TROUBLE SHOOTING BY SIGNAL TRACING

Most of the troubles that occur in radio are due to open circuits and short circuits, either complete or partial. It is the serviceman's job to locate the cause of trouble in a radio unit and repair the unit in as short a time as possible. This could be done by testing each part individually for open or short circuits, but there are much quicker and better methods of locating defective units. If the stage that is not operating properly in a multi-stage receiver can be found quickly, the defective part may be located by simple resistance and voltage checks.

One widely used method of locating a defective stage in a receiver is called *signal substitution.* For example, each stage of an audio amplifier may be checked for normal operation by using the signal from an audio generator instead of depending on a receiver signal. If the audio generator is connected to the input of the final amplifier of a two-stage amplifier and a normal signal is heard in the speaker that stage would be considered to be operating correctly. If the audio generator were then connected to the input stage of the amplifier and no signal were heard in the speaker, then the input stage must be defective. Once this is determined, the tube socket terminals should be checked to see that voltages are applied to the tube. If the plate voltage is lacking, the parts in the plate circuit should be checked for open or short circuits. If the plate and other voltages are correct, the input device should be checked for defects.

A second method of signal tracing is to connect the audio generator to the input of the amplifier and to use a separate indicator for tracing the signal. This indicator could be another audio amplifier with speaker, an oscilloscope, or even a sensitive output meter. The indicator should be first connected to the input device of the unit being checked to be sure that a signal is reaching the grid of the first audio tube. If a signal is present, the indicator should then be connected to the plate of the tube or to the output device to see if a signal is present. If no signal is indicated, the component parts of the plate circuit should be checked for defects. If a signal is present, the indicator should be connected to the grid of the next tube and the signal checked. If a signal is present, the indicator should then be connected to the plate of the tube and a check made for signal. If no signal is indicated the voltages and parts in this circuit should be checked. If the plate circuit of the tube is operating in a normal manner, the secondary of the output transformer will probably have an open or shorted output winding and can be checked with an ohmmeter. The point where the signal disappears will indicate the approximate location of the trouble.

It is evident that the path of a signal through an amplifier may be checked by one of several indicating units, such as a similar amplifier, an output meter, an oscilloscope, or the commercial signal tracing units.

One of the simplest ways to determine if an amplifier is operating is to quickly remove and reinsert the first amplifier tube. If the circuits are in operating condition, a loud click will be heard in the speaker. It is caused by the breaking and remaking of the electrical contacts of the first tube. This interruption or noise is amplified by the following tubes, and causes a click in the speaker. If removing the first tube did not produce a click in the speaker, the second tube should be removed and re-inserted. If a click is heard, it means that the first tube is bad, or it has no plate voltage, or the coupling device (condenser or transformer) between the two tubes is defective. This quick check may be made before applying the tests as outlined in this experiment. Indicator units used in signal tracing should be of a type suitable for the circuit under test. The audio amplifier would use such indicators as output meter, speaker, oscilloscope, etc. Amplifiers operating at radio frequency would require a test instrument that would give an indication at radio frequencies. Vacuum tube voltmeters, r-f oscilloscopes, detectors with an audio amplifier, etc., would be satisfactory for this purpose.

Signal tracing in an r-f amplifier is very similar to that in an audio amplifier. The circuits operate in much the same manner except that all signals are at radio frequency.

In signal tracing the unit used as an indicator must be capable of operating at the frequencies used in the amplifier, or it must be capable of accepting the radio frequency signal and converting it to an audio signal. Such an instrument would be a detector, or rectifier, followed by an audio amplifier. With this combination a speaker or output meter could be used to indicate the presence or lack of a signal in the r-f amplifier. The detector could be connected to the various stages of the r-f units so their output can be checked. If a signal were present in the output of the first amplifier tube but missing at the output of the second stage, a defect would be indicated in the second stage. Once the trouble was localized, a volt-ohmmeter could be used to check the parts associated with that particular tube and the exact trouble determined.

Signal tracing in an r-f amplifier can be done by both the "signal substitution" method and the indicator method. In the first method, the detector should be connected to the output terminals of the r-f amplifier and the signal generator successively connected from the output coil to the input circuit. The point where the signal disappeared would indicate the location of the defective stage. In the indicator method the signal generator should be connected to the input of the r-f amplifier and the detector successively connected from the r-f amplifier input terminals to the output terminals. Here again, the point where the signal disappeared would indicate the location of the defective stage.

