TV INPUT TUNERS

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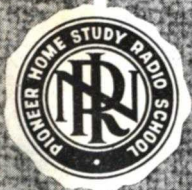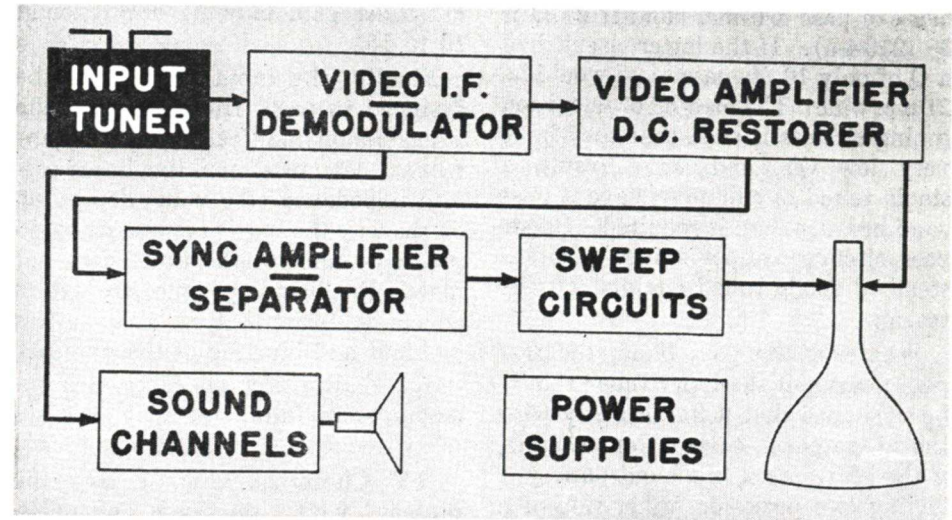
STUDY SCHEDULE No. 52

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

PRECEDING LESSONS of this television series have introduced you to the basic idea of producing a picture by means of a television system—you have been introduced to the basic circuits, and have made a detailed study of the television picture tube.

In this Lesson, you will continue your detailed study of the sections of a TV receiver with the section called the "input tuner." This section is also known by other names; some manufacturers call it the "r.f. unit," others call it the "front end" or the "head end." Regardless of the name, it corresponds to the preselector-converter section of a sound receiver.

You have studied r.f. amplifiers, band-pass tuners, oscillators, and converters in your Fundamental Lessons, so in this text we shall primarily discuss the special requirements of TV—the basic theory will not be repeated fully here. If you find that you have forgotten some of the fundamentals, review the Lessons in which they were presented. The better you understand how these sections operate, the easier

it will be to service them quickly and professionally.

Duties. The input tuner, as a preselector-converter, must initially select the desired signal and, by the heterodyne process, produce from it an i.f. signal. Hence, the input tuner must be tunable to the television channels that are in use. When tuned to any one channel, it should have sufficient selectivity to eliminate at least image interference; some are designed to reduce other interferences as well.

The preselector must pass at least the full 6-megacycle band occupied by each television channel. The passband depends on both the resonant frequency and the Q of the tuning circuits, as follows:

$$\text{Pass band} = \frac{\text{Resonant Frequency}}{Q}$$

Hence, at the high carrier frequencies used in television, wide passbands are obtainable with a single resonant circuit having a reasonably low Q. For example, a circuit tuned to 60 mc. can pass a band of 6 mc. if its Q is 10 (60÷6). One tuned to 210

mc. can pass a 6-mc. band if its Q is 35 (210÷6). If the latter circuit had a Q of only 10, its pass band would be 21 mc. wide! The loading of television tuning circuits is such that they have very low Q's, and, as a result, a single tuned circuit may have a pass band broader than is required. Band-pass circuits are sometimes used instead of single tuned circuits for this reason.

Whatever the pass band, the response curve of the input tuner should be so shaped that it fits properly with the i.f. response curve. For example, if the i.f. response is a band-pass type having two peaks on either side of a resonance point, the response curve of the input tuner should have a single peak that occurs in the valley of the i.f. response; the over-all response of the two will then be relatively flat. We'll discuss this later at greater length.

An input tuner cannot have much gain. Its gain depends on the impedance of the resonant circuit used as the load for the input tuner r.f. stage. This impedance depends upon the Q of the circuit, which, as we just said, is kept low. In addition, the converter has very low gain, so the over-all in-put-tuner gain may be only around 10 to 15.

Finally, the input tuner must be designed to work from some specific transmission line (lead-in from the antenna). A transmission line has a certain impedance (the value depending on the way the line is made); if the input impedance of the tuner does not match the line impedance, reflection effects will exist that can cause a loss of input and blurring of the picture.

We shall study all these requirements more fully, but first let's see what frequencies we are dealing with.

TV Channels. Fig. 1 lists the present v.h.f. television channels. Each of these channels is 6 mc. wide and is designed to contain one complete video and accompanying sound signal. To identify the channels conveniently, they are numbered from two to thirteen. Originally there was a channel No. 1 between 44 and 50 megacycles; this is now assigned to other services, but, since many receivers having channel selectors marked for channel 1 had already been produced by the time this channel was abandoned, the channel numbers have never be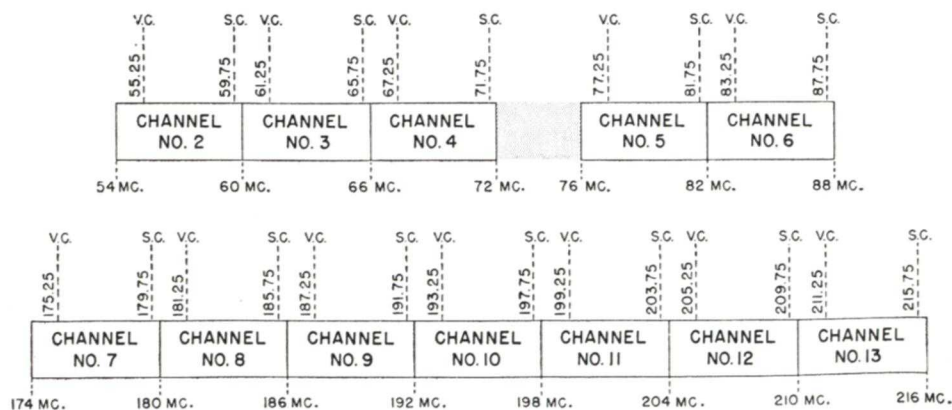en changed. Many television sets are still made with the original thirteen-channel selector with a "dead" channel No. 1.

The television channels are not consecutively assigned; there is a small gap of 4 mc. between channels 4 and 5, and a large one of 86 mc. between channels 6 and 7.

Ignoring the small gap, channels 2 to 6 inclusive are called the "low band," and channels 7 to 13 inclusive are called the "high band" or "upper band."

INTERFERENCE PROBLEMS

Interference is more annoying in a television receiver than in a radio, because the eye is far more critical than the ear is. Consequently, television sets are designed to eliminate interference as much as possible. Let's see what can be expected of the input tuner in this respect.

Man-Made Interference. Interference resulting from the operation of electrical apparatus can best be eliminated at the source, as has been shown in another Lesson. About all that can be expected of an input tuner in eliminating such noise is that it should be able to reject noise, whose frequency is as far from that of the desired signal as the image frequency is. Fortunately, many common noise sources produce relatively low-frequency interference that does not affect TV reception seriously. The most troublesome sources are diathermy (medical) instruments and ignition systems.

Harmonics. The TV channels are subject to harmonic interference from other services. F.M. transmitters cause considerable TV interference, for example, because the second harmonic of the f.m. band (88 to 108 mc.) is from 176 to 216 mc. and hence lies in the upper TV band. Of course, the amount of second-harmonic radiation from an f.m. transmitter is kept down at the station, but if the TV set is too close to an f.m. transmitter, it may pick up second-harmonic interference from this station. Fortunately, the second-harmonic radiation dies down rapidly with distance, and it is rather small anyway, so it is unlikely that there will be interference from very many stations in any one locality.

F.M. transmitters are not the only ones producing interference of this kind. For example, second harmonics of the 10-meter amateur band lie within channel 2. In other localities, other services may similarly cause harmonic interference. There is, of course, nothing that the input tuner can do about such interference, since it occurs on the same frequency as the channel being picked up.

Adjacent - Channel Interference. The i.f. amplifier is the section that is supposed to keep down interference from stations on adjacent channels—the input tuner is far too broad to be of much help if the adjacent-channel interfering signal is strong. The present station assignments help in this by skipping adjacent channels in any one locality. Of the twelve channels, no more than seven are given to any one area. Thus, large metropolitan areas such as New York, Chicago, Los Angeles, and Washington-Baltimore are assigned the seven channels 2, 4, 5, 7, 9, 11, and 13. (Note that Washington and Baltimore are in the same area.)

The in-between or alternate channels are assigned to cities between these localities. Thus, channels 3, 6, 10, and 12 are assigned to Philadelphia, which is about half way between New York and the Washington-Baltimore area. In any of these areas, there is little signal pickup from any of the others, and consequently the problem of adjacent-channel interference is re-

FIG. 1. These are the channels presently assigned to television.

duced. In localities between these major centers, however, it may be possible for a set to pick up signals on adjacent channels. Thus, in a location half-way between New York and Philadelphia, it may be possible to receive some signals from both cities. However, they will be on adjacent channels and not on the same channel, so the amount of interference will depend on the adjacent-channel selectivity of the set.

Some television receivers are primarily designed for use in the large metropolitan areas and are therefore built with somewhat less gain and possibly less adjacent-channel selectivity. Used in their proper localities, such sets are satisfactory. On the other hand, in outlying areas where signal strengths are low, and where it is possible to pick up stations on adjacent channels, sets with more sensitivity and better selectivity are required. These are made by changing the design of the i.f. amplifier.

Images. Image interference should be eliminated by the input tuner, but only the more recent designs do so well. As you know, the image is above the desired signal by twice the i.f. For example, let's suppose we have a TV set with an i.f. pass band from 21.5 mc. to 26 mc. When the set is tuned to channel 2, the local oscillator is at about 81 mc., so any station between 81 + 21.5 (102.5 mc.) and 81 + 26 (107 mc.) will be an image and will be capable of feeding through the i.f. amplifier if it can get through the input tuner. There are f.m. stations in this particular frequency range; if the set is near one of these stations, interference is rather likely.

Since the Q of preselector circuits of TV input tuners is low to give the required pass band, they cannot offer very good image rejection, as they

have poor selectivity. For this reason, many modern receivers have wave traps at the input of the tuner that permit one interfering station to be cut out. This will not, of course, eliminate interference from another station on a different channel.

If the i.f. were higher, the front end would be better able to cut out image interference because the image and the desired frequencies would then be separated by a wider band. This is one of the reasons for a move toward intermediate frequencies in the neighborhood of 40 mc. in modern sets. Even with this higher i.f., however, it is still desirable to increase the selectivity of the input tuner; for this reason, the use of band-pass couplers is becoming popular in modern sets.

I.F. Interference. The frequency of the i.f.'s used in TV receivers corresponds to carrier frequencies used by other services. If the TV set is near a strong station using some carrier frequency in the i.f. region, it is quite possible for this signal to get through the preselector (unless it is fairly selective) and thus cause interference. Such interference can be eliminated by using a wave trap at the input of the set. We will describe such traps later in this Lesson.

Cross-Channel Interference. Sometimes TV signals interfere with one another. For example, it is possible for channel 7 to interfere with reception on channel 5, as follows:

When the set is tuned to channel 5, and is using an i.f. for the video carrier of 25.75 mc., the oscillator in the set will be adjusted to 103 mc. If the oscillator signal radiates or is conducted to the r.f. tube grid, it will mix with the incoming signals. Should the channel 7 station be nearby and powerful, its signal may be strong enough to overload the r.f. stage and cause it to act as a first detector on these mixed

signals. If this occurs, a beat will be produced between the 103-mc. oscillator signal and the 179.75-mc. sound carrier of the channel 7 station; this beat will have a frequency of 76.75 mc., which lies in channel 5. In other words, when the set is tuned to channel 5, the local oscillator may beat with a carrier from channel 7 and produce a channel frequency. This beat signal will, of course, go through all the tuned circuits with the desired signal.

