading increases above the previous reading of 16 volts, the maneuver is repeated until a maximum voltage is obtained. If the output meter reading does not increase, the receiver tuning condenser is rocked in the other direction; that is, the receiver is tuned slightly lower than 600 kc, such as 595 kc, and the 600 padder is adjusted. The output is noted. If there is an increase, the condenser is rocked still lower, the padder is adjusted again, and the peak output is noted. The rocking and padding adjustments are made and repeated until maximum output is reached.

The adjustment of the high-frequency oscillator trimmer is then checked at 1,500 kc for peak response at the high-frequency end of the broadcast band.

Adjusting the wave trap. The last step in receiver alignment is adjustment of the wave trap. The signal generator is connected to the antenna and ground of the receiver, the "hot" lead fed through a 0.1 mfd/600-volt condenser. The generator is then adjusted to give a strong response at the intermediate frequency of the receiver, say 455 kc. The receiver is tuned to 1,000 kc, approximately the center of the tuning range. Then the wave trap is adjusted to give minimum response in the output meter. The receiver is now completely aligned.

SUMMARY OF ALIGNMENT PROCEDURE

1. Set receiver controls for maximum gain.
2. Connect ground lead from signal generator to receiver chassis (or *B* minus in the case of an AC/DC receiver).
3. Connect output meter to plate pin of second AF tube and chassis.
4. Allow signal generator and receiver to operate for 15 min as a warm-up period before aligning.

Signal generator		*Receiver*			*Notes*
Frequency setting, kc	*Dummy antenna, mfd*	*Generator "hot" lead to receiver terminal*	*Tuning condenser setting, kc*	*Adjustment*	
455 or IF	0.1	Mixer grid	Any	IF trimmers	1, 2
			Maximum capacity	Tuning dial pointer	
600	0.00025	Antenna	600	600 padder	
1,500	0.00025	Antenna	1,500	High-frequency oscillator trimmer	
1,400	0.00025	Antenna	Tune for maximum output	RF and antenna trimmers	
600	0.00025	Antenna	600	600 padder	3
1,500	0.00025	Antenna	1,500	High-frequency oscillator trimmer	4
455	0.1	Antenna	1,000	Wave trap	5

Notes:

1. Short oscillator section of gang tuning condenser.
2. Align IF trimmers in the following order:
   a. Detector input trimmer (secondary of second IF transformer).
   b. IF plate trimmer (primary of second IF transformer).

c. IF grid trimmer (secondary of first IF transformer).

d. Converter plate trimmer (primary of first IF transformer).

e. Repeat the adjustment of the trimmers in the same order.

3. Rock the tuning condenser during this adjustment as follows: Turn the rotor of the gang condenser back and forth and adjust the 600 padder until a peak is obtained.

4. This step is a check to see whether the previous adjustment of the 600 padder has affected the setting at the high-frequency end. If the high-frequency trimmer requires considerable readjustment, the 600 padder must also be readjusted by repeating the previous step.

5. Adjust for minimum output.

24 SURVEY OF THE F-M RECEIVER

The A-M signal. The trend toward incorporating A-M and F-M receivers, as well as the use of F-M signals in the audio system of television, has made the study of frequency modulation more important than ever. In this book, we shall study frequency modulation as found in the A-M/F-M receiver.

We begin with a comparison of the A-M and F-M signals as received at the antenna, disregarding how the transmitters achieve their purposes.

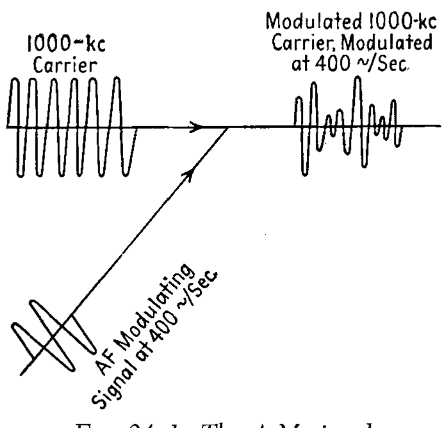


FIG. 24–1. The A-M signal.

What is implied in an A-M signal? First, every station is assigned a specific carrier frequency. Thus, in New York City, station WCBS has a carrier frequency of 880 kc, and station WOR has a carrier frequency of 710 kc.

Second, the A-M carrier is made to carry intelligence (speech or music) by varying the carrier amplitude. The rate at which the amplitude is varied is the pitch of the modulating note. For example, look at the A-M signal shown in Fig. 24–1. The pitch of the modulating note is 400 cycles per second. The carrier is at 1,000 kc. The A-M signal is shown at the right of the diagram, where the amplitude of the original carrier varies up and down 400 times a second.

Third, the A-M carrier must also carry the loudness of the original modulating signals. Loudness in an A-M signal is indicated by the extent to which the amplitude of the carrier is varied. The two wave forms in Fig. 24–2 make this point clear. The greatest permissible loudness is that in which the amplitude is reduced to zero (100 per cent modulation). To go beyond this point would result in a distorted signal. Hence, the modulating process is carefully controlled at the broadcast station.

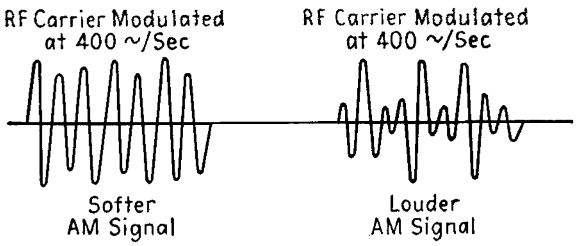


FIG. 24–2. Soft and loud A-M signals.

The fourth consideration with respect to the A-M signal is that known as "sidebands." Modulation of a carrier frequency produces a mixture of frequencies, representing the mixing of the carrier and modulating frequencies. The spread of this mixture is dependent on the frequency of the audio-modulating signal. The spread on each side of the carrier is known as the "upper" and the "lower" sideband. Thus, if the carrier

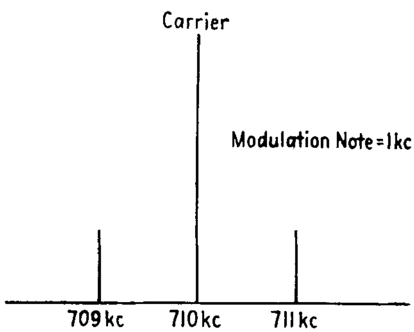


FIG. 24–3. Sidebands in an A-M signal.

frequency were at 710 kc and the modulation note were at 1,000 cycles per second, the lower sideband frequency would be 710 minus 1, or 709 kc, and the upper sideband frequency would be at 710 plus 1 or 711 kc. This relationship of upper and lower sideband frequency is shown in Fig. 24–3. With a few exceptions, A-M broadcast stations are restricted to a bandwidth of 10 kc, that is, 5 kc on either side of the carrier. This means that, for the most part, no audio note can go above 5 kc. The station, therefore, suppresses any note above that frequency at the transmitter, thereby failing to give true fidelity. Fortunately, the quality of radio reception is generally satisfactory even though some of the high notes are missing.

The F-M signal. Now compare the F-M signal with the A-M signal described above. The same considerations manifest themselves, but in a different manner. Again, every F-M station is assigned a carrier frequency. Thus, in New York City, WRCA—F-M operates at 97.1 mc, and WOR–F-M operates at 98.7 mc. The complete F-M band is from 88 to 108 mc.

The second consideration is that of how the carrier is modulated to carry intelligence. In the frequency-modulation system, the mixing of the audio-modulation note and the carrier results primarily in a frequency variation above and below the carrier frequency at a rate equal

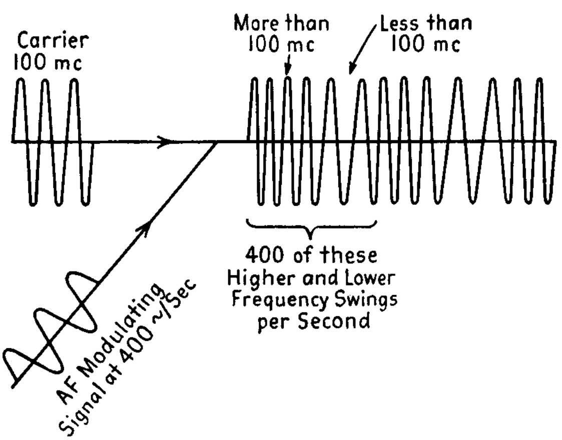


FIG. 24–4. The F-M signal.

to the frequency of the modulating note. Inspection of Fig. 24–4 will make this point clearer.

Recall that in the A-M system, the highest permissible audio note was 5 kc because of sideband limitations. In the F-M system, audio modulation does not affect the sideband considerations. Hence, higher-frequency audio signals are permitted and greater fidelity results.

The third consideration is the loudness of the modulating sound. In the F-M signal, the louder the modulating sound, the greater the extent to which the frequency of the carrier swings above or below the carrier center frequency. Again, inspection of Fig. 24–5 will make this point clear. Note that the rate at which the frequency swings around the center carrier frequency is the same for both a loud or a soft sound. However, the amount of swing or deviation is different for the two signals.

Since the amount of deviation of carrier frequency is of little concern in the F-M system, the FCC has given 75 kc on each side of carrier frequency to each station. This permits the receiver to give truer response with respect to the loudness of the modulating sounds. To prevent overlapping of stations, the FCC further allots 25 kc at each end beyond the 75-kc deviation range. The two extreme protective bands are known as "guardbands."

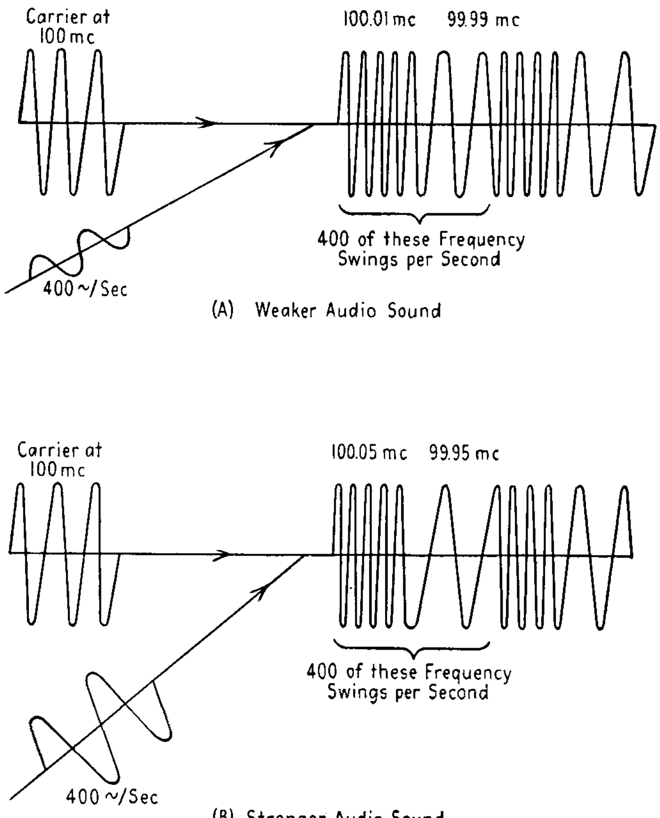


FIG. 24–5. Soft and loud F-M signals.

Advantages of the F-M receiver. There are two main advantages of the F-M receiver over the A-M receiver. From the previous description it can be seen that the former is capable of reproducing the original audio sounds with truer fidelity. Higher-frequency sounds can be handled better, as well as the loudness of those sounds. Of course, if the audio system of the F-M receiver is poorly designed, these advantages may be lost.

The second advantage is the rejection of noise, particularly that resulting from a spark discharge. Noise essentially causes an amplitude modulation of the signal. Since the F-M receiver responds, by design, only to frequency variations, the noise becomes a nonfunctional factor. This premise is true, however, only if the carrier comes in with a minimum signal strength. That is why antenna design for the receiver is so important. But more on this later!

Comparison of A-M and F-M receivers. In many respects, the F-M receiver is similar to the standard A-M superheterodyne receiver. The primary difference lies in the second detector stage before the audio-amplifier input. In the F-M receiver, this second detector stage is of the

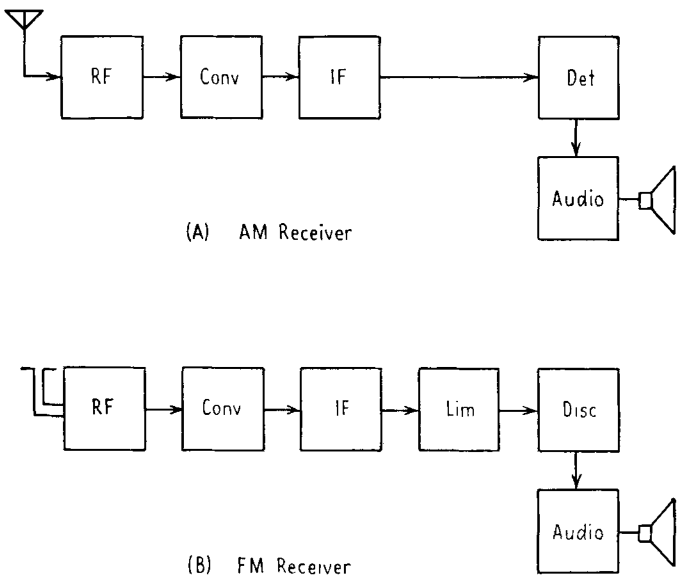


FIG. 24–6. Comparison of A-M and F-M receivers.

discriminator or ratio detector type. Examine Fig. 24–6 for block diagrams of an A-M and an F-M receiver. Note the similarity of stages used. In the case of the F-M receiver with its discriminator, a limiter stage is used. It is a specialized IF stage whose function will be described in detail later.

Let us now analyze the various stages of an F-M receiver as compared with the familiar A-M superheterodyne receiver stages. In most cases, the function is similar, although design will differ considerably.

The RF stage. The RF stage in an F-M set serves the same function as the similar stage in an A-M set, namely, to amplify the antenna signal. However, new problems present themselves because of the high frequencies handled in the F-M band. Careful design is necessary to prevent the RF stage from oscillating. Special miniature tubes are used to handle the high frequencies properly. Examples of these special high-frequency pentodes are the 6BJ6 and 6CB6 tubes in standard RF circuits. Another technique is to feed the signal to the cathode of a triode tube and to ground the grid, as shown in Fig. 24–7. When this is done, the cathode varies with respect to the grid rather than the grid varying with respect to the cathode, and the tube still acts as an amplifier. However, the grounded grid acts to prevent the tube from oscillating by shielding the input from the output circuit.

To handle the broad band of frequencies, use is made of impedance coupling. Note coil *L* and condenser *C* functioning in this regard.

A final difference to be noted is the type of coils used in the tuning circuits. At the frequencies involved, these are just a few turns of heavy wire.

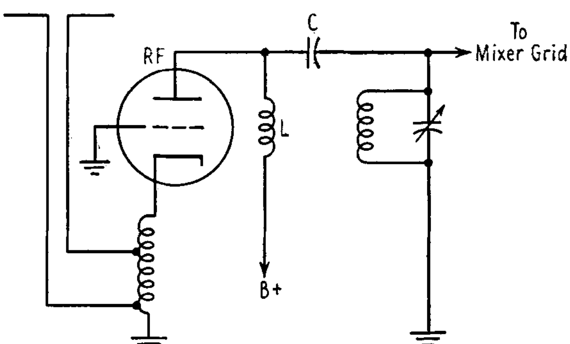


FIG. 24–7. RF stage in an F-M receiver, using a grounded-grid triode.

Frequency conversion. Again, the frequency converter in F-M sets has the same function as in A-M sets. However, the higher frequencies involved in the former case make for new design considerations. Most sets have separate mixer and oscillator tubes, instead of a single converter. In A-M/F-M sets, the oscillator section of the A-M converter, like the 6BE6, is often used with proper switching as the oscillator for the F-M mixer. Such a typical setup is shown in Fig. 24–8. A 6AB4 is used as a triode mixer. Coupling between the oscillator and the mixer is by means of a 2.2-mmfd condenser.

Another high-frequency problem is the tendency for the oscillator frequency to drift, primarily because of temperature effects on the oscillator tuned circuit, and this produces fading in the set. Several devices are used to overcome this defect. Sometimes use is made of a negative temperature-coefficient condenser across the oscillator tuned circuit. This condenser responds in such manner as to offset temperature effects on the other circuit components. Another device to neutralize oscillator drift is the use of an automatic frequency-control (AFC) tube. This does for the oscillator frequency what an AVC circuit in A-M radio does for signal strength. And still another device is to have the oscillator tuned circuit operate at half the required frequency and to utilize the second harmonic for feeding into the mixer. The oscillator frequency is more stable at this lower half-frequency.

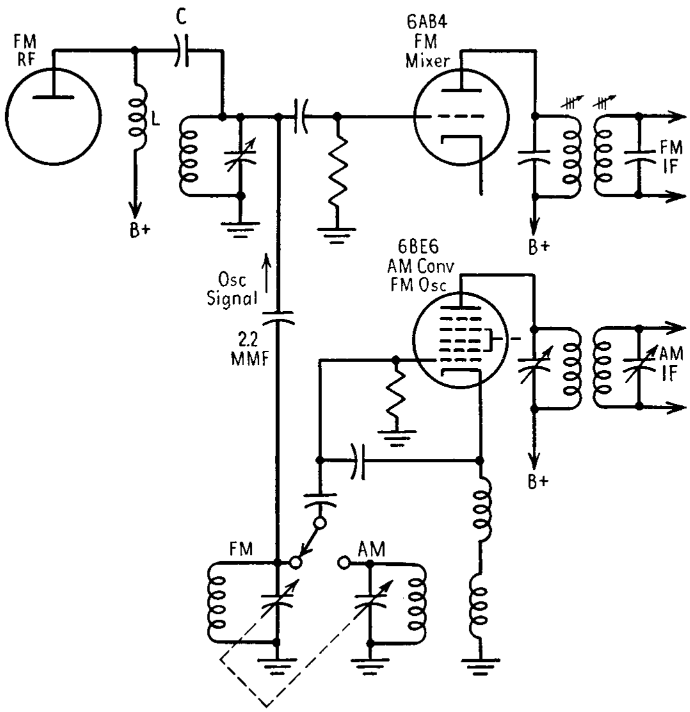


FIG. 24–8. A typical F-M converter system.

The IF amplifier. Again, the IF amplifiers of F-M and A-M sets serve similar functions. A few differences should be noted. Many F-M sets use two or three stages of IF amplifiers, the last of them, known as the "limiter," having a special function to be described later.

In Fig. 24–9 is shown a typical IF amplifier. Condenser *C*-2 and resistor *R*-2 make up a plate-decoupling filter to avoid coupling between the various stages. These should be carefully identified, since they frequently give service difficulty. Note also how degeneration is introduced to offset the tendency of the IF stage to oscillate. This degeneration is introduced by omitting the bypass condenser across self-bias resistor *R*-1. Note that a common practice is to operate the plate and screen of the IF amplifier at the same voltage, from about 85 to 100 volts.

You recall that image-frequency interference was a problem in A-M receivers. In F-M sets, this is almost never a problem, since almost all utilize an RF stage, and the intermediate frequency is more or less standardized at 10.7 megacycles. Thus, if you take twice the intermediate frequency (21.4 megacycles) and add it to the lowest F-M frequency (88 megacycles), you get 109.4 megacycles, which is outside the F-M band.

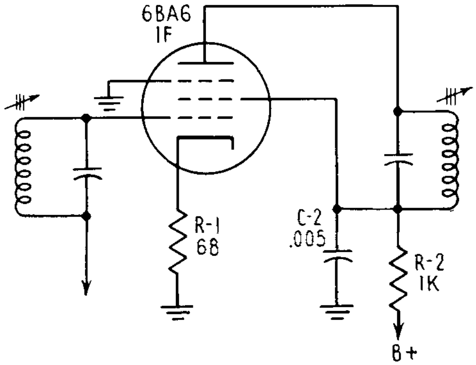


FIG. 24–9. A typical F-M IF amplifier stage.

The limiter. Here is the first point at which we seem to depart from the standard A-M superheterodyne receiver in function. But this is not so. The limiter stage is simply a specialized IF amplifier. Its action is indicated in Fig. 24–10.

Why is the limiter necessary? The F-M signal, as it travels through the receiver signal chain, receives amplitude modulations of various sorts because of air static, nearby spark discharges, receiver noise, etc. To

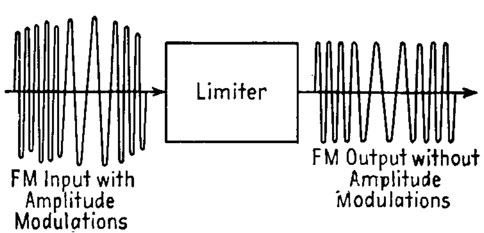


FIG. 24–10. Representation of limiter action.

eliminate these noise effects from the loudspeaker, the amplitude variations must be eliminated before they get to the discriminator detector. The limiter stage performs the job.

The limiter tube is a sharp cutoff tube with grid-leak bias, operating at reduced plate and screen voltages, so that it is readily driven to saturation. It is this saturation point which removes the amplitude modulations that produce noise in the receiver.

A strong input signal is required at the input of the limiter stage. If the signal is weak, the amplitude variations ride through and produce noise, as shown in Fig. 24–11. For this reason, a good antenna installation is important for noise-free F-M reception. For the same reason, most F-M receivers utilize an RF stage and two IF stages before the limiter to get additional gain.

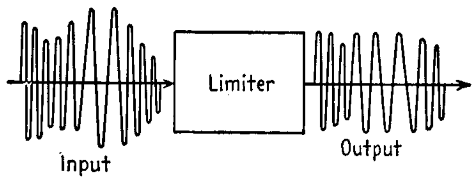


FIG. 24–11. Limiter action when the input signal is too low.

The limiter is used to develop AVC voltage in addition to its limiting action. Here use is made of the fact that grid current flows, and the grid circuit acts as a diode rectifier. A typical circuit for this limiter function is shown in Fig. 24–12. The low plate and screen potentials are obtained by using a large dropping resistor in the supply circuit. This also acts as the decoupling filter for the stage.

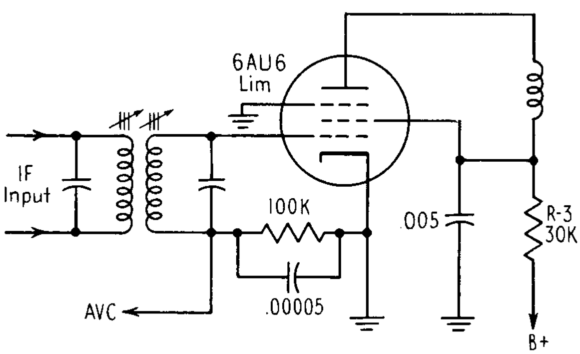


FIG. 24–12. A typical F-M limiter stage.

The discriminator. It is at the discriminator that we encounter the first major difference between the A-M and F-M sets. In A-M receivers, amplitude variations result in voltage variations fed to the grid of the first AF amplifier. In F-M sets, there are no amplitude variations after the limiter. It becomes necessary to change the rate of frequency variations into voltage variations fed to the first AF grid. That function is performed by the discriminator.

It is beyond the scope of this book to go into the complex theory involved in the discriminator. But we should be familiar with the circuit. A common circuit is the Foster-Seeley discriminator, shown in Fig. 24–13. Other variations are found as well.

Note resistor R and condenser *C* in the discriminator output circuit. They make up what is known as a "deemphasis network." At the transmitter, the high-frequency notes are amplified in order to get a better signal-to-noise ratio for those frequencies. Recall that noise is primarily high-frequency sounds. However, to get a natural relationship of all frequencies, the high-frequency notes are reduced or deemphasized at the receiver by the deemphasis network.

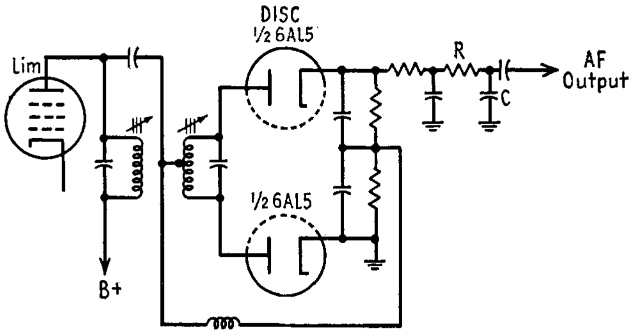


FIG. 24–13. A typical Foster-Seeley discriminator.

The AF section. The audio system of an F-M receiver is the same as that of an A-M set. In some cases, it is designed more carefully to handle properly the greater range of audio frequencies and volume inherent in the F-M system. Especially in high-fidelity F-M sets is this true, with push-pull output feeding treble and bass loudspeakers. Tone controls for treble and bass control are present also.

The F-M receiver antenna. Many types of antennas are in use with F-M receivers today. Although reception is possible without any specific antenna, the need for a strong signal makes one desirable. Several common antennas are shown in Fig. 24–14. The antenna installation of Fig. 24–14*A* is frequently used. It consists simply of a 50-mmfd condenser connected from the antenna post of the receiver to the power line cord.

Another common type is the line-cord wire, shown in Fig. 24–14*B*. Here, a third unconnected wire is included in the line cord to the receiver. It then feeds to the antenna post. The antenna wire is about 5 ft in length.

The type of antenna shown in Fig. 24–14*C* is frequently used in the console type of F-M radio. It consists of two 5-foot lengths of twisted hookup wire tacked around the cabinet and connected at the ends to the antenna input. Or, a slit 5-ft section of television twin lead is similarly connected. All the above are built-in types of antenna.

Where a more efficient antenna is needed, as in a fringe area, an external dipole antenna is used, like those shown in Fig. 24–14*D*. The simple dipole was previously mentioned in the chapter on antennas. This dipole is a circuit resonant to a signal whose wave length is twice the length of the dipole from tip to tip. Since it must respond to all frequencies from 88 to 108 mc, how long must the dipole be? The usual practice is to cut it to a length so that it is resonant at the middle of the band, namely, at 98 mc. The formula for computing the dipole length is

$$L = \frac{5{,}904}{\text{frequency (mc)}} \text{ inches}$$

This gives us the usual length of about 60 in. from tip to tip.

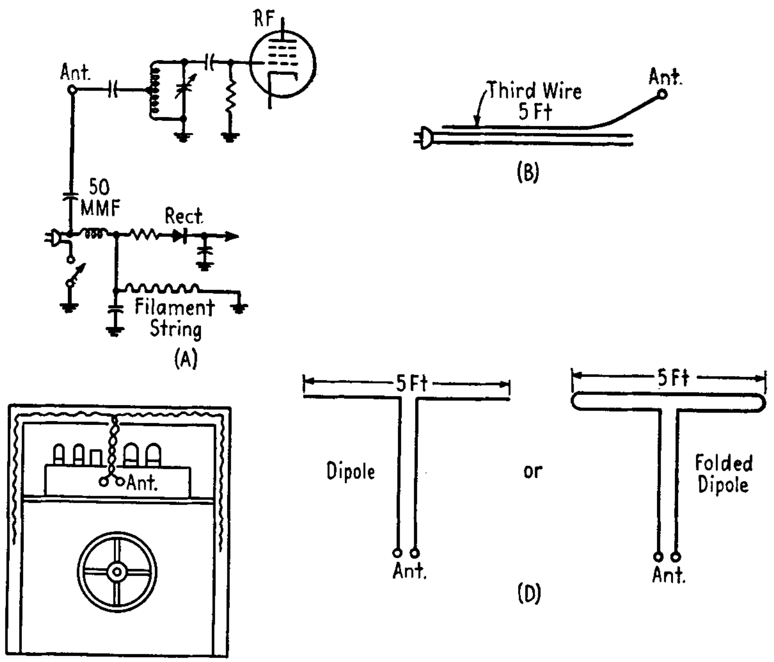


FIG. 24–14. Various F-M antenna systems.

For best efficiency, the simple dipole must be matched to the input of the receiver. The impedance of a simple dipole is about 73 ohms. It must be matched with a transmission line with an impedance of 73 ohms. A twisted pair transmission line meets this requirement. This transmission line in turn is connected to the receiver with an input impedance of 73 ohms.

However, most receivers have an input impedance of 300 ohms. To meet this condition, use is made of the folded dipole, shown in Fig. 24–14*D*, which is a variation of the simple dipole. It consists of an aluminum tube, folded like a trombone slide into two parallel sections.

Its over-all length is the same as the simple dipole. The two parallel sections are separated by a few inches and the transmission line is connected to the two ends, located at the center. Such an antenna has an impedance of about 300 ohms. The transmission line is usually a twin lead line with a 300-ohm impedance. This is suitable for connection to the receiver with a 300-ohm input impedance.

The simple and folded dipole receive most efficiently when the broad side faces toward the transmitting station. It is usual practice to rotate the antenna so as to get best results from most F-M stations. At best, this will be a compromise condition that serves no one station best. For better results, the antenna is sometimes mounted on a motor-driven rotator to give best efficiency for each station.

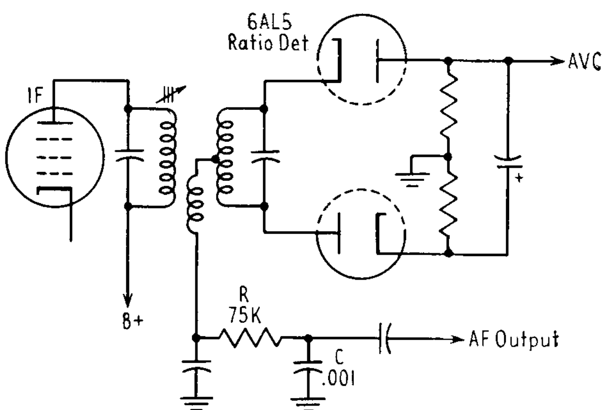


FIG. 24–15. A typical ratio detector circuit.

The Ratio detector. Before leaving the analysis of the F-M radio, reference must be made to a second type of detector that is also used. This is the ratio detector. In Fig. 24–15 is shown the circuit of a typical ratio detector. Its function is the same as that of the discriminator, namely, to change the rate of frequency variations into voltage variations fed to the AF section. Note, however, that the detector is fed directly by an IF amplifier, not a limiter. It is a characteristic of the ratio detector that it does its own limiting. Such a setup saves the manufacturer one stage.