Other indicators may be used in checking r-f amplifiers. The oscilloscope, if its amplifiers will pass radio frequency, is very good. The scope should be adjusted to show the modulated r-f signal. A vacuum tube voltmeter is an instrument that will read radio frequency and may be used as an r-f output meter.

Hum, oscillation, and noise are common troubles which are sometimes very difficult to locate, because often they may not be determined by the use of voltage, current, or resistance checks. They must sometimes be found by careful recognition of slight differences between sounds from the speaker.

Hum may originate in the power supply, due to defects in the ripple filter. Open filter condensers, or condensers having reduced capacity due to the drying of the electrolyte, are the most common cause of this kind of hum. Shorted or partially shorted filter chokes are another cause.

If the tube filaments are shunted with center-tapped resistors, with the center-tap grounded, an open half of the resistor will cause hum. Very often these resistors are constructed with variable center-taps. In this case hum will result if the resistor is out of adjustment.

Closely associated with this trouble is leakage between the heater and cathode of indirectly heated tubes, which will vary the emission of the cathode at the heater supply frequency.

Magnetic coupling between a power transformer and filter choke (or audio transformer) will also produce hum; however, this is unlikely to occur in well designed commercial radios. It is possible though, where original components are replaced, and their position changed or shields not replaced.

If the laminations of a power transformer become loose, a characteristic buzz, very similar to a hum, will be produced. This buzz may be definitely determined by placing the ear very close to the transformer, and then to the speaker. If the buzz is louder at the transformer loose laminations are the trouble. This buzz is not conveyed through the speaker, but is heard directly from the part itself.

The types of hum already mentioned are steady in character and independent of dial setting. Another type of hum, which occurs only when in tune with a signal, is called modulation hum. It is caused by the modulation of a carrier signal by the a-c power supply frequency. When a-c heater leads are brought into the range of grid leads, or by-passing is inadequate, or line-buffing condensers are open, this trouble may be produced. Cathode to heater tube leakage may also cause this trouble. Very often, by-passing one or both sides of the power line to ground (at its entrance to the chassis) will eliminate modulation hum. Reversing the line plug will sometimes affect this hum, particularly if the grounding of the set is poor.

Oscillation is generally caused by some kind of inter-stage coupling, and may occur in more than one tube circuit. Coupling between the plate circuits of different stages and the screen grid circuits of different stages is the most frequent cause of oscillation. This coupling generally results from open by-pass condensers in the plate or screen grid circuits, or shorted r-f chokes.

High resistance connections between shields and ground may also cause this trouble. Shields should always be carefully replaced in original positions, when replacing coils, tubes, etc. If leads from sensitive r-f and i-f circuit parts are placed in different positions from the original, oscillation may result. Manufacturers often place the plate and grid leads in such a relation as will produce certain critical degrees of regeneration. Altering these constants may cause oscillation, or too much regeneration.

Noise is sometimes one of the most difficult troubles to locate. It may occur in any part of a radio—in fact, in almost any connection. Radio noise may be classified as natural atmospheric static, interference from other electrical devices, and noise originating in the set itself. Noises external to the set may usually be determined by shorting the antenna and ground terminals of the set, and noting whether the noise persists. If so, the noise is likely to be coming from the set itself, if not, it is likely to be coming from outside the set. However, this test will depend considerably on how well the set is shielded.

Set noises may be caused by loose connections, broken leads, leaky or arcing condensers, noisy resistors, noisy tubes, dirty or loose switch and socket contacts, rosin joints, corroded or dirty variable condenser wiping contacts, scraping variable condenser plates, noisy audio transformers, loose speaker cones, dragging voice coils, and many other troubles.

A good test to make for noise is a slight jarring of the chassis, and moving of leads, and parts. Thumping of tubes will often disclose a noisy tube. Condensers and resistors must sometimes be disconnected or replaced, as a definite check of their condition. Practical, common sense is necessary to dictate the best procedure to employ under particular conditions. Very often noises are intermittent, making their location very difficult.