This interference is gradually being eliminated by advances in design and shielding. However, in some of the earlier television receivers, the manufacturers had to include traps to cut down on the r.f. grid signal from the local oscillator; they also sometimes

used attenuators in the transmission line to cut down on the strength of the signal received from the interfering station.

Incidentally, it is possible for a set to radiate a signal from its local oscillator on a frequency that can cause interference in nearby receivers. Any kind of a set (not necessarily a television receiver) can produce the interference if the fundamental or harmonic radiation of its oscillator is in a channel to which a television receiver is tuned.

Now that you have reviewed the duties of a preselector-converter and know something about the interferences found in television, let's discuss some of the special problems of TV input tuners.

TV and V.H.F. Requirements

Since the input tuner now handles frequencies between about 54 mc. and 216 mc. (and will eventually go higher if the 500-mc. band is opened), the design and layout of the circuits are far more critical than for, let us say, broadcast-band frequencies. Because the positioning of the parts and the shielding is so critical, the input tuner is usually manufactured as a complete unit on its own sub-chassis; then, when it is completed and aligned, this sub-chassis is mounted on the main television receiver chassis. This simplifies the problems of layout and shielding.

Because of the nature of the input tuner, some specialty firms make complete tuners just as other firms make condensers, resistors, tubes, and other parts. For this reason, you will find that a particular tuner may be used on several different brands of tele-

vision receivers. Since only a few firms specialize in making these tuners, and not very many receiver manufacturers make their own, only a few basic types of tuners are now in use. We shall study each of these after we learn more about the problems and requirements of tuners.

INTERNAL NOISE

The television picture is greatly affected by even small amounts of noise, and because the eye is very sensitive to such degrading of the picture, considerable effort is made to get a high signal-to-noise ratio at the output of the set. The ultimate limit on this ratio (in the absence of interference) is the noise level in the input tuner. (Incidentally, the *sound* is f.m. and is not affected by small noise levels; it is the amplitude-modulated *picture* signal that is upset.)

Let's see what the sources of noise in the tuner are.

Thermal Agitation. You are familiar with the fact that heat causes an agitation of the electrons within materials—in fact, if the heat is great enough, electrons will be emitted from the material. That is why electrons are emitted from the cathode of a vacuum tube.

Even at room temperatures, there is an agitation of the electrons in all conductors, so there is an irregular and random electron motion within all parts of a receiver. When signal or supply currents flow through these parts, they are varied or modulated by these irregular motions; as a result, a noise component is added to the signal.

The hotter it gets, the greater this noise becomes. TV sets run warmer than sound receivers because they have many more tubes and transformers, so this thermal agitation is higher in them than in sound receivers.

The amount of this noise depends on the band width and on the resistance of the parts being affected as well as on the temperature.

The random electron motion that causes the noise occupies an infinite frequency band—some electrons move at very slow or audio rates, whereas others move extremely fast. Therefore, since the noise energy is scattered throughout a very wide frequency band, the amount of noise energy that we get will depend upon how much of the frequency band is being handled by the system at that time. The wider the pass band, the greater the amount of noise energy passed, and hence the higher the noise voltage. As an example, assuming room temperature, an amplifier with an input resistance of 1 megohm and a pass band of 10,000 cycles may have

a noise voltage of 10 to 15 microvolts —about what is developed in the input circuit of a broadcast band receiver r.f. stage. If we have the same input resistance for a band width of about 6 mc., we will find that the noise level will be up over 200 microvolts. This large increase is produced entirely because we are covering a wider band and therefore are collecting more of the noise energy.

Such a noise level is avoided in TV by limiting the resistances or impedances in the input circuit of the r.f. stage to low values around 300 to 10,000 ohms, which are required anyway to provide the impedance matching and tuned-circuit loading that we need. Such low resistances limit the thermal noise to 10 or 15 microvolts even at TV band widths.

It is particularly important to keep the noise down in the first r.f. stage, because this is the stage in which the signal is weakest. Once the signal has been amplified by the first stage, noise added by succeeding stages (except for the converter) has little effect on the signal-to-noise ratio.

Tube Noise. The tubes also contribute considerably to the total noise. One cause of tube noise is that the electrons traveling to the plate have a random variation or fluctuation. Instead of moving as a steady, regular stream, they tend to travel in bunches; hence, there are variations in the rate at which they arrive at the plate of the tube. The average of this electron flow is the plate current. The fluctuations above this average constitute noise. When amplified, this noise sounds as if the plate were being bombarded with pebbles, or as if a shower of shot were falling upon a metal surface. It is therefore called "shot noise."

The internal tube noise also depends upon the number of elements that are drawing current. There is a random distribution of this fluctuating noise energy between the plate and the screen grid, for example, with the result that the plate current noise is doubly varied—in fact, the noise level in the average pentode is about 3 to 5 times as great as that in a triode producing an equivalent amplification. This has caused many designers to use triode tubes in input tuners.

These internal tube noises arise in the plate circuit. In determining the input signal-to-noise ratio, tube noises are referred to the grid circuit by the relationship:

$$e_g = i_p \div G_m$$

where e_g is the equivalent noise voltage that would cause the noise plate current i_p. This voltage e_g combined with the thermal agitation noise gives the effective noise at the input of the set. Once again, keeping the input impedance low reduces the effects of the noise. Also, notice that tubes with higher G_m (mutual conductance) effectively have less equivalent input noise, another reason for using such tubes in TV.

Converter Noise. As we mentioned, the only *amplifier* noise of importance is that generated in the input tube and its grid circuit, because here the signal is the lowest. However, there is another troublesome noise source in the mixer-detector stage. Here the usual internal tube noise is increased because the oscillator signal varies the detector plate current so that it is near zero part of the time, and at such times the noise component is a greater portion of the total signal. Therefore, any tube used as a mixer-first-detector will have a far greater noise level than the same tube will when it acts as an amplifier. As a

matter of fact, both triodes and pentodes have about four times as much noise when used as mixer-detectors as when used as amplifiers. The pentagrid-converter tubes commonly used in sound radio receivers have such high noise levels that they are not used in TV sets.

INTERELECTRODE CAPACITIES

At the v.h.f frequencies handled by the input tuner, the designer has to worry about tube characteristics other than mutual conductance, plate resistance, and amplification factor. A very important consideration is the tube interelectrode capacity.

You will recall from your fundamental studies that capacities exist between the tube elements, as shown in Fig. 2. Considering just the basic capacities themselves, you can see from Fig. 2 that the capacity C_{GK} be-
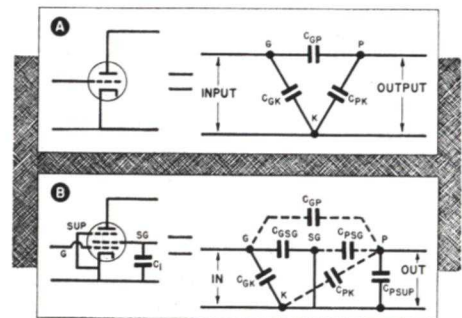

FIG. 2. The inter-electrode capacities of a triode (A) and of a pentode (B).

tween the grid and cathode is across the input and is itself shunted by several combinations of other capacities. For example, in the triode in Fig. 2A, the grid-plate capacity and the plate-cathode capacity in series are also across the input. The output of the stage is similarly shunted, this time

primarily by the plate-cathode capacity with the other two in series.

The input capacity of the pentode (Fig. 2B) is primarily the grid-cathode capacity shunted by the capacity C_{GSG} between the grid and screen grid. This comes about because the screen grid is effectively tied to the cathode through a by-pass condenser (C_1) in all practical circuits. Certain other capacities are present in pentodes. These, however, are diminished because of the presence of the suppressor grid and screen grid, which is why they are shown by dotted lines.

At the output of the pentode, the capacity between the plate and suppressor grid, in combination with the plate-screen-grid and such plate-cathode capacity as exists, represents the output capacity.

At broadcast-band frequencies, these capacities are troublesome enough, but in the tuning range used in television, ordinary tube types have far too much capacity. Even miniature tubes, in which the capacity is reduced by making the tube elements physically smaller, by shortening the leads from the elements to the socket, and by removing the base dielectric material, have appreciable interelectrode capacities at television frequencies. Hence, it is customary in most television receivers to use the internal tube capacities as the tuning capacities, dispensing entirely with a tuning condenser. In such cases, variable inductances are used to get the final alignment to the desired frequency. This is the only way that a desirable L-C ratio can be maintained. If we tried to use tuning condensers, there would be so much capacity in the circuit that we would have to use extremely small inductances—and we are already down to values that are represented by straight pieces of wire!

Miller Effect. The input capacity of a triode is actually far larger than just the internal tube capacity, because there is an interaction between the output and input circuits through the grid-plate capacity. The signal voltage developed across the load feeds back through the grid-plate capacity to the input with the result that the grid-plate capacity acts as if it were increased by as much as the amplification factor of the tube. The exact amount of this increase depends on the stage gain and on whether the load is purely resistive or has a reactive component. However, the result is that if the gain of the stage is high, the input capacity is effectively much increased. This apparent increase in the input capacity is known as the "Miller" effect. This effect is not very important in the pentode, because it has only a small grid-plate capacity.

The output capacity is not amplified this way. However, the load is in parallel not only with the output capacity of one tube but also with the input capacity of the next tube, so this shunting capacity can have a considerable effect on the load also.

INPUT RESISTANCE

Another problem at v.h.f. is that a tube often acts as if it had a low resistance between the grid and the cathode. You may recall from an earlier Lesson that the feedback through the grid-to-plate capacity can cause this effect in a triode. However, at TV frequencies, transit time and inductive cathode leads produce far more trouble of this kind, even with pentodes.

Transit Time. You will recall that problems arise because it takes a certain finite time—called "transit time" —for electrons to move from the cathode to the plate of a tube.

As long as the frequency is low enough so that electrons can get through the tube before the grid can change appreciably in voltage, the plate current is unaffected by the transit time through the tube. However, at very high frequencies, the grid voltage changes so rapidly that an electron may be acted on by a considerable part of a grid-voltage cycle before escaping the influence of the grid. Thus, an electron being speeded on its way by a positive grid may not get so far away that the following negative grid swing will not slow it down. Similarly, an electron that is first retarded by a negative grid action may be speeded up by the following positive swing. As a result, electrons tend to bunch up in the tube space, traveling in "clouds" rather than in a fairly steady stream. As a cloud of electrons approaches the grid, the negative charge of the cloud causes electrons to be forced out of the grid; then, as the cloud moves away, electrons flow back toward the grid. A current flow is produced in the grid circuit by this electron movement, just as if there were a low resistance between the grid and cathode elements within the tube.

This effect is quite remarkable in a tube having a long transit time. For example, a pentode tube that is commonly used in sound receivers may have an input resistance of several megohms at broadcast-band frequencies, but at around 100 megacycles it may act as if its input resistance were only 1000 to 2000 ohms. Such a drop in the input resistance would obviously load the input circuit heavily.

The answer is, of course, to reduce the transit time as much as possible.

Obviously, if the spacing between the cathode and the plate is reduced, it will take an electron traveling at a fixed rate a shorter length of time to travel the distance. Making tubes with smaller cathode-plate spacing is therefore one way to reduce transit time. A triode can be made better than a pentode in this respect, because the pentode must have a large enough cathode-plate space to accommodate three grids. Modern miniature pentodes are still usable at the TV frequencies in use today, but if television transmission eventually moves up into the u.h.f. bands around 500 mc., entirely different tube structures will become popular.

Cathode-Lead Inductance. As you know, even a straight piece of wire has some inductance, small though it may be. At TV frequencies, the inductance of a straight piece of wire begins to become important.

In one television receiver, for example, a straight piece of wire provides inductive coupling between two circuits. This piece of wire is in one circuit, and the second resonant circuit is tapped on the wire about two inches from the grounded end. These two inches of wire provide sufficient common inductance to the two circuits to give band-pass coupling!

Because lead lengths are so extremely important in TV sets, the input tuner has to be designed as a complete unit, with all wiring carefully taken into consideration. It isn't practical to replace parts haphazardly in such a tuner, because any disturbance whatever in the lengths of leads or their positioning could easily throw the tuner completely out of alignment on the upper channels. In fact, many input tuner r.f. amplifiers are aligned by bending the inductance wires. (Of course, this is a factory job—not something a serviceman should try!)