Note, also, the AVC voltage tap in the detector. As explained previously, the AVC voltage was obtained from the limiter when the discriminator was employed. Since we have no limiter here, the AVC voltage must be found in the detector itself.

And finally, note the deemphasis network, made up of resistor R and condenser C. It serves the same function as that described in the section on the discriminator.

The combined A-M/F-M receiver. Many home receivers combine the A-M and F-M receivers in one unit, with a switching arrangement for function selection. The block diagram of such a setup is shown in Fig. 24–16. There are many other variations. Sometimes a separate A-M converter tube is used and the F-M section uses separate oscillator and

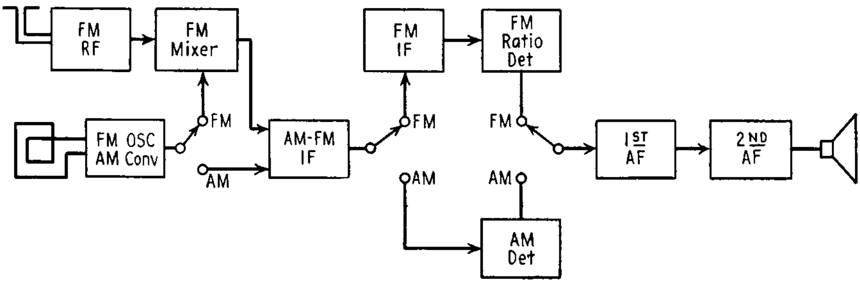


FIG. 24–16. Block diagram of a typical A-M/F-M receiver.

mixer tubes. Sometimes separate IF tubes are used for the A-M and F-M functions. In other sets, one tube serves as an A-M converter and an F-M oscillator with a separate F-M mixer tube. The block diagram in Fig. 24–16 has been chosen because it shows some interesting points.

Note that separate antennas are used. The F-M antenna is either a

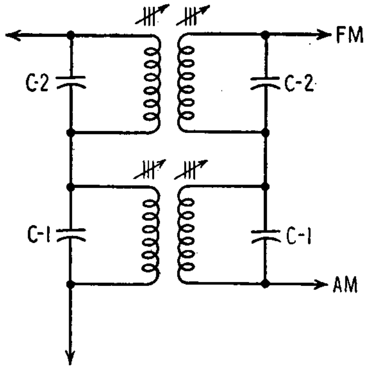


FIG. 24–17. IF transformer assembly for an A-M/F-M receiver.

dipole or line-cord antenna, while the A-M antenna is usually the standard loop. The functions are selected by a ganged set of function switches which select the antenna input, the required oscillator, and the A-M or F-M demodulator. Note also that the first IF stage is common to both A-M and F-M operation. This point requires a little further investigation.

The IF transformers for both functions are often connected in series and placed within one shield can, as shown in Fig. 24–17. Because the

A-M coils operate at 455 kc and the F-M coils at 10.7 mc, the former coils have many more turns and higher inductance than the latter. As a result, when operating on the A-M function, the A-M signal at 455 kc meets very little impedance from the small F-M coil. The signal behaves as though the F-M coil is shorted out. When operating on the F-M function, condenser *C*-1 across the A-M coils offers almost no impedance to the F-M signal at F-M frequencies, and serves to short out the A-M coils. Thus, the IF transformers do not affect each other and may be connected as a single unit.

Figure 24–18 shows a typical A-M/F-M receiver, the Zenith Model J733. Many of the points mentioned are illustrated in the diagram.

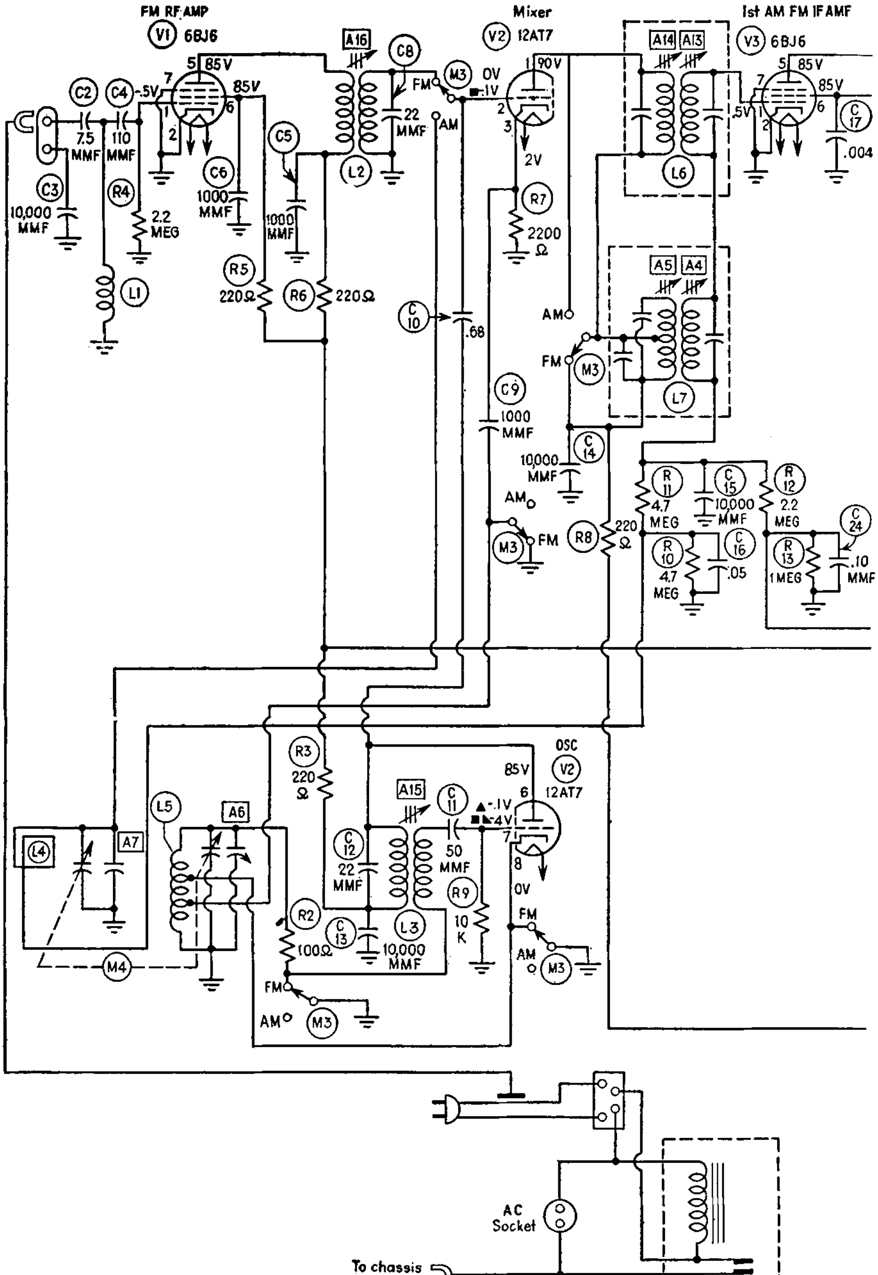
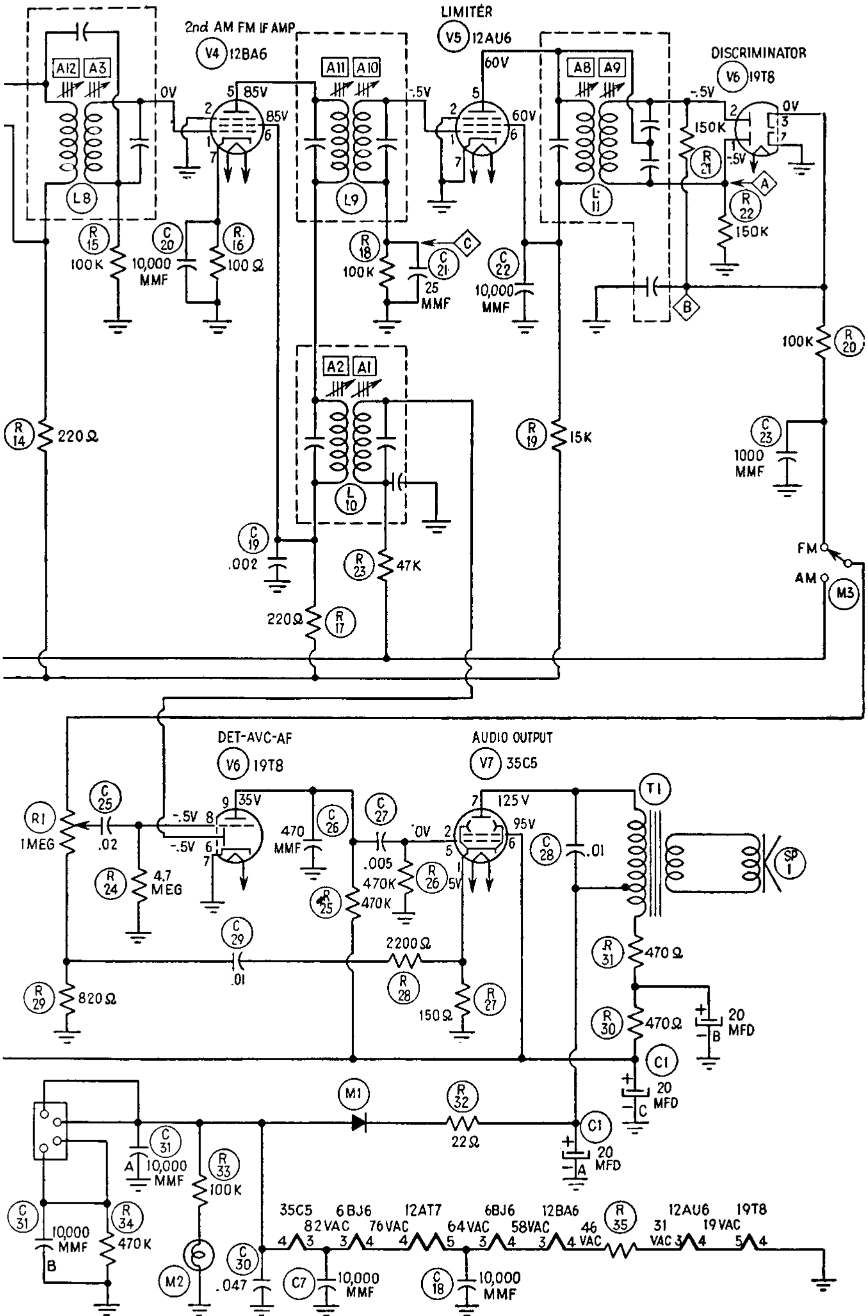


FIG. 24–18. Schematic diagram of the



Zenith Model J733 A-M/F-M receiver.

25 SERVICING THE A-M/F-M RECEIVER

Since the major portion of the market for F-M receivers is of the A-M/F-M type, we shall confine this chapter to the servicing of that type. The servicing procedure may then be easily simplified and adopted to fit the receiver made only for F-M.

The block diagram of Fig. 25–1 has been chosen as being representative of most A-M/F-M receivers. Keep this diagram in mind as we present the servicing procedure. Although many other possible circuit arrangements may be found, this one is basic enough to give an understanding of the others.

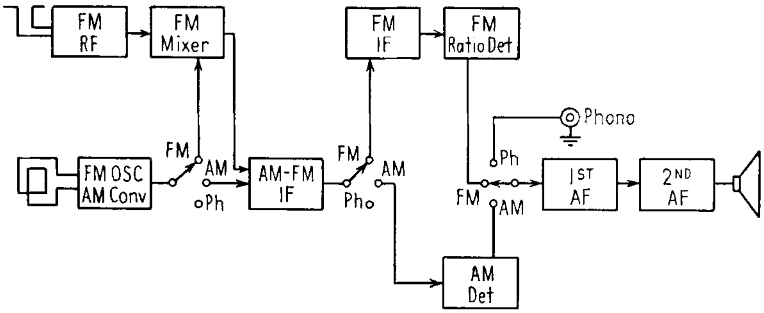


FIG. 25–1. Block diagram of a typical A-M/F-M receiver.

The servicing of A-M/F-M receivers need not be a frightening task. It is in many respects so similar to the servicing of the familiar A-M set that it is unnecessary to present the detailed analysis given earlier in the book. An over-all approach will be presented which will well serve the purpose.

The over-all approach. In working on an A-M/F-M receiver, the standard servicing procedure can be applied. First we want to know whether the tubes light and what the voltage is at the *B* plus point. Then we establish that an audio-test signal at the volume control will produce the test note in the loudspeaker. Then, with the function switch in the A-M position, we can drive IF and RF test signals through the A-M stages. In all this work, we are on familiar ground, and the standard A-M checks need very little adaptation to be applied to the A-M/F-M receiver. This approach will solve most of the service problems that arise. Finally, if the trouble is in the F-M section, a similar set of quick checks using an ordinary A-M signal generator will localize the F-M stage where the defect exists. Then tube substitution, a voltmeter check, or a resistance check of the components in the stage discloses the cause of the trouble.

Checking A-M operation. Having determined that the power supply and audio amplifier are working, begin with a standard check of the A-M section. Set the function switch to the A-M position. Feed a modulated IF signal at 455 kc to the IF grid. Be sure to feed this signal to the A-M/F-M IF grid, and not to an IF tube functioning only in the F-M section. Then feed the same signal to the A-M mixer grid. In each case, the modulation note should be heard from the speaker. The first point at which it fails to be heard indicates that the stage between the point and previous test point is defective. Then feed a modulated signal at 600 kc to the mixer grid. Tune the set to 600 kc. If the oscillator is functioning, the modulation note should be heard. Finally, feed the same signal to the antenna. Failure to hear the note indicates trouble in the antenna input circuit. The test points are indicated in the block diagram in Fig. 25–2.

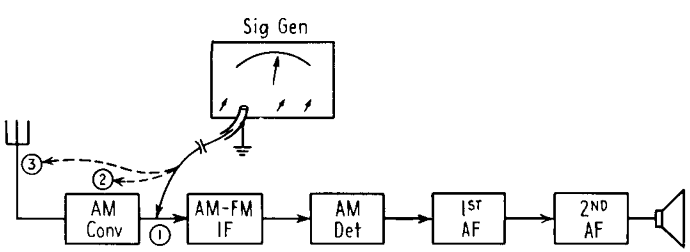


FIG. 25–2. Signal checks in the A-M section of an A-M/F-M receiver.

Quick check for the stages in an F-M receiver. If the A-M section is found to be in good operation, then the F-M section should be checked. The block diagram for the two basic F-M sections are shown in Fig. 25–3. The one in Fig. 25–3*A* utilizes the Foster-Seeley discriminator. The one in Fig. 25–3*B* utilizes the ratio detector. The same check works for both types. The over-all procedure for checking the F-M section is performed with a standard A-M signal generator whose frequency range goes up to about 15 mc. Set the receiver for F-M operation.

Feed a modulated signal at 10.7 megacycles (the intermediate frequency) to the last IF tube grid. Remember that the limiter is considered to be the last IF stage. Adjust for full output and wobble the frequency control to each side of 10.7 megacycles. If the demodulators (discriminator or ratio detector) are operating properly, the modulation note will be heard in a specific way. A little off frequency, the modulation note will be fairly loud. As you come onto frequency, the modulation note dips sharply in loudness. As you move off frequency on the other side, the modulation note rises back to its previous loudness. The wobble procedure should be performed slowly to hear the sharp dip in

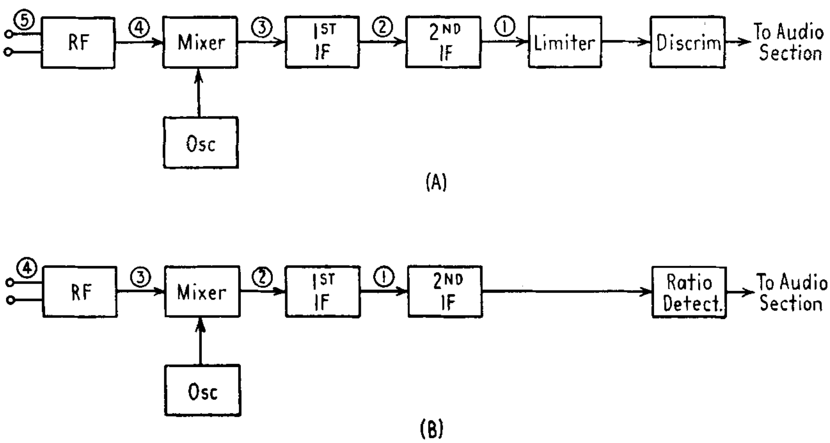


FIG. 25–3. Signal checks in the F-M section of an A-M/F-M receiver.

loudness. The procedure is illustrated in Fig. 25–4. This is the quick check for normal operation of the F-M demodulator.

Then feed the same signal to the preceding IF tube grid. If that IF stage is not functioning, the note will not be heard. If the note is heard, feed the same signal to the first IF tube grid. Failure to hear the note indicates that the second IF stage is not functioning. To simplify this

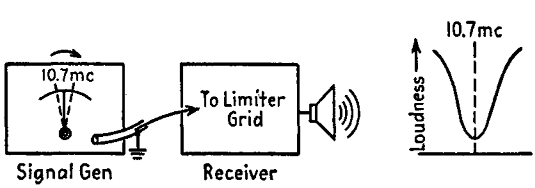


FIG. 25–4. Characteristic dip in volume on signal check in F-M receivers.

quick check from the second IF tube grid on, the hot clip lead from the signal generator may be latched onto an insulated section of the grid wire or to the insulated body of the grid resistor. This loose coupling may be even more desirable than direct contact where the signal-generator test signal is very large. It is also advisable to reduce the test signal by means of the attenuator to as low a level as possible. If the note from the first IF grid is heard, feed the same signal to the mixer grid. Failure to hear the note indicates a defect in the first IF stage or in the mixer. If the note is heard, those two stages are working.

The next check is that of the converter and RF stages. Here a new consideration comes up. The F-M band is from 88 to 108 megacycles, while the signal generator goes up to 15 megacycles. This calls for a special test instrument. However, the 15-megacycle signal generator may be used if you take advantage of the harmonic output from the generator. If you set the latter at 8 megacycles, the eleventh, twelfth, and thirteenth harmonics will be 88 megacycles, 96 megacycles, and 104 megacycles, respectively. All these are within the F-M band. Thus, feed a modulated signal at 8 megacycles to the mixer grid. Tune the F-M tuner to 88 megacycles, 96 megacycles and 104 megacycles. At each of these positions, the modulation note will be heard if the oscillator is good. Then feed the same signal to the antenna terminal, and again tune the receiver to 88 megacycles, 96 megacycles, and 104 megacycles. Failure to hear the modulation note indicates trouble in the antenna input or RF stage.

The F-M servicing procedure. The quick checks just given located the defective stage in either the A-M or F-M sections. The next job is to localize the specific defective item. This technique, so far as the A-M section of the receiver is concerned, is essentially the same as that for our familiar A-M-only radio. The technique for locating defects in the F-M section is fairly similar. For the remainder of this chapter, emphasis will be on the F-M section.

The generalized approach to trouble shooting the individual stages is as follows: Check tubes, then make voltage and resistance checks. Test data for this approach will now be given. For purposes of analysis, the schematic diagram of a basic A-M/F-M receiver, shown in Fig. 25–5, has been synthesized and will be used throughout. Variations will be taken up with each stage. The basic set uses a ratio detector. Service analysis of a limiter-discriminator detector system will follow.

The A-M/F-M receiver power supply. The AC power supply is essentially similar to those used in small AC sets of the A-M variety. Service notes on the power transformer and filter components have been described in Chap. 8, and need no further elaboration. An over-all voltage analysis of a typical A-M/F-M receiver will be given later in this chapter.

Some A-M/F-M receivers use an AC/DC power supply. Here, because of the greater number of tubes employed, the line voltage of 117 volts is insufficient with a tube rectifier. The tube rectifier is replaced with a selenium rectifier. The latter, with no filament drain, makes the line voltage just right for the rest of the tubes. The selenium rectifier is usually larger than those found in three-way portable receivers. One

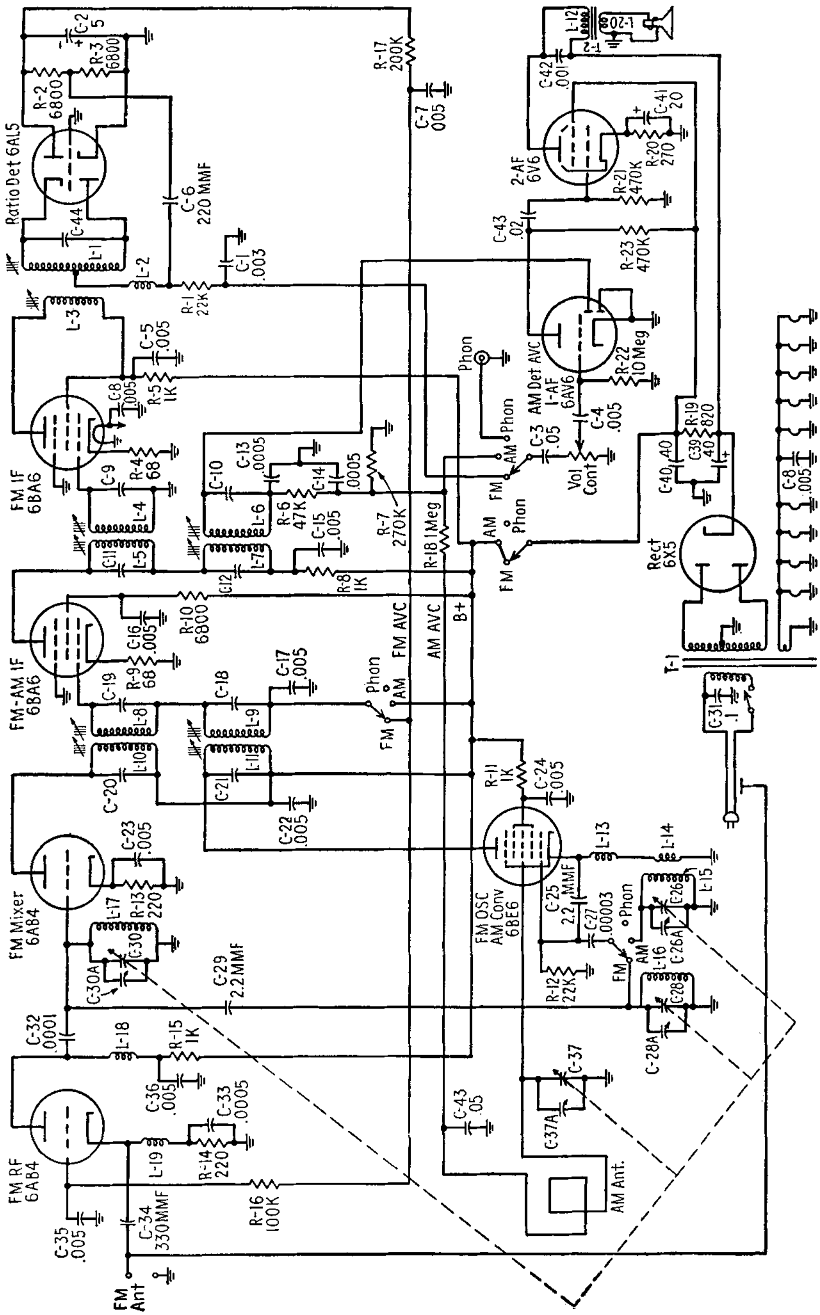


FIG. 25–5. Schematic diagram of a basic A-M/F-M receiver.

capable of delivering 100 ma is a good replacement size when needed. Service notes on selenium rectifiers are given in Chap. 19. A typical AC/DC power supply is illustrated in Fig. 25–6.

Note the use of the RF choke *L*-20 and filter condensers *C*-23, *C*-24, and *C*-25 in the filament line. Similar filters are found in AC power supplies as well. They serve to remove RF currents out of the filament circuit. Rarely do they present any service problems.

Also, note resistor *R*-22 in series with the tube filament string. It serves as a voltage-dropping device. The tube complement in the circuit shown in Fig. 25–6 is as follows: three 12BA6 tubes, one 12AT7, one 12AU6, one 19T8, and one 35B5. Adding the nominal voltages brings this string to a total of about 114 volts. This voltage requirement is a little too low to run from the usual line. The 39-ohm resistor *R*-22 is added to the string to make it suitable for the usual line voltage. Some

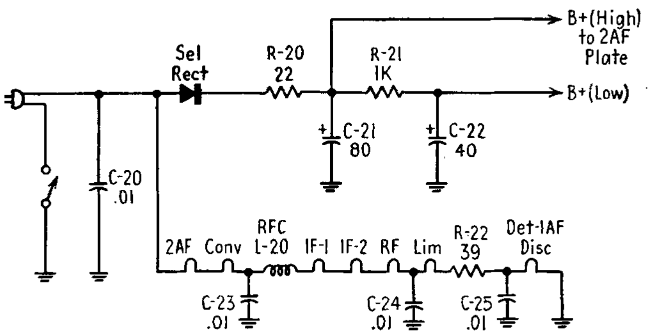


FIG. 25–6. Typical AC/DC power supply for an A-M/F-M receiver.

manufacturers may leave it out with a tube complement like the above, relying on the fact that tube life will not be too adversely affected by such a slight voltage overload. The usual dropping resistors used are of the flexible wire-wound type.

When the resistor opens, the tubes fail to light. The resistor must then be replaced. Use a replacement like the original. If this is not available, choose a heavy enough replacement, since this resistor dissipates considerable heat. A 39-ohm/2-watt replacement resistor will do for the circuit of Fig. 25–6. Where more voltage must be dropped, a 5-watt resistor will be more suitable.

The A-M/F-M receiver audio section. Similarly, the audio section of the A-M/F-M receiver presents no new servicing problems. The same procedure is followed as was presented in Chap. 10. Refer to Fig. 10–18 for specific reference to such an audio section.

The ratio detector. The ratio detector of our typical set is shown in Fig. 25–7. The tube used is a 6AL5 twin diode with a grounded shield to separate the two halves. Note that the stage is permeability-tuned. Condenser *C*-1 and resistor *R*-1 make up the deemphasis network. Resistors *R*-2 and *R*-3 make up the ratio-detector load. Condenser *C*-2 is known as the "stabilizing" condenser and serves to eliminate ampli-

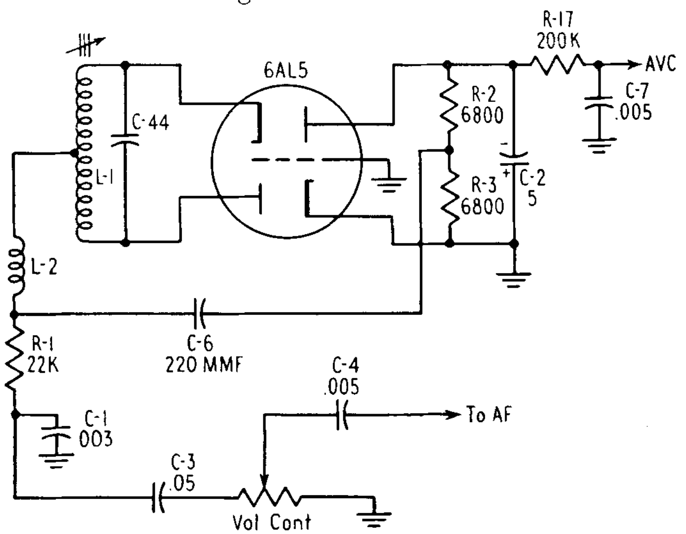


FIG. 25–7. Ratio detector of the basic receiver.

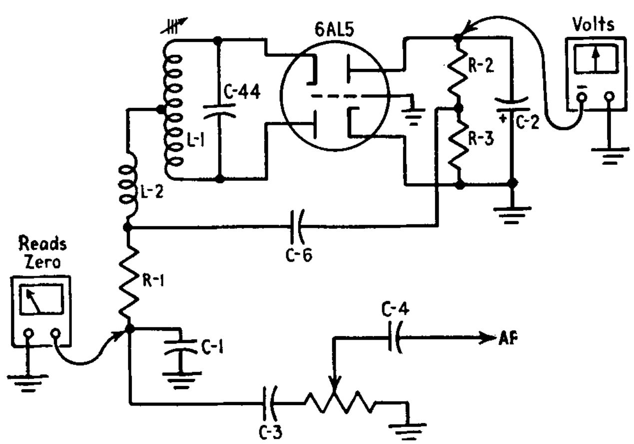


FIG. 25–8. Checking operation of the ratio detector.

tude variations from the output. Other tubes encountered in ratio-detector circuits are half a 6T8 and the 12AL5 tubes.

An over-all check of the ratio detector may be made with an A-M signal generator and a vacuum-tube voltmeter or a 20,000-ohms-per-volt voltmeter. The setup is shown in Fig. 25–8. The meter is connected from the audio input to the chassis. Now feed an unmodulated RF signal at 10.7 megacycles into the second IF tube signal grid. The meter should read zero unless alignment is bad or a defect exists in the detector circuit. In the next chapter, we shall see how to align the set. Now connect the meter from the plate end of resistor R-2 to the chassis. The voltage at this point depends on the strength of the input signal. The size of this voltage is unimportant for the signal check, but its absence indicates trouble in the stage.

The tubes are the most likely source of trouble in the ratio-detector circuit. Loss of emission will cause a weak signal and distortion. The condition is cleared when the tube is replaced with a new one. If re-

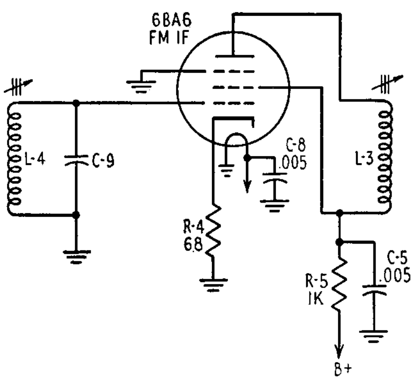


Fig. 25–9. F-M IF amplifier of the basic receiver.