The most helpful procedure to follow in trying to determine the cause of hum, oscillation, or noise, is to localize the trouble. The simplest method is either to remove one tube at a time (beginning with input tube), or to short out the input circuit of each tube (beginning with output tube). By this method, a particular circuit will be reached where the trouble is not indicated by the speaker; upon moving to the next circuit, the trouble is indicated by the speaker. The trouble is between these two points.

When the trouble originates in the power supply, or some circuit common to several stages, this method will have to be used with reservation. For instance, trouble may appear to be coming from the output stage, when it is actually coming from the supply to this stage.

Conclusions: It is evident from this that signal tracing on an r-f amplifier is similar to that of an audio amplifier. The method is the same, but an indicator that will respond to radio frequency signals is necessary.

Notes: If a separate indicator is not available the detector and audio amplifier of a receiver may be used to check the r-f stages provided the detector and audio amplifier are operating satisfactorily. There are several commercially manufactured indicator units. They usually contain r-f and audio amplifiers, an oscillator, and a detector; and are so arranged that any stage of a receiver may be checked. They may use a vacuum tube voltmeter, or an oscilloscope, or even an electron-ray tube to indicate the presence and strength of the signals in the receiver.

IDENTIFYING POWER TRANSFORMER LEADS

It is necessary to identify the leads or terminals of a transformer before it can be tested or properly installed. Incorrectly connecting a transformer generally causes serious damage to it, and quite often, to other parts.

There are several windings on a power transformer, which are the primary, high voltage secondary, and the low voltage secondary windings used to supply heater power. Transformers used to supply power to radio apparatus will have at least two windings, a primary and a secondary.

The first step is to relate the leads to their respective windings. There are at least two leads for each winding. Some windings are tapped, which means there will be as many leads or terminals as there are taps plus the ones for the beginning and end of the coil.

The high voltage winding has the greatest number of turns, hence will most likely have the highest resistance because of the greater length and smaller diameter of the wire used.

The primary is the next highest voltage winding, and probably will have the next highest resistance. The filament windings have only a few turns of heavy wire and thus have the lowest resistance. Therefore, the various windings may be located with the aid of an ohmmeter. This is done by first using the ohmmeter as a continuity checker to group the leads. Any leads showing continuity are grouped as belonging to the same winding. The leads of any group are next checked to determine the resistance for comparing with that of the other windings when trying to decide which winding is the primary, high voltage, or low voltage winding. When checking windings that are tapped, remember that the leads that have the highest resistance are the beginning and ending of the winding. If a winding is center tapped, it will have approximately the same resistance for either half.

As an additional check on transformers already installed, the power may be turned on and voltage measurements made on the windings. Before installing transformers, the same test can be made by temporarily connecting to the a-c line. Voltmeter readings will definitely identify the various windings.

Unless the transformer is known to have high voltage and filament windings, it is best to apply the a-c power to the winding having the highest resistance. Measurement of the voltages on the other windings will indicate whether the winding connected to the a-c is actually the primary. This is an extremely valuable precaution when testing a transformer having only a primary and secondary of unknown voltage.

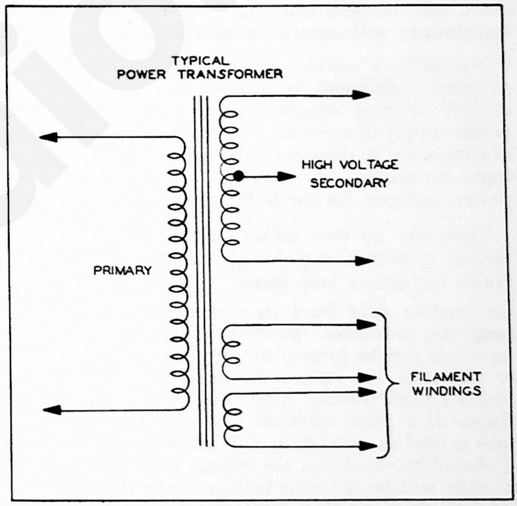


FIGURE 1

Making a mistake in the identity of the leads of a power transformer might result in any of the following:

1. Burned out line fuse due to excessive current.
2. Burned out transformer winding.
3. Burned out filaments of one or more tubes.
4. Shorted or open coils and resistors.

To prevent such trouble, take every precaution to properly identify the leads before installing any part.