The tubes used in input tuners today are almost invariably the minia-

ture types so that the lengths of the leads from the elements to the circuit are as short as possible. However, as shown in Fig. 3A, the cathode lead (between the actual cathode and the common point of connection to the grid and plate circuits at the tube socket) has a certain amount of in-

ductance. The a.c. plate current flowing through this inductance will cause a voltage drop across it. This voltage will reduce the input voltage just as if the grid were drawing more current. Effectively, then, the grid input resistance is again reduced, thus further loading any input device there may be between grid and cathode.

To reduce the effects of an inductive cathode lead, many of the tubes specifically designed for use in TV and f.m. receivers have two leads coming from the cathode to the tube pins (see Fig. 3B). Now, if the a.c. plate circuit is attached to one terminal and the grid return to the other, the inductive drop will no longer matter. Although there is an inductance in each lead, the a.c. plate current gets to the cathode through one lead, and the grid is connected to the cathode by the other, so the voltage drop caused by the plate current is not applied to the grid circuit.

Practical circuits are shown in Figs. 3C and 3D. Fig. 3C shows the connection used when a separate source of C bias is employed. Fig. 3D shows how it is possible to get self bias with such a tube. Remember that it is not the d.c. plate current but the a.c. or signal plate current that causes the trouble. Therefore, as shown in Fig. 3D, B— can be connected to the cathode lead to which the grid circuit is connected provided the plate and screen-grid by-pass condensers go to the other cathode lead. When these connections are made, the a.c. signal returned from the plate and screen circuits goes directly to the cathode, and only the d.c. plate current is involved in producing the C bias.

In servicing TV receivers, you will have to watch out for connections like this. Although both pins 2 and 7 of the tube are connected to the cathode, it is very important that the respec-
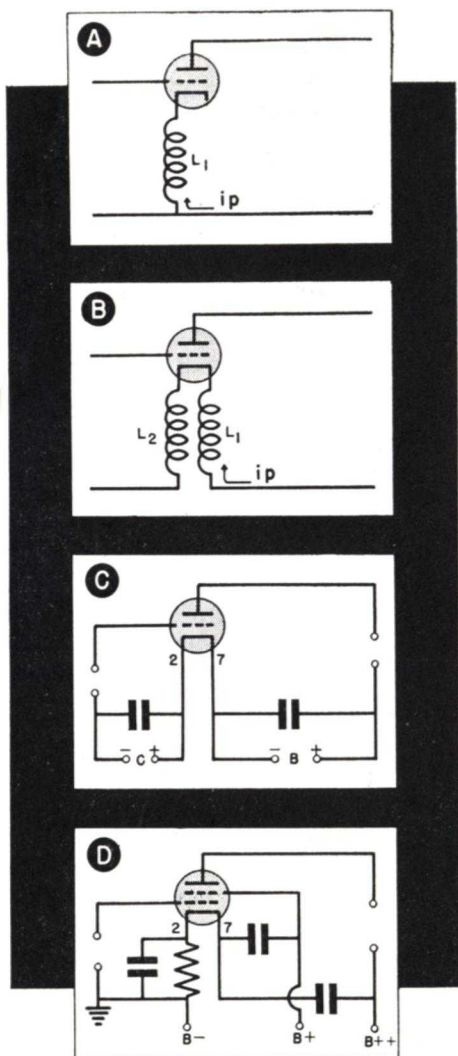
FIG. 3. To eliminate the coupling between the plate and grid circuits caused by the inductive effects of the cathode lead (A), many TV tubes have two cathode leads (B). Sketches (C) and (D) show practical circuits.

tive grid- and plate-circuit by-pass condensers be connected to the proper pins. Hence, in replacing a by-pass condenser, not only must you position it properly and keep its leads to the same length as those of the one you are replacing, you must also connect it to identically the same points in the set.

Originally, input tuners almost always used a tuned-plate circuit in the r.f. stage rather than a tuned-grid circuit. Although the latter is preferable because it makes it easier to eliminate strong interference, the excessive loading and the high input capacities both tended to prevent the proper use of a tuned-grid circuit. However, since cathode-lead inductance effects and input capacity effects have been overcome by proper tube design, more manufacturers have begun to use tuned-grid circuits.

Now that you understand some of the problems involved in the design of input tuners, let's study some practical r.f. and converter stages.

The R.F. Stage

As you have learned, the r.f. stage of a TV set must be designed so that its impedance matches that of the transmission line, to have as much selectivity as possible, and at the same time to maintain an adequate pass band. In addition, it should have as much gain as possible so that there will be a good signal-to-noise ratio when the input is low. Every bit of gain ahead of the converter is important when weak signals are being received, because any such gain increases the signal strength so that the converter noise is easier to overcome. (Even at best, however, the amount of gain obtainable at the r.f. level is small—the television set depends on the i.f. amplifier for most of its gain, just as sound receivers do.)

Even though the loads used in TV tuners are much lower than those that are generally used with pentodes, a pentode will still give more gain in an r.f. stage at TV frequencies than a triode will. However, as we have pointed out, the triode is far less noisy. Also, transit time effects are somewhat worse in the pentode, making it have lower input resistance than the triode.

Because of the importance of reducing noise in TV tuners, designers would probably prefer the triode to the pentode even though the pentode gives more gain. However, the triode tube, because of grid-to-plate feedback, either requires neutralization or must be used in a grounded-grid circuit.

Neutralization. Fig. 4 gives two examples of neutralized triode amplifiers. In Fig. 4A is a neutralization system for a single tube, in which the condenser C_N feeds back part of the energy from the plate tank to the grid circuit so as to counteract that coming through the internal grid-plate capacity.

In Fig. 4B is shown a circuit for a push-pull triode amplifier. Such push-pull circuits have been used by a number of manufacturers for several reasons, one of which is that the input capacities are in series across the input, an arrangement that effectively cuts the net capacity in half. This arrangement also gives a "balanced"
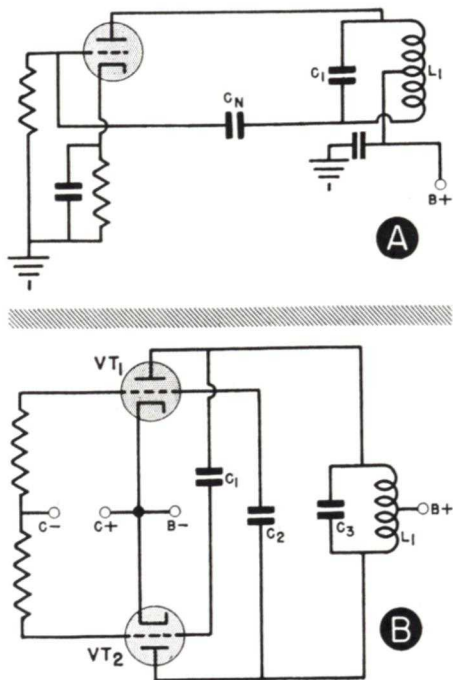
FIG. 4. Two kinds of neutralized triode amplifiers.

input and permits neutralization without the loss of loading that is caused by the tapped coil in Fig. 4A.

In Fig. 4B, the condensers C_1 and C_2 are the neutralizers. C_1 is connected from the plate of VT_1 to the grid of VT_2, and C_2 is connected from the plate of VT_2 to the grid of VT_1. Because of the phases across the resonant circuit C_3-L_1, these two condensers provide the proper neutralization feedback.

Neutralization will work over a very wide number of channels only if the different tuning coils are carefully designed to provide the proper feedback ratio. To avoid such problems, many sets use the grounded-grid amplifier instead.

Grounded-Grid Circuit. As you will recall from your studies of fundamental r.f. stages, the standard (grounded-cathode) stage shown in

Fig. 5A has the signal source between the grid and ground. In the grounded-grid circuit in Fig. 5B, the signal is between the cathode and ground, and the grid goes directly to ground. Insofar as the grid action is concerned, either position of the signal source will produce the same result, because it is the voltage between the cathode and the grid that matters. However, the grounded-grid circuit shown in Fig. 5B has the control grid at ground potential, so that it effectively acts as a shield between the signal source and the plate. As a result, the grid-plate capacity no longer provides a feedback path, so neutralization is generally unnecessary. However, the grounded-grid circuit usually gives less gain than does a neutrodyne, because the signal source is in the plate circuit and hence effectively feeds into a low resistance. The signal source is therefore heavily loaded, and if it is a tuned circuit, its Q and gain will be lowered.
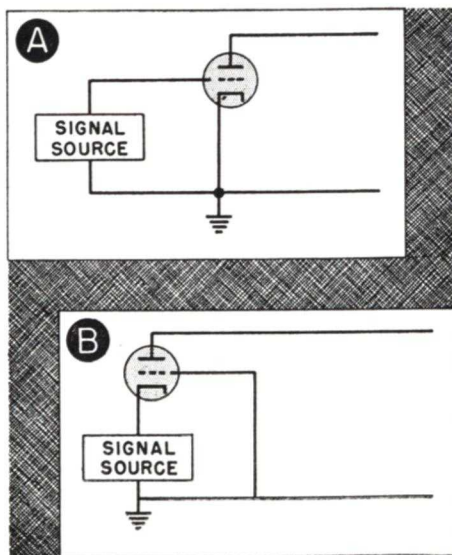

FIG. 5. This illustration shows the basic difference between the common grounded-cathode amplifier (A) and the grounded-grid amplifier (B).

Thus, neither the triode nor the pentode is markedly superior to the other for use in the r.f. stage of a TV set; the pentode gives more gain, but is noisier. As a result, both kinds of tubes are used in modern sets. The pentode is perhaps slightly more popular, but there are a number of triode circuits used, which makes the r.f. circuit of a TV set quite different from that of a sound receiver.

Now, let's study the input and output connections of the r.f. stage.

INPUT CONNECTIONS

The input of the r.f. amplifier is connected to a two-conductor transmission line that is used to feed a signal from the antenna to the receiver. Another Lesson will go fully into the theory of television antennas and transmission lines. Briefly, however, we can say that the television antenna acts as a low-impedance source and that the transmission line has a "surge" impedance that depends upon the size of the conductors and the spacing between them. It is chosen so that its surge impedance will effect some compromise match with the antenna impedance for maximum power transfer.

At the receiver, it is quite important that the surge impedance of the line be matched by the input of the set. If the receiver end of the line is not matched, the energy coming down the line will not all be absorbed, and some will be reflected back up the line. This energy will then be reflected again at the antenna unless there is a perfect match here, with the result that the signal will appear a second time at the receiver end of the transmission line. This second signal will at least cause blurring of the original signal and may produce what is known as a "ghost" (a second image, much weaker than the original image and

displaced to the right from it, on the screen of the picture tube). Of course, any such blurring and ghosts are very undesirable. They can be reduced or eliminated merely by matching impedances at the input of the receiver.

Types of Lines. Physically, the transmission lines now used consist of two types, one known as twin-lead and the other as coaxial cable.

The twin-lead type consists of two parallel wires embedded in a plastic insulation. Each wire goes to one leg of a dipole or doublet antenna as shown in Fig. 6A. To reduce interference pickup to a minimum, neither wire is directly grounded; instead, they are connected to ground through equal impedances so as to give a "bal-
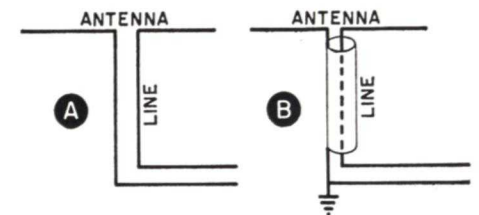

FIG. 6. Schematic representation of (A) twin-lead and (B) coaxial transmission lines.

anced" input at the set. Any currents caused by interference picked up by the conductors in the line will flow in opposite directions through the input device to ground, so they will tend to cancel. The desired signal does not go to ground so it does not cancel. Even with this interference cancellation feature, however, these lines still may feed in considerable interference.

The coaxial line consists of a wire surrounded coaxially by and insulated from a hollow flexible braid or tube of metal. The wire is one conductor and the outer shell the other. Its connections are shown in Fig. 6B. The outer shell of the coaxial line is always grounded; it therefore acts as a shield and virtually eliminates interference

pickup. Because one conductor is grounded, the coaxial line produces an unbalanced input.