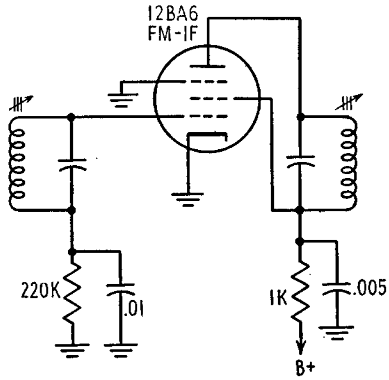


Fig. 25–10. A variation of the IF amplifier in an A-M/F-M receiver.

placing tubes does not help the situation, then a resistance check of individual components is necessary. In this regard, remember that condenser C-2 is an electrolytic condenser and may in time lose capacity. When that happens, the circuit loses the ability to remove amplitude variations of the signal, and the set becomes noisy like any A-M set. A short in condenser C-2 would make the set completely inoperative. This condenser is checked in the usual manner, except that one end should be disconnected when checking to separate it from the shunt resistive load.

The F-M IF amplifier. The second IF amplifier is shown in Fig. 25–9. Note the absence of a bypass condenser across the self-bias resistor R-4. This device is used to introduce degeneration and to reduce the possibility of the tube's falling into oscillation. Where a little more gain is wanted, the bypass condenser is used. Bias on the tube is about one volt.

Resistor R-5 and condenser C-5 make up the plate decoupling circuit. Decoupling condensers are of the ceramic disk or button variety. Frequently they grow leaky or short. When this happens, a large *B* current flows through the decoupling resistor and tends to burn it up. When this is the case, *B* voltage on the plate of the IF tube drops very low. An ohmmeter check from the plate to the chassis would show a short, rather than the measurements as indicated from the circuit diagram.

When making the repair job, be sure to replace the condenser with a similar ceramic disk type. Do not try to replace it with a higher voltage paper condenser. The long leads of the latter may introduce unwanted coupling and produce oscillation. Try to place the replacement condenser in the exact position of the old one. And do not overlook the decoupling resistor. It should be checked with an ohmmeter to see if it is burnt up and requires replacement.

The tube used is the 6BA6 pentode. Other tubes commonly employed are the 6AU6, 12BA6, or the 6BJ6. Like other tubes, they go bad in time and may be checked by replacement with a new one.

Condenser *C*-8 is a filament string filter condenser. It filters RF currents out of the filament line. Rarely does it present any service difficulty.

There is an interesting variation of the IF amplifier. Its circuit diagram is shown in Fig. 25–10. Note that there is no cathode self-bias resistor in the circuit. Grid bias is obtained by means of the 220,000-ohm bias resistor. An IF amplifier of this type is subject to the same troubles mentioned for the more basic circuit. The special bias circuit rarely causes any service difficulty.

The A-M/F-M IF amplifier. The A-M/F-M IF amplifier is similar in operation to the F-M IF amplifier. It differs in that provision is made for handling both intermediate frequencies (455 kc and 10.7 megacycles). The circuit is shown in Fig. 25–11. Note the series connections of the A-M and F-M intermediate-frequency coils *L*-8, *L*-9 and *L*-5, *L*-7. The operation of this circuit was explained in Chap. 24.

Note that the grid-return lead is connected to a switch for the AVC connection. This switch is part of the function switch. It taps AVC voltage from the A-M detector for A-M operation, or AVC voltage from the ratio detector for F-M operation. Note that resistor *R*-9 in the cathode circuit is unbypassed to introduce degeneration.

Resistor *R*-8 and condenser *C*-15 make up the plate-decoupling circuit. The same servicing difficulties that were given for the second IF amplifier apply in this stage and are handled in the same manner.

And finally, note that the screen is operated at a slightly lower voltage than the plate of the tube. Shorting of the ceramic disk screen bypass condenser *C*-16 would cause *B* voltage to drop and would probably burn up screen-dropping resistor *R*-10. When replacing condenser *C*-16, be sure to check to see the extent of damage to resistor *R*-10.

Variations of this circuit may use alternate tubes, bypass the cathode resistor, or use one voltage supply for both plate and screen circuits. Another variation omits an AVC voltage on F-M operation. None of these variations introduces any special servicing problems.

The F-M frequency-conversion system. There are several ways of achieving frequency conversion in F-M systems. However, it is almost a universal practice to use a separate oscillator and a separate mixer stage. The circuit of Fig. 25–12 is typical.

The 6BE6 tube serves as both the A-M converter and the F-M oscillator. The coils *L*-14 and *L*-15 make up the A-M oscillator coil, functioning when the function switch is in the A-M position. Coil *L*-16, the F-M

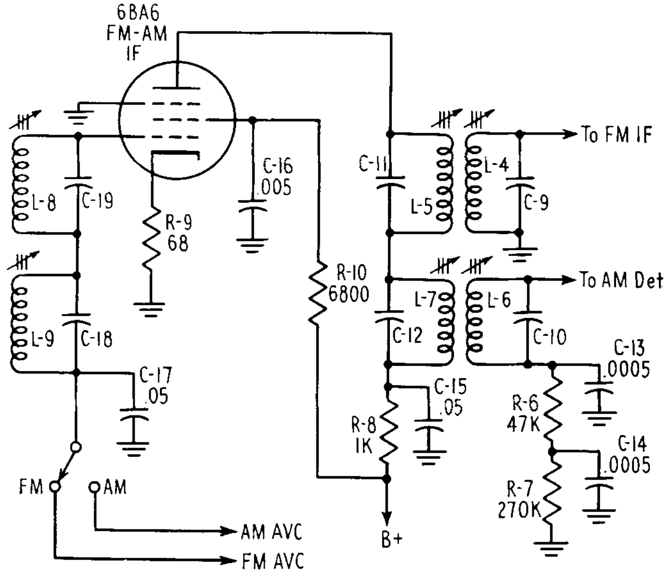


Fig. 25–11. A-M/F-M IF amplifier of the basic receiver.

oscillator coil, is connected to the oscillator grid when the function switch is in the F-M position. Condenser *C*-25 serves as the F-M oscillator feedback path. Output from the F-M oscillator is coupled through condenser *C*-29 to the F-M mixer grid. The mixer, half a 6AT7, feeds the IF signal to the primary of the F-M intermediate-frequency transformer *L*-10. The 6BE6, when acting as an A-M converter, feeds the A-M intermediate-frequency signal to *L*-11, the primary of the intermediate-frequency transformer.

Note the ganging of the tuning condensers. It is common practice in all A-M/F-M sets to gang all manual-tuning circuits for operation by one knob. The dial scale will show the A-M and F-M ranges.

The F-M frequency-conversion system presents, for the most part, the usual servicing difficulty. Condenser *C*-24 is the F-M oscillator anode condenser. It is usually of the ceramic disk type. If it shorts, *B* voltage drops to a very low value and resistor *R*-11 usually burns up. When making a replacement with an exact duplicate, be sure to check to see whether or not the resistor must also be replaced.

If the oscillator does not work in the A-M mode of operation, try replacing the 6BE6 tube, when voltages seem normal. A critical oscillation condition may be the defect. If it still fails to function, check the function switch by connecting an ohmmeter from condenser *C*-27 to coil

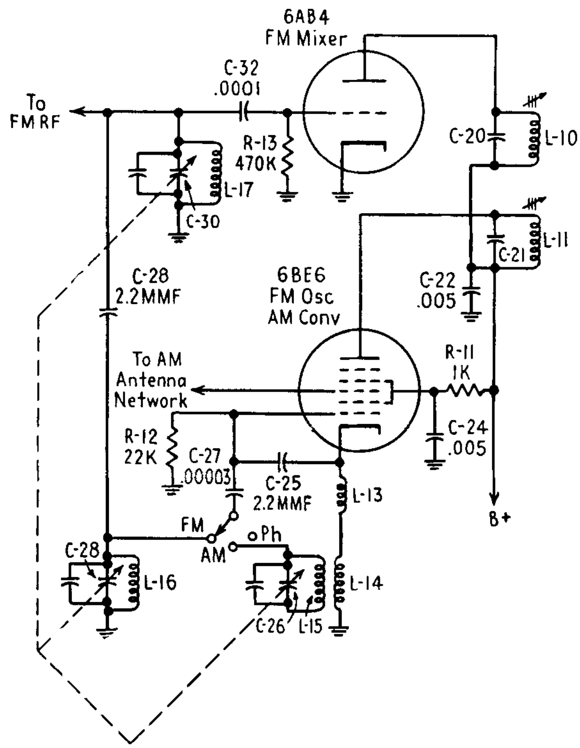


FIG. 25–12. Converter in the basic receiver.

L-15, across the switch in its A-M position. A switch-cleaning job or replacement may be indicated.

If the oscillator functions in the A-M position, but not in the F-M position, then the switch must definitely be checked. A dirty or broken contact may be the cause. Be sure, in addition, to check that no dirt is shorting the oscillator-tuning condenser *C*-28.

There are many other circuits for A-M/F-M frequency conversion. However, the same basic possibilities for defects exist in all of them; and the same check procedure holds. Two typical variations are shown in Figs. 25–13 and 25–14.

Examine Fig. 25–13. Half a 12AT7 tube is used as an F-M oscillator and the other half as the F-M mixer. A separate 6BE6 tube is employed as the A-M converter. Note how the function switch removes *B* voltage from the A-M converter in the F-M mode of operation. And in the A-M

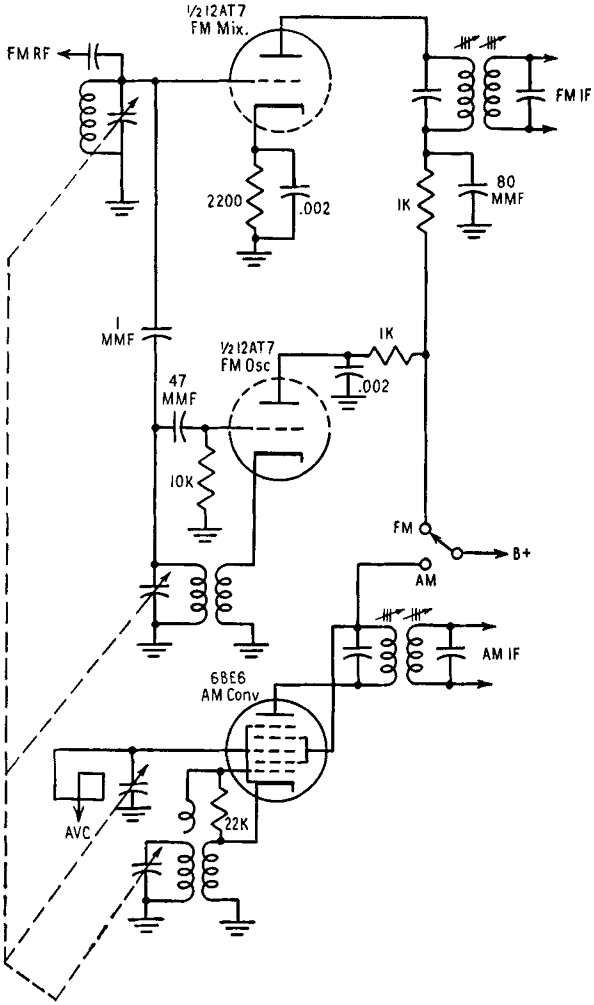


FIG. 25–13. A-M/F-M converter with separate oscillator tube.

mode of operation, the function switch removes *B* voltage from the F-M oscillator and mixer.

Now examine Fig. 25–14. Here, one half of a 12AT7 operates as an A-M and F-M oscillator. The function switch selects the A-M or F-M oscillator coil, depending on the desired mode of operation. The other half of the 12AT7 serves as the F-M mixer. By means of the function switch, the 12BA6 tube is either an A-M mixer stage or the first F-M intermediate-frequency amplifier. Note how the cathode of the 12BA6 tube is grounded in the F-M position. Bias is then derived by means of the resistor and condenser in the grid circuit. In this circuit, as in the previous one, *B* voltage is switched. In A-M operation, *B* voltage is removed from the F-M mixer. In F-M operation, *B* voltage is applied to all tubes.

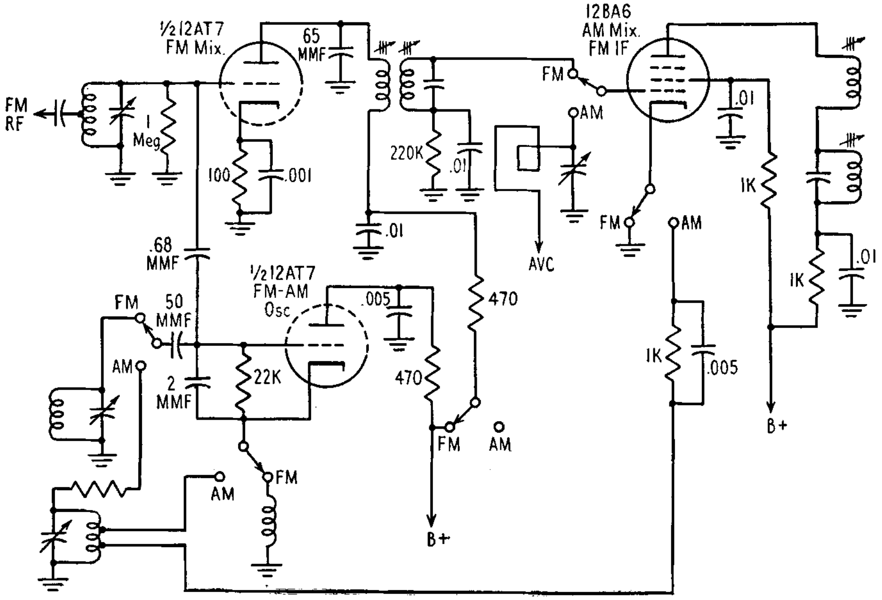


FIG. 25–14. A-M/F-M converter with a combination A-M mixer and F-M IF amplifier tube.

The F-M RF amplifier. The RF amplifier in the A-M/F-M receiver is usually employed on only the F-M mode of operation. Its function is the same as that of a similar amplifier in the A-M sets. However, new problems present themselves because of the high frequencies involved in frequency modulation. The basic RF circuit is shown in Fig. 25–15.

This circuit is an unusual one and requires further explanation. It is known as a grounded-grid amplifier. Let us examine an ordinary amplifier, as depicted in Fig. 25–16. Resistor *R*-2 and condenser *C*-2 supply the self-bias to the grid of the tube. The signal is fed from grid to cathode in series with the self-bias system. The signal on the grid causes grid voltage to rise above and fall below its bias value with respect to cathode. It is important to get this grid-cathode relationship in order to get amplification.

Now, let us examine the basic simplified grounded-grid amplifier in Fig. 25–17. Resistor *R*-1 and condenser *C*-1 serve the same purpose—

to develop self-bias for the grid with respect to the cathode. The signal is now fed to the cathode instead of the grid. The cathode voltage now rises above and falls below the bias value with respect to the grid which remains at ground potential. This grid-cathode relationship is just as feasible for amplification as the previous circuit. It has, however, the

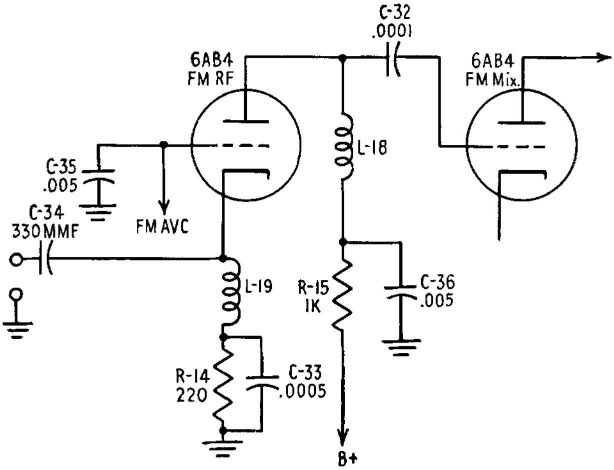


FIG. 25–15. RF amplifier of the basic receiver.

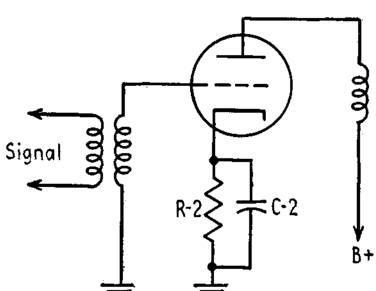


FIG. 25–16. Conventional triode amplifier.

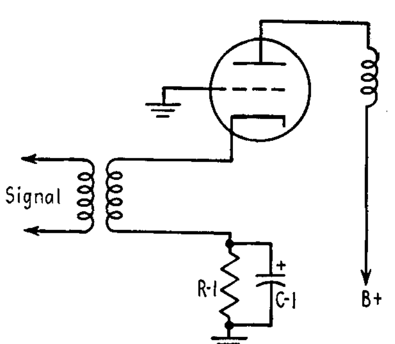


FIG. 25–17. Simplified grounded-grid triode amplifier.

advantage of furnishing a grounded screen (the grid) between cathode and plate, which is better for higher frequencies.

Return to the circuit of Fig. 25–15. The 6AB4 is the triode employed. Resistor *R*-14 and condenser *C*-33 furnish self-bias for the tube. The signal is fed through condenser *C*-34 to the cathode. Choke *L*-19 prevents the signal from going to ground across *C*-33. So far as the signal is concerned, the grid is grounded through condenser *C*-35. This is similar to the grounding of a pentode screen through a condenser. Condenser

C-35 also acts as an AVC bypass condenser. Note the impedence coupling to the F-M mixer.

Other triodes are used in similar circuits. Some sets utilize half a 12AT7 or a 19J6. But the basic circuit is the same.

Common troubles in the RF amplifier are the usual ones: tubes and decoupling filters. These are found by the standard procedure. The unusual feature is that test signals are fed to the cathode rather than to grid.

Many A-M/F-M sets utilize special high-frequency pentodes as an F-M RF amplifier. Such tubes are the 6CB6, 12BA6, 6BA6, 6AU6, and 6BJ6. A typical circuit is shown in Fig. 25–18.

The stage is checked like any other pentode amplifier. Note the plate- and screen-decoupling circuit made up of resistor *R*-1 and condenser *C*-1. When *C*-1 shorts, *B* voltage drops and *R*-1 probably burns up, as

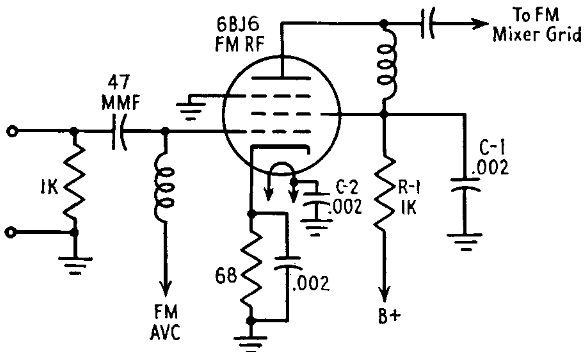


Fig. 25–18. RF amplifier using a pentode tube.

was explained in the IF amplifier. Note *C*-2, the filament filter condenser. Also observe that impedance coupling is used.

The F-M antenna. For the F-M tuner function, A-M/F-M sets commonly use the line-cord type or built-in dipole antenna for indoor installation. The outdoor dipole is found less often. All of them are satisfactory.

However, the complaint of weak operation of a set may sometimes be made where an indoor installation is found. If a signal check indicates that the receiver is good, investigation of the possibility of improvement with an outdoor installation should be made. Improvise a simple outdoor dipole antenna with several lengths of wire. If improvement is evident, proceed with the installation of the more permanent outdoor dipole.

Advantage may be taken of an existing TV antenna installation, if present. For checking to see if an outdoor antenna is necessary, connect the TV antenna to the F-M tuner. You can even go further. Connect the F-M tuner and TV set to the same TV antenna installation. Check to see that F-M operation does not affect TV reception. If it does not, you may maintain the partnership as a permanent installation.

The Foster-Seeley limiter and discriminator. Many receivers utilize a Foster-Seeley discriminator instead of the ratio detector. In this circuit, a separate limiter stage is needed. A basic circuit of the limiter and discriminator stages is shown in Fig. 25–19.

To the serviceman, the limiter is simply the last IF stage, utilizing a sharp-cutoff tube and operating at lowered plate and screen voltages. The tube most commonly found is a 6AU6. The 12AU6 is found in AC/DC receivers. Bias for the tube is obtained by means of resistor *R*-5 in the grid-return lead. Since this voltage is developed by signal strength and varies with signal strength, it is tapped off from point *A* in the diagram to be used for AVC voltage where desired. The voltage at point

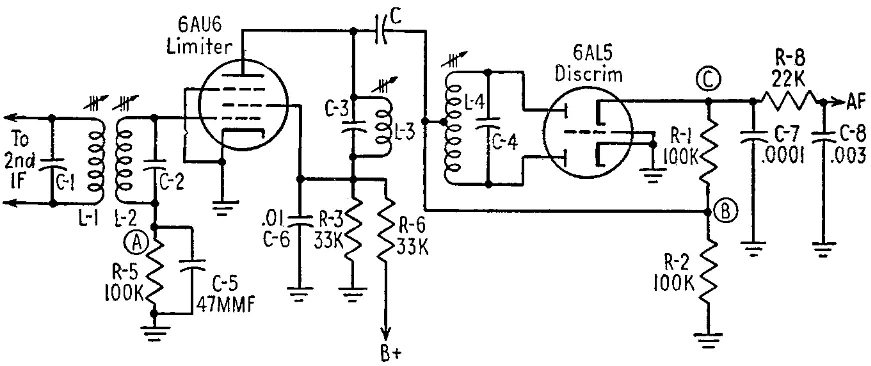


FIG. 25–19. Basic limiter-discriminator circuit.

A is of value in service work for showing the presence and amount of signal. The lowered plate and screen voltages for the limiter are obtained from the voltage divider consisting of *R*-3 and *R*-6. Condenser *C*-6 is the bypass to ground.

The discriminator tube is usually a 6AL5 twin diode. In AC/DC receivers, the twin-diode half of a 19T8 is common. Condenser *C*, coupling the limiter and discriminator tubes, is part of the discriminator-transformer assembly (*L*-3, *L*-4). Resistors *R*-1 and *R*-2 make up the diode loads, across which the audio output voltage appears. Condenser *C*-8 and resistor *R*-8 make up the deemphasis circuit. Troubles in the limiter and discriminator stages are due to defective tubes, shorts or leakage in decoupling condenser *C*-6, and misalignment. Tubes are checked by the substitution procedure. Voltage analysis discloses defects in screen condenser *C*-6. Misalignment causes poor tone quality and a weak signal. Alignment may be checked as follows. Connect a vacuum-tube voltmeter probe to the junction of the diode-load resistor, point *B*; connect the common voltmeter lead to ground. Feed an unmodulated signal at 10.7 mc to any convenient IF grid. Wobble the signal generator for a peak indication on the meter. Then shift the voltmeter prod to point *C*. The reading should be zero. Any voltage at this point—plus or minus—indicates misalignment. A complete alignment procedure is given in the following chapter.

Voltage checking the A-M/F-M set. The signal check is effective in locating a defective stage. After that, voltage checking a defective stage becomes a powerful weapon in locating the specific defective components. The value of this technique is indicated in the skeleton *B* circuit, shown in Fig. 25–20. The signal circuits have been deliberately

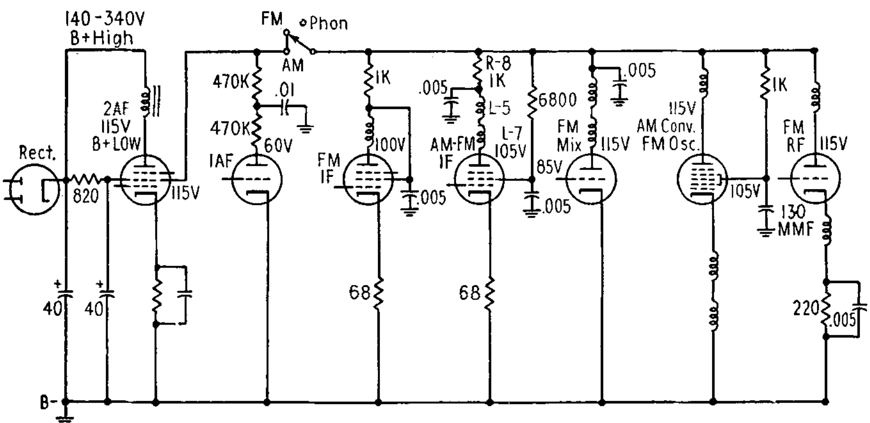


FIG. 25–20. Skeleton *B* circuit of the basic A-M/F-M receiver.

omitted to simplify observations. Note that the A-M detector and the ratio detector have been omitted also, because they are not in the *B* circuit. It is good practice to make similar skeleton diagrams for other sets to be serviced.

Normal voltages at various test points are included in the diagram. Note the voltage drop across decoupling resistors. Servicemen look for this drop in service work, since absence of the normal drop means that the stage is not drawing current. Zero voltage for any plate or screen, with normal voltages for the other tubes, indicates an open in the plate or screen supply for that tube. Zero voltage for any tube, with lower voltages for the other tubes, indicates a short in the *B* supply line to that tube.

As an example of this, assume that decoupling condenser *C*-15 in the A-M/F-M IF stage shorts. The diagram clearly shows what would happen. The *B* current would flow from the ground through the shorted condenser and decoupling resistor *R*-8 to *B* plus (low), rather than through its normal path through the tube and associated coils. Voltage at the tube plate would be zero. Resistor *R*-8 would be carrying more than its normal current and would probably burn up. The set would be dead and *B* voltages at the other tubes would be low, because of the overload. The overheated resistor *R*-8 would be the main clue to the stage involved.

Other defects have been mentioned in the data on the various stages. Analysis by means of the skeleton diagram will make their effects more clear.

Note other details from the diagram. Only the second AF amplifier tube plate goes to *B* plus (high). All other plates and screens go to *B* plus (low) through the function switch. Therefore, do not neglect to check the switch when hunting for trouble in the *B* circuit. When the function switch is in the PHONO position, *B* voltage is removed from the RF and IF amplifier tubes. Only the audio section receives *B* voltage. Note the decoupling filters in each RF and IF amplifier stage.

Normal Voltage Data. Normal voltage data for AC-type A-M/F-M receivers are given below:

Chassis to rectifier cathode	150–350 volts
Chassis to *B* plus high	140–340 volts
Chassis to *B* plus low	90–130 volts
Chassis to tube screens	90–115 volts

The high voltages for rectifier cathode and *B* plus high are found in sets with high-fidelity audio systems. The high voltages are present in only the audio amplifier. The RF and IF tubes are operated from the *B* plus low line.

For AC/DC-type A-M/F-M sets, *B* voltages run a little lower, as a rule. Voltage data for such sets are given below:

Chassis to *B* plus high	90–130 volts
Chassis to *B* plus low	90 volts
Chassis to tube screens and plates	80 volts

Limiter *B* voltages in AC or AC/DC sets using the limiter tube run about 20 to 60 volts.

Tracing unwanted oscillations in an F-M set. In the A-M mode of operation of an A-M/F-M set, oscillation may be checked by the usual procedure. However, in the F-M mode of operation, a different technique is employed. The procedure depends on the fact that, when no signal is riding through the receiver, no signal voltage should appear at the ratio detector or at the limiter grid in the discriminator type of detector. If it does, then one of the amplifier stages is oscillating.

Set the receiver tuning dial at a non-station position. Now place a voltmeter across the stabilizer condenser of the ratio detector, or across the limiter-grid resistor, as shown in Fig. 25–21. Any voltage indication is due to oscillation. Try replacing the RF and IF tubes. If this fails to stop oscillation, try placing a test condenser across all bypass condensers. If oscillation still continues, you must re-align the set, as explained in the next chapter.

Service notes on the function switch. Function switches are usually wafer types of the kind described in Chap. 12 for radio-phonograph combinations. There is such great variation in the use and wiring of these switches that a study of any one in a receiver would be of little aid in understanding that of another.

Trouble in the *B* circuit section of the switch would appear in a voltage check. Troubles in the signal-circuit sections would appear in a

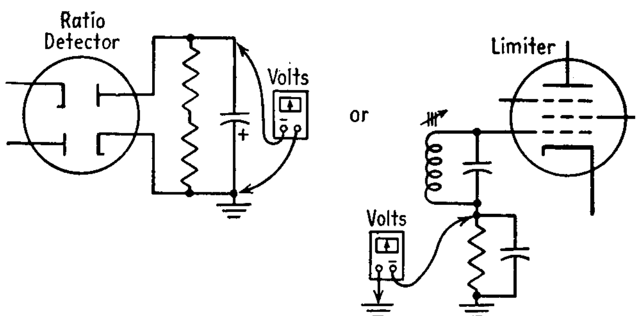


FIG. 25–21. Meter connections for checking oscillation.

signal check. These were mentioned where appropriate in the previous description of the stages.

The usual trouble in the switch is caused by dirty contacts or sprung contact wipers. The application of a cleaning agent, followed by snapping the switch through its positions, takes care of dirty contacts. Sprung wipers are found by visual inspection. Pressure applied with long-nose pliers is usually effective in reestablishing good contact.

Replacement precautions in A-M/F-M sets. Because of the high frequencies involved in F-M sets and because of the greater possibilities of unwanted coupling of circuits, special precautions must be taken when replacing parts. Lead dress is extremely important. Route wires in the same positions they had originally. To do this, try to use exact replacement parts for similar positioning. Do not make ground connections where most convenient, but connect parts to their original grounding points. Failure to do so may produce undesirable coupling and unwanted oscillations.

SUMMARY

Servicing procedure for FM sections

1. Routine voltage check:

Check *B* plus high.

Check *B* plus low.

2. Routine stage check:

Signal check of stages to locate defective stage.

Substitute new tube.

Make careful voltage check of stage.