IDENTIFYING RECTIFIER SOCKETS AND "B" SUPPLY TERMINALS

Since the rectifier is the next link in the a-c power supply, it is important to know the makeup of the rectifier and the connections of socket terminals and rectifier tube elements.

The rectifier tube socket may be located visually by observing where the power transformer is located, since the high voltage leads will connect to the rectifier socket. The terminals to which they connect will be the plate terminals of the rectifier socket. In tracing the transformer leads, bear in mind that the filament leads as well as the high voltage leads will connect to the same socket. Also, the rectifier may be the half-wave or the full-wave type. In the former case, only one high voltage lead from the transformer will connect to the socket. The power supply may be of the full-wave type using two separate half-wave rectifier tubes such as is done in high voltage high power supplies. Again, only one high voltage lead from the transformer will connect to each socket.

Naturally, a rectifier socket will not be found in equipment designed to receive plate supply voltage directly from a dynamotor, batteries, or from the power supply of another piece of equipment. A piece of equipment so designed will have at least four power input terminals; two for the low voltage filament power, and two for the high voltage plate supply.

After the rectifier socket has been located, the various terminals may be identified by a combined visual inspection and voltage check. By removing the rectifier tube from its socket, and using a high range a-c voltmeter (0-1000), the plate terminal or terminals can be located by measuring from B minus or chassis to the various terminals. The terminal at which a high reading is obtained with respect to the chassis is a plate terminal. If a full-wave rectifier tube is used as such, there will be two such terminals. It should be noted that the voltage reading from plate to plate will be the total voltage across the high voltage secondary winding, while the reading from either plate to B minus will be half the plate to plate reading; because, in measuring from plate to B minus, the meter is actually connected across one half of the high voltage secondary. When the high voltage terminals have been found, a lower range on the voltmeter can be used to determine the filament terminals. If the tube is a directly heated cathode type, the filament terminals can be readily identified since there will be only these two additional connections. With the indirectly heated type cathode, there will be the two filament terminal connections and the cathode connection to the filter circuit.

Important reference test points in any receiver are the B plus and B minus terminals of the plate supply. To quickly identify these points, certain simple relationships can be used.

An examination of the schematic diagram will reveal the circuit arrangement of the parts of the power supply. If the schematic shows that the filter choke is connected to one side of the rectifier filament, one can expect that in the power supply one lead from the choke will connect to a filament terminal of the rectifier socket. The other side of the choke, as shown on the schematic, connects to the B plus terminal of the power supply output. Therefore, locating this lead in the chassis and tracing it from the choke to a terminal will locate the B plus point in the chassis.

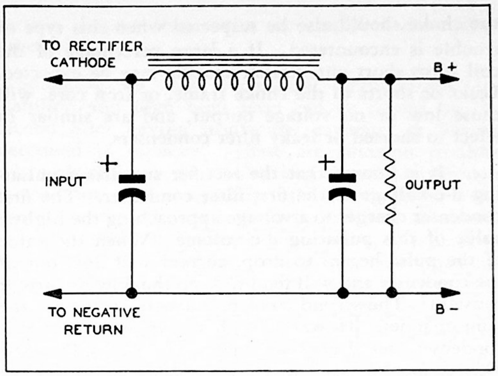
Checking with the schematic indicates that one filter condenser is connected from each side of the choke to B minus. By locating the filter condenser and identifying the leads connecting to the choke, the remaining condenser leads can be traced to B minus. Electrolytic condenser leads or terminals are usually color coded, although a standard code does not apply to all circuits. In general, it can be said that the black lead from the electrolytic condenser will connect to B minus.

The visual check outlined above can be supplemented by a continuity check with an ohmmeter. In many cases the actual circuit wiring is such that some of the leads are buried in cabling or hidden from sight. For such conditions, the use of a low range ohmmeter, aids in tracing the leads.

TESTING "B" SUPPLY FILTER CIRCUITS

a. One method of testing filter circuits for defective parts is by resistance analysis of the input and output circuits. By comparing the readings taken with those which are normal, and using a practical application of Ohm's Law for series-parallel circuits, the defective part may be determined. An advantage of this type of testing is that the power supply is inoperative during test; therefore, no damage can result to any part due to excessive current flow, should a short-circuit exist. By referring to Figure 2 it may be seen that the input of the filter is actually the output of the rectifier, and the output of the filter is the final output of the whole power supply.