Although the coaxial line has the advantage of eliminating interference pickup, twin-lead is preferred in many locations where interference is not a problem because it attenuates the signal less. Of course, the impedance of the line is also an important consideration. Either type could be made to have almost any desired impedance, but manufacturers have practically standardized on a twin-lead having an impedance of about 300 ohms and on a coaxial line having an impedance of 72 ohms. Therefore, practically all television receivers are made for one or the other of these two values, or both.

Balanced Inputs. If a balanced transmission line is used, the lines must be kept at equal impedances

with respect to ground. The grid circuit of a tube is ordinarily unbalanced in that whatever is connected to the grid has its other end directly connected or by-passed to ground. Fig. 7A shows how a balanced transmission line can be fed through a transformer input to an unbalanced grid circuit. The primary coil L_1 has a center tap that goes to ground, so the impedance between ground and each wire of the line is the same. Any noise voltage that is developed between the line and ground will cause currents that will flow from point 1 to ground and from point 2 to ground (or vice versa). Since these currents will flow in opposite directions through the two halves of L_1, their inductive effects will virtually cancel. The desired signal voltage, since it is applied across the transmission line by the antenna, will cause current flow through the whole

of L_1 (from 1 to 2 or from 2 to 1, but not from either point to ground).

This desired signal current will induce a voltage in L_3. (Sometimes a tank circuit L_2-C_1, shown by dotted lines in Fig. 7A, is placed so that the signal will be inductively transferred from L_1 to L_2 and thence to L_3. In this case, the tank circuit is tuned to the desired frequency by C_1.)

The load the transmission line "sees" is the impedance, as it appears through the transformer, of R_1 shunted by the input impedance of the tube. If the turns ratio and coupling of the transformer L_1-L_3 are properly chosen, any value of R_1 can be matched to the transmission line. Since the transmission line impedance is 300 ohms, the usual practice is to make R_1 this value also, in which case the input impedance of the tube is of little importance. Then, the L_1-L_3 transformer is made to match 300 ohms directly to 300 ohms.

Should L_3 be made resonant, R_1 would be whatever value was necessary for loading the tuned circuit, and the transformer would be designed to provide the necessary match. If L_3 is untuned, it must cover the television band and must be carefully designed to prevent the input capacities from causing resonance at an undesired point.

Coil L_3 is coupled to the grid through blocking condenser C_2 because a gain-control voltage is being fed through R_1. We'll go into this gain control later in this Lesson.

Some manufacturers use different input coils for the low and the high television bands, particularly when a tuned input is employed. In such a case, a switching arrangement like that shown in Fig. 7B is desirable. When the switches are in the position shown, the low-band coils L_1 and L_2

are energized. When the switch is thrown, the high-band coils L_3 and L_4 are connected into the circuit. With this arrangement, the electrical connections will be like those shown in Fig. 7A except for the switching.

Fig. 7C shows the means of feeding from a balanced transmission line into a push-pull r.f. stage. Here, the center-tapped coil L_1 balances the transmission line to ground. Resistors R_1 and R_2 are 150 ohms each; their total impedance (300 ohms) matches that of the transmission line.

Blocking condensers C_1 and C_2 are needed because a gain-control voltage is fed through R_1 and R_2.

Coil L_1 is not really necessary in this circuit, because the resistors could provide the balance to ground for the transmission line. However, if it is properly chosen, the coil can help reduce interference. Since its inductive reactance depends on the frequency, it can be made to be practically a short circuit at frequencies below the low TV band, thus almost eliminating signals of these frequencies, and yet be enough above the resistor values in impedance at TV frequencies so that the line will be matched.

Notice that a push-pull input is already balanced, so a transformer between the line and the grids is not necessary if the resistor values match the impedance of the transmission line.

Fig. 7D shows how it is possible to get a balanced input to a single tube without using a transformer. Practically speaking, this is a combination of a grid-fed and a grounded-grid circuit in that the input signal across the upper half of L_1 is fed to the grid and that across the lower half of L_1 is fed to the cathode. Resistors R_1 and R_2 together match the transmission line,
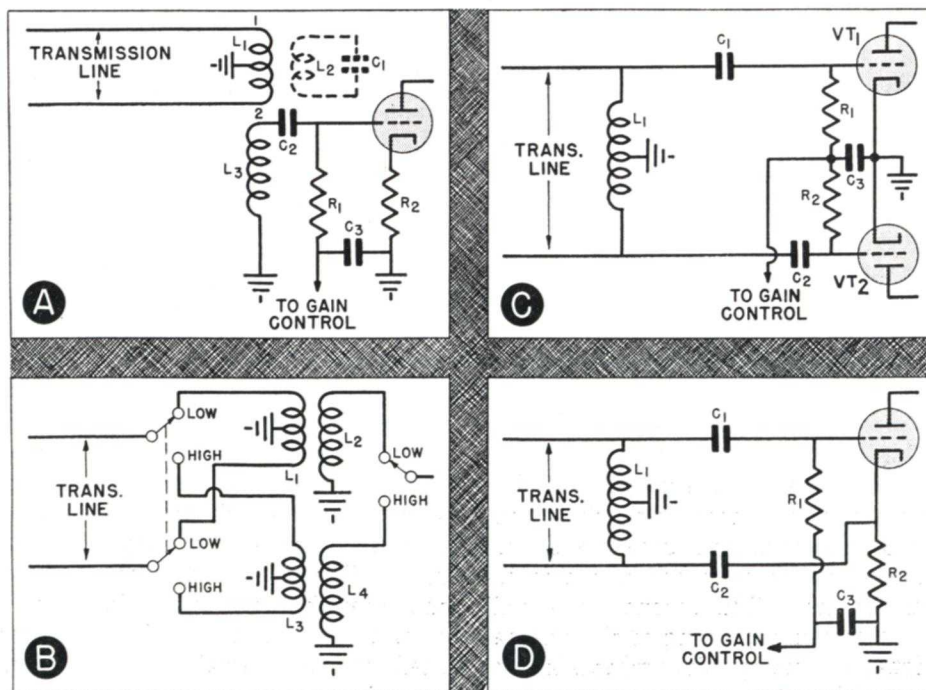

FIG. 7. Methods of coupling a balanced transmission line to various input circuits.
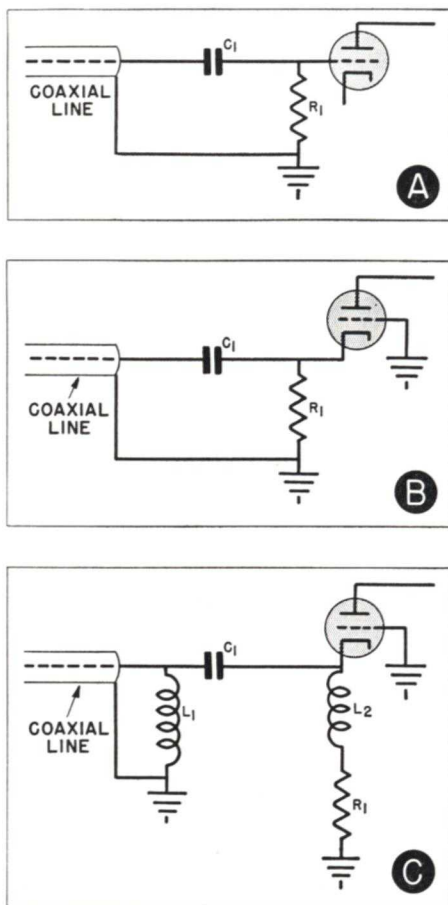
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FIG. 8. Ways of coupling an unbalanced transmission line to various input circuits.

and coil L_1 provides the balance to ground, as before.

Although we have shown triode tubes in these figures, pentodes are also used in the same circuit arrangements.

Unbalanced Inputs. When a coaxial line having a grounded shield is to be used, an unbalanced input arrangement is necessary. Since the grid circuit of a tube is naturally an unbalanced input, it can be connected directly to a coaxial line as shown in Fig. 8A. Here, resistor R_1 is chosen to match the line impedance, which is usually **72** ohms.

The grounded-grid circuit shown in Fig. 8B is more commonly used when an unbalanced input circuit is wanted. As you will observe, the signal is now fed into the cathode circuit. A somewhat more elaborate arrangement for a grounded-grid input is shown in Fig. 8C. Here, coil L_1 is again used to act as a low impedance for frequencies below the TV bands and thus to reduce interference. The load for the transmission line is a combination of R_1 and coil L_2. This particular combination of an inductance and resistance may be used to eliminate a possible capacitive unbalance, thus keeping the loading on the transmission line more nearly constant over the desired frequency range.

Of course, the grounded-grid connection is most commonly used with triode tubes. The circuit shown in Fig. 8A is the one that would more probably be used with a pentode. A coil like L_1 in Fig. 8C may be added to this circuit.

Dual Inputs. In receivers that use a transformer input, it is possible to match either the 72-ohm coaxial line or the 300-ohm twin lead. The arrangement is shown in Fig. 9. The coupling between L_1 and L_2 is adjusted so that a resistor (not shown) connected to L_2 appears as a 300-ohm impedance across L_1. Therefore, the impedance of a 300-ohm line will be
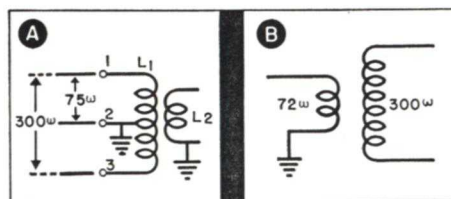

FIG. 9. Some sets (A) have dual inputs to which a balanced or an unbalanced line may be connected. The transformer (B) can be used to connect an unbalanced line to a balanced input.

matched if the line is connected to terminals 1 and 3 of L_1.

When the impedance appearing across the whole coil is 300 ohms, the impedance across half the coil is one-quarter this value, or 75 ohms. This is close enough to 72 ohms for all practical purposes, so the impedance of a 72-ohm line will be matched if the line is connected to terminals 1 and 2 (or 2 and 3) of coil L_1. Basically, therefore, a receiver with a dual input is actually a balanced-input receiver so arranged that an unbalanced line may be matched to it.

The balanced input of a set having an input circuit like those in Figs. 7C and 7D can be preserved by interposing a transformer like that shown in Fig. 9B between the set and the line when a 72-ohm unbalanced line is to be used. This transformer matches 72 ohms to 300 ohms. Such transformers are available because some sets are designed only for balanced inputs, and local noise conditions may be such that a shielded transmission line is necessary. It is also possible to reverse this transformer if a 300-ohm twin lead is to be used on a set designed for a coaxial line. This would happen only if a special antenna were being used.

Wave Traps. Since it is undesirable to amplify interfering signals any more than is necessary, it is common practice to place wave traps in the input coupling to reduce the strength of such interferences. Such wave traps are arranged to act as short circuits to the undesired signal. Fig. 10 shows how such wave traps may be connected to the input. Fig. 10A shows a balanced line connection, in which resistors R_1 and R_2 load the line, and coil L_3 provides the ground connection. There are two wave traps (L_1-C_1 and L_2-C_2) used here, one between

each side of the line and ground. Both traps are tuned to the interfering frequency. Since they are high-Q series-resonant circuits, they are practically short circuits at their resonant frequency but offer a fairly high impedance at other frequencies. Therefore, they short out the undesired signal but affect other signals very little.

These traps are sometimes tuned to interfering signals occurring in the i.f.
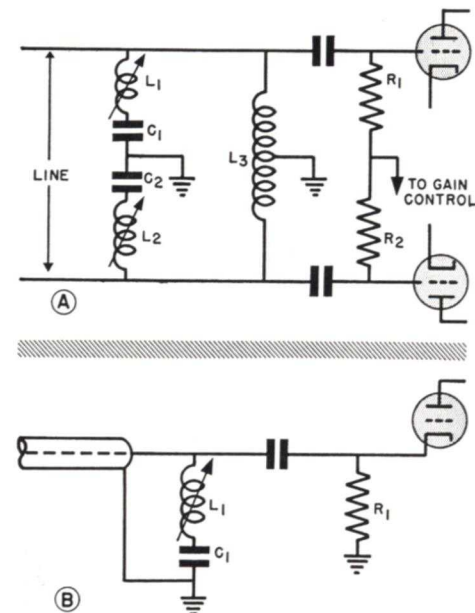

FIG. 10. Two ways in which wave traps can be used.

pass band, or to f.m. stations, or even to the second harmonic of the oscillator if co-channel interference is a problem.