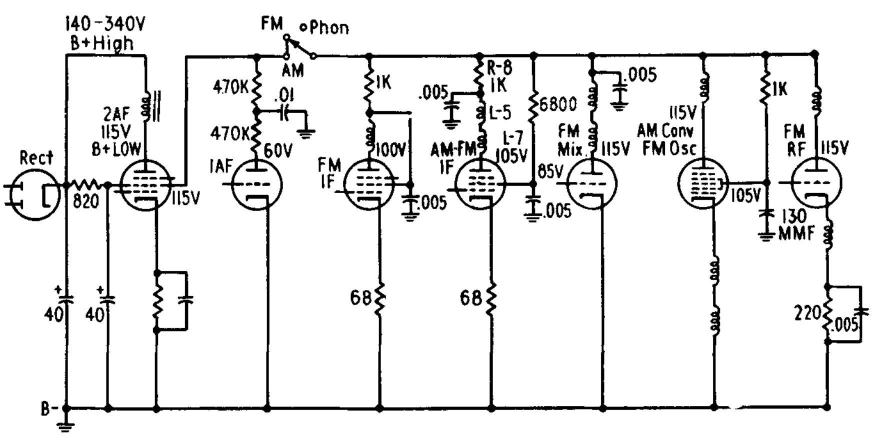
Make resistance check of stage.

Check individual components in stage.

3. Check alignment.

Routine voltage check

The abbreviated skeleton diagram shown below is used for *B* voltage checks.



Normal voltage data

Normal voltage data for AC-type A-M/F-M receivers are given as follows:

Chassis to rectifier cathode	150–350 volts
Chassis to *B* plus high	140–340 volts
Chassis to *B* plus low	90–130 volts
Chassis to tube screens	90–115 volts

The high voltages for rectifier cathode and *B* plus high are found in sets with high-fidelity audio systems. The high voltages are present in only the audio amplifier. The RF and IF tubes are operated from the *B* plus low line.

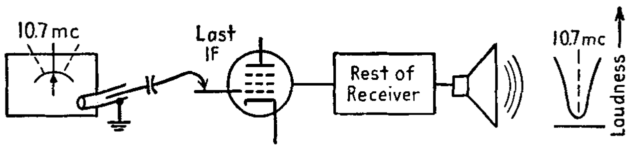
For AC/DC-type A-M/F-M sets, *B* voltages run a little lower, as a rule. Voltage data for such sets are given below:

Chassis to *B* plus high	90–130 volts
Chassis to *B* plus low	90 volts
Chassis to tube screens and plates	80 volts

Limiter *B* voltages in sets using the limiter tube runs about 20 to 60 volts.

Quick Signal Check of Stage

1. Demodulator check:



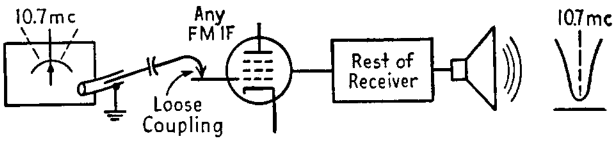
Connect signal generator to last IF grid.

Feed modulated signal at 10.7 megacycles from generator.

Wobble frequency control slowly around 10.7 megacycles.

Get modulation-note dip response.

2. F-M IF check:



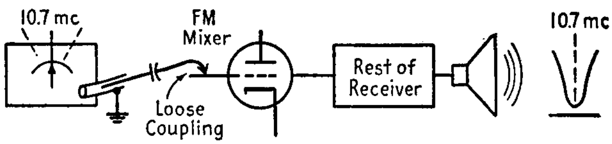
Couple signal generator output loosely to any IF grid to be checked.

Feed modulated signal at 10.7 megacycles from generator.

Wobble frequency control around 10.7 megacycles.

Listen for modulation note.

3. F-M mixer check:



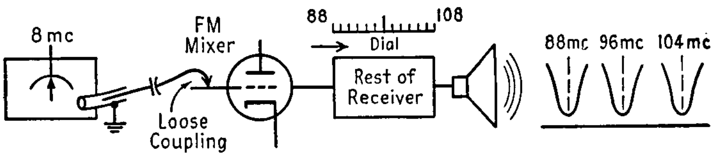
Couple signal generator output loosely to F-M mixer grid.

Feed modulated signal at 10.7 megacycles from generator.

Wobble frequency control around 10.7 megacycles.

Listen for modulation note.

4. F-M oscillator check:



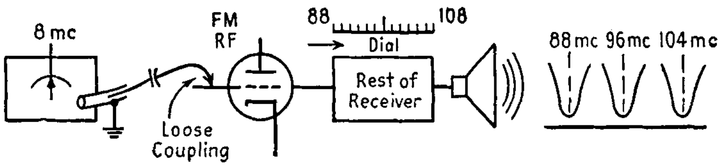
Connect signal generator output loosely to F-M mixer grid.

Feed modulated signal at 8 megacycles from signal generator.

Swing receiver tuning dial through its range.

Listen for modulation note at 88 megacycles, 96 megacycles, and 104 megacycles.

5. F-M RF check:



Connect signal-generator output loosely to F-M RF grid.

Feed modulated signal at 8 megacycles from signal generator.

Swing receiver tuning dial through its range.

Listen for modulation note at 88 megacycles, 96 megacycles, and 104 megacycles.

QUESTIONS

1. An A-M/F-M Phono receiver operates for phonograph response, but fails to operate on A-M or F-M. The *B* plus high and *B* plus low check normal. What is a likely cause of the trouble? Which stages are the probable ones to investigate?

2. An A-M/F-M set, in the FM mode of operation, is dead. A routine voltage check discloses the following data: all *B* voltages are low; the voltages on the plate and screen of an IF amplifier are zero. What has probably happened in that stage? What is a likely component to investigate?

3. An A-M/F-M set, in the F-M mode of operation, gives oscillation squeal. Investigation discloses a paper condenser in the plate decoupler circuit where a ceramic disk type previously existed. The paper condenser checks perfect. What is a possible cause for the oscillation?

4. What precautions in regard to lead dress should be taken when replacing a component? What conditions might result from improper lead dress?

5. A receiver, in the F-M posiiton, squeals when stations are tuned in. A voltmeter check discloses a voltage at the F-M limiter grid with no signal input. What is the cause of the squeal? How would you fix this set?

6. An A-M/F-M Phono combination has good tone and volume on A-M and Phono. On F-M the volume seems low, and it is difficult to tune in stations so as to get good tone. What is likely to be wrong? How would you check?

26 ALIGNMENT OF F-M RECEIVERS

The aligning of A-M/F-M receivers takes on the nature of a twofold job, because there is an A-M function and an F-M function. Because of the different frequencies involved, there is no interaction between the two modes of operation. As a result, the A-M section and F-M section may be aligned separately.

The procedure for aligning the A-M section is the same as that for the familiar A-M set. A generalized procedure was given in Chap. 23 and need not be repeated here. The emphasis in this chapter is on the aligning of the F-M section of the receiver. The procedure to be presented is performed with the function switch in the F-M mode of operation. Although it is most advisable to follow the manufacturer's specific alignment notes, the generalized procedure given will serve when such notes are not available.

Circuits involved in alignment are the discriminator transformer, IF transformers, oscillator coil, and RF coil. The discriminator and IF coils are usually permeability-tuned, and tuning-slug adjustment is involved. The oscillator and RF coils are usually condenser-tuned and are adjusted by means of trimmer condensers.

When to re-align. The serviceman, when deciding whether or not to re-align the F-M section of the receiver, is guided by the symptoms of trouble and by his own purposes. The receiver should not be re-aligned unless, by a process of elimination of causes for poor operation, that procedure is shown to be necessary.

What symptoms indicate the need for re-aligning? The signal check can point up several conditions. If the receiver gives a weak response to a 10.7-megacycle signal and varying of the alignment adjustments give some improvement, re-alignment is indicated. Or if the modulated test signal sounds distorted, re-alignment is again indicated.

Whenever a component of a tuned circuit is replaced, it is usually routine procedure for the serviceman to re-align the set. Such re-alignment assures optimum performance.

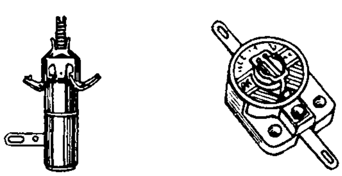
And finally, the set may be re-aligned to remove undesired oscillation.

However, before proceeding, be sure to substitute new tubes, to check for open bypass condensers, and to check lead dress carefully for unwanted coupling of circuits.

Location of alignment adjustments in a receiver. Before attempting alignment, the serviceman must be able to locate the adjustment screws and must know which circuits are being adjusted. In this regard, the manufacturer's service notes serve best. However, the following hints will be helpful where such notes are not available.

The adjustment screws involved in alignment are those for the discriminator transformer, the IF transformers, the oscillator coil, and the RF tuner. The discriminator transformer is the one that feeds the second detector, whether of the Foster-Seeley or of the ratio-detector type.

The discriminator and IF transformers are normally located in metal cans on the top side of the chassis. Most frequently, their slug-adjustment screws are located at the top and bottom of the can. This arrangement necessitates setting the receiver on its side position so as to make both adjustments accessible.



(A) (B)

FIG. 26–1. High-frequency trimmers used in A-M/F-M receivers.

The question arises as to which screw, top or bottom, aligns the primary or secondary winding of the transformers. This is of no great importance except for the discriminator transformer. Usually the primary coil adjustment will be found at the top of the can. In other cases, the primary adjustment screw will be found by trial and error during the alignment procedure.

If manufacturer's service notes are not available, it would seem that confusion might arise in determining which are the F-M IF cans and which are the A-M IF cans. In some cases, the cans have identifying labels. But where such markings are not found, a simple experiment will disclose which are which. As part of the alignment procedure, feed a 10.7-megacycle test signal to the stage, and adjust the aligning screw involved. If no effect appears on the output indicator, then the IF can belongs to the A-M section.

The next question is how to tell an IF transformer can from the discriminator transformer can. The latter is usually a little larger than the other IF cans and it is the one nearest to the second detector.

The RF and oscillator trimmer adjustment screws are usually located on the ganged tuning condenser, in their appropriate sections of the gang. Sometimes, the F-M oscillator trimmer condenser is found on the underside of the chassis. These oscillator condensers are often of a type different from those found in A-M sets. Two typical ones are illustrated in Fig. 26–1. One is the tubular kind with a projecting screw adjustment. The other is of the flat ceramic type with a center screw adjustment.

The layout diagram of Fig. 26–2 shows an A-M/F-M receiver of the AC type, employing a ratio detector. Note the four sections of the ganged tuning condenser. The A-M sections (A-M mixer and A-M oscillator) are the larger condensers. The F-M sections (F-M oscillator and F-M mixer) are the smaller condensers with fewer plates. The F-M oscillator section may be identified by the special trimmer condenser mounted on it. Or it may be identified by touching the ungrounded section with your finger; this section detunes the set off a station.

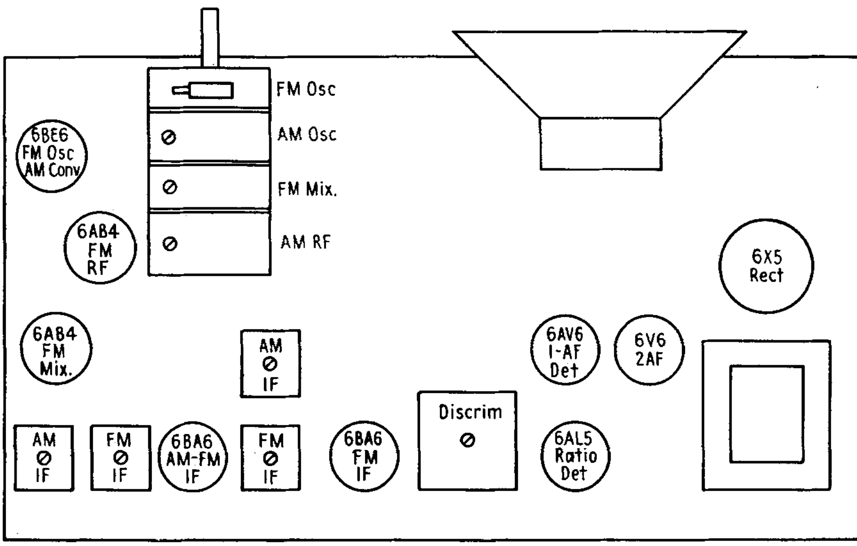


FIG. 26–2. Layout diagram of an A-M/F-M receiver.

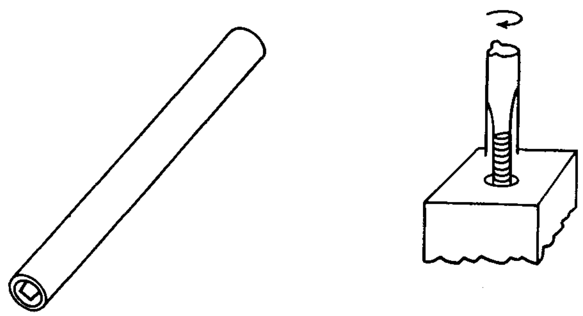
Learning tube types and their functions aids in the job of identification. Note the discriminator transformer can nearest to the ratio detector. Also, note the first A-M and F-M intermediate-frequency transformer cans between the A-M and F-M mixer tubes and the A-M/F-M intermediate-frequency amplifier tube. The second A-M and F-M intermediate-frequency transformer cans are between the A-M/F-M IF tube and the F-M IF tube. Keeping the block diagram of the A-M/F-M receiver in mind will be of great aid in locating these components.

Two alignment methods. There are two basic techniques for aligning the F-M section of an A-M/F-M receiver. Generally, manufacturers list both methods in their service notes. One procedure utilizes an A-M signal generator and an output voltmeter. It is known as the "meter method"—a method somewhat similar to our standard A-M alignment procedure. The other method utilizes a special type of signal generator, known as a "sweep-signal generator," and a cathode-ray oscilloscope as an output indicator. It is known as the "visual alignment procedure."

Both methods will do the job. However, the visual alignment method is generally considered to be a more refined technique. The procedure that is followed by the serviceman will depend on the instruments available to him. Both will be described in this chapter.

Equipment needed for the meter method of alignment. The first requirement in the meter method is an A-M signal generator with a frequency range up to about 15 megacycles. Such a test instrument takes care of the intermediate frequency of 10.7 megacycles. Its harmonic content takes care of any other RF frequency in the 88- to 108-megacycle range. The usual test oscillator for servicing A-M receivers may be used.

The second requirement in the meter method is a vacuum-tube voltmeter or a 20,000-ohms-per-volt voltmeter. The meter leads should



(A) (B)

FIG. 26–3. Recessed nib alignment tool.

terminate at one end with alligator clips for ease in connection to the various test points.

Another alignment instrument recommended for both methods of alignment is a recessed-nib screw driver, such as the one shown in Fig. 26–3A. The hollow screw driver fits over the adjustment screw which is then engaged by the recessed nib, as shown in Fig. 26–3*B*. This tool is extremely useful when aligning permeability-tuned IF transformers.

The setting up of equipment for meter alignment. When preparing to align the F-M section, place the receiver on its side, properly supported. This position enables you to work from the top and bottom of the receiver without moving it. For AC receivers, connect a piece of bonding between the signal generator and the receiver chassis. Then run a connection from the bonding to a good ground, like a grounded water pipe. This setup is shown in Fig. 26–4.

For AC/DC receivers, the ground clip should be connected to the receiver chassis through a 0.1-mfd/400-volt paper condenser. The condenser may be omitted if the receiver is connected to the line through an isolation transformer.

When using a 20,000-ohms-per-volt meter as the output indicator, an isolating resistor of about 50,000 ohms should be connected in series with the hot lead. This resistor prevents the meter leads from affecting the circuit under test. An isolating-resistor clip lead, like the one shown in Fig. 26–5, is convenient.

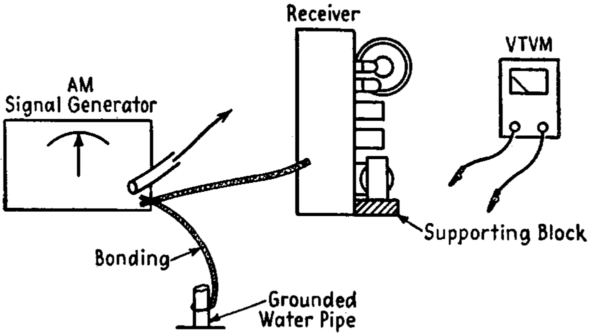
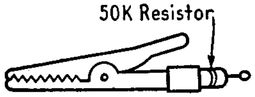


FIG. 26–4. Setting up equipment for meter alignment.

The resistor clip lead is unnecessary when using a vacuum-tube voltmeter, since these instruments are already equipped with an isolating resistor located in the test prod of the hot lead. Connections for both types of instruments are shown in Fig. 26–6.

FIG. 26–5. An isolating-resistor clip lead.



The dummy antenna. The hot lead of the signal generator must always be connected in series with a dummy antenna to the receiver. For IF alignment (IF transformers and discriminator transformer), such an antenna is a .001-mfd/600-volt condenser. For RF alignment, the dummy antenna is a 270-ohm/1-watt resistor.

Limiter-discriminator type receiver: IF alignment. The over-all procedure for aligning the IF stages of an F-M receiver with a limiter and discriminator is as follows: Align the discriminator transformer primary coil, then its secondary coil, then the limiter, then each successive IF stage working back, and finally repeat the complete procedure. This will now be taken up, stage by stage.

Turn the receiver tuning condenser to the extreme high-frequency end so that the plates are fully open. If there is an AFC control on the receiver, turn it to its OFF position. Turn on the signal generator and receiver and allow a warm-up period of fifteen minutes.

Before proceeding, consider the circuit diagram of the limiter and discriminator in Fig. 26–6. Resistors *R*-1 and *R*-2 are the diode load resistors across which voltages are developed. Note the polarity of the voltage drop across these resistors. This condition exists because currents through them from their junction point are in opposite directions. When the primary coil of the discriminator is properly aligned, the voltage across either *R*-1 or *R*-2 is as large as possible when an unmodulated 10.7-megacycle signal is fed to the limiter grid.

When the secondary winding of the discriminator transformer is properly aligned, the voltage drop across the two load resistors is equal and

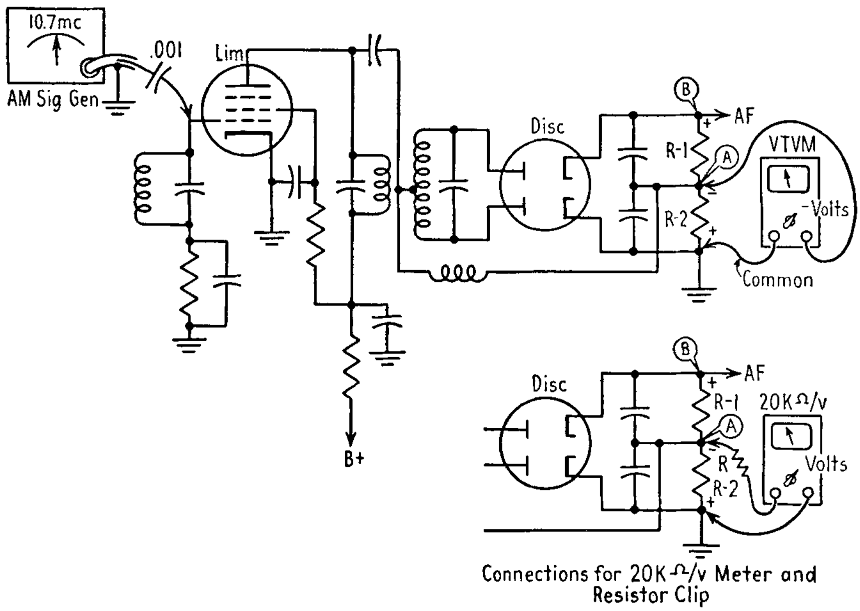


FIG. 26–6. Alignment of a Foster-Seeley discriminator.

opposite for the same signal as above. Thus, if a voltmeter were connected from point *B* to the ground, with the unmodulated 10.7-megacycle signal fed to the limiter grid, the reading would be zero. This measurement and the one given just previously serve as the basis for the alignment procedure for the discriminator transformer.

Feed a 10.7-megacycle unmodulated signal from the generator to the limiter grid, as shown in Fig. 26–6. The figure shows the vacuum-tube voltmeter connected across load resistor *R*-2 for alignment of the primary winding *L*-1. The common lead of the meter, as usual, is connected to ground. The hot lead goes to negative point *A*, and the voltmeter function switch is set to minus volts. Beneath the setup in Fig. 26–6 is the analogous setup when using a 20,000-ohms-per-volt voltmeter. Here, the negative lead goes to point *A* and positive lead goes to the ground. The resistor clip is in the negative lead.

Now proceed to adjust the tuning-slug screw of the primary winding *L*-1 of the discriminator transformer so as to get a peak reading on the voltmeter. Assume that the top adjustment screw of the discriminator can is the primary. If a normal peak cannot be obtained, try the other adjustment screw on the bottom of the can. It is good practice to rock the control screw through the peak in ever smaller swings until the true peak is achieved.

Now align the discriminator transformer secondary winding. Shift the hot voltmeter lead from point *A* to point *B* as in Fig. 26–6. Adjust the tuning slug screw of the secondary winding *L*-2 until the voltmeter reads zero. To be sure that this is the true zero, rock the slug screw to either side of the zero. On one side, the voltmeter swings sharply up the scale with a negative voltage. On the other side, the voltmeter needle swings sharply down the scale with a positive voltage. Having established the two meter swings, adjust the slug screw for zero between the two swing points.

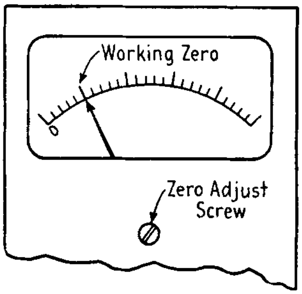


FIG. 26–7. Adjusting a meter to get an off-zero, no-voltage point.

In this step, it is desirable to have a voltmeter with a zero in the center of the scale. If such an instrument is not available, a little tricky maneuver will suffice. Simply throw the pointer of the unconnected voltmeter to a convenient marker above the indicated zero by means of the manual zero adjustment screw. This new scale line may now be used as your working zero. Adjust the secondary winding alignment screw so as to bring the meter pointer to the working zero. This indication is shown in Fig. 26–7.

The third step is alignment of the limiter stage. The setup is shown in Fig. 26–8. The 10.7-megacycle test signal is fed to the grid of the IF amplifier tube before the limiter. The hot voltmeter lead is connected to point *C*, the negative end of the limiter-grid resistor. Remember to couple the signal generator loosely to the grid and to turn down the attenuator. Then, by means of the adjustment rocking procedure, align the IF transformer *L*-3 and *L*-4 by adjusting each for a peak reading on the voltmeter. It is usual procedure to align the secondary coil before aligning the primary coil. However, no great harm results if the order is reversed when identification is difficult.

The remainder of the procedure is the alignment of the other IF stages, as shown in Fig. 26–9. Throughout the alignment of the IF stages, the voltmeter is left across the limiter-grid resistor, as was done in the previous step. Remember to couple the signal generator loosely to the set and to turn the attenuator down.

Feed the 10.7-megacycle unmodulated signal to the first IF grid. Then adjust the alignment-slug screws of IF transformers *L*-5 and *L*-6 in the usual manner to get peak readings on the voltmeter. Again, no great harm is done if the primary coil is aligned before the secondary coil.

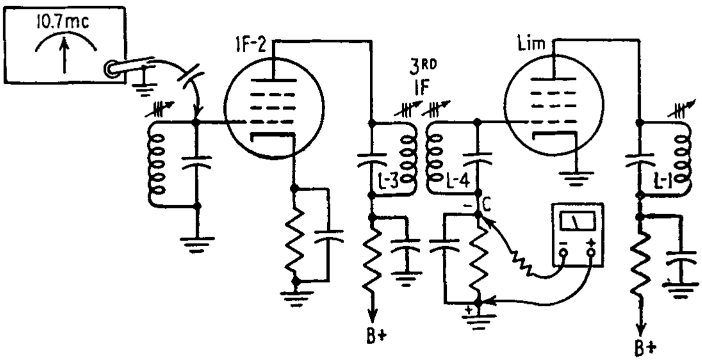


FIG. 26–8. Aligning the third IF transformer.

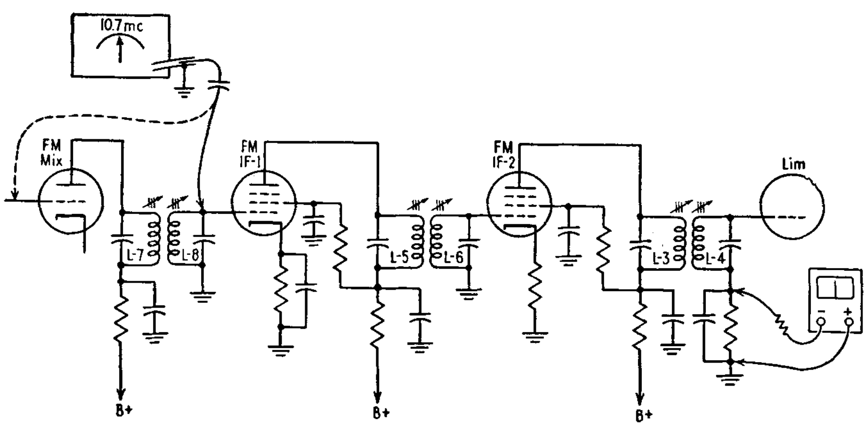


FIG. 26–9. Aligning the second and first IF transformers.

Finally, shift the signal-generator hot lead to the F-M mixer grid and peak IF transformer *L*-7 and *L*-8 for maximum reading on the voltmeter in the same manner as was done for the previous step. Repeat the entire procedure for final touchup alignment. As a last step, check to see that the discriminator audio output is zero.

Limiter-discriminator type receiver: oscillator and RF alignment. The F-M oscillator is aligned in a manner similar to that of the A-M radio. It is only necessary to recognize the special oscillator trimmer condenser previously described.

Begin by rotating the tuning condenser to the extreme low-frequency end of the dial (plates fully engaged). If the dial is not on the last calibration mark of the scale, set it there. For the rest, follow the setup shown in Fig. 26–10. Leave the voltmeter across the limiter-grid resistor.

Feed an unmodulated signal at 8 megacycles to the antenna input. Note the dummy antenna resistor *R*-1 whose resistance is 270 ohms. Remember that you are now going to rely on the harmonic output of the signal generator at 104 megacycles. Be sure that coupling to the receiver is loose and that the attenuator is down. Set the tuning dial to a non-station position at 104 megacycles. Adjust the oscillator trimmer condenser *C*-1 to give peak output on the voltmeter.

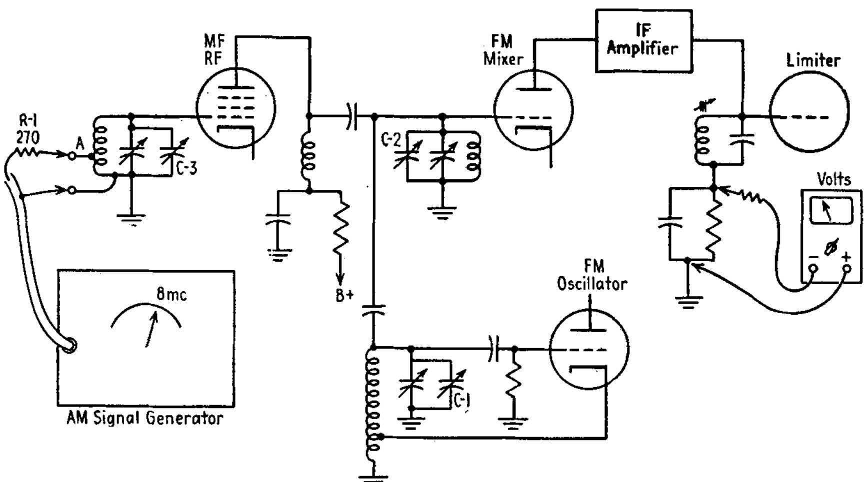


FIG. 26–10. Aligning the RF end of the receiver.

There remains only the mixer and RF trimmer adjustments, *C*-2 and *C*-3, respectively. With the receiver set at 104 megacycles, adjust trimmer *C*-2 for a peak response on the voltmeter, still across the limiter-grid resistor. Finally, adjust trimmer *C*-3 for maximum reading on the voltmeter. The set is now completely re-aligned.

Ratio detector type receiver: IF alignment. The procedure for re-aligning a ratio detector type of F-M receiver is essentially the same as the basic one just presented. However, because of circuit variations, the output voltmeter must be connected at a different point for readings.

In the ratio detector, the diodes are connected in series through the load resistors *R*-1 and *R*-2. See Fig. 26–11. Current flows in the same direction through these resistors. As a result, the voltage drops across them do not buck each other, but are additive.

The voltage across these resistors is at a maximum when the IF amplifier and primary winding of the discriminator transformer is tuned to

10.7 megacycles. Therefore, the voltage at point *A*, the ungrounded end of the load resistors, may be used as the test point for alignment of the IF trimmers and the discriminator primary coil.

In the ratio detector, the discriminator secondary coil is properly balanced when the voltages in the two diode circuits are equal for an unmodulated signal. This condition may be measured by zero voltage between the tapoff for the audio output of the detector and the midpoint of the stabilizer condenser terminals. In Fig. 26–11, the audio-output tap is labelled point *B*, and the midpoint or balance reference point is labelled *C*. These points *A*, *B*, and *C* are important alignment points in the ratio-detector type of receiver.

There are several variations of the ratio detector, especially where some manufacturers use point *A* as the source of negative AVC voltage.

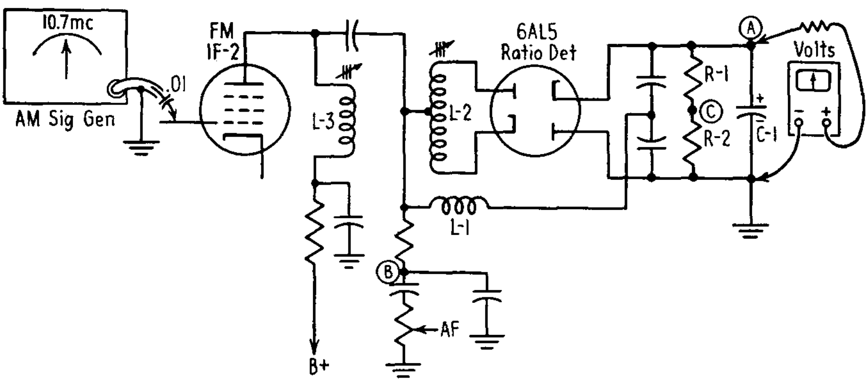


FIG. 26–11. Alignment of the ratio detector, with test points indicated.