If the ohmmeter test prods are connected across the input terminals of the filter circuit, a reading will be made of the equivalent resistance of a complex network, composed of the resistance of the choke in series with the parallel resistance of the second condenser leakage and bleeder resistor. See Figure 3.



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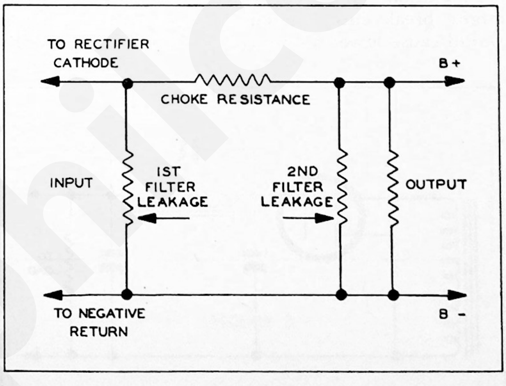
TYPICAL FILTER

FIGURE 2

As the leakage resistance of normal electrolytic condensers is relatively very high, for practical purposes it will not greatly affect resistance conditions. The ohmmeter would really read the resistance of the filter choke in series with the resistance of the bleeder resistor.

If the ohmmeter prods are connected across the output terminals of the filter circuit, a reading will be made of the equivalent resistance of the bleeder resistor, shunted by the leakage resistance of the second condenser, and also shunted by the resistance of the choke in series with the first condenser. In this case the ohmmeter would read, for practical purposes, the resistance of the bleeder resistor only. Thus the resistance of the input circuit is higher than that of the output circuit by the value of the choke.



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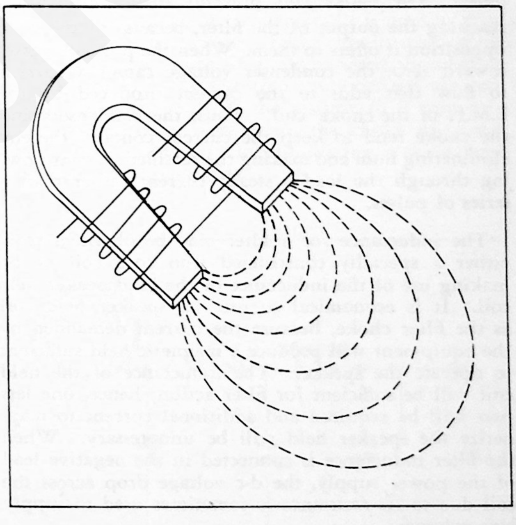
EQUIVALENT LEAKAGE

FIGURE 3

If the choke were short-circuited the readings at both input and output would be identical. If the choke were open-circuited the input reading would be very high (leaking resistance of first condenser), and the output reading would remain practically the same. If either condenser were open-circuited both readings would remain about the same. If the first condenser were short-circuited the input resistance would be low, and the output reading would be the value of the bleeder resistor in parallel with the choke. If the second condenser were short-circuited the input reading would be the value of the choke, and the output resistance would be very low. Likewise, other possible troubles may be found by similar analysis.

b. The choke performs a very important function in the operation of a filter circuit. To understand its action it will be necessary to review some fundamental ideas.

When direct current starts to flow through an inductance it is opposed by an opposition that is different from resistance. The opposition is a counter-E. M. F. set up in the inductance when the coil current, changing from zero, changes the magnetic field. The magnetic field was non-existent, or zero, until current started to flow.



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Since a change in the magnetic field of a coil will produce an E.M.F., the variation in the magnetic field due to the current change, will produce an E.M.F. or voltage that opposes the change in current. Because of this, the current does not immediately reach a value as determined by resistance and the applied voltage according to Ohm's Law. The time required depends upon the inductance of the coil. The larger the inductance, the longer the time required for the current to reach its final value. If then, the applied voltage is suddenly decreased or removed the current in the coil will begin to decrease. This again will produce an inductive voltage, but it will have a polarity that will tend to sustain the current for some time after the applied voltage has decreased to zero. The characteristics of choke coils account for the opposition they offer to changes in current. When alternating current is applied to an inductance the current encounters this opposition as well as the opposition due to resistance. The opposition that an inductance offers to the change in current, or to a-c because of self-induced voltage, is called inductive reactance. Inductive reactance becomes greater as either the inductance, or frequency of the applied voltage is increased. Hence, the limiting or opposing action to the flow of current becomes greater when either the inductance or the frequency of the current is increased.