The connection shown in Fig. 10B is for an unbalanced line. It operates in the same manner as the one in Fig. 10A, but only a single trap is used.

GAIN CONTROL

You may have noticed that the schematics given so far of the r.f. stage usually indicate that the grid return

goes to a gain-control voltage source. Later, when we take up other stages, we will show that the gain of the r.f. stage is not varied in most TV sets until the input signal is so strong that it threatens to overload the mixer or a later i.f. stage. In other words, the gain of the set is controlled primarily in the i.f. amplifier. If the signal is very strong, however, the r.f. stage gain may have to be reduced to prevent overloading.

Incidentally, many television receivers have a manual control, whereas others use an automatic gain control that is practically identical to automatic volume control (a.v.c.) circuits used in sound receivers.

Also, when you study antennas and transmission lines, you will find that even this method of gain control may
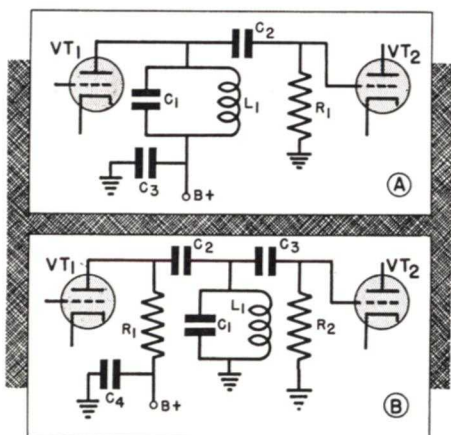
FIG. 11. Two forms of resonant coupling used between the r.f. and converter stages.

prove unsatisfactory in locations very near a powerful television station. In such cases, resistive voltage dividers called attenuators are inserted in the transmission line to decrease the signal from the powerful station to a level that can be comfortably handled by the set.

COUPLING TO MIXER

Because of the difficulties with input resistance, and the requirement of transmission-line matching, many TV sets do not use input tuning. However, whether input tuning is used or not, all TV sets use resonant coupling between the r.f. and converter stages. Some use only a parallel resonant cir-
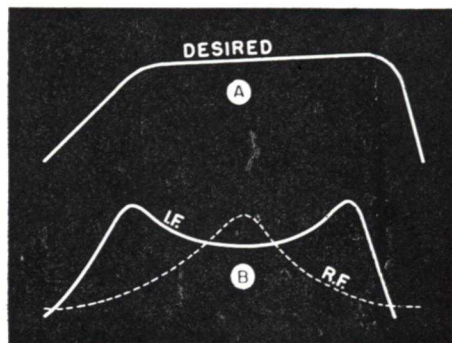

FIG. 12. The desired over-all response (A) of the r.f. and video i.f. sections can be secured by matching the response of the two sections (B).

cuit as the plate load, but many use some form of band-pass coupling.

Fig. 11A shows a basic tuned-plate coupling. We need tuning to give initial selectivity and whatever image rejection the set may have. Once again, however, we must compromise between gain and selectivity. It would be quite desirable to use a high-impedance load for the r.f. tube so as to get sufficient gain, but we could not then get the necessary band width for fidelity. In the circuit shown in Fig. 11A, the resistor R_1 loads the tuned circuit to broaden its response, making the resultant load for VT_1 quite small. If the detector bias is obtained from a grid-leak action, the grid resistor R_1 should have reasonably high resistance. In such cases, the arrangement shown in Fig. 11B may be used. Here, the resistor R_1 loads C_1-L_1, and grid resistor R_2 can then be a higher value.

If the i.f. response is properly designed, this problem is not difficult. We must pass a band of about 6 megacycles, but we need not get flat amplification over this entire band if the video i.f. response is designed to make up deficiencies in the r.f. response. Fig. 12A shows the over-all response desired for the r.f. and video i.f. stages. (This curve is non-symmetrical because trap circuits are used to reject the sound and adjacent-channel signals.) This response can be obtained by a combination of an i.f. response and an r.f. response like those shown in Fig. 12B. Notice that the r.f. response can have a single peak that is compensated for by a dip in the i.f. response.

Before leaving the parallel resonant circuit, let us point out that it is important that you realize the effect of shunting capacities. For example, the diagram of one set has the circuit connections shown in Fig. 13, except that C_0 is not on the schematic. Con-
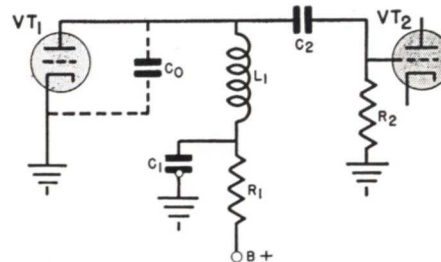

FIG. 13. Although internal tube capacities are not marked on schematic diagrams, they are actually part of the circuit in r.f. sections of TV sets.

denser C_1 is a trimmer condenser and, with coil L_1, apparently constitutes the tuned circuit. This looks like a series-resonant circuit, which would offer *minimum* impedance at resonance. Actually, however, the internal tube capacities of tube VT_1 and the input capacities of VT_2, which are represented by condenser C_0, are in

parallel with L_1. (Since schematic diagrams do not show internal tube capacities, you must be careful to remember that this capacity exists when you are analyzing operations at TV frequencies.) As a result, what appears to be a series resonant circuit is
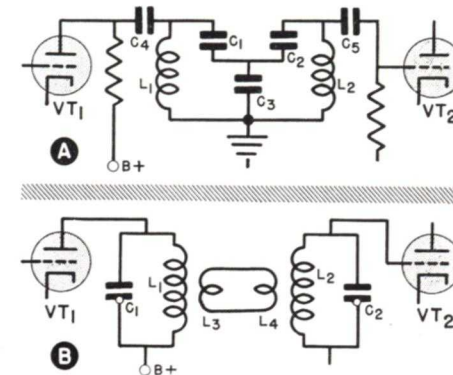

FIG. 14. Basic band-pass circuits.

actually a parallel resonant one, which it must be to provide the proper load for VT_1.

Even with the tubes used in television sets, the capacity of C_0 is so high that it is hard to get reasonable sizes for L_1 in the high band. Therefore, condenser C_1 is added in series with L_1 so that it is effectively in series with C_0. Since C_1 is a small capacity, and since the capacity of condensers in series is always less than the smallest, adding it to the circuit effectively reduces the capacity of C_0 enough to make the combination provide the proper tuning capacity for a coil L_1 of practical size. Because C_1 is a trimmer condenser, it may be used to compensate for such variations in C_0 as may exist in different receivers.

Band-Pass Coupling. Some manufacturers make the r.f. stage have a band-pass response that is flat-topped and about 6 megacycles wide by using two resonant circuits that are tuned

to the same frequency and are coupled to give the appropriate response.

Basic band-pass circuits are shown in Fig. 14. In Fig 14A, the two resonant circuits consist of L_1-C_1-C_3 and L_2-C_2-C_3. Condenser C_3 is common to both resonant circuits, and the drop across this condenser provides the coupling between the two circuits. Resistors load each resonant circuit to make the over-all response flatter.

Another form of coupling is shown in Fig. 14B. Here, a link consisting of coils L_3 and L_4 provides the coupling.

It is also possible to couple two resonant circuits through a third one that is tuned to resonance at a mid point, thus providing a three-peaked response characteristic. In general, however, band-pass units follow the standard a.m. practice that you have studied in your fundamental Lessons.

The Converter Section

The converter section of a television receiver, like that of a radio, consists of a mixer-detector and an oscillator, which together produce an i.f. signal from the incoming signal. The pentagrid converter is commonly used in sound receivers for both these functions, but the oscillator is always a separate tube in television sets (although it may be in the same envelope as a mixer-detector), principally because the pentagrid converter is a poor oscillator at TV frequencies and is extremely noisy.

Let's study the requirements of a mixer-detector a little more fully.

MIXER-DETECTOR

One of the most important sources of noise in a radio is the mixer-detector. The internal tube noise in this stage is considerably higher than in the average amplifier, even when both use the same tube. Both pentodes and triodes used as mixer-detectors are about four times as noisy as they are when used as amplifiers. Since, as you have already learned, pentodes are generally noisier than triodes, the latter are more commonly used in mixer-detector circuits. Pentodes are used only where there is sufficient gain in

the r.f. amplifier or where the signal is normally so strong that the converter noise can be completely over-ridden.

The gain we can expect from a mixer-detector stage depends upon the load in the plate circuit and upon what is known as the conversion conductance of the tube. The conversion conductance expresses the efficiency of the tube as a detector; it is equivalent to transconductance except that it is always less—only about one-quarter of the actual transconductance in the case of triodes. We must use this special term because, when a tube is acting as a detector, we are interested not in the total change in plate current but in that part of the plate current that represents the desired i.f. signal. All other a.c. components of the plate current, such as signals at the original and oscillator frequencies, and various harmonics of all these, are undesirable and are by-passed. With normal efficiencies of operation, therefore, we find that a tube used as a converter gives only about one-quarter of the gain that it would as an amplifier.

CIRCUIT TYPES

The standard mixer-detector is fed at its grid by both the oscillator signal

and the incoming signal from the tuning arrangement at the output of the r.f. stage. The oscillator signal may be connected to the grid circuit through a link coupling to the tuned circuit, or it may be fed in through a coupling condenser.

The converter is usually self-biased by a grid-leak and condenser, because it is desirable to ground the cathode circuit. Except for this and for the use of triode (or pentode) tubes, the mixer-detector in a TV set is much like that in a sound receiver.
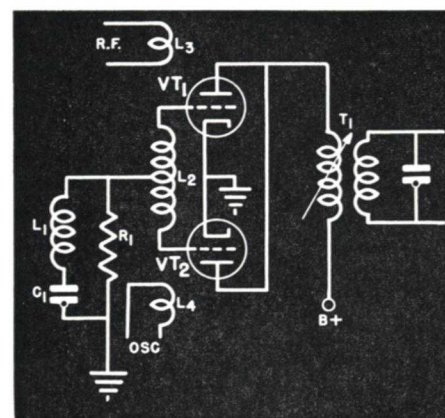

FIG. 15. A push-pull input, parallel output converter stage.

An interesting variation is the type shown in Fig. 15. Here, coil L_2 is one of the preselector circuits; it is tuned by the input capacity of the two tubes VT_1 and VT_2 that together act as the detector. Coil L_3 feeds the incoming r.f. signal into L_2, and L_4 feeds in the signal from the oscillator. The converter bias is obtained from the drop across resistor R_1, which uses C_1 plus stray circuit capacity as its grid condenser. Transformer T_1 is the first i.f. transformer, both windings of which are tuned. The primary of T_1 is a parallel resonant circuit that uses the output capacities of the two tubes as its tuning capacity.

The signals from L_3 and L_4 are applied to both tube grids simultaneously. When the two signals are mixed and detected, the beat products (i.f. signal) at the two plates will be in phase. Therefore, the tube plates are connected in parallel to the primary of T_1. As far as the individual input components (the r.f. input signals and the oscillator signal) are concerned, however, the two grids are being fed in push-pull; therefore, the two plate current components resulting from each input component will be out of phase, and, because the plates are connected in parallel, these plate-current components will cancel. In other words, the output of the stage will contain neither of the original input signals—only their difference frequency, which is the desired i.f., and a few undesired harmonics. This push-pull input, parallel output connection also tends to cancel any incoming interfering signals at the i.f. frequency, because they are fed to the grids in push-pull just as the desired incoming signal is.

I.F. Trap. The combination L_1-C_1 and the halves of L_2 form a series-resonant circuit from each grid to ground. The upper half of L_2 plus L_1-C_1 is the circuit for VT_1, and the lower half of L_2 plus L_1-C_1 is the series circuit for VT_2. These circuits, which are made resonant to the i.f. frequency, serve two important purposes.

One is that they keep the two tube grids at a very low impedance with respect to ground at the i.f. frequency. Therefore, interfering signals at the i.f. frequency cannot drive the grids much.

Another important purpose they serve is to prevent oscillation in the mixer. With *triode* mixers, feedback from the plate to the grid circuit could

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make the stage oscillate at the i.f. frequency. This could occur because the resonant input circuit consisting of coil L_2 and the input capacities is tuned to the incoming signal, which is higher than the i.f. in frequency. Hence, this circuit is inductive at the i.f. frequency, which means that feedback through the grid-plate capacity will be applied to the grids in the proper phase to cause oscillation at the i.f. frequency. As we said earlier, however, the series resonant circuits keep the impedances between the grid and ground very low at the intermediate frequency; therefore, whatever i.f. feedback exists from plate to grid is unable to develop more than a very small grid signal, so oscillation will not occur.