These are shown in Figs. 26–12 and 26–13. To keep the description given above consistent, analogous points *A*, *B*, and *C* have been indicated on the variations.

In some circuits, like that in Fig. 26–13, the load resistors across the stabilizer condenser are not two resistors with equal resistance. Instead, a single resistor is used. In that case, to get the balance reference point, temporarily solder two resistors of about 100,000 ohms each across the stabilizer condenser *C*-1, and use the middle junction. The resistor connections are indicated by the dotted lines in the diagram. Remove the resistors after the discriminator alignment.

Begin by connecting the voltmeter with the hot lead to point *A* and the other to the ground. Observe proper polarity for that point. Such a connection is shown in the diagram of Fig. 26–11. Turn the receiver-tuning condenser to the fully open position and turn the AFC switch, if present, to the off position. Loosely couple the signal generator to the second FM-IF tube grid and feed in an unmodulated signal at 10.7

megacycles. Adjust the tuning slug alignment screw of the discriminator transformer primary coil *L*-3, so as to get a peak reading on the voltmeter.

Now shift the voltmeter, so that one lead goes to the balance reference point *C* and the other to AF output point *B*. Such a connection is shown in Fig. 26–13. Adjust the tuning slug alignment screw of the secondary winding *L*-2, so as to get a zero reading on the voltmeter. The discriminator transformer is now properly aligned.

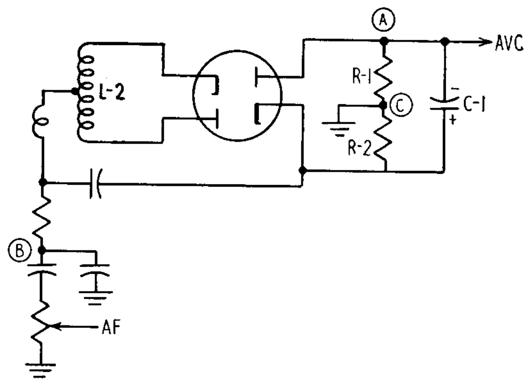


FIG. 26–12. Alignment test points for a ratio-detector variation.

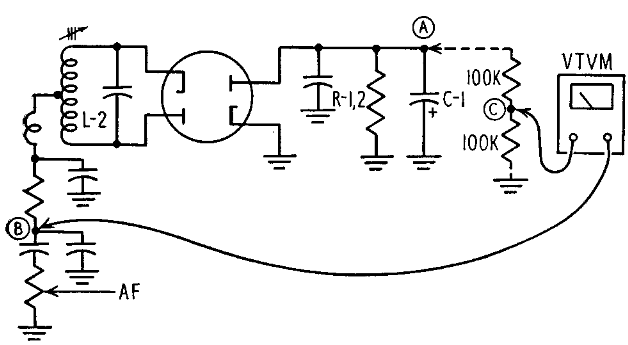


FIG. 26–13. Making up a test point for a ratio-detector variation.

The remainder of the procedure is the alignment of the IF stages. Throughout the alignment of these stages, the voltmeter is left connected from point *A* to the ground. Refer to Fig. 26–14.

Now feed a 10.7-megacycle unmodulated test signal to the first A-M/F-M intermediate-frequency amplifier tube grid, loosely coupled with the attenuator down. Adjust the tuning slug alignment screws of IF transformer windings *L*-4 and *L*-5 so as to give peak readings on the voltmeter.

Then feed the signal to the F-M mixer grid, with loose coupling and with the attenuator down. Adjust the tuning slug alignment screws of IF transformer windings *L*-6 and *L*-7 so as to give peak readings on the voltmeter. Repeat the entire procedure for final touchup alignment.

Ratio detector type receiver: oscillator and RF alignment. The alignment of the oscillator and RF stages is identical with that of the limiter-discriminator type of receiver. The only difference is that the voltmeter is retained from point *A* to the ground. The oscillator trimmer and mixer trimmer are peaked as usual with the unmodulated 8-megacycle test signal fed to the antenna input. The receiver is now completely realigned.

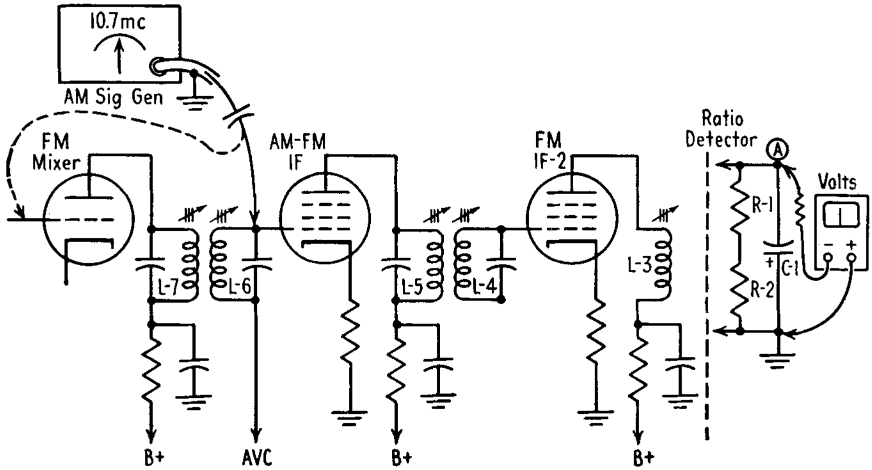


FIG. 26–14. Alignment of the IF stages of a ratio-detector type of receiver.

Equipment used in visual alignment. In visual alignment, the sweep generator replaces the A-M signal generator as the source of test signal and the oscilloscope replaces the voltmeter as the output indicator. Essentially, the same test points are used for alignment in both methods.

Most manufacturers, in their service notes, confine the visual-alignment procedure to that for the discriminator and IF stages. For the oscillator and RF stages, the standard meter method is followed. That will be the plan in this book, even though the oscilloscope method could be used for the latter stages. Now, let us familiarize ourselves with the visual-alignment test instruments.

The sweep frequency signal generator. This instrument is often called the "F-M signal generator." There are many varieties of the sweep generator to serve many purposes. For any one specific instrument, it is most advisable to read the manufacturer's service notes to learn how to put the instrument to best use. However, for the purpose of F-M alignment, we shall fabricate a sweep generator and its controls. Although no instrument has these specific controls, all have similar controls to do the job. This synthesized sweep generator is shown in Fig. 26–15.

At the upper right-hand corner is the RF frequency control which selects the center frequency of the FM output. This frequency-modulated RF output is obtained at the leads of the shield cable connected to the RF OUTPUT jack. The lead connected to the shield is the ground lead. The magnitude of output voltage is controlled by the RF GAIN control—our familiar attenuator.

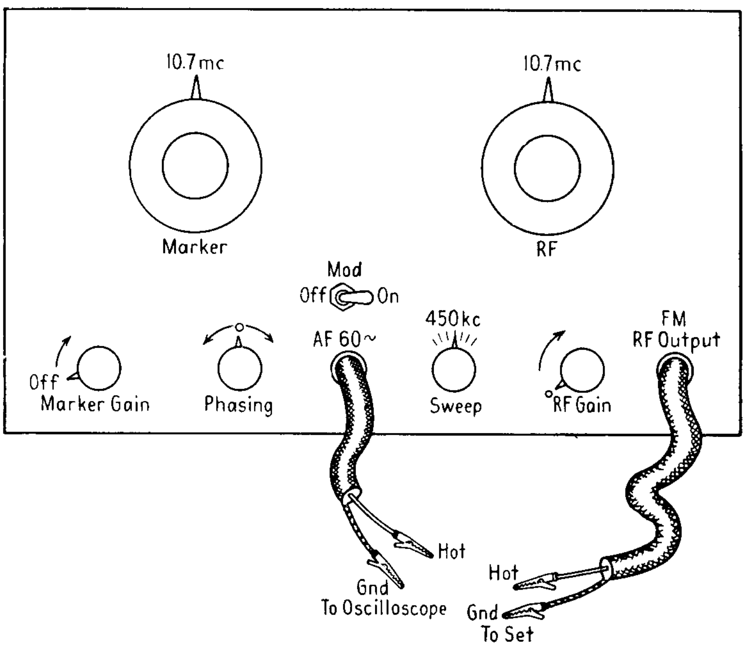


FIG. 26–15. Controls of a basic sweep-frequency signal generator.

The modulation, when the MOD. switch is in the ON position, is an internal 60-cycle voltage. It causes the F-M carrier (shown at 10.7 megacycles) to deviate above and below the center frequency sixty times a second. This modulating voltage is tapped at the AF-60~ jack by means of a shielded cable for connection to the oscilloscope. Again, the shield lead is the ground lead. The frequency deviation of the F-M carrier is determined by the amplitude of the 60-cycle modulating voltage. This amplitude is controlled by the SWEEP control, which is calibrated in frequency deviation. For our F-M alignment, a frequency sweep or deviation will be 450 kc—225 kc each side of carrier.

The PHASING control is a built-in phase-shifting network to avoid double images on the oscilloscope. By adjustment of this control, double images tend to be superimposed upon each other to produce a single image.

The MARKER control is used to locate the frequency of the center of a trace on the oscilloscope. It is a separate RF oscillator whose frequency is selected by the control knob. Its output is through the F-M RF OUTPUT cable. Below it is the MARKER GAIN control. In its OFF position, it removes marker voltage from the output. As the knob is turned clockwise, the voltage of the marker signal is increased.

To summarize, the sweep generator, as used for F-M alignment, produces an RF carrier voltage at 10.7 megacycles, deviating 225 kc each side of 10.7 megacycles. This deviation swing is repeated 60 times a second. The 60-cycle modulation voltage is brought out through a separate cable for connection to an oscilloscope.

The cathode-ray oscilloscope. The oscilloscope, like the sweep generator, exists in a variety of forms. For any specific instrument, the manufacturer's service notes should be read carefully. But, once again, we shall synthesize an oscilloscope and its controls for the sake of the alignment procedure. Every commercial instrument will have these controls in one form or another. The synthesized oscilloscope is shown in Fig. 26–16.

The heart of the oscilloscope is the cathode-ray tube. In this tube, a stream of electrons from a cathode is made to focus to a fine dot on the face of the tube. The face is coated on the inner side with a fluorescent phosphor which glows when hit by the electron stream.

The electron stream, on its way to the face, passes through two sets of plates known as deflection plates. A front view of these plates is shown in Fig. 26-17*A*. The pair above and below the stream are known as the vertical deflecting plates. The pair to each side of the stream are known as the horizontal deflecting plates. By placing a voltage across the vertical deflection plates, the electron stream is deflected up or down. As a result, the dot is similarly deflected on the screen. If rapid pulses of voltage are placed across the vertical plates, the dot will move up and down rapidly. When this movement is rapid enough, persistence of vision will make the dot appear to be a continuous vertical line, as shown in Fig. 26-17*B*.

Similarly, by the placement of a voltage across the horizontal plates, the dot may be displaced to the right or left on the screen. And if very rapid pulses of voltage are placed across these plates, the dot appears to be a continuous horizontal line on the screen.

If voltages are applied to the horizontal plates at the same time as voltages are applied to the vertical plates, the dot takes positions up and down and to the right and left. If the pulse voltages applied to the plates are very rapid and repeat themselves, a figure appears on the screen. That is what happens in alignment work.

Now, return to our synthesized oscilloscope. In the center is the face or screen of the cathode-ray tube. The face is often covered with a cross-section screen, as an aid in judging the trace image.

At the top right corner is the horizontal centering control to move any image to the right or left of the screen. Opposite it is the vertical centering control to move the image up or down on the screen. The INTENSITY control makes the image brighter or fainter. Usually, it is toned down to

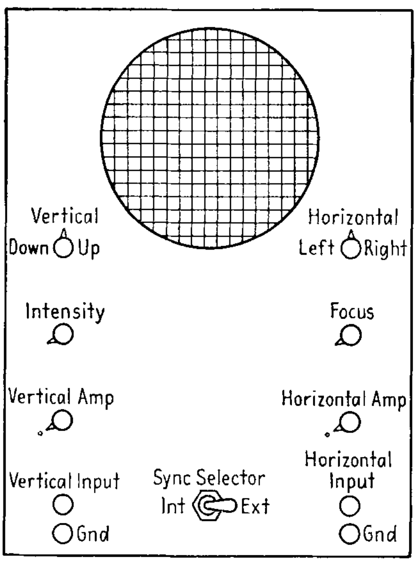


FIG. 26–16. Controls of a basic oscilloscope.

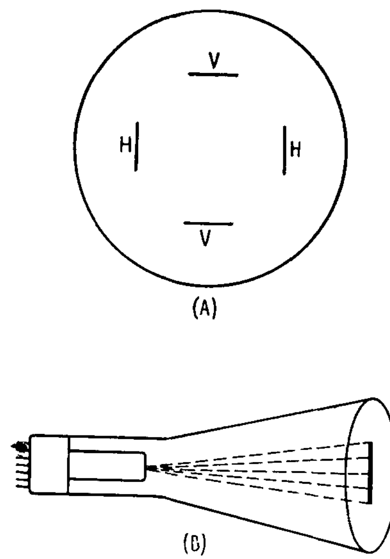


FIG. 26–17. Deflecting plates and their action in a cathode-ray tube.

save the screen face life. The FOCUS control is used to make the image sharper if it is blurred.

At the bottom on the left are two input terminals marked VERTICAL INPUT. Signal voltages are fed through these terminals to the vertical deflection plates of the cathode-ray tube. One of these terminals is a ground terminal. Since signal voltages fed to them are usually not strong enough to give enough vertical deflection, an internal vertical amplifier is included in the instrument. The knob marked VERTICAL AMP controls the gain of this amplifier.

Similarly, signal voltages are fed to the horizontal deflection plates through the HORIZONTAL INPUT terminals. Again, an internal horizontal amplifier is included to give greater horizontal deflection. Its gain is controlled by means of the HORIZONTAL AMP knob.

There is an internal synchronizing oscillator in the oscilloscope which feeds pulse voltages to the horizontal plates to produce a regular and repeated horizontal deflection or sweep of the fluorescent dot. When the SYNC SELECTOR switch is in its EXT position, it becomes possible to use an external pulse voltage to give the repeated horizontal sweep. Thus, we can use the 60-cycle modulating voltage from a sweep generator to give the synchronizing sweep to the oscilloscope. The external pulse voltage is fed to the horizontal plates of the instrument.

Setting up the equipment for visual alignment. With the brief description of the test instruments just given, we are now prepared to set up the equipment for the visual alignment of the IF section of the F-M receiver. Refer to Fig. 26–18.

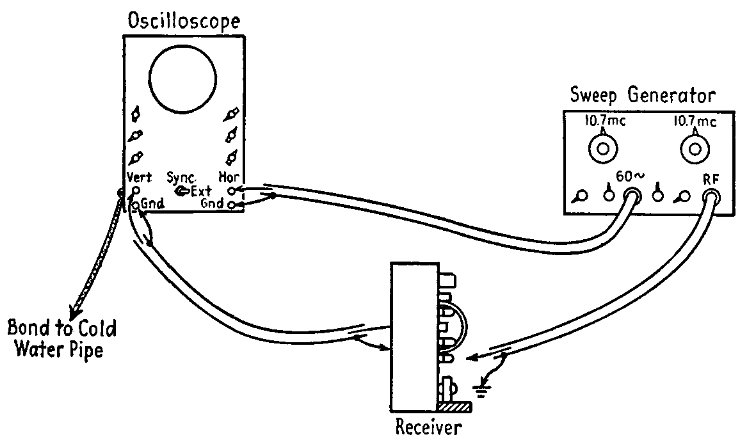


FIG. 26–18. Setting up the equipment for visual alignment.

Place the receiver on its side, properly supported, so that the top and bottom of the chassis is readily accessible for connection and adjustment. Then, ground both test instruments by running a bond jumper from a metal screw connected to the test instrument chassis to a ground, like a cold water pipe. Turn on the receiver, sweep generator, and oscilloscope for a fifteen minute warm-up before beginning the alignment procedure. If an AFC control is present, turn it off.

Connect the 60-cycle modulation output from the sweep generator to the horizontal input terminals of the oscilloscope by means of the generator cable. Be sure to connect the ground terminal of the cable to the ground terminal of the oscilloscope. Set the frequency control of the generator to 10.7 megacycles, set the modulation switch to its ON position, and turn the sweep control to a frequency deviation of 450 kc. Adjust the market dial to 10.7 megacycles and turn its gain control down to zero.

On the oscilloscope, set the SYNC SELECTOR switch to its EXT position.

A horizontal trace line now appears on the screen. If the line is displaced from center, adjust it by means of the centering controls. Adjust the FOCUS control so as to get a sharp unblurred line. Turn the INTENSITY control down so as to get a trace that is bright enough to see but not so bright as to damage the screen. And finally, if the horizontal line is too narrow, spread it horizontally by adjusting the HORIZONTAL AMP control. We are now ready for the alignment.

Limiter-discriminator type receiver: IF alignment. Connect the ground leads of the sweep generator and of the oscilloscope to the receiver chassis. Feed the 10.7-megacycle signal to the second IF grid through

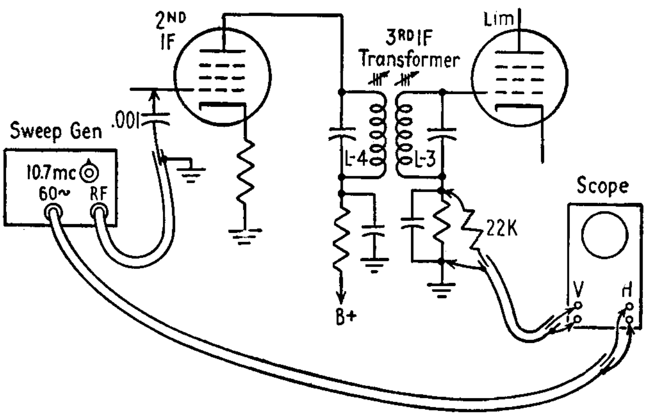


FIG. 26–19. Visual alignment of the third IF transformer.

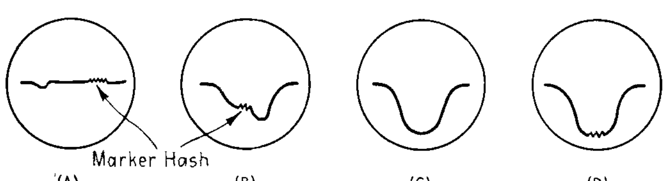


FIG. 26–20. Oscilloscope traces in alignment of the third IF transformer.

a 0.001-mfd condenser dummy antenna. Connect the vertical hot lead of the oscilloscope to the hot end of the limiter grid resistor through a 22,000-ohm resistor. The setup is illustrated in Fig. 26–19.

If the IF transformers are considerably out of alignment, there may be no indication other than that of the horizontal trace line. Turn up the RF GAIN control of the generator and the VERTICAL AMP control of the oscilloscope until some sort of small pip appears on the screen. To determine if this pip is at 10.7 megacycles, set the marker frequency control of the generator at 10.7 and turn up the MARKER GAIN control. A hash marker response will appear on the screen at the 10.7-megacycle position. If alignment is very poor, the marker hash and response curves will not coincide, as shown in Fig. 26–20*A*.

Adjust the RF frequency control of the generator to bring the marker hash to the center of the screen. Then adjust alignment slug screws for the IF transformer *L*-3, *L*-4 to increase the peaking of the response image and to center it on the 10.7-megacycle marker hash, as shown in Fig. 26–20*B*. If a double response curve appears on the screen, adjust the PHASING control of the signal generator to get a single image. The lopsided curve of Fig. 26–20*B* indicates a rough alignment where the alignment screws are close to their correct settings at 10.7 megacycles. Then turn down the marker gain, and slightly retouch each screw so as to get the symmetrical curve of Fig. 26–20*C*. To make sure that the response

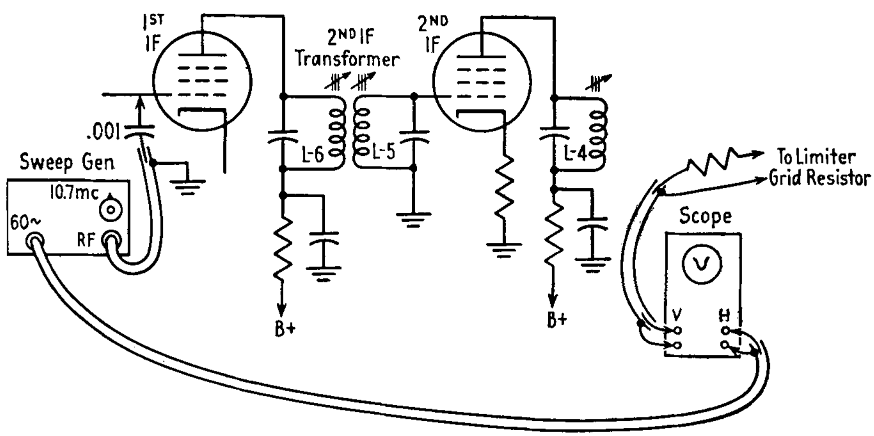


FIG. 26–21. Alignment of the second IF transformer.

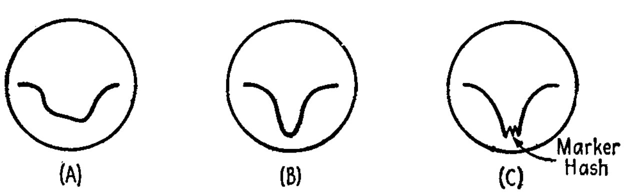


FIG. 26–22. Traces in the alignment of the second IF transformer.

curve centers at 10.7 megacycles, turn up the generator MARKER GAIN control and be sure that the hash is at the center of the response curve, as shown in Fig. 26–20*D*.

Then move the hot lead of the signal generator to the grid of the first IF tube, as shown in Fig. 26–21. If coils *L*-5 and *L*-6 are way out of alignment, the trace might be shorter and broader than when last viewed, and the symmetry could be poor, as seen in Fig. 26–22*A*. Adjust the tuning slug screws for IF transformer coils *L*-5 and *L*-6 for peak height and symmetry, as shown in Fig. 26–22*B*. When the trace gets too large, reduce the RF GAIN control of the generator to keep it on the screen. The final trace should not be as broad as the peak trace (Fig. 26–20*C*) for the second IF stage. Finally check centering by turning up the MARKER GAIN control. The marker hash should appear as shown in Fig. 26–22*C*.

Now shift the hot lead of the signal generator to the grid of the F-M mixer tube, as shown in Fig. 26–23. The vertical input lead of the oscilloscope is still at the limiter-grid resistor. Adjust the alignment screws of input IF transformer *L*-7, *L*-8 by the same procedure for maximum height and symmetry. The final response curve will be even less broad than that of Fig. 26–22*B*.

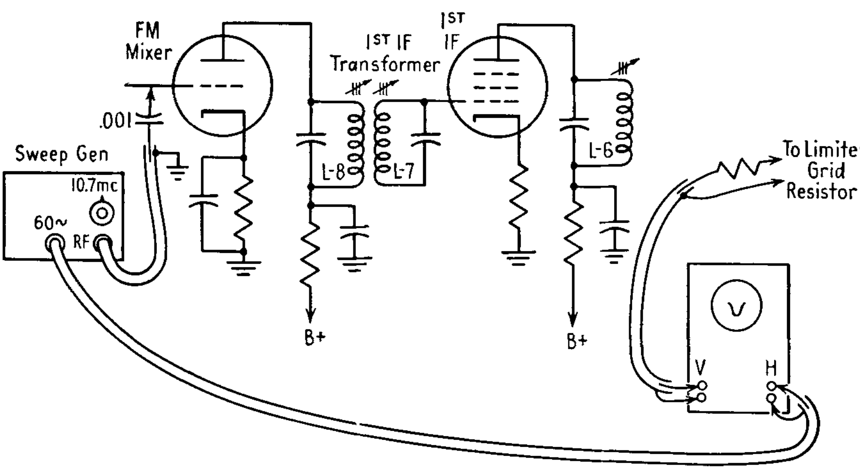


FIG. 26–23. Aligning the first IF transformer.

The discriminator stage is now ready for alignment. Shift the hot probe of the vertical input of the oscilloscope to audio-output point *B* of the discriminator, as shown in Fig. 26–24. Adjust the alignment tuning slug screw for the secondary of the discriminator transformer *L*-2 until you get a trace like that shown in Fig. 26–25*A*. Then adjust the primary screw of coil *L*-1 for peak amplitude. Retouch both adjustment screws so as to get symmetry of the curve as shown in Fig. 26–25*A*. The center slant trace should be straight, and the upper and lower peaks should be equal in height. Finally, check that 10.7 megacycles is in the center of the trace, by turning up the MARKER GAIN control. The marker hash should appear as shown in Fig. 26–25*B*.

The IF section of the F-M receiver is now completely aligned. As previously stated, the RF alignment is preferably performed by the output meter method.

Ratio detector type receiver: IF alignment. The visual alignment of the IF and detector section of a ratio detector type of F-M receiver is similar to the procedure described above. The difference lies primarily in the points to which we connect the oscilloscope. Refer to Fig. 26–26.

Connect the generator and oscilloscope in the same manner as was done in the previous procedure. Disconnect stabilizer condenser *C*-1.

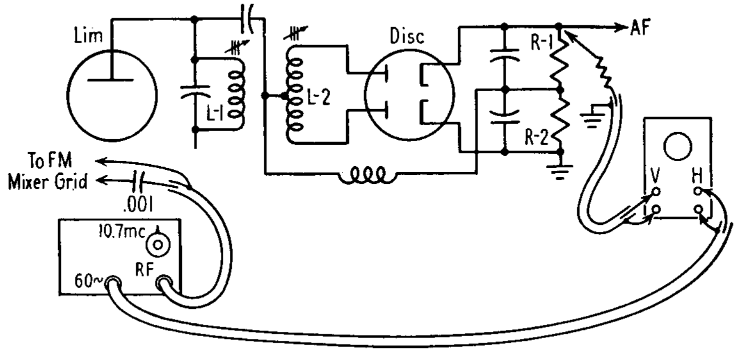


FIG. 26–24. Aligning the Foster-Seeley discriminator.

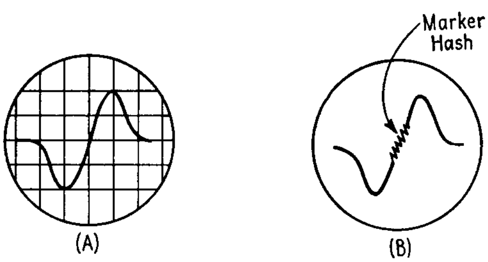


FIG. 26–25. Trace in alignment of the secondary of the discriminator transformer.

Connect the hot lead from the oscilloscope to point *A*, the ungrounded end of the load resistors. Feed a 10.7-megacycle signal from the sweep generator (60-cycle modulation and 450-kc frequency deviation) to the second IF tube grid through a 0.001-mfd condenser dummy antenna. Turn up the marker gain, until the marker trace is visible. Adjust the alignment screw of primary winding *L*-2 of the discriminator transformer to center the response curve on the marker hash. Then turn off the marker signal, and retouch the primary adjustment for height and symmetry. The trace should look like that of Fig. 26–20*C*.

Shift the hot lead of the generator to the grid of the A-M/F-M IF tube and adjust the alignment screws of the IF transformer between that tube and the second F-M IF tube to get a peak response like that of Fig. 26–22*B*. Again check center frequency by means of the marker signal.

Then shift the generator hot lead to the F-M mixer grid. Adjust the alignment screws of the IF transformer between the mixer and the A-M/F-M IF tube, so as to get a peaked and symmetrical trace. Check again with the marker signal.

Reconnect stabilizer condenser *C*-1. Connect the hot lead of the vertical input of the oscilloscope to point *B*, the audio-output point. Feed the

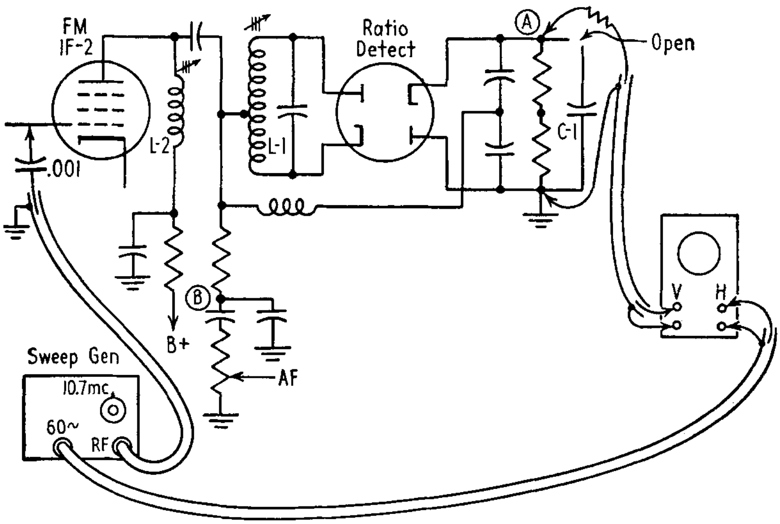


FIG. 26–26. Visual alignment of the ratio detector.

10.7-megacycle signal to the mixer tube grid. Then adjust the alignment screw of the secondary winding *L*-1 of the discriminator transformer so as to get the S-curve of Fig. 26–25A. By means of the marker, check to see that the center of this trace is at 10.7 megacycles. Shut off the marker signal and slightly retouch the aligning screw of primary winding *L*-2 to get a peak trace with a straight center-slant line. The alignment of the IF section is now complete.

SUMMARY OF ALIGNMENT PROCEDURE

Meter method

1. Receiver in F-M position; turn off AFC control, if present.
2. Use unmodulated signal from an A-M generator.
3. Bond signal generator and receiver to ground.
4. Allow receiver and test instruments a 15-min. warm-up period.
5. Connect common lead of VTVM to receiver chassis unless directed otherwise.