The ability of an inductance to store electric energy as a magnetic field and then later to return this energy to the circuit, together with the opposition it offers to changes in current, is put to good use in filter circuits. The current from a rectifier is a series of pulses. During a part of the rectified pulse the current increases from zero toward some maximum value. In this time the first filter condenser charges to a voltage approximately equal to the maximum value of the rectified pulse. The choke coil prevents these pulses from reaching the output of the filter, because of the high opposition it offers to them. When the pulse decreases toward zero, the condenser voltage causes a current to flow that adds to the current produced by the E.M.F. of the choke coil. Thus, the condensers and the choke tend to keep the current contant, thereby eliminating hum and making the rectified current flowing through the load a steady current rather than a series of pulses.

The inductance for a filter may be obtained from either a specially constructed iron core coil or by making use of the inductance of the loudspeaker field coil. It is economical to use the speaker field coil as the filter choke, because the current demanded by the equipment will produce a magnetic field sufficient to operate the speaker. The inductance of the field coil will be sufficient for filter action; hence, one less part will be required and additional current to magnetize the speaker field will be unnecessary. When the filter inductance is connected in the negative lead of the power supply, the d-c voltage drop across the coil due to its resistance is sometimes used to supply bias voltages.

Common troubles in filter chokes are: open or partially open coils, internal shorts across the terminals of the coils, leaks or partial leaks to the frame of the inductance, and shorted turns.

An open choke will be the cause of no voltage output from the power supply, and a partially open choke coil causes low voltage output. High hum or ripple in the output voltage will result if the coil develops a short across its terminals. Sometimes the filter condensers develop an internal short from one positive lead to the other. This will effectively short out the choke and cause a hum. Condensers that are used to resonate the choke should also be suspected when this type of trouble is encountered. If a large percentage of the coil turns short out, similar trouble may be expected. Leaks or shorts to the choke frame, or iron core, will cause low or no voltage output, and are similar in effect to shorted or leaky filter condensers.

c. It is known that the rectifier supplies a pulsating d-c voltage to the first filter condenser. The first condenser charges to a voltage approaching the highest value of this pulsating d-c voltage. When the value of the pulse begins to drop, current will flow out of the condenser and will tend to keep the flow of current constant. The second condenser acts in somewhat the same manner. However, both the input and output condensers serve another purpose as well. The first filter condenser serves as a low impedance path for the high voltage a-c applied across the rectifier. Hence, there will be very little drop in this a-c voltage. Therefore, the resultant rectified voltage will be higher than if no condenser were present at this position. The second condenser can be thought of as acting as a short circuit for any a-c voltage. Hence, no a-c voltage will be present at the output of the filter.

It is evident that if the capacity of the first condenser is low, the output voltage of the filter will be lower than normal, and will have considerable ripple voltage in it. This will cause the radio apparatus to work inefficiently, and hum.

Lack of sufficient capacity in the second filter condenser will cause the filter circuit to act in a similar manner as to the hum or ripple voltage, but the d-c output voltage will be only slightly affected. Sometimes insufficient capacity will cause motor-boating or oscillation, because of the common impedance path that the filter presents to the signal currents. If the second filter is large enough, and in good condition, there will be no common impedance in the filter circuit, as the condenser will act as a short circuit across the impedance. Therefore, there will be no common coupling impedance to cause either regeneration or degeneration. If regeneration occurs, the equipment might break into oscillation whereas degeneration would cause lower amplification. This may cause dis-

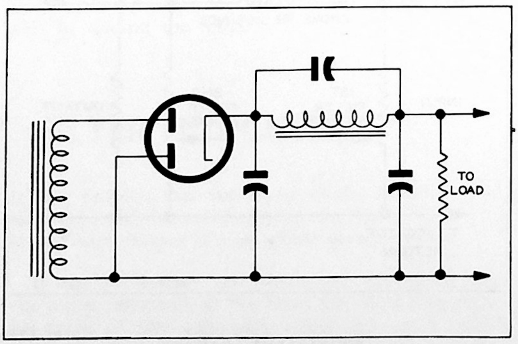

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FIGURE 4

tortion if some frequencies are amplified more than others.