A similar oscillation problem exists even with a single-ended triode stage, so almost all triode TV converters have such series trapping arrangements to prevent an i.f. voltage from being developed at the grid. These traps are unnecessary in converter stages using pentodes, since such tubes have very little plate-to-grid capacity.

OSCILLATORS

The oscillator is inductively or capacitively coupled to the first detector by the usual methods. In general, as in standard radios, the oscillator signal should be about ten times the strength of the incoming signal so that linear mixing will occur without distortion of the modulation of the input signal.

In most modern TV receivers, the oscillator is above the incoming frequency by the amount of the i.f. frequency. There are a few exceptions, however.

In one of these, the oscillator is above the signals on the low band but is below those on the upper band. This switch is possible only because the

set in question uses an "intermodulation" sound system, which we shall study elsewhere. When the "standard" sound system is employed, the oscillator must either be above all incoming channels or below all, so that the proper intermediate frequency will be produced.

Even though the band widths of television i.f. amplifiers are broad, they must have sharp sides to give reasonable adjacent-channel selectivity. Therefore, since the signal fills the whole band width, a considerable portion of the signal would be cut off if the oscillator frequency should drift even slightly. Temperature-compensated parts are commonly used in the oscillator circuit to help minimize this drift. Most generally, a temperature-compensated condenser is added to the tuning circuit. It is possible to make such a condenser either increase or decrease in capacity with changes in temperature. Therefore, the manufacturer determines how the oscillator circuit of a run of sets tends to drift, then installs a compensated condenser that drifts the other way. As a result, the net oscillator drift is minimized (though seldom eliminated completely).

Tuning. There are two basic tuning systems—continuous tuning much like the ordinary manual tuning of sound receivers, and step tuning much like the push-button systems of sound receivers.

In the continuous tuning systems, variations in the oscillator frequency can be compensated for by retuning. This may mean that a compromise position is used that detunes the preselector to keep the oscillator in step, but this won't matter much if the preselector is sufficiently broad.

When step tuning is used, the oscillator is aligned approximately for

each channel by the parts inserted by the switching mechanism. Then, to get the oscillator to the exact frequency, it is standard practice to include some means of adjusting the oscillator. Manually, this may be done by what is called the "fine-tuning" control, which is a small variable condenser in the resonant circuit that acts as a trimmer. This may be adjusted from the front of the set when necessary.

Instead of a fine-tuning control, a number of television receivers use automatic frequency control (a.f.c.) to adjust the oscillator. The control voltage, which is obtained from the discriminator in the sound channel, is coupled to the oscillator tuning circuit. Let's review automatic frequency control briefly.

A.F.C. As you learned in your fundamental Lessons, an a.f.c. system consists of a discriminator circuit that determines whether the oscillator circuit is producing the proper i.f. frequency with the incoming signal. If it is not, the discriminator produces a voltage that can be used to control the oscillator frequency through what is called the control tube. This control tube is a tube that is set up to act as a capacity or as an inductance; it is connected across the oscillator resonant circuit and can therefore be used to shift the frequency of the oscillator.

A typical circuit diagram is shown in Fig. 16. Here, VT_1 is the discriminator in the sound system of the television set. Briefly, the signal from the resonant circuit C_1-L_1 is coupled by mutual inductance into the L_2-C_2 resonant circuit, and, through blocking condenser C_5, the same signal is also applied to coil L_3. As a result, two different voltages are applied to each diode plate of VT_1 in such a way that the two diode plate voltages are exactly equal at resonance. When these

plate voltages are equal, the diode currents through R_1 and R_2 are also equal. Since these currents flow in opposite directions, and since the resistors R_1 and R_2 through which they flow have the same resistance, the resulting voltage drops across these resistors are equal and opposite.

Tube VT_2, the oscillator, is used in an ultra-audion circuit. Tube VT_3, the control tube, is connected to the oscillator tank in such a way that it always draws a current that is out of phase with its plate voltage—in other words, the tube acts like a reactance.
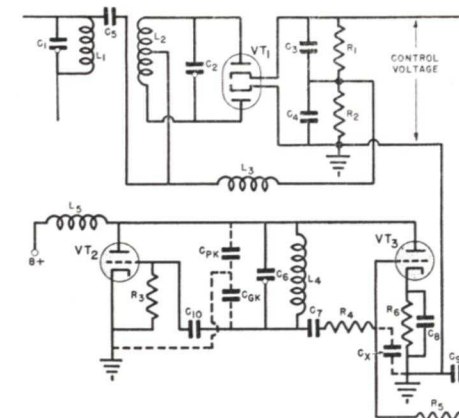

FIG. 16. A typical a.f.c. system.

In the particular circuit shown, it is adjusted so that it acts like a condenser.

If the oscillator frequency drifts, the i.f. signal produced in the sound channel and applied to VT_1 will not be the correct i.f. to which the tank circuits C_1-L_1 and L_2-C_2 are tuned. The voltages will then be different on the two diode plates, with the result that there will be a net control voltage across R_1 and R_2. This voltage will change the bias applied to VT_3, thereby either raising or lowering the plate current so that the tube acts like a bigger or smaller capacity, whichever

is needed to retune the oscillator to the correct frequency value.

The action of this circuit was covered in detail in one of your earlier Lessons, to which you should refer if you wish a fuller explanation. At the moment, all you need to remember is that a drift in the oscillator frequency can be automatically corrected by an a.f.c. system.

OSCILLATOR CIRCUITS

As you learned in your fundamental Lessons, television receivers most commonly use the ultra-audion oscillator. This is the variation of the Colpitts oscillator in which the internal tube capacities set the feedback voltages. In addition, the tuned-plate push-push oscillator is used in a few sets, and the Hartley oscillator in a very few.

One of the reasons why the ultra-audion oscillator is so popular in television sets is the fact that the Miller-effect capacities are small in this circuit. At the frequencies involved, the tuning capacities needed are quite small, so the tube and circuit capacities must be kept down.

For example, in the ultra-audion circuit shown in Fig. 17A, the internal tube capacities are across the resonant circuit L_1-C_1 as shown by the dotted lines. Effectively, the C_{PK} and C_{GK} capacities are in series, so the net capacity is less than that of the smaller of this pair. The grid-plate capacity C_{GP} is also across the tank circuit, but only as it exists in the tube; in a tuned-grid or tuned-plate oscillator having an inductive load, this capacity would be multiplied by as much as the gain of the tube because of the Miller effect. Therefore, the total amount of capacity shunting the tuned circuit in Fig. 17A is less than it is in

a tuned-grid or tuned-plate oscillator, so, for fixed sizes of the tank circuit parts, it is possible to tune this ultra-audion circuit to higher frequencies than can be reached with either a tuned-grid or a tuned-plate oscillator.

Fig. 17B shows the capacities shunting the tuned circuit in the tuned-plate push-push oscillator. Here the
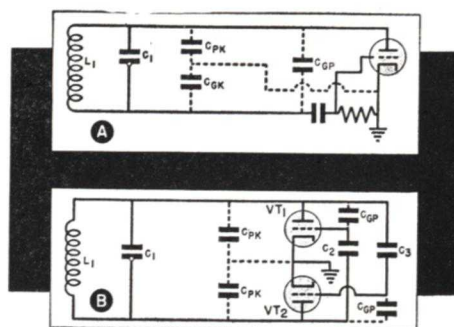

FIG. 17. Internal tube capacities in the ultra-audion circuit (A) and in the tuned-plate push-push oscillator (B).

plate-cathode capacities of the two tubes are effectively in series, an arrangement that reduces their effects considerably. Although the feedback condensers C_2 and C_3 provide paths for the grid-plate capacities to be in shunt with the tuned circuits, these feedback condensers are small enough to prevent the grid-plate capacities from having too much effect.

In all TV oscillators, the internal tube capacity does affect the frequency by being part of the tuning circuit. When it becomes necessary to replace an oscillator tube, it is necessary that one be found that has internal capacities not too far different from those of the original tube, or else the receiver may not tune over the proper range. Hence, it may be necessary to try several tubes to find one that permits the normal tuning range.

Tuning Systems

Now that you have a general understanding of the circuits used, let's study some of the physical details of input tuners.

We have already mentioned that each of these tuners is on its own sub-chassis, which is mounted on the main chassis after the input tuner has been assembled and aligned. Operating voltages are obtained from the low-voltage supply of the receiver. To prevent leakage of the r.f. and oscillator signals, R-C filters are used in the B+ leads (and, of course, the unit is shielded). The by-pass condensers used must be non-inductive, so it is fortunate that small by-pass values are effective at these frequencies. In the r.f. and i.f. sections, the by-pass condensers are usually ceramic or mica types rather than paper. The ceramic types are preferred because of their small physical size. Incidentally, these condensers closely resemble resistors in size and shape, so don't identify them wrongly when you examine a TV receiver.
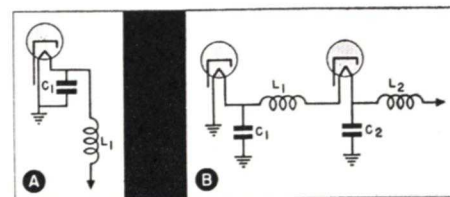

FIG. 18. Filtering systems used with (A) parallel and (B) series filaments.

Appreciable by-passing of the B+ leads is secured just by running these leads next to the chassis, so don't move leads carelessly in TV sets!

The filament leads of input tuners are elaborately by-passed and filtered. Fig. 18A shows the choke and con-

denser combination used for parallel filaments; Fig. 18B shows a series filament filter. These filters prevent stray r.f. from traveling through the filament leads to other sections of the set.

Mechanically, tuning systems may be divided into continuous tuners and step tuners. A continuous tuner uses a variable inductance or a variable condenser and is so arranged that it tunes over a complete band of frequencies that includes all TV channels.

In one form of continuous tuner, the tuning mechanism tunes all the way from about 50 megacycles to the upper end of channel 13. This means that it covers a number of other channels too, including the f.m. band. A set with this kind of tuner can therefore be used as an f.m. radio receiver when it is tuned to this band.

Other "continuous" tuners are actually two-band tuners in that they tune through the low band, and then a switch is thrown (sometimes automatically) to allow them to tune through the high band. In these sets, the intervening bands assigned to f.m. and other services are not tuned in.

A step tuner has some form of switching mechanism that throws in resonant circuits (in both the oscillator and preselector) that are tuned to the respective television channels. Some of these switches are rotary types, some are slide switches, and some are push-button arrangements, but they are all arranged to connect in the necessary resonant circuits, which have been pretuned to the desired channels.

Now let's study the continuous tuner in more detail.
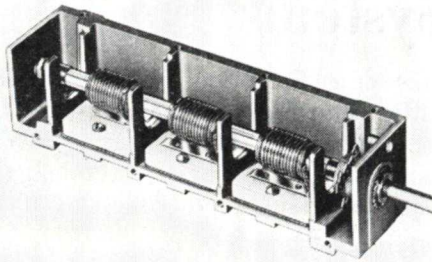
Courtesy P. R. Mallory and Co., Inc.

FIG. 19. This is the Mallory Inductuner (Trademark registered U.S. Patent Office) that is used in several brands of TV sets.

CONTINUOUS TUNER

One of the very popular continuous tuning systems used by a number of set manufacturers contains the Mallory Inductuner that is shown in Fig. 19. This tuning unit consists of three coils wound on ceramic forms that are mounted on a single insulated shaft. A sliding contactor or shoe rides in "trolley" fashion between the coil wire and a plate, and maintains a constant contact between the two. As the tuning mechanism rotates the coil, this shoe moves along the coil, thus shorting out an increasing number of turns. This system of shorting the inductance makes it possible to vary the total inductance from approximately one microhenry to .02 microhenry, which is a change of about 50 to 1. This provides a very wide tuning coverage—the unit covers the entire low and high band as well as the f.m. band in between.

Fig. 20 shows a schematic of an input tuner that uses the system shown in Fig. 19. The black box encloses the three coils that are the variable portion of this tuner.