IF Alignment (Ratio Detector)

Dummy antenna	*Sig. gen. to*	*Sig. gen. frequency*	*Connect VTVM to*	*Adjust*	*Meter response*	*Notes*
0.001 mfd	F-M IF grid	10.7 mc	High side of load resistors	Discriminator primary	Peak volts	
0.001 mfd	F-M IF grid	10.7 mc	Hot to audio output. Common to balance reference point	Discriminator secondary	Zero volts	Plus and minus reading will be found on each side of the correct setting
0.001 mfd	A-M/F-M IF grid	10.7 mc	High side of load resistors	Second IF transformer	Peak volts	
0.001 mfd	F-M mixer grid	10.7 mc	High side of load resistors	First IF transformer	Peak volts	Finish with check of discriminator secondary

IF Alignment (Limiter-Discriminator)

0.001 mfd	Limiter grid	10.7 mc	Junction of load resistors	Discriminator primary	Peak volts	
0.001 mfd	Limiter grid	10.7 mc	Audio-output point	Discriminator secondary	Zero volts	Plus and minus reading will be found on each side of the correct setting
0.001 mfd	F-M IF grid	10.7 mc	Hot end of limiter-grid resistor	Third IF transformer	Peak volts	
0.001 mfd	A-M/F-M IF grid	10.7 mc	Hot end of limiter-grid resistor	Second IF transformer	Peak volts	
0.001 mfd	F-M mixer grid	10.7 mc	Hot end of limiter-grid resistor	First IF transformer	Peak volts	Finish with check of discriminator secondary

Visual method

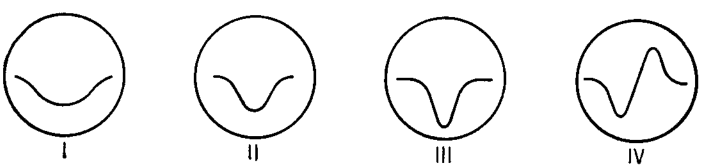
1. Use sweep frequency generator, 60-cycle modulation, 450-kc sweep.
2. Bond sweep generator and oscilloscope to ground.
3. Use a 22k isolation resistor in hot vertical input lead to oscilloscope.

IF Alignment (Ratio Detector)

Dummy antenna	*Swp. gen. to*	*Swp. gen. frequency*	*Connect scope to*	*Adjust*	*Scope response*	*Notes*
0.001 mfd	F-M IF grid	10.7 mc	Ungrounded end of load resistors	Discriminator primary	I—below	Disconnect stabilizer condenser. Adjust for peak and symmetry
0.001 mfd	A-M/F-M IF grid	10.7 mc	Ungrounded end of load resistors	Second IF transformer	II-below	Adjust for peak and symmetry
0.001 mfd	F-M mixer grid	10.7 mc	Ungrounded end of load resistors	First IF transformer	III-below	Adjust for peak and symmetry
0.001 mfd	F-M mixer grid	10.7 mc	Audio-output point	Discriminator secondary	IV-below	Reconnect stabilizer condenser. Adjust for symmetrical S-curve. Check center with marker. Retouch primary for height and straightness of center slant line

IF Alignment (Limiter-discriminator)

Dummy antenna	*Swp. gen. to*	*Swp. gen. frequency*	*Connect scope to*	*Adjust*	*Scope response*	*Notes*
0.001 mfd	F-M IF grid	10.7 mc	Hot end of limiter-grid resistor	Third IF transformer	I-below	Adjust for peak and symmetry
0.001 mfd	A-M/F-M IF grid	10.7 mc	Hot end of limiter-grid resistor	Second IF transformer	II-below	Adjust for peak and symmetry
0.001 mfd	F-M mixer grid	10.7 mc	Hot end of limiter-grid resistor	First IF transformer	III-below	Adjust for peak and symmetry
0.001 mfd	F-M mixer grid	10.7 mc	Audio-output point	Discriminator secondary	IV-below	Adjust for symmetrical S-curve. Check with marker
0.001 mfd	F-M mixer grid	10.7 mc	Audio-output point	Discriminator primary	IV-below	Adjust for peak and straightness of center-slant line



F-M RF alignment

1. VTVM to ungrounded end of load resistor for ratio-detector type.
2. VTVM to hot end of limiter-grid resistor for limiter-discriminator type.

Dummy antenna	*Sig. gen. to*	*Sig. gen. frequency*	*Receiver dial*	*Adjust*	*Meter response*	*Notes*
0.001 mfd	FM mixer grid	8 mc	104 mc	Oscillator trimmer	Peak volts	13th harmonic of signal generator used
270-ohm resistor	Antenna input	8 mc	104 mc	RF and mixer trimmers	Peak volts	13th harmonic of signal generator used

27 SURVEY OF THE SERVICING PROCEDURE

The preceding chapters of this book have analyzed each stage of the receiver and discussed troubles that might arise from defective components within each stage. The emphasis has been primarily on defects that produce no reception or weak reception.

However, when a defective receiver is brought in for servicing, the defective stage is not usually self-evident. It is therefore necessary to present an over-all servicing procedure for tracking down troubles. In addition, other defects, like hum, distortion, motorboating, modulation hum, noise, and intermittent operation, which have been treated incidentally, require an over-all approach. It is the purpose of this chapter to present such an inclusive procedure for all the defects listed.

SERVICING PROCEDURE FOR NO RECEPTION

When the complaint is "no reception," the trouble may be caused by breakdown of almost any component throughout the receiver signal chain. For the beginner or servicing apprentice, a routine check of tubes, followed by a routine voltage check, is a good approach. But it is too time-consuming for the more experienced serviceman, who will begin with a routine signal check. The following steps represent the more experienced approach:

1. Check the power supply. The serviceman will ask himself various questions with respect to the inoperative receiver. Do all the tubes in the receiver light or warm up? Is there any sign of unusual overheating? Is the hum excessive? Does *B* plus measure its normal 200 to 300 volts? If the answers to these questions are those applicable to a normal receiver, he proceeds to the next stage. If not, there is trouble in the power supply and it must be found.

The causes for lack of receiver reception originating in the power supply are listed as follows:

Open line fuse
Defective line switch
Defective line cord
Open power transformer primary
Dead rectifier
Open filter choke (speaker field), or filter resistor
Filter choke winding that shorts to chassis
Shorted filter condensers
Short in the *B* plus line
Open voltage divider resistor

2. *Check the speaker.* If the power supply checks perfect, the speaker comes up for inspection. To check its normal operation, momentarily unseat the second AF tube. If a loud click is heard in the speaker, the latter is not the cause of inoperation, and the serviceman goes on to the next check.

If the click is not heard, the speaker may be defective in some respect. Possible causes for inoperation originating in the speaker or associated circuits are:

Open speaker voice coil
Open speaker voice-coil leads
Open output transformer primary
Dead second AF tube

3. *Check the second AF stage.* If the speaker is perfect, the serviceman proceeds to check the second AF stage. A plugged-in soldering iron is applied to the signal grid pin of the second AF tube. If a low growl is heard in the speaker, the stage is all right, and the next stage is checked.

If the growl is not heard, the trouble is in the second AF stage, which is then subjected to a voltage and resistance check to localize the cause of the trouble. Causes of lack of receiver reception originating in the second AF stage are as follows:

Dead second AF tube
Open output transformer primary
Shorted plate by-pass condenser
Open cathode self-bias resistor

4. *Check the first AF stage.* With all previous checks showing normal conditions, the serviceman proceeds to check the first AF stage. When a plugged-in soldering iron is touched to the ungrounded end of the volume control, a very strong growl should normally be heard in the speaker. If it is heard, the serviceman may go on to check the next stage in the signal chain.

If the growl is not heard, the cause of no reception is in the first AF stage and its associated parts. Such possible causes are:

Dead first AF tube
Open coupling condenser in the grid or plate circuit
Open volume control
Volume-control lug shorting to chassis
Short in grid wiring (shielding)
Open cathode self-bias resistor

5. *Check the detector stage.* The detector stage is the next check when all previous check results are normal. A modulated signal at the intermediate frequency of the receiver is fed to the grid of the IF tube. If the signal-generator modulation note is heard in the speaker as the generator frequency control is wobbled around the intermediate frequency, the detector is all right. The serviceman then goes on to check the IF amplifier stage. With due regard for the different intermediate frequency involved, the same signal check will work for F-M receivers.

If the modulation note is not heard, the trouble is in the detector stage or the IF tube. Possible causes of receiver inoperation here are:

Dead IF amplifier tube
Shorted grid circuit in the IF tube
Open or shorted plate, screen, or cathode in the IF tube circuit
Defective output IF transformer:
a. Open windings
b. Shorted trimmers
c. Leads shorting to the shield can
Defective detector tube
Open volume control
Misalignment of the IF transformer

6. *Check the IF stage.* When the modulated signal-generator output is fed to the control grid of the IF tube and its note is heard, indicating normal detector operation, the "hot" lead is shifted to the mixer grid of the converter. If the note is now heard at greatly increased volume, the mixer and IF amplifier are functioning. The serviceman then proceeds to check the oscillator of the converter.

If the signal-generator note is not heard when the "hot" lead is applied to the mixer grid, the following factors may be defective:

Dead mixer (converter) tube
Shorted mixer grid circuit (tuning condenser)
Shorted or open plate, screen, or cathode circuits in the mixer circuit
Defective input IF transformer:
a. Open windings
b. Shorted trimmers
c. Leads shorting to the shield can
Misalignment

7. *Check the oscillator circuit of the converter.* After the signal-generator output is fed at the intermediate frequency of the receiver to the mixer grid and its note is heard, the receiver dial is set near the low-frequency end of its tuning range. The signal-generator frequency control is then wobbled back and forth around this frequency. If the note is now heard at about the same volume as the former modulated IF signal, the oscillator circuit is functioning, and the serviceman proceeds to the next check.

If the modulation note from the generator is not heard, the oscillator circuit is inoperative. Possible causes are:

Defective oscillator (converter) tube
Open oscillator coil (either winding)
Open or shorted oscillator anode by-pass condenser
Open oscillator anode dropping resistor
Short or resistance in the oscillator section of the gang tuning condenser
Defective oscillator padder condenser
Defective oscillator grid condenser
Defective oscillator grid resistor

8. *Check the mixer circuit of the converter.* If the oscillator is functioning normally, the "hot" lead of the signal generator is shifted to the control grid of the RF tube, or to the antenna if there is no RF stage. The receiver dial is set near the high-frequency end of its tuning range, and the signal generator is wobbled around this frequency. If the modulation note is heard at increased volume, the mixer circuit is functioning.

If the note is not heard, the trouble lies in a component between the RF grid (or antenna) and the mixer grid, and these might be:

Dead RF tube
Shorted RF control grid circuit (tuning condenser)
Open or shorted plate, screen, or cathode circuits in the RF stage

9. *Check the RF input circuit.* If the signal-generator modulation note is heard when the hot lead is connected to the RF grid but there is no reception from the antenna, the trouble must be in the antenna coil or leads. Possible causes in this regard are:

Antenna lead shorting to chassis
Open connection between antenna and antenna coil
Open or burned antenna coil primary

A 2-point check of a superheterodyne receiver. As the serviceman gains in experience, he develops shorter methods of procedure which reduce the time consumed. Such a short cut is the 2-point servicing procedure for checking an inoperative superheterodyne receiver.

If visual inspection does not disclose the source of the trouble, the tip of a plugged-in soldering iron is applied to the ungrounded end of the volume control. This is the beginning of the AF signal chain. Normally, a strong growl from the speaker should be heard. If it is not heard, the trouble is in the audio amplifier (first AF, second AF, and speaker) or the power supply, and they are checked stage by stage for the specific defect. If the strong growl is heard, this one check clears the first AF stage, the second AF stage, the speaker, and the power supply of blame for the receiver inoperation.

The serviceman then moves on to the second check point. This is the mixer grid of the converter. A modulated test signal at the intermediate frequency of the receiver is fed to this mixer grid. The normal response is the modulation note of the signal generator in the speaker. If this note is not heard, the trouble is in the IF amplifier or the detector stage. The signal-generator output is increased and the frequency control is wobbled around the intermediate frequency to see if the receiver is misaligned. If the response is still not heard, the test signal is fed to an IF grid to localize the defect further.

If the normal response is heard when the modulated IF test signal is fed to the mixer grid, the IF amplifier and detector stages may be presumed to be functioning. The signal-generator frequency control and receiver dials are set near the low-frequency end of the tuning range in order to check the oscillator circuit of the converter.

The normal response in this latter check is the signal-generator modulation note from the speaker. If it is not heard, the oscillator circuit is not functioning. A voltage check of the converter stage is then made.

If the normal response is heard, the defect must be before the converter. A check of the RF amplifier stage and the antenna circuits is now in order.

By this short 2-point check, the signal channel may be quickly analyzed into three blocks, which are checked over all before resorting, if necessary, to stage-by-stage checking.

SERVICING PROCEDURE FOR WEAK SIGNALS

The defects that cause weak reception are different from those which result in no reception. However, the servicing procedure that localizes the stage in which the defect lies is the same signal check just outlined for the complaint of no reception. The main difference in the two checks is the receiver response to the generator signal.

For a dead receiver, all signal checks result in a normal speaker response until the defective stage is reached. At that point, the receiver will give no response. For a weak receiver, all signal checks give a normal response until the defective stage is reached. At that point, the receiver will give a weak response, as shown by a loss or no gain over the last normal check before this check.

Many factors within the receiver may result in weak response. These are tabulated below:

1. Weak tube in any stage
2. Short in the power transformer winding
3. Short in the filament wiring
4. Jammed voice coil in the speaker
5. Weak excitation circuit for the speaker field
6. Shorted turns in the output transformer
7. Open cathode by-pass condenser in the second AF, IF, converter, and RF stages
8. Open AVC by-pass condenser
9. Receiver misalignment
10. Open plate by-pass condenser in the IF, converter, and RF stages
11. Open antenna coil
12. Resistance in the gang tuning condenser
13. Poor wiper contact in the gang tuning condenser

SERVICING PROCEDURE FOR HUM

A common receiver defect is a hum level that is so high that it mars normal receiver reception. This section will describe the type of hum that appears all over the receiver dial.

Checking the power supply. When a receiver is being serviced for the complaint of an abnormally high hum level, the most common defect that causes this condition is the breakdown of the power-supply filter condensers. This is usually due to the aging of these condensers.

The first step, therefore, in trouble shooting for hum is to connect a substitute condenser across each of the power-supply filter condensers in turn. If the hum level is reduced as a result, the defective filter condenser is replaced. The filter choke of the power supply must also be checked for a short that results in inadequate filtering.

Tubes as a source of hum. If the filter condensers check perfect, a good second step is to replace the tubes with new ones, one at a time. Tubes often introduce hum, especially the AF tubes. Such hum results from heater-cathode leakage through their insulation, capacitive coupling between the heater and other electrodes, and emission from the heater to other electrodes or vice versa. Although elimination of hum from these sources is primarily a design problem, replacement of tubes with new ones may reduce the hum level.

Grid circuits as a source of hum. Another possibility for hum is an open grid circuit in any stage of the receiver. This type of hum results from a build-up and discharge of signal at the open grid at a rate that may be close to the power-supply hum, and is mistaken for it.

The next check in hum elimination, therefore, is a continuity check made with an ohmmeter of all grid circuits.

Previous service work as a source of hum. If the cause of hum still proves elusive, the next check is to see if previous service work may not have introduced the trouble. For instance, replacement of part of a speaker may have resulted in the reversal of polarity of the hum-bucking coil. Or the wiring may have been disturbed with resulting poor lead dress, particularly in the region of the detector and first AF tube. The diode-plate leads, volume-control leads, and first AF grid leads must all be short. They should be dressed close to the chassis and away from the filament or other wiring that carries 60-cycle current.

Tracking down elusive hum. The suggestions made above should locate most of the common causes of hum. Occasionally, an elusive cause will escape the normal procedure that has been suggested. In such a case, the receiver must be examined stage by stage.

To do this, remove all the receiver tubes, except the rectifier. Since it is dangerous to operate a power supply without any load, a heavy-duty 5,000- to 10,000-ohm/25- to 50-watt resistor should be connected as a load from *B* plus to ground. Then turn the receiver on and listen for hum. If hum is present, it is due to some factor that was overlooked in the power supply, and it must be carefully sought for.

If the hum level is normal, insert the second AF tube and remove the power-supply resistor load. If the hum now is heard, it is due to some defect in the second AF stage. If the hum level is normal, insert the first AF tube and listen for hum. In this way, the tubes are reinserted, one stage at a time, until the offending stage is reached. Then the components of only one stage need be carefully checked to find the defect.

In the case of an AC/DC receiver, where tube heaters are in series, tubes may not be removed, as above. The stages must be made inoperative in another manner. A short from the second AF grid to ground makes everything before this point inoperative, so far as their effect on the speaker is concerned. Any hum present limits the defect to the power supply or second AF plate circuit. If the hum level is normal, the short is shifted to the first AF grid and ground. This adds the first AF plate circuit and the second AF grid circuit to the part of the receiver being checked. Thus, in shifting the short to ground from grid to grid of the various tubes, more and more parts of the receiver that will affect the speaker are brought in for check until the point of hum is located.

Once the tube-removal procedure or grid-grounding procedure has localized the stage in which hum originates, nothing in this stage should be overlooked in the careful recheck. On some infrequent occasions, a new tube that replaces a bad one may have a similar defect that still results in hum. If all else in the hum-producing stage has been found to be good it may be necessary to replace the old tube with several new ones before the hum disappears.

Another possibility in the careful recheck of a stage is the possibility of leakage between sections of a bypass condenser block. For example, a line filter condenser or a condenser connected to a heater lead will carry alternating current. If they are part of a block, leakage to other condensers in the same block may introduce hum.

Normally, condensers are checked for opens, shorts, leakage, and intermittent opens. None of these checks requires the removal of the condenser from the circuit. However, in making a careful recheck of a stage, the condenser lead must be opened, and a substitute condenser connected in its place. This procedure will take care of leakage between sections of a block.

Summary of the causes of hum in receivers. The causes of hum in a receiver may now be summarized for quicker use.

1. Open power-supply filter condensers
2. Defective tubes (cathode-heater leakage)
3. Open grid circuit
4. Reversed speaker hum-bucking coil
5. Closeness of audio grid leads to wiring carrying 60-cycle current
6. Leakage between sections of a by-pass or filter condenser block
7. Shorted filter choke

SERVICING PROCEDURE FOR NOISY OPERATION

When a receiver is brought in with the complaint that it is noisy, the condition is one of hissing and crackling sounds that are extraneous to the desired station signal. Noise may result from any one of a great number of causes, including noise pickup by the antenna, a noisy power line, and noise produced by defective units within the receiver itself. The first two are installation problems. A procedure for handling them is given in Chap. 17.

Determination of the receiver as the source of noise. The serviceman must be able to determine by check if the noise results from some defect within the receiver. This check is best handled on the service bench, where noise from antenna and power line pickup is either absent or, at least, is a factor whose normal level is known.

To determine if the receiver itself is the source of noise, the antenna and ground connections to the receiver should be removed, and the antenna and ground terminals of the receiver connected together by means of a short link. Then, if the receiver is turned on and noises are heard in the speaker, especially when the receiver is jarred, the noise is due to a defective component within the receiver.

Causes of noise within a receiver. The components in a receiver that usually cause noisy operation are as follows:

1. Noisy tubes (loose elements)
2. Corrosion in coil windings:
   a. RF transformers
   b. IF transformers
   c. Audio transformers
   d. Speaker fields
3. Speaker defects:
   a. Rubbing voice coil
   b. Torn paper cone
   c. Loose rim
4. Poor connections
5. Noisy volume control
6. Swinging shorts in IF transformers
7. Conductive dirt in vital spots (like sockets)
8. Tuning condensers (shorts and poor wiper contacts)

Locating the source of noise in a receiver. Several of the causes of noise within the receiver have already been presented in previous chapters. Chapter 9 gives the checks for the speaker defects that cause noise, and these checks may be used in noise analysis. Probably, replacement with the bench test speaker will disclose this source. In Chap. 14, the noisy tuning condenser is described. In Chap 11, defective volume controls are described. Both of them are common sources of noise and are easily identified as the sources, since the noise comes on when the controls are adjusted. A procedure for cleaning tuning condensers is given in Chap. 14. A noisy volume control should be replaced as described in Chap. 11.

A good procedure to follow when hunting for the source of noise is similar to that used in checking for hum. Remove all the tubes, except the second AF tube and rectifier tube. In the case of the AC/DC receiver, connect a short between the second AF grid and ground. Tap the tube and other components in the second AF stage and listen for noise. If the noise is heard, all connections and components in the second AF stage and power-supply stage are checked until a poor joint or defective component is found. If the noise is not heard, the second AF and power-supply stages are probably in good condition. The first AF tube is then added, or the ground connection is moved to the first AF grid. Then components in this stage are checked as before. If they prove satisfactory, the procedure is repeated for each stage in the receiver until the troublesome stage is found. The search within the defective stage must be thorough and not overlook any odd and unusual condition of a component.

As each tube is replaced or made operative, it should be slightly jarred by tapping the radio sharply. When this is done, a noisy tube will become more noisy. Then replacement with a new tube followed by the jarring test will tell if the tube was at fault. In some cases, simply replacing one tube at a time with new ones and tapping the receiver sharply will locate a noisy tube.

The stage-by-stage analysis may show a noisy stage. If the defect is due to corrosion in coil windings, jarring the radio will not affect the noise. In this case, the defective winding can be found by an ohmmeter check. Good windings in RF and IF transformers normally measure less than 100 ohms; a corroded winding usually measures several hundred ohms. The resistance measurement of AF transformers and chokes also increases when they are corroded. In the case of F-M receivers, good RF and IF transformer windings measure less than 1 ohm. They rarely corrode.

Often, unsoldered or poorly soldered connections, or bits of solder or other conducting dirt, may be the cause of noise in a stage. They may be difficult to locate because they may be in an out-of-the-way place. Such defects may cause intermittent noise or intermittent operation. Jarring the receiver usually increases the noise when those defects are the cause. An extremely careful search must be made for them.

If the procedure localizes the IF amplifier as the source of noise, remove the IF transformers from their shield cans for a careful inspection. Even though an ohmmeter check shows freedom from corrosion, the leads from the coils to the trimmers, which lie along the shield can, may vibrate into contact with the can, producing noise. Inspect the leads and route them so that they cannot possibly touch the shield can.

SERVICING PROCEDURE FOR INTERMITTENT OPERATION

Intermittent reception can be divided into two main groups. In one, the radio suddenly clicks off and remains inoperative for a while; then, just as mysteriously, it resumes normal operation. In the other type, the volume decreases and then returns to normal a little later. Sometimes, these changes are gradual rather than sudden. This condition is often called "fading."

Causes of intermittent operation. Intermittent operation (often accompanied by noise) may be due to intermittent breaks or other defects in the antenna-ground system, which should be carefully checked for breaks, as described in Chap. 17.

In the receiver, many components may be the cause. To tackle the complaint, the serviceman might replace all components likely to cause the trouble, hoping by elimination to remove the cause. Or, he might track down and repair the causative factor. The first procedure is expensive; the second is time-consuming.

The wholesale replacement of suspected receiver components includes

1. All tubes
2. All by-pass and coupling condensers
3. Any resistors that dissipate heat and may change in ohmic value as a result, like voltage-divider resistors
4. The volume control

In addition, the condenser gang should be cleaned and overhauled. Finally, a thorough search should be made for poorly soldered connections.

Tracking down intermittent reception. In tracking down the cause of intermittent reception, the receiver is allowed to play on the service bench until the fading out occurs. This condition may be hastened by jarring the receiver; or, the receiver may be made to operate inside a packing box to cut off ventilation and produce overheating; or, it might be operated through an autotransformer connected to the power lines, so that it operates under the condition of an abnormally high line voltage.

Then when the receiver fades out, any accompanying symptom, like noise or squeal, will be of aid in locating the trouble. If the receiver stays out, it is serviced as though it were a dead or weak one. If reception is resumed before any conclusive evidence has been reached, the serviceman waits for the next fade-out, or attempts once again to induce it.

SERVICING PROCEDURE FOR MODULATION HUM

"Modulation" hum is the name applied to a hum that is heard together with the station voice or music only when a station is tuned in. The hum level is normal at an off-station position on the tuning range. This type of defect in receivers is also called "tunable" hum.

Causes of modulation hum. The most common cause for this condition is an open line filter condenser, or inefficient grounding of the receiver. When a receiver is checked at the service bench for a complaint of tunable hum, the first step is to operate the receiver on a station where the hum is very noticeable. No ground lead should be connected to the receiver, since the home installation may not use one. Then connect a condenser of similar capacity across the line filter condenser and listen for a reduction in the hum. If this step is not effective, try connecting the condenser from the other side of the line to the chassis, as shown in Fig. 27–1.

If the modulation hum still persists, the next likely cause is leakage or capacity effects from the heater to other elements in the RF or converter tubes. The next step, therefore, is the substitution of tubes, known to be good, for the RF and converter tubes.

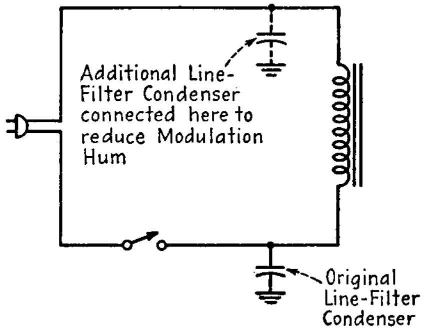


FIG. 27–1. Procedure for reducing modulation hum.

SERVICING PROCEDURE FOR SIGNAL DISTORTION

Distortion in a receiver results in poor tone quality from the loudspeaker. It is usually due to the overloading of some stage in the receiver by a signal that is too large for the stage to handle.

Causes of receiver distortion. It is unusual for the signal to be too large. The common difficulty is that the stage operation has deteriorated to a point where it cannot handle a signal of normal strength.

The usual difficulty is trouble in the grid-bias circuits, which is found by voltage analysis. The speaker, of course, is another possible cause of poor tone. This condition is checked by substituting the bench test speaker for the receiver speaker. A more complete list of possible causes of receiver distortion is given below.

1. Rubbing speaker voice coil due to
   a. Off-center voice coil
   b. Warped speaker cone
   c. Off-center speaker field gap
2. Shorted cathode bypass condenser in the second AF stage
3. Changed value of second AF bias resistor
4. Open grid leak in the first or second AF stage
5. Open volume control
6. Defective tubes
7. Shorted or leaking audio coupling condensers
8. Shorted or leaking AVC by-pass condensers
9. Misalignment, especially in F-M receivers

Less frequent causes of poor tone quality are those resulting from previous replacement of defective parts. These include a mismatch resulting from the replacement of a speaker or output transformer; a replacement plate circuit bypass condenser in the second AF stage that is too high or low in capacity, resulting in too high or low a response; rarely, side-band cutting resulting from the use of an IF replacement transformer with extreme selective characteristics. In the latter case, the side-band cutting may be reduced by slightly mistuning each IF trimmer, broadening its response characteristic.

SERVICING PROCEDURE FOR MOTORBOATING

Motorboating is a defect in a receiver that results in a put-put noise similar to the exhaust of a motorboat. The most common cause for motorboating is an open output filter condenser in the power supply. The only other common cause is an open grid circuit in any of the stages of the receiver.

Removing motorboating in a receiver. A servicing procedure for this defect in a receiver is to bridge the output filter condenser in the power supply with a test condenser of similar capacity and to see if the trouble is eliminated. If this proves ineffective, the serviceman proceeds to make an ohmmeter check of all grid circuits, looking for an open. In this regard, it should be remembered that AVC decoupling filter resistors are part of their grid circuits. They must not be overlooked, even though they rarely open. The most common opens occur in the grid-load resistors of the first and second AF stages.

SERVICING PROCEDURE FOR SQUEALS AND OSCILLATIONS

There are many types of squeals and howls in a receiver, all of which are classified under the general term of "oscillation." Their causes are many and varied and call for different servicing procedures.

Chirps or birdies. First, there is the type of squeal or birdie that appears to spoil reception from only one or two stations. This is probably image-frequency interference. A procedure for handling these is given in Chap. 16.

Microphonic noise. There is another type of howl known as "microphonic" noise. It usually starts on a loud signal, or when the radio is jarred, and builds up to a strong howl that drowns out all reception. It can be caused by loose elements in a tube or by vibrating tuning condenser plates. The howl is started by either the jarring of the receiver or the vibration resulting from a loud signal from the speaker. The loose elements begin to vibrate rapidly and introduce sustained high-pitched AF notes into the tube.

When a receiver with microphonic howl is serviced, the receiver is operated at low volume. Each tube in turn is gently tapped. When the offender is reached, a "bong" is started which soon dies out, since the speaker volume is too low to sustain the vibration. Any tube in the receiver may be the cause of the microphonic howl. However, the detector first AF tube is the most common offender.

If a check of the tubes discloses no defect, the tuning condenser should be investigated. Microphonics due to the tuning condenser are usually found in small receivers, where the speaker and tuning gang assembly are in close proximity, or in large receivers designed for and operated at high-volume levels. In both cases, original design takes care of the condition by mounting the tuning condensers or the chassis, or both, on a rubber suspension. Sometimes, even the speaker is mounted on rubber to dampen vibrations. It is only necessary thereafter to check the mounting provisions to see that the rubber has not become old and cracked, or that the suspended mounts are still floating freely.

Squeals over the major part of the receiver tuning dial. Another type of squeal is the one that occurs over the entire tuning range of the receiver or a large part of it. If this squeal is affected somewhat by tuning, the defective component is usually in the RF or IF portions of the receiver. If the squeal is unaffected by tuning but is affected by the operation of the tone control, the defective component is probably in the audio end of the receiver. However, these considerations are not of too great consequence, since the servicing procedure is the same for both conditions.

Squeals of either type are usually caused by regenerative coupling. The latter is usually caused by poor contact between a shield and the chassis or by the opening of a bypass condenser. The service procedure is suggested by the cause. Shields are checked for their contact to the chassis. Ohmmeter checking is inadequate, since even a small resistance contact (too small to be read on the ohmmeter) may still cause inadequate shielding. The best procedure is to clean and tighten all shield-ground contacts. Where a tube shield has been inadvertently discarded, it should be replaced by the serviceman. This shielding is especially important in the case of a high-gain tube like the IF amplifier.

Open bypass condensers are checked by bridging a test condenser across each bypass condenser in the receiver. It is important when making these checks to short the terminals of the test condenser after each condenser is checked.