Summing up these facts, low amplification, instability, and high hum level can be caused by the second filter having insufficient capacity, or having decreased in capacity. These are common troubles when electrolytics dry out or lose electrolyte through evaporation or decomposition, the results being a decrease in capacity, and the troubles just discussed. When a condenser decreases in capacity, it is equivalent to a good condenser that is partially open-circuited. Shorted filter condensers are the cause of very low or no voltage output from the filter.

Partially shorted filter condensers cause the voltage to be lower than normal, and the hum level to be high. The resistance of the dielectric used in filter condensers other than electrolytic types should be several megohms. Values of 20 to 100 megohms are not uncommon for these types. For electrolytic filter condensers to be considered good, the dielectric resistance should be higher than 500,000 ohms; however, they often work satisfactorily with leakage resistances of 100,000 ohms. Generally, if the leakage resistance of electrolytic filter condensers is less than 100,000 ohms, they should be replaced. Exceptions to this are cathode by-pass condensers or other low voltage by-pass condensers of the electrolytic type, as leakage values of less than 100,000 ohms in these types are often not troublesome. These figures are arbitrary, being dependent upon the satisfactory operation of the equipment. The voltage applied and the capacity of the condenser, are factors that influence the leakage resistance. Increasing the applied voltage and the capacity of the condenser, increases the leakage. Another method of stating the condition of an electrolytic condenser is in terms of milliamps per microfarad. Usually 0.5 milliamp per microfarad is the maximum acceptable leakage current. An 8-mfd. condenser with a leakage current of 4 milliamps would just pass as being acceptable. Leakage current higher than this would mean that the condenser should be replaced.

Some filter circuits use a condenser across the filter choke to resonate it to the frequency of the hum voltage. (See Figure 4.) Since a parallel resonant circuit offers very high impedance to its resonant frequency, very little hum voltage will be apparent at the output of the filter.

When the current taken from the power supply is low, the choke can be dispensed with, if efficiency is not of paramount importance. Instead of the choke coil, a resistor can be used (see Figure 5) to offer opposition to the hum frequencies. Unfortunately, the resistor offers practically the same resistance for both the hum frequencies and the d-c flowing through it. Since this will cause a d-c power loss, this type filter is not as efficient as the choke type of filter. However, it is much cheaper to construct, and is very compact. As the resistor offers nearly the same opposition to a wide range of frequencies, it is used to good advantage in many circuits. Filter circuits making use of this idea use a resistor of a few hundred ohms before the filter choke. (See Figure 6.) Condensers are connected across the ends of the resistor to B minus in the same way they were when the choke was used. This circuit is effective in eliminating a wide band of disturbance frequencies.

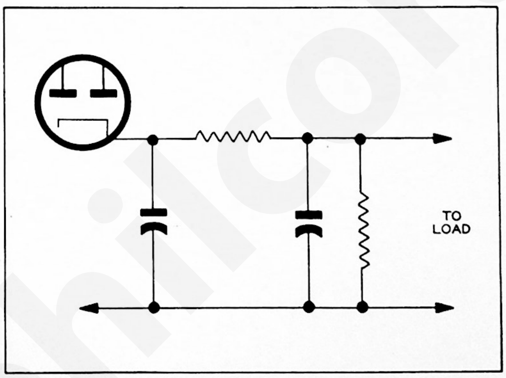

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FIGURE 5

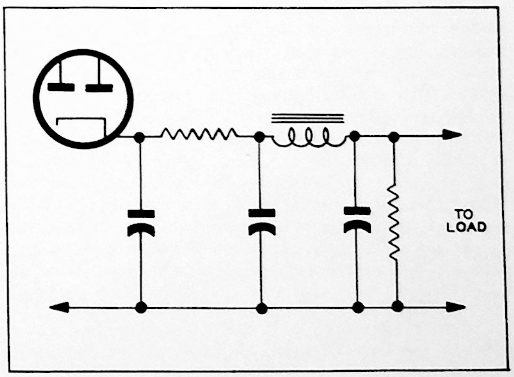

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FIGURE 6

1950 RADIOS AND RADIO-PHONOGRAPHS