Tube VT_1 is a grounded-grid r.f. amplifier. The signals are fed into the cathode. Since this is an unbalanced input, a coaxial transmission line will be used.

The load for VT_1 is a band-pass tuner. One section consists of L_3-L_1-C_3-C_4, and the other consists of L_4-L_2-C_5-C_4. Since C_4 is common to both circuits,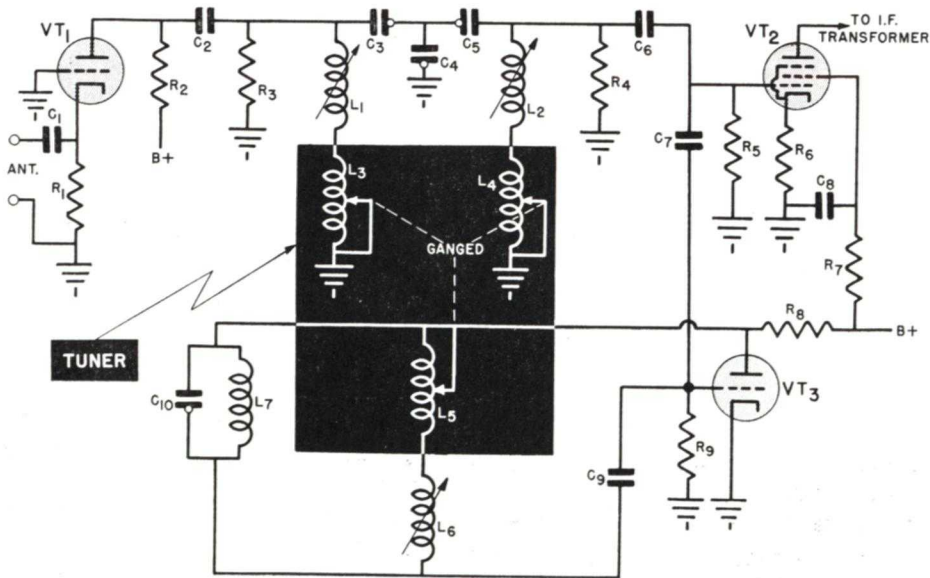 it provides the coupling between the two sections. Resistor R_3 loads one section of this tuner, and R_4 loads the other. Condensers C_2 and C_6 are d.c. blocking condensers.

Tube VT_2 is the mixer-detector. Notice that it is a pentode.

The oscillator tube VT_3 uses the ultra-audion circuit. The tuning inductance consists of L_7 in parallel with a series combination of L_5 and L_6. Condenser C_{10} plus the internal capacities of the tube provide the capacity.

When this circuit is aligned at the factory, the tuning inductances L_3, L_4, and L_5 are set at minimum inductance, and the inductances L_1, L_2, and L_6 are adjusted to bring in channel 13. The oscillator frequency is then higher than that of the incoming signal. It is possible to get an alignment at another television channel by adjusting C_3, C_5, and C_{10}, and then adjusting C_4 to change the coupling between the band-pass sections. Some of these adjustments can be made only by the manufacturer.

Obviously, this continuous tuner provides a very simple front-end construction. The only basic difficulty with it is the fact that a number of spurious responses are obtainable at various points over the tuning range. Once the receiver owner learns to ignore all but the correct response points, which are approximately marked on the tuning dial, this arrangement is quite satisfactory. Having the device tunable through the f.m. range means that the receiver can also be used as a sound receiver for f.m. signals. When this is desired, a switch can be thrown to cut off the picture tube and its associated circuits.

TWO-BAND TUNERS

In the second form of continuous tuning, the band over which the set will tune can be selected by throwing a switch. In this form, all those frequencies between the lower and the upper band are skipped, a fact that makes a somewhat different design possible. Some two-band continuous tuners of this kind use variable inductances, and some use variable condensers. Let's study both briefly.

Variable Inductance. A variable-inductance tuner is shown in Fig. 21. In this unit, the coils are made of flat copper ribbons wound spirally around the coil forms. The tuning arrangement varies the permeability by moving powdered-iron cores in and out of the coil forms. These cores are mechanically ganged so that they move
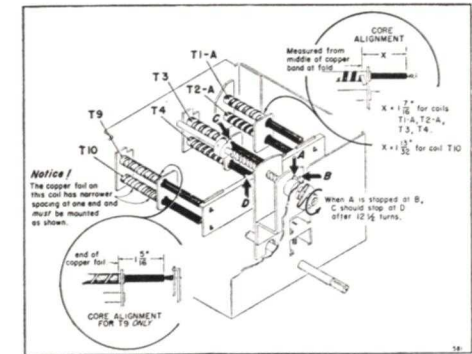
Courtesy Belmont Radio Corp.

FIG. 21. A variable-inductance 2-band continuous tuner.

in unison as the receiver is tuned. A spiral gear arrangement, driven from the tuning knob, moves the insulated plate on which the cores are mounted toward or away from the coils.

The schematic diagram of a set using a tuning arrangement of this kind is shown in Fig. 22. Starting at the antenna terminals, you will observe that this receiver is designed for a balanced input and has a high-low switch that permits the proper coils for each of the bands covered to be thrown in. The primary of the antenna coil feeds into a tuned secondary, which is somewhat unusual
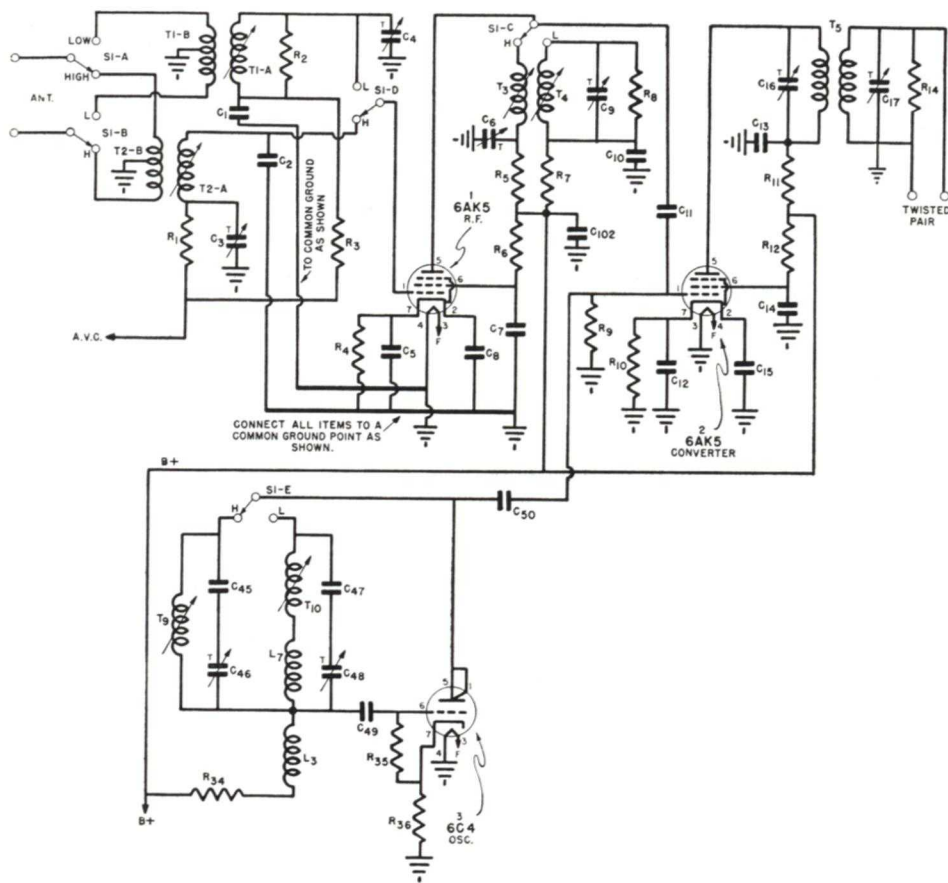

FIG. 20. The schematic of an input tuner in which the Mallory Inductuner is used.

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STEAM POWERED RADIO.COM

FIG. 22. The schematic diagram of a set using the continuous tuner shown in Fig. 21.

in television. The pentode r.f. tube is coupled to a pentode mixer through a parallel-resonant circuit. With the switch in the high position as shown, the coil T_3 is the plate tuning inductance; it is tuned by the output capacities of the r.f. tube in parallel with the input capacities of the mixer. To reduce the effects of this capacity, and to make it possible to adjust for differences in tubes, the trimmer C_6 is connected in series with T_3.

When the switch S1-C is thrown to the low position, coil T_4 becomes the tuning inductance. This is shunted by additional tuning capacity C_9 and is loaded by R_8.

The oscillator is again our familiar ultra-audion type, with a separate resonant circuit for each band.

Variable Capacity. Fig. 23 shows a tuner that uses variable condensers. This is somewhat similar to the tuning condenser with which you are familiar on sound receivers except for the unique arrangement whereby a large capacity variation is obtained. As shown in Fig. 24, this unit is so constructed that there are two tuning condensers in series for each tuning section of the condenser. Since condensers in series always have a capacity less than that of the smallest,

and since both of these are varied simultaneously by the tuning control, the range is greatly extended over that of the usual tuning condenser. Furthermore, the amount of capacity is quite small considering the sizes of the plates that are used.

In the particular unit shown in Fig. 23, a band-change switch is actuated by the tuning control when the control is moved from channel 6 to channel 7 (or vice versa). To mark the proper positions for each channel, this tuner has a notch or detent cut so that the person tuning the unit can feel the "bump" as the correct position is reached.

The particular tuner shown uses a band-pass preselector that has inductive coupling between the sections.

Dust and grime must not be allowed to accumulate on the plates of a variable condenser used in a TV set. Although ordinary sound receivers may work satisfactorily with heavy

Courtesy Howard W. Sams and Co., Inc.

FIG. 23. A variable-capacity two-band continuous tuner, made by the General Instrument Corporation.

accumulations of such particles, a television receiver can be considerably upset by their presence. Dust shields are necessary.

The tuners we have described so far were originally developed for individ-

ual set manufacturers, but most are now used by other manufacturers as well. Therefore, you can usually expect to find the same tuner used in several different receivers. Even when the same tuner mechanism is used, however, it is possible for the manufacturer to change the electrical circuit.
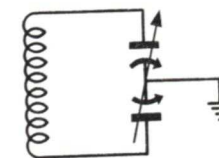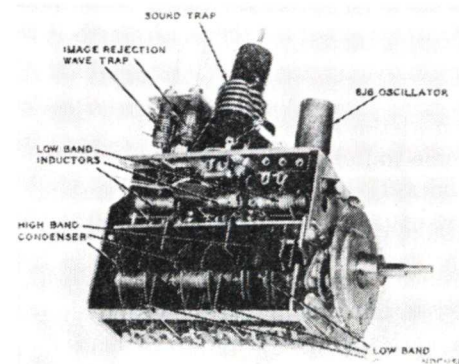

FIG. 24. This special arrangement provides a large capacitive variation in the tuner in Fig. 23.

cuit. For this reason, it is always advisable to consult the manufacturer's manuals whenever you have to service these units.

STEP TUNERS

There are many different kinds of step tuners that are designed to tune directly to specified television channels. All involve some form of switch —a rotary-selector switch, a sliding-turret switch, or a push-button unit. Basically, regardless of the switching mechanism, there must be an arrangement whereby the inductance, the capacity, or both are changed in each resonant circuit to tune in the proper channel for each switch position.

Incidentally, receivers vary somewhat in regard to the number of channels to which they will tune. Most manufacturers who use a step tuner arrange it so that it will tune to all twelve of the channels in use today. This permits them to ship their sets anywhere, with the expectation that all the local television stations can be picked up. However, a few manufacturers save a little on the cost of their receivers by making them tune to only seven or eight channels. Since no locality at the present time has more

than seven channels assigned to it, the manufacturer need supply only this number of tuning circuits. The distributor or local dealer then adjusts the set to receive the local channels before he delivers it.

Since adjacent channels are never used in the same locality, most such sets use a "choice" arrangement. For example, one switch position may be adjusted to tune to either channel 12 or channel 13. The local dealer or serviceman merely makes sure that whichever of the two channels is in use locally is the one the set is adjusted for, and so on down the line.

Let's now look over some typical step tuners.

ROTARY SWITCHES

Fig. 25 shows one of the most widely used types of rotary switch selectors. In this unit, tuning to lower-frequency channels adds inductance to the circuit. The inductance coils are arranged right on the switch decks.