A test condenser of about 0.1 mfd can be used for all low-frequency RF bypass condensers, even though the condenser being tested differs considerably from that capacity. The substitution box described in Chap. 28 is very convenient for rapid testing of this type. The audio bypass and the power-supply filter condensers should not be neglected in this test. The long leads of the substitution box make this procedure unusable in high-frequency circuits, like those in F-M receivers. In this case, the best procedure is temporarily to solder a 0.01-mfd test condenser across the suspected component. Use a ceramic disk type with short leads.

Sometimes, the broad squeal is due to an error that crept in during previous service work. Disarranged or poorly dressed leads may come about in the replacement of an IF or RF transformer. Or, an inverse feedback winding from the secondary of an output transformer may have been reversed during the replacement of the transformer. In the former case, the leads may couple with other parts of the receiver and deliver regenerative feedback. In the latter case, a reversed inverse feedback winding may deliver regenerative feedback, rather than degenerative feedback. As a result, an audio oscillation is set up.

Poorly dressed wiring may be checked by moving the suspected wires with a bakelite rod, while the receiver is oscillating. A change in the squeal indicates that the wire is at fault. Generally, the grid and plate leads are the "hot" leads and should be routed close to the chassis and direct to their connection points without crossing each other or coming close to other wiring.

The reversed inverse feedback winding may be checked for by reversing the primary or secondary wires of the output transformer and by observing if there is any improvement.

A summary listing of factors that might cause broad squeals and oscillations follows:

1. Open power-supply output filter condenser
2. Open second AF plate bypass condenser
3. Reversed feedback winding (after output transformer has been replaced)
4. Open shielding
5. Incorrect lead dress
6. Open AVC bypass condenser
7. Open screen bypass condenser in the RF, IF, or converter stage
8. Open plate decoupling bypass condenser in the RF, IF, or converter stage

AIR CHECK OF A RECEIVER

The final step in servicing a receiver is first to check that the original complaint has been removed, and then to check the receiver in all respects for normal operation. This final check is known as the "air check."

To make the air check, the receiver is connected to an antenna and turned on. The tuning dial is rotated to a non-station position, and the hum level is noted for normal operation.

At the same dial position, the volume control is rotated from minimum to maximum, in order to determine if it is noisy. The same is then done for the tone control, if present.

Then the dial is rotated to the low-frequency (550-kc) end, the volume control is set for a moderate volume level, and the dial is rotated toward the high-frequency (1,500-kc) end. The stations are checked off as they appear. This procedure checks the dial calibration and the sensitivity of the receiver. All stations that the serviceman knows are normally picked up in his locality should be picked up by the receiver being checked. Failure to receive any of them indicates a weak receiver. Good judgment should be used by the serviceman in this test. Obviously, a sensitive superheterodyne receiver with an RF stage and two IF stages should pick up more stations than a receiver with no RF stage and only one IF stage.

As the stations are picked up, the selectivity of the receiver may be determined by the dial space that each station covers, especially the strong local stations. If a strong local station stretches over 30 kc of the dial, the receiver selectivity is poor and should be checked. Misalignment is indicated.

Tone quality is most easily checked by listening to speech rather than to music. Clear, crisp, intelligible speech is a sign of good tone quality, especially for the high audio frequencies. Then turn to some symphonic music program, and listen for the response to the low frequencies.

The next check is for the power handling of the receiver—from whispers to the limit that the speaker will take without rattling. This will not be much for a small speaker. But a large speaker in a high-fidelity receiver ought to be capable of roaring with good tone quality.

The course over the tuning dial will disclose whistles, birdies, and squeals. The serviceman must be on the alert for these effects. A sharp slap on the receiver will show up any noisy conditions.

The final step is the check of the operation of any other controls on the receiver, like fidelity controls, function switches, push buttons, short-wave operation, and F-M operation.

CASE HISTORIES OF DEFECTIVE RECEIVERS

At this point, it is advisable to examine the work of a practical serviceman making repairs on the bench. The following tabulations are the actual case-history records made by a serviceman with wide experience.

Case 1. Complaint: Receiver is dead.

1. Applied AF signal to first AF grid	Normal
2. Applied IF signal to IF grid	Normal
3. Applied IF signal to mixer grid	No response

4. Replaced mixer tube	Receiver operates normal
5. Air check	O.K.
Case 2. Complaint: No reception.	
1. Signal to first AF grid	Normal
2. IF signal to second IF grid	No response
3. Replaced second IF tube	Receiver operates normal
4. Checked:	
Sensitivity	O.K.
Selectivity	O.K.
Quality	O.K.
Dial mechanism	Worn
5. Replaced dial belt	
Case 3. Complaint: Noisy and fading.	
1. Jarred receiver while playing	Very noisy
2. Lightly tapped tubes and components	Noise all over chassis
3. Replaced tubes one at a time and tapped	No effect
4. Continued tapping to find place of greatest effect	Tapping of condenser drive mechanism sometimes caused fading
5. Opened condenser cans and the coil to condenser connections	
6. Ohmmeter check of each condenser, and tapped each	One condenser could be tapped from open to dead short
7. Inspected that condenser	Stator rod touching the chassis
8. Insulated stator rod	
9. Checked condenser for short	None
10. Reassembled radio and tried	No noise, no fading
11. Re-aligned	
12. Checked performance	O.K.
Case 4. Complaint: Car radio, no signal.	
1. Removed radio from car	
2. Checked *B* voltage	None
3. Checked filter for short	None
4. Checked buffer condenser	Short
5. Replaced buffer condenser	Receiver operates
6. Checked:	
Sensitivity	O.K.
Selectivity	O.K.
Quality	O.K.

7. Replaced in car	
8. Checked for motor noise	O.K.

Case 5. Complaint: AC/DC receiver, intermittent reception.

1. Checked performance	O.K.
2. Left playing	Died in ½ hr. No tubes lit
3. Checked tube filaments	50L6 open
4. Replaced 50L6	
5. Checked performance	O.K.
6. Left playing	O.K.

Case 6. Complaint: No signal.

1. Signal to first AF grid	No response
2. Checked second AF plate voltage	None
3. Checked second AF screen voltage	None
4. Checked voltage across rectifier	High
5. Checked speaker field	Open
6. Replaced speaker	
7. Checked performance	O.K.

28 THE SERVICE BENCH

Much has been written about the radioman's service bench, and trade journals have sponsored contests for the best ones. Photographs of the winners have shown beautiful specimens. But in many cases, some of the tools indispensable to the serviceman seem to be lacking, or are perhaps in the back room. It is quite true that the customer must be impressed by an orderly setup, but this does not mean that the service bench must look as though nothing ever happened on it. Instruments and tools must be readily available, and ample working room must be provided. Therefore, this chapter will concern itself with the bench for work, not the one for show alone.

Physical make-up of the workbench. Dimensions and construction details will not be given, since these depend largely on the available space and the individual's preferences. The information given is in the form of general suggestions to fit a particular need.

The most important consideration is the available space, since the bench usually fills up one wall or one corner. Regardless of other dimensional considerations, a minimum clearance of 2 by 4 ft for working space should be provided. This area can accommodate even a large chassis, with its speaker, loop, power-supply chassis, etc. The bench top should be made of wood or other insulating material. Metal trim should be avoided because of the danger of short circuits.

Behind and above the working area, the serviceman can install shelving and panels for meters, manuals, replacement parts, etc. To the right of the working area should be the soldering-iron stand and a bench vise. If space permits, a bench grinder is another useful appliance to have available. Both the vise and the grinder should be installed as far from the working area as possible, to minimize the possibility of getting metallic filings in a receiver on the bench. Figure 28–1 shows an arrangement for a bench top 6½ ft by 3 ft.

The height of the working area should be such as to be comfortable for the serviceman—either standing at his work or sitting on a high stool; about 40 in. is a good average. Tall men may prefer a bench top an inch or two higher than this.

Below the working area should be suitable knee space. Flanking it, there can be drawers for tools. The back of the knee space, near the wall, can be built up with shelves for large materials that are infrequently used, such as a storage battery and charger. The tool drawers should be set back about 4 in. from the front of the bench top. Directly beneath this top, in the knee space, a strip of wood containing electrical outlets should be mounted. This same strip can have a small drawer in it for frequently used small hand tools and test leads.

A good place for another strip of outlets is directly below the meter shelf. This same strip can contain connections for the shop antenna and test speaker, as well as the resistor and condenser substitution box. A shelf above the meter panel can accommodate manuals and trade literature. Space on each side of the test panel can be used for drawers to hold small parts.

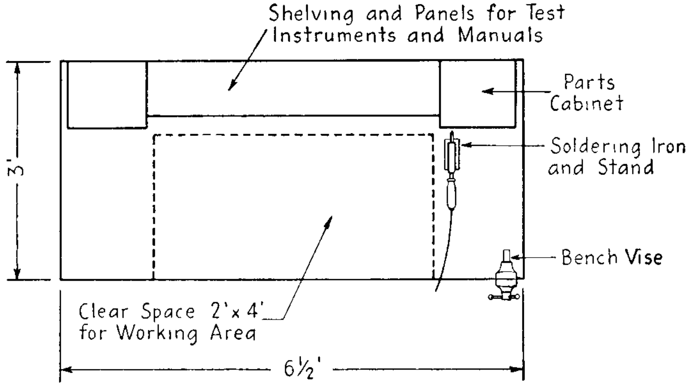


FIG. 28–1. Service bench—top view.

Below the test instruments is a convenient place to mount spools of hookup wire and solder. These can be mounted and made to unwind on a dowel stick.

Figure 28–2 shows the front view of such a service bench. The test instruments should be mounted at about eye level, 60 in. or more from the floor, depending on the serviceman's height. These should be, as a minimum, those necessary for service work: the signal generator and the multimeter. These may be of the panel-mounting type. Carrying-case units are equally good and have the advantage of being portable for use away from the bench. They merely rest on a shelf. But, lest they be yanked off, a screw through the shelf or some other easily removed holding device should be installed. The test speaker and substitution panel described in this chapter can be permanently mounted in a test panel.

The bench test speaker. The bench test speaker should be so constructed as to be easily connected to any receiver. Since there are many types of speakers as well as many methods of connections in different receivers, a universally applicable test speaker for any receiver is not easy to design. The assembly shown in Fig. 28–3 has been used with considerable success.

The speaker used is a 10- or 12-in. P-M dynamic speaker, capable of handling the output of any receiver. It should be a high-quality speaker, since it will be used to check for the cause of poor tone in a receiver and must not have its own poor tone.

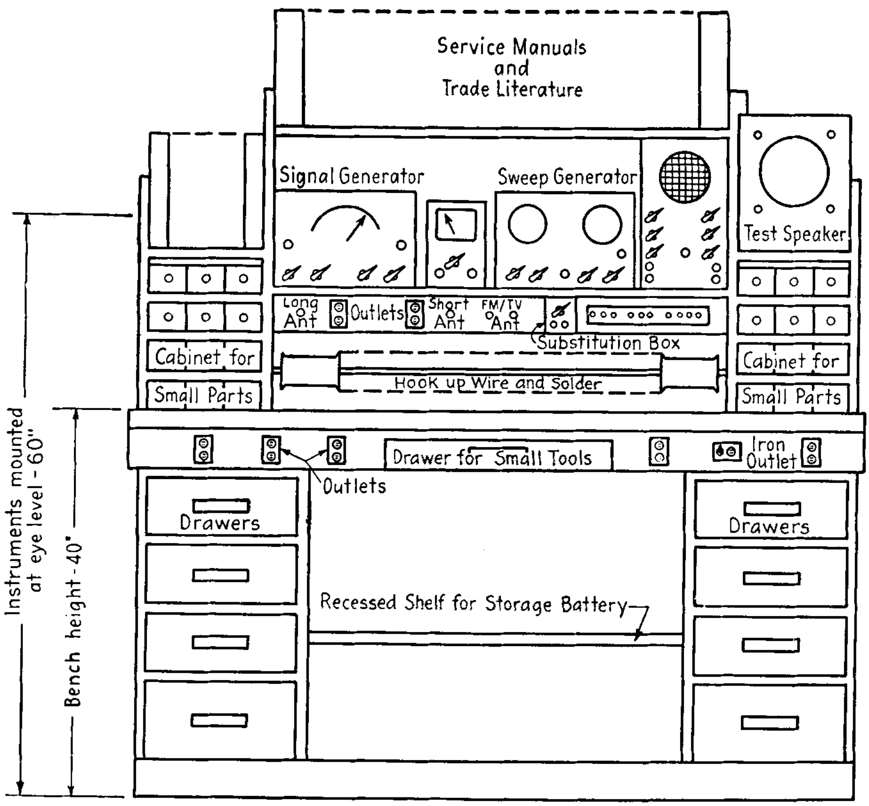


FIG. 28–2. Service bench—front view.

The output transformer is of the push-pull type, which permits connection to push-pull tubes. For use with a single tube output stage, half the winding will match a low-impedance output tube. The full winding, disregarding the center tap, will match a high-impedance output tube.

When the receiver being tested utilizes a speaker field winding that is wired directly across the rectifier (see Fig. 9–3), no provision need be made for the field at all.

When the field winding is part of the filter or voltage divider circuits (see Figs. 9–2 and 9–4), the original speaker field coil may be used, other connections to the receiver speaker being removed. If it is desired to replace such a field coil for test purposes, it may be replaced by the choke and resistor assembly of the test speaker. The choke is rated at about 20 henrys and is capable of safely carrying a current of about 100 ma. It should have an ohmic resistance of approximately 400 ohms.

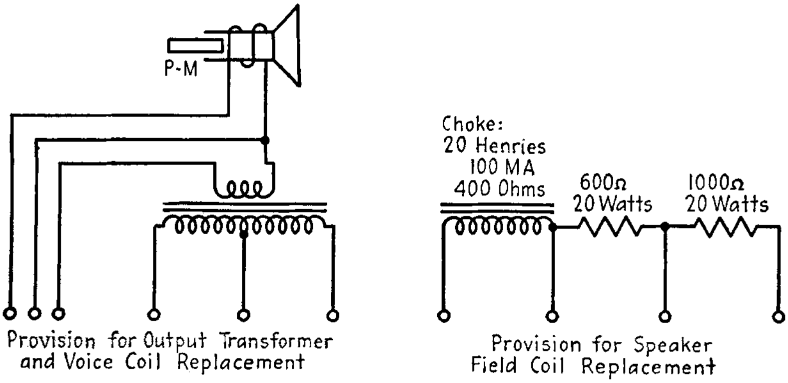


FIG. 28–3. Bench test speaker.

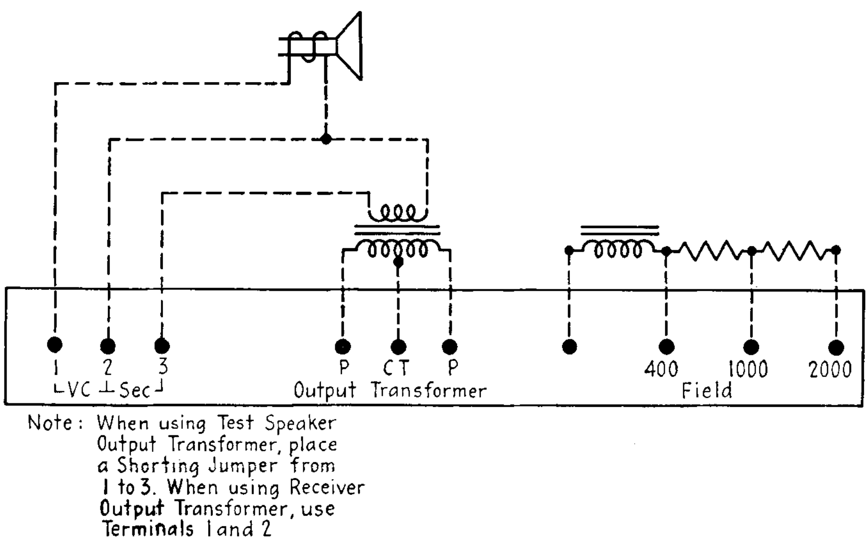


FIG. 28–4. Binding-post strip for the bench test speaker.

The two series resistors are 600 and 1,000 ohms, respectively, and are rated at 20 watts. The choke and resistors, all connected in series, will replace a speaker field of approximately 2,000 ohms.

The speaker, choke, and resistor leads should be cabled and brought to a binding-post strip, mounted under the speaker panel, and labeled as shown in Fig. 28–4. The binding posts should have a hole through the screw portion for convenience in attaching pin tips.

How to use the bench test speaker. The use of the test speaker can be illustrated by an example. Assume a receiver like our standard, shown in Fig. 1-1. Assume further, a defect consisting of some shorted turns in the primary of the output transformer. This defect will result in a very weak signal output, since most of the signal will be feeding the shorted turns. On check, the power supply will show normal readings, but there will be either a very weak click or no click when the second AF tube is momentarily unseated. This places the trouble probably in the speaker and

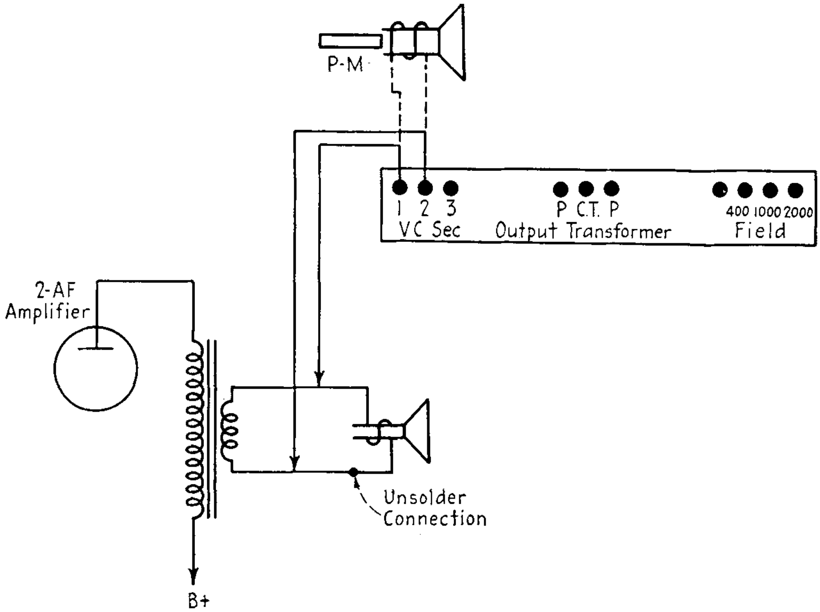


FIG. 28-5. Checking a speaker voice coil by substituting the bench test speaker.

would indicate a weak field or a frozen voice coil. Normal power-supply readings indicate a normal speaker field, which is confirmed by checking the magnetic pull with a socket wrench. The voice coil is then disconnected and the test speaker voice coil is substituted, as shown in Fig. 28-5. The result clears the voice coil, since the output is still weak.

The trouble may now be in the output transformer or the second AF stage. Voltmeter and ohmmeter checks may still show normal readings, since the shorted turns may not materially affect the resistance of the transformer primary. The second AF stage therefore seems to be all right. The test speaker and its output transformer are now substituted for the receiver speaker and output transformer. This is done by opening one of the transformer primary leads—plate or *B* plus, whichever is more convenient. Because the standard receiver uses an output tube that requires a high-impedance load, the test speaker is substituted, as shown in Fig. 28–6. The result is a normal response with the test speaker. This proves that the output transformer is defective and must be replaced.

The test speaker is used to confirm any troubles that seem to point to the speaker, as indicated in Chap. 9. Results with the test speaker should be interpreted with good judgment. For example, when it is used with the usual AC/DC receiver, the serviceman should expect excellent tone and volume as compared with the normal response from the 4- to 6-in. speaker, which is usual for these receivers.

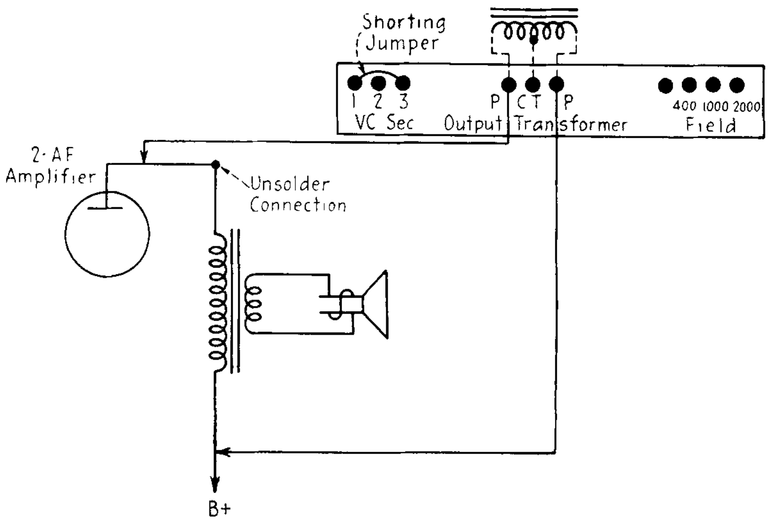


FIG. 28–6. Checking a receiver output transformer by substituting the bench test speaker.

Speaker-plug wiring. Speakers, as used in receivers, often have their leads terminated in plugs, which are connected to the receiver chassis. These plugs are usually 4- or 5-point units. The R.T.M.A. has set up standard methods of connection for these plugs, the more common of which are shown in Fig. 28–7.

Since there is considerable variation and since many receivers do not follow the standards shown, the serviceman should provide himself with several cable and plug assemblies, so that he can connect any receiver to his bench test speaker. These should include a 4- and 5-prong plug with coded leads attached.

Figure 28–8 shows the connections for hooking the test speaker to a receiver using a high-impedance output tube, a 1,000-ohm field coil, and a standard 4-prong plug arrangement.

In general, it is best to check the receiver schematic diagram against the receiver being serviced for speaker pin connections rather than to assume that one of the standard speaker connection diagrams of Fig.

28–7 is being used. A variation, commonly encountered, is the use of the speaker plug as a link that breaks the power-supply input if the speaker plug is removed. This is a safety device to prevent damage that might be caused if the power supply were allowed to operate with no load, as would normally happen when the speaker plug is removed. Such a speaker-plug connection is shown in Fig. 28–9.

Antennas for the test bench. Every test bench for radio work should be provided with antennas of various types to match conditions in any

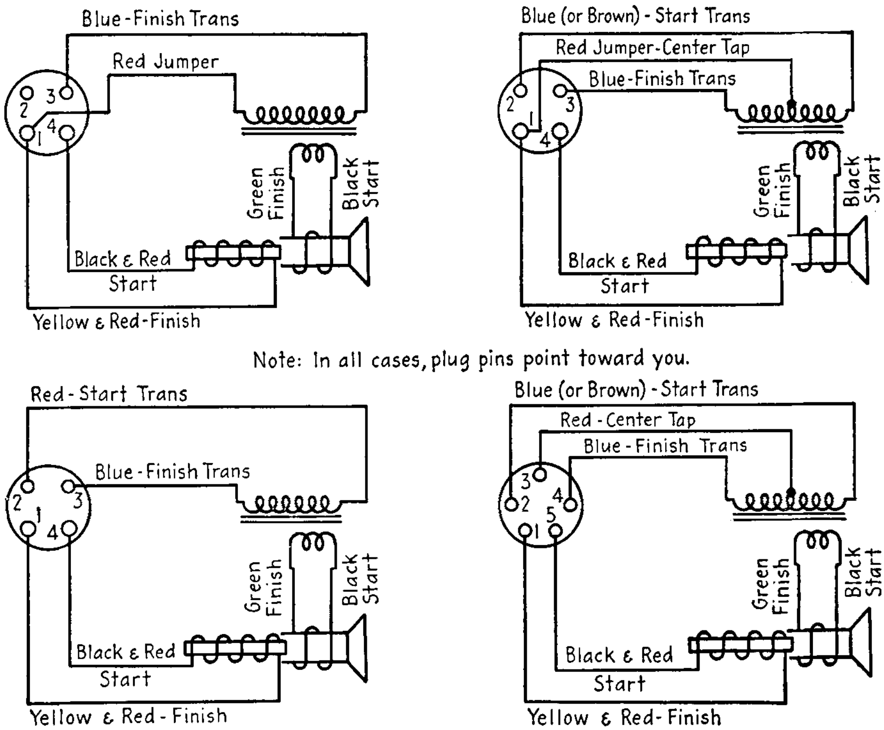


FIG. 28–7. R.T.M.A. speaker-plug wiring systems.

home or car installation. In this way, servicing problems may be tackled with at least one known factor—antenna efficiency.

There ought to be one good antenna, long and high, for good signal strength and minimum noise pickup. This will give best results with any home receiver. But there is no point in using it with a receiver whose home installation does not have a large, efficient, outdoor antenna.

Therefore, the test bench should also be equipped with a short antenna to match conditions where a short indoor antenna is used as the home installation. For this antenna, the serviceman must take cognizance of his own shop conditions. If his shop has a metal ceiling—a common con-

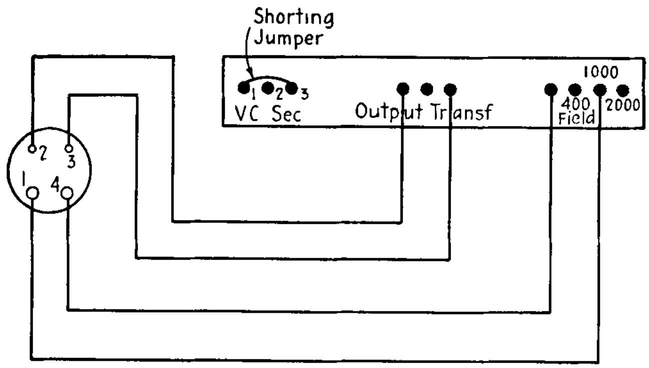


FIG. 28–8. Connecting the bench test speaker to a receiver using a standard four-prong speaker-plug arrangement.

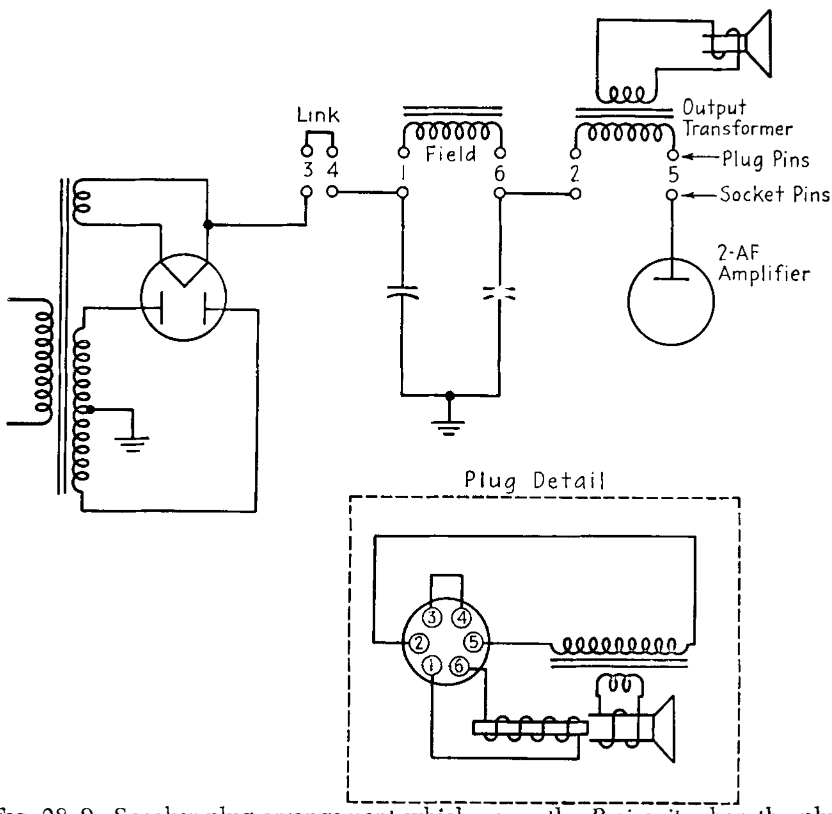


FIG. 28–9. Speaker-plug arrangement which opens the *B* circuit when the plug is removed.

dition—or if he is located on the street floor of a large steel building, a short indoor antenna will not be the equivalent of a short indoor antenna in the average home. Under these shop conditions, signal pickup would be so low and noise pickup so high with the short antenna that similar reception would not be tolerated by a radio owner. To match the condition of a normal indoor antenna in an electrically quiet residential section, the serviceman may require at least a 20-ft outdoor lead-in wire to be used for his short indoor antenna.

An antenna suitable for testing automobile receivers should also be available on the service bench. Both the long outdoor antenna and the short antenna would provide too much signal for the average automobile

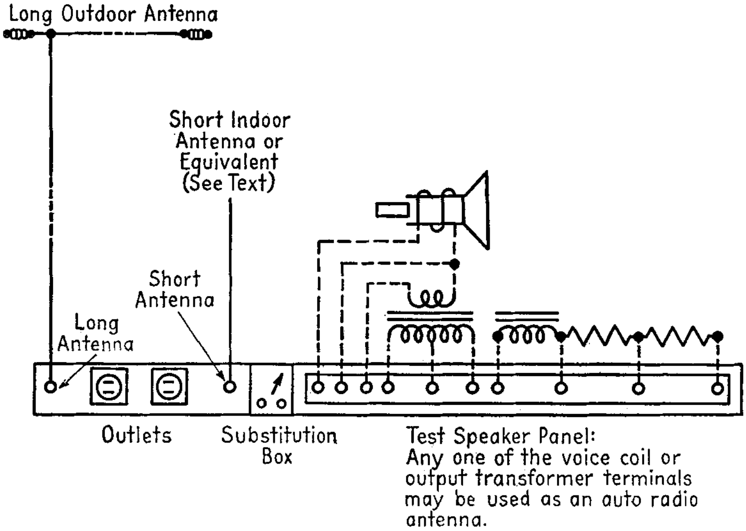


FIG. 28–10. Panel on test bench showing antenna leads.

receiver, which normally operates with a very short antenna. A good equivalent antenna for an auto radio may be had by clipping the antenna lead to any one of the test points of the bench test speaker. The test speaker cable contains nine wires, which will be 2 to 5 ft long, depending on bench conditions. If this is not satisfactory because of high noise level at the test bench, a flagpole antenna like the one described in Chap. 17 should be tried. The lead between the test bench and the window should be low-capacity shield wire, the shield being grounded only at the auto receiver chassis. Figure 28–10 shows bench conditions for the three antenna types.

If the test speaker wiring is satisfactory as an auto radio antenna, the serviceman may be confident that signal pickup and noise conditions at his test bench will also be satisfactory for the operation of loop receivers.

If it is not satisfactory, he should realize the limitations of his location and make due allowance when servicing this type of receiver. F-M receivers should be serviced with the same antenna system which is used in the home, usually an indoor type. Where shop conditions are poor for reception in this manner, install a standard outdoor TV antenna for testing these sets.

The bench, of course, should be equipped with a good ground connection.

The resistor and condenser substitution box. Often, test procedure calls for the bridging of condensers in the receiver with similar ones to check for hums, squeals, etc. Similarly, a resistor that is suspected of being open is also bridged with a similar part. Sometimes, the serviceman often wishes to short two points in a receiver for test purposes. For example, to localize the starting point of a hum that is not due to the filter circuit, he will short the second AF grid to ground. If the hum ceases, the second AF stage does not cause it, and he will then short the first AF grid to ground, and so on back through the receiver.

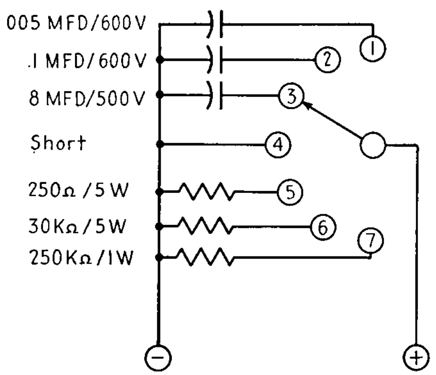
It would be convenient to have these shorts, resistors, and condensers readily available at the ends of a pair of test prods. This function is served by a substitution box that allows them to be connected to the test prods by turning a switch.

Any number of different condensers and resistors may be used, since the switches may have up to 24 positions. However, too many condensers and resistors would make the switching too slow and cumbersome. A smaller number of clearly marked positions would be more convenient. Of course, this reduces the possible number of resistors and condensers available. But this is no disadvantage, since, in test work, the bridging of a component need not be made with an exact duplicate. For example, when a receiver has an open screen bypass condenser, the squeal will stop or be materially reduced when the defective condenser is bridged with any condenser with a capacity from about 0.01 mfd and up. Similarly, in checking filter condensers for hum, even a 4-mfd condenser will show considerable improvement over results with an open 20-mfd condenser. Likewise, with resistors, an ohmic value wrong by 100 per cent or more will show a marked improvement in results from those obtained when the resistor is open.

Of course, the actual replacement in the receiver should be made with the correct value. But for test purposes, the number of components and consequent test points on the switch may be reduced for greater convenience.

A 7-point switch should be sufficient for all test work: 3 for condensers, 3 for resistors, and 1 for a short. The schematic circuit of such a substitution box and the uses of each component are shown in Fig. 28–11.

The values of components indicated at the left of the diagram are recommended as a test substitution for any value within the limits shown at the right of the schematic diagram. A paper condenser is recommended for the filter condenser, although an electrolytic condenser may



COMPONENT USE

(1) For low-capacity bypass, 0.002–0.01 mfd.
(2) For cathode, plate, or screen bypass, 0.02–0.5 mfd.
(3) For power supply filter condensers, 4–20 mfd.
(4) For shorting out a circuit or component.
(5) For cathode self-bias resistors, 150–1,000 Ω.
(6) For voltage dividers, 5,000–50,000 Ω.
(7) For plate and grid loads, 0.1–1 megohm.

FIG. 28–11. Schematic diagram of resistor and condenser substitution box.

be used. In this case, the serviceman must observe polarity, as indicated on the diagram. A paper or electrolytic condenser with a rating of 500 volts may be used for test purposes in an AC/DC receiver. However, if

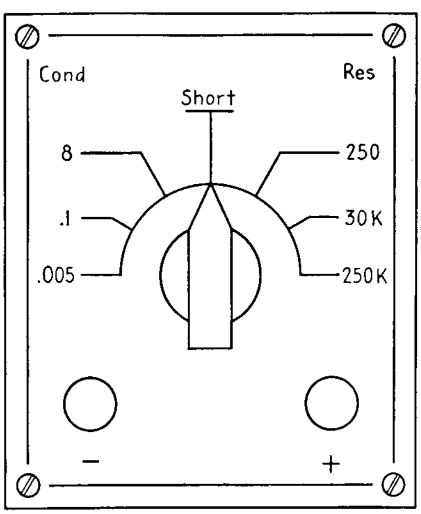


FIG. 28–12. Front panel of resistor and condenser substitution box.

a replacement is made, the serviceman must be sure to use the proper voltage rating (150 volts).

It is not recommended that condensers of the order of 0.0005 mfd be used in the substitution box, since the capacity, inductance, leakage, and

RF pickup of the leads and substitution box will affect circuits using these low capacities.

The front panel of the substitution box appears as shown in Fig. 28–12. The seven positions are clearly marked and will be an aid in fast checking. The polarity indication on the test jacks may be neglected, if the 8-mfd condenser is a paper condenser.

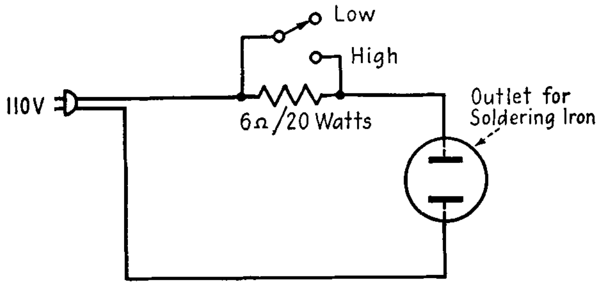


FIG. 28–13. Schematic diagram of a "high-low" soldering-iron outlet.

In using the substitution box for condensers, the serviceman should establish the habit of shorting the test leads together after each application of the test prods. This is important because the test condenser may become charged with the voltage in a circuit. The condenser may then discharge into another receiver circuit being tested, with disastrous results. To establish this habit, the serviceman might do well by shorting all test leads after use, regardless of the component being used.

Soldering-iron service hint. The soldering iron in most common use by a serviceman is a 100-watt unit. To save time, it must be hot at all times when in use on the bench. However, it will overheat if left connected to the power line and will need constant retinning of the tip. A method for

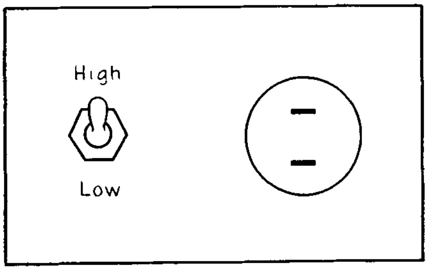


FIG. 28–14. Front view of a "high-low" soldering-iron outlet box.

overcoming this difficulty is to leave the iron connected to the outlet at all times when the bench is in use, but to place a dropping resistor in series with it. The ohmage of the dropping resistor should be so chosen that the iron will not overheat yet will remain sufficiently hot to solder small joints. Then, if a considerable amount of soldering is to be done or if a heavy joint is to be soldered, a toggle switch is used to short out the series resistor. A 6-ohm/20-watt resistor may be used, as shown in the circuit of Fig. 28–13.

The resistor and switch should be mounted in a conventional 3-in. electrical outlet box to prevent accidental touching of the hot unit. The switch should be labeled HIGH and LOW, to indicate high and low heat, as shown in Fig. 28–14.

Bench lighting. Lighting is important for the serviceman, since a receiver is full of many small and crowded components. It is recommended that large incandescent lamps with wide metal shades be used. If fluorescent lighting is used above the bench, adequate filters should be installed in them to reduce noise radiation. Even with filters installed, there may be some interference picked up by a loop-operated receiver directly under the lamps.

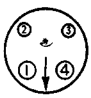
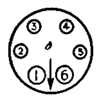
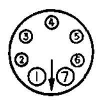
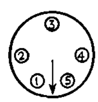
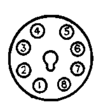
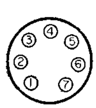
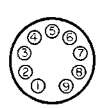
For convenience, the serviceman can use lamp fixtures with extra-long lead wires. He might thereby raise and lower the fixtures as the needs of a situation demand.

APPENDIX

SYMBOLS AND ABBREVIATIONS

A	Heater or filament circuit
AC	Alternating current
AF	Audio frequency
A-M	Amplitude modulation
amp	Amperes
ant	Antenna
AVC	Automatic volume control
B	Plate circuit
BC	Broadcast
BFO	Beat frequency oscillator
C	Capacitance
C	Grid circuit
CT	Center tap
DAVC	Delayed automatic volume control
DC	Direct current
E	Volts (in Ohm's law formulas)
F-M	Frequency modulation
gnd	Ground
h	Henry
I	Amperes (in Ohm's law formulas)
IF	Intermediate frequency
k	1,000
kc	Kilocycles (or kilocycles per second)
L	Inductance
L-C	Inductance-capacitance
ma	Milliamperes
mc	Megacycles (or megacycles per second)
meg	Megohms
mfd	Microfarads
mh	Millihenrys
mmfd	Micro-microfarads
P-M	Permanent magnet
R	Resistance
R	Ohms (in Ohm's law formulas)
Ω	Ohms (in figures)
R-C	Resistance-capacitance
RF	Radio frequency
rpm	Revolutions per minute
rms	Effective value (as of voltage)
SW	Short wave
TRF	Tuned radio frequency
v	Volts
W	Watts
Z	Impedance

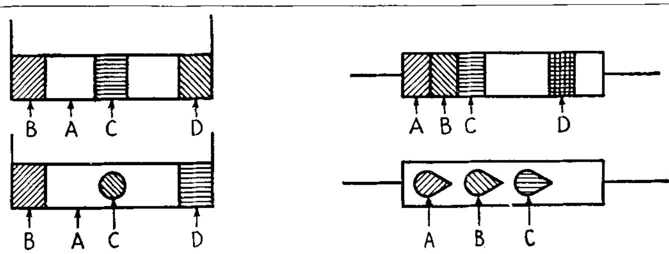
TUBE PRONG NUMBERING SYSTEM

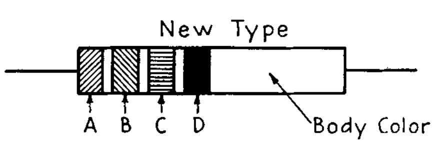
Tube base (bottom view)	*Identifying tube prongs*
  	The four-prong tube has two large and two small prongs. The large prongs (1 and 4) are filament connections. The six-prong tube has two large heater prongs (1 and 6). The seven-prong tube has two large prongs (1 and 7) for the heater connections.
	All prongs in the five-prong tube are the same size. Prong 3 has more separation than the others. The heater prongs are 1 and 5.
	There are two eight-prong bases, the octal and lock-in types. In both cases, numbering begins from the left of the key slot and continues in a clockwise direction.
 	In the miniature seven-prong and nine-prong tube bases, numbering begins at the left of the wide space and continues in a clockwise direction.

R.T.M.A. COLOR CODE FOR RESISTORS (OHMS)

Basic Reference Chart

Color	*1st figure (A)*	*2nd figure (B)*	*Multiplier (C)*	*Tolerance (D)*
Silver			0.01	10%
Gold			0.1	5%
Black		0	1.0	
Brown	1	1	10	1%
Red	2	2	100	2%
Orange	3	3	1000	3%
Yellow	4	4	10000	4%
Green	5	5	100000	
Blue	6	6	1000000	
Purple	7	7	10000000	
Gray	8	8	100000000	
White	9	9	1000000000	
No color				20%





For new type only, body color indicates type of resistor as follows: black—composition, noninsulated; any color other than black, tan preferred—composition, insulated; dark brown—wire-wound, insulated.

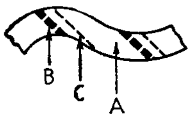
An example will indicate the use of the new type of resistor coding. Assume the following with colors are given: *A*, red; *B*, green; *C*, orange; *D*, silver.

Decoding, we get

A	*B*	*C*	*D*
2	5	1,000	10%

The resistor has a value of 25 times 1,000, or 25,000 ohms, and a tolerance of ± 10 per cent.

R.T.M.A. COLOR CODE FOR FLEXIBLE RESISTORS



The same color code holds for flexible resistors as for carbon resistors. For flexible resistors the first digit is the body color (A). The second digit is the thick thread color (B). The multiplier is the thin thread color (C).

OHM'S LAW AND ITS DERIVATIVES

Where E = volts, I = amperes, and R = ohms,

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

$$E = I \times R$$

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

Where E = volts, I = amperes, R = ohms, and W = watts,

$$W = I^2 \times R$$

$$I = \sqrt{\frac{W}{R}}$$

$$R = \frac{W}{I^2}$$

$$W = I \times E$$

$$I = \frac{W}{E}$$

$$E = \frac{W}{I}$$

$$W = \frac{E^2}{R}$$

$$E = \sqrt{W \times R}$$

$$R = \frac{E^2}{W}$$

PREFERRED VALUES

The average values for resistors used in diagrams in this book have been expressed in round numbers for the sake of simplicity. Actual resistors in use have been standardized at preferred values. For example, where we speak of a 500k resistor, the actual resistor will be 470k. There are three common listings of preferred values, based on tolerance ratings of 20, 10, and 5 per cent.

20 per cent	*10 per cent*	*5 per cent*
10	10	10
		11
	12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
		30
33	33	33
		36
	39	39
		43
47	47	47
		51
	56	56
		62
68	68	68
		75
	82	82
		91

The listed numbers are the basic numbers. Resistors will have these values or values that are multiples of 10 of these numbers. For example, a preferred value resistor may be one of 33, 330, 3300, 33k, 330k ohms, etc., or 3.3 megohms, etc.

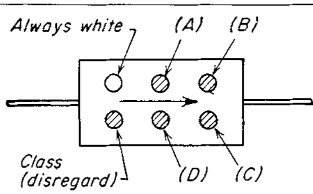
Most manufacturers use resistors with a 10 per cent tolerance rating. In service work, use the nearest value in the 10 per cent column for replacement of a resistor whose value is given in round numbers.

R.T.M.A. COLOR CODE FOR CAPACITORS (MMF)

Basic Reference Chart

Color	1st figure (A)	2nd figure (B)	Multiplier (C)	Tolerance (D)
Black	0	0	1	20%
Brown	1	1	10	1%
Red	2	2	100	2%
Orange	3	3	1000	2½% or 3%
Yellow	4	4	10000	
Green	5	5		5%
Blue	6	6		
Violet	7	7		
Gray	8	8		
White	9	9		10%
Gold			0.1	
Silver			0.01	10%

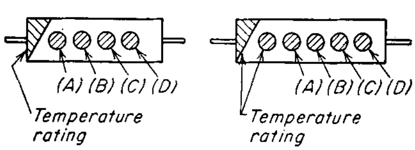
Molded Mica Condensers



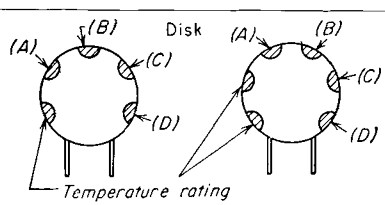
First dot is always white. This indicates a molded mica condenser. Direction for reading indicated by arrow or equivalent marking.

Ceramic Condensers

Tubular



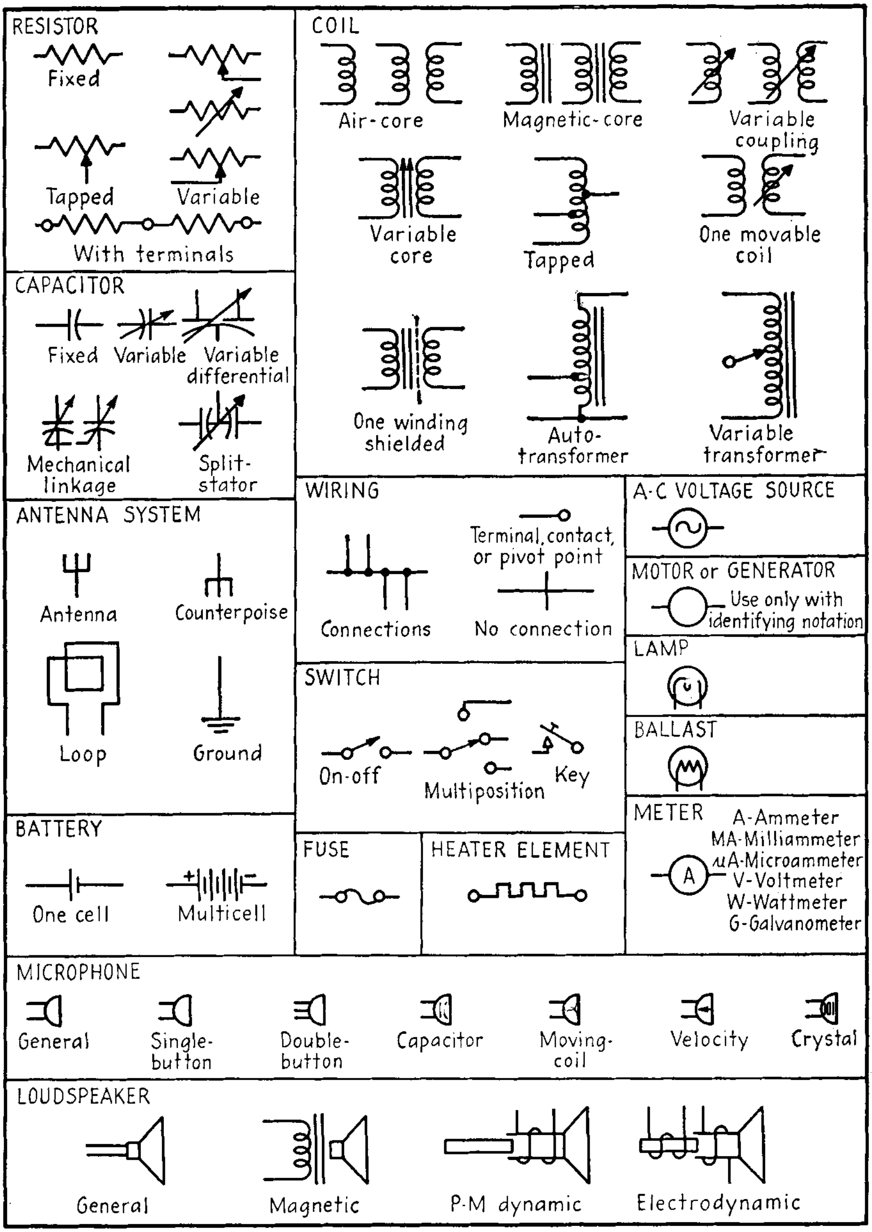
Tubular condensers read from the end color to the right. End color identifies inside lead. Leads may be axial or radial.



Disk condensers are read from left to right with leads held downward.

For replacement purposes in tuned circuits, use ceramic condensers with the same temperature markings as the original.

GRAPHIC SYMBOLS



GRAPHIC SYMBOLS

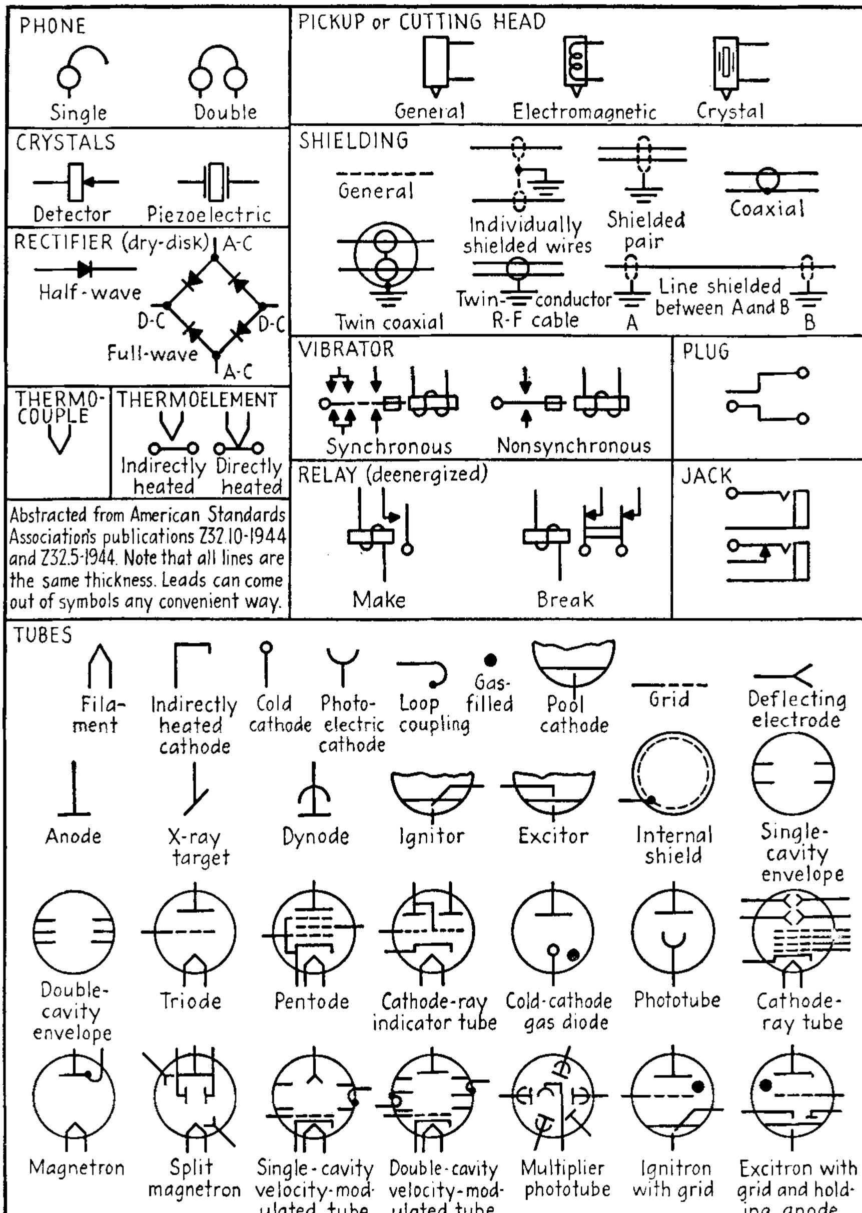


CHART SHOWING AUTOMOBILE BATTERY GROUNDS

Car	1946	1947	1948	1949	1950	1951	1952	1953
Buick	N*	N	N	N	N	N	N	N
Cadillac	N	N	N	N	N	N	N	N
Chevrolet	N	N	N	N	N	N	N	N
Chrysler	P*	P	P	P	P	P	P	P
De Soto	P	P	P	P	P	P	P	P
Dodge	P	P	P	P	P	P	P	P
Ford	P	P	P	P	P	P	P	P
Frazer	P	P	P	P	P	P	P	P
Henry J.	—	—	—	—	—	P	P	P
Hudson	P	P	P	P	P	P	P	P
Kaiser	P	P	P	P	P	P	P	P
Lincoln	P	P	P	P	P	P	P	P
Mercury	P	P	P	P	P	P	P	P
Nash and Rambler	P	P	P	P	P	P	P	P
Oldsmobile	N	N	N	N	N	N	N	N
Packard	P	P	P	P	P	P	P	P
Plymouth	P	P	P	P	P	P	P	P
Pontiac	N	N	N	N	N	N	N	N
Studebaker	P	P	P	P	P	P	P	P
Willys	P	P	P	P	P	P	P	P

* N = Battery negative pole grounded
P = Battery positive pole grounded

CORRELATED LIST OF VISUAL AIDS

The visual aids described below and on the following pages can be used to supplement much of the material in this book. Motion pictures and filmstrips are included in this list, the character of each being indicated by the self-explanatory abbreviations "MP" and "FS." Immediately following this identification is the name of the producer, and if the distributor is different from the producer, the name of the distributor follows the name of the producer. Abbreviations are used for these names and are identified in the Directory of Sources at the end of this bibliography. Unless otherwise indicated, the motion pictures are 16mm sound black-and-white films and the filmstrips are 35mm black and white and silent. The length of motion pictures is given in minutes (min), of filmstrip in frames (fr).

This bibliography is a selective one, and film users should examine the latest annual edition and supplements of *Educational Film Guide,* a catalogue of 11,000 films published by the H. W. Wilson Company, New York. The *Guide,* a standard reference book, is available in most college and public libraries.

A special series of six filmstrips has been prepared by the Text-Film Department of McGraw-Hill Book Company, Inc., to correlate and illustrate visually specific items in this book, namely:

Converter. Parts 1, 2, and 3: Oscillator Stage; Mixer Stage; Identification of Parts

How to Use the Signal Generator

Alignment. Parts 1 and 2: IF Amplifier; Front End

Complete descriptions of the individual filmstrips are given in this visual bibliography.

Alignment. Part 1: IF Amplifier (FS McGraw 37fr). Shows how to align the IF amplifier in superheterodyne receivers in a step-by-step procedure. Detailed diagrams and photographs clarify the generator-receiver-output meter connections as well as their adjustments.

Alignment. Part 2: Front End (FS McGraw 39fr). The same procedure is continued, showing connections and adjustments pertaining to the front end of the receiver. This includes adjustment of the oscillator, dial, mixer, RF stage, and wave trap as well as notes on tracking.

Basic Electricity (MP USAF/UWF 19min color). An animated cartoon explaining the fundamentals of electricity, including voltage, current, resistance, magnetic fields, induction, primary and secondary coils, and series and parallel circuits.

Basic Electronics (MP USAF/UWF 18min color). An animated cartoon explaining the meaning of the atom and electron, vacuum tube, cathode, rectifier tube, amplifier tube, grid, and bridge circuit.

Basic Principles of Frequency Modulation (MP USA/UWF 31min). Describes what F-M is in radio communication, how it is used, and what its advantages and limitations are.

Circuit Testing: Signal Generators (MP USA/UWF 26min). Explains the theory and operation of the signal generator, including oscillating circuits, audio oscillators, radio-frequency oscillators, and frequency meters.

Coaxial and Microwave Miracles (MP AT&T 11min). Explains the functions of coaxial cables and microwave booster stations in the transmission of radio signals.

Converter. Part 1: Oscillator Stage (FS McGraw 34fr). The nature of an oscillation is depicted by a series of developmental drawings. Practical electronic oscillators are described, and the function of the oscillator stage in the superheterodyne receiver is presented.

Converter. Part 2: Mixer Stage (FS McGraw 36fr). The problem of frequency conversion is broken down to a step-by-step presentation. The mixer stage is integrated with the oscillator to give an over-all picture of the converter. Circuits used in modern receivers are illustrated. A summary highlights important points of superheterodyne operation.

Converter. Part 3: Identification of Parts (FS McGraw 39fr). Identifies converter components in actual photographs of superheterodyne receivers. Service notes pertaining to testing and replacing converter parts are portrayed.

The Effects of the Ionosphere on Radio Wave Propagation (MP USA/UWF 29min). Explains the characteristics of propagated radio waves at various frequencies. Also, explains ground and sky waves, the effect of the ionosphere on sky waves, and the effects of favorable and unfavorable atmospheric conditions.

How to Use the Signal Generator (FS McGraw 39fr). This servicing tool is described functionally. The operations of the controls are explained in detail as they are used in a basic generator. Similar controls are then identified on several commercial instruments. Illustrations show how to connect the generator to receivers for various tests.

Naturally It's FM (MP GE 17min color). Explains the differences between A-M and F-M radio broadcasting and the relative advantages and disadvantages.

Principles of Electricity (MP GE 20min color). Explains electrons, current, ohms, amperes, volts, magnetism, and magnetic fields.

Radio Antennas: Creation and Behavior of Radio Waves (MP USAF/UWF 12min). Explains electric and magnetic fields, generation of electromagnetic waves, and behavior of radio waves in space. Also, explains ground wave, reflection and refraction, the ionosphere, and causes of fading.

Radio Antennas: Fundamentals of the Antenna (MP USAF/USCAA 13min). Depicts various types of antennas and explains some of the fundamental characteristics of each. Explains how the effective length of an antenna can be altered and how standing waves are prevented from forming in transmission lines. Shows typical circuits for voltage and current-fed antennas.

Radio Interference from Rural Power Lines (MP USDA 45min). A classroom demonstration, using models, charts, and blackboard explanations, of the causes of radio interference from power lines in rural areas.

Radio Receivers: Principles of Radio Receivers (MP USAF/UWF 17min). Portrays the principles and workings of typical radio receivers, including crystal and tube detectors, radio- and audio-frequency amplification, and the superheterodyne circuit.

Radio Technician Training (MP series USN/UWF). Fifteen films dealing with specific aspects of radio servicing. Titles and running times are:

Audio Oscillator Operation (9min)
Capacitance (31min)
Inductance (34min)
Oscillators (13min)
Periodic Functions (17min)
Radio Shop Techniques (38min)
RCL: Resistance, Capacitance (34min)
Rectangular Coordinates (13min)
Signal Generator Operation (9min)
Standing Waves on Transmission Lines (23min)
Synchro Systems, Part 1 (15min)
Synchro Systems, Part 2 (13min)
Tube Tester Operation (9min)
Vectors (12min)
Volt Ohmmeter Operation (15min)

Safety Precautions for Electronics Personnel (MP USN/UWF 18min). Shows electrical and mechanical hazards which electronics technicians encounter in their normal work and stresses precautions which should be employed to prevent accidents.

Directory of Sources

AT&T—American Telephone & Telegraph Company, 195 Broadway, New York 7, N.Y., or local Bell System Telephone offices.

GE—General Electric Company, 1 River Road, Schenectady, N.Y., or branch offices in principal cities.

McGraw—McGraw-Hill Book Company, Inc., Text-Film Department, 330 West 42d St., New York 36, N.Y.

USA—U.S. Department of the Army, Washington 25, D.C. (Films distributed by United World Films, Inc.)

USAF—U.S. Department of the Air Force, Washington 25, D.C. (Films distributed by United World Films, Inc., and U.S. Civil Aeronautics Administration.)

USCAA—U.S. Civil Aeronautics Administration, Washington, 25, D.C.

USDA—U.S. Department of Agriculture, Washington 25, D.C.

USN—U.S. Department of the Navy, Washington 25, D.C. (Films distributed by United World Films, Inc.)

UWF—United World Films, Inc., 1445 Park Ave., New York 29, N.Y.

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