The schematic diagram of a tuner that uses this system is shown in Fig.
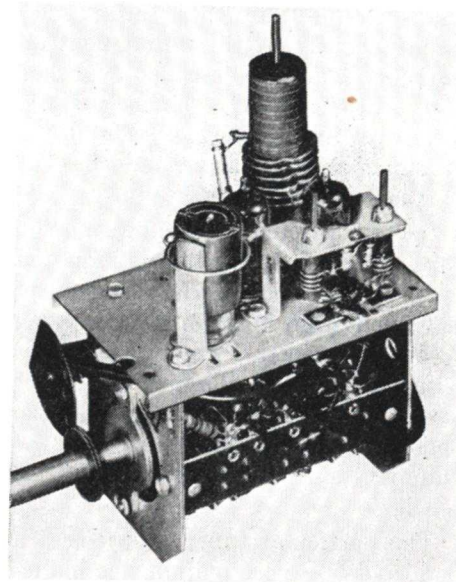
Courtesy RCA

The side view of the tuner in which the switch deck in Fig. 25 is used.

26. The selector switch blades slide along the contacts numbered from channel 1 to channel 13. (Channel 1 is commonly indicated as a "position" on the selector switches, although it is no longer assigned to television.)

Let's run through the circuit. Starting at the antenna terminals, we first come to balanced wave traps L82-C22 and C21-L81. These wave traps are used to tune to any station that may be interfering. Choke T1 is used to reduce signals having frequencies lower than the lowest television channel. Resistors R3 and R13 load the transmission line and provide signals to the grids of the push-pull r.f. triodes. Since triode tubes are used here, neutralizing condensers C3 and C4 are necessary.
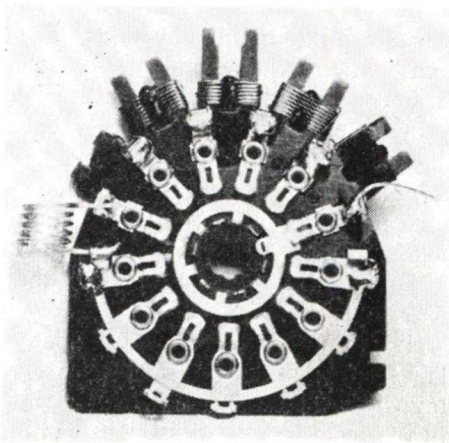
When the selector switch is set for channel 13, the tuned circuit in the plate of the push-pull r.f. stage consists of coils L25 and L26. As the selector is tuned to other channels, additional inductances are added in

Courtesy Radio Maintenance Magazine

FIG. 25. One of the switch decks used in the r.f. section of an RCA tuner. The inductance for the high band is provided by the semi-circular loop of metal at the bottom of the deck.

series with each of these coils. The added "inductances" for the upper channels (L13 to L24) are actually just short pieces of wire soldered between the switch terminals.

As the switch is moved from channel 7 to channel 6, the inductances L11 and L12 provide the rather large frequency change from 174-180 mc. to 82-88 mc. Then the coils L10 to L1 are added for the lower channels. Even here, the inductance needed is quite small, so these coils are wound in a "figure-eight" form so as to have minimum inductance. Effectively, this tuner is just a tuned line except for the inductances L11, L12, L25, and L26.
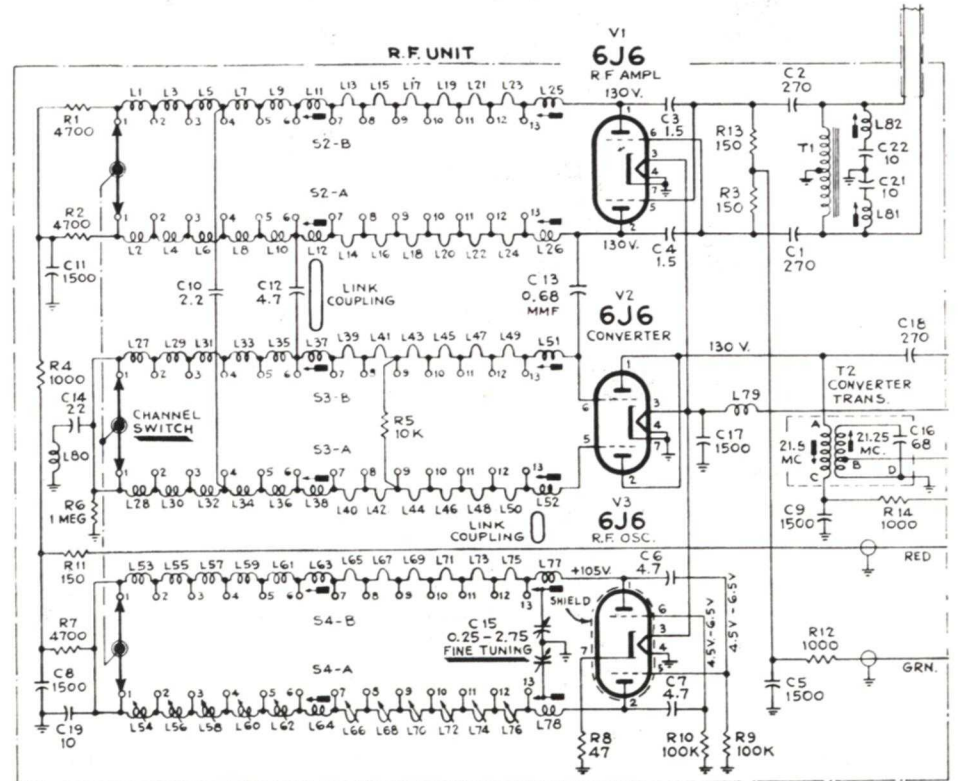
The tube capacities form the capacitive element. The only adjustable parts are coils L25 and L26 for channel 13 and L11 and L12 for channel 6. To make adjustments for any other channel, the manufacturer must shorten, lengthen, or bend the wires forming the inductances.

Coupling to the grid circuit of the converter tube V2 is through coupling condenser C13 for channel 13. For other channels, additional couplings are provided, first through a link coupling and then through two additional coupling condensers for lower channels (where more coupling is necessary).

Courtesy RCA

FIG. 26. The schematic diagram of the tuner in which the switch deck shown in Fig. 25 is used.
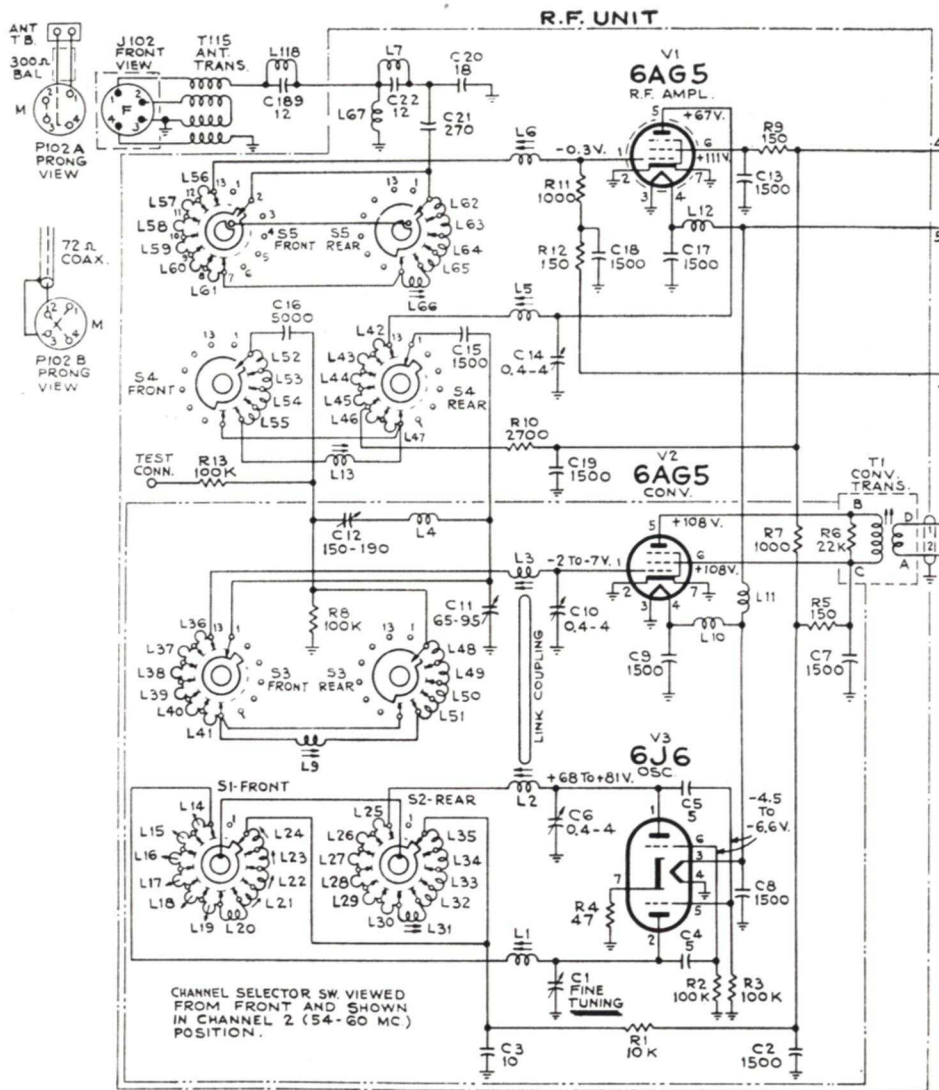
FIG. 27. Another kind of circuit in which a rotary selector switch is used.

In addition, since the coils are mounted on switch wafers, there can be additional inductive coupling between the coil units if this is wanted.

In any event, the tuned-plate r.f. circuit is coupled to a tuned-grid converter, which forms a band-pass tuner. The converter input for channel 13 consists of the coils L51 and L52, which in turn are tuned by the input tube capacities. The grid resistor R6

has an i.f. wave trap connected across it, designed so that L80, C14, and the channel tuner coils act as a series-resonant circuit at the i.f. frequencies.

The plates of the converter tubes are connected in parallel. Transformer T2 is both the i.f. transformer and a sound trap used to take the sound signal from the output of the converter. That is, the primary of transformer T2, along with the tube ca-

pacities, is a parallel-resonant circuit across which the sound and video i.f. signals are developed. The video signal is fed through coupling condenser C18 to the video r.f. amplifier, and the sound signal is taken from the secondary of transformer T2.
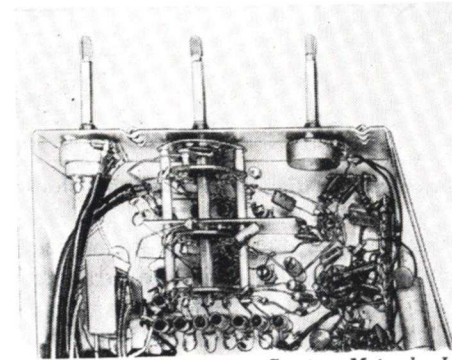
The oscillator is a tuned-plate push-push type. The oscillator signal is fed to the converter through a coupling link.

Many other circuits may be obtained using such a rotary selector switch. One of these is shown in Fig. 27. In this particular circuit, the input feeds in through an antenna matching transformer that permits either balanced or coaxial transmission lines to be used. Then the signal is fed through a series of traps into a tuned-grid circuit in which a pentode is used. The plate circuit of this tube also has a resonant circuit, which is band-pass-coupled to the grid tuning of the converter stage. The converter is also a pentode. The oscillator is a tuned-plate push-push type.

Although the electrical connections are quite different, the same basic switching arrangement is used here that is used in the circuit in Fig. 26. Extra sections are used to short-circuit unused coils, but the general ar-

rangement of the switch and the coils is otherwise the same.

EIGHT-POSITION SWITCH

The same basic switch used in the last two examples can be used in a set that is intended for coverage of only seven or eight bands. An example of such a tuner is shown in Fig. 28, and its schematic is shown in Fig. 29. In this particular receiver, the selector switch is wired to coils that are mounted individually on the set chassis. This is one of the few examples of this kind of wiring used in television.

As you can see from the schematic, the input is designed for either the balanced or unbalanced type of transmission line. From the line, the signal is fed through a coaxial loop to a bus-bar wire that acts as the coupling inductance. That is, the bus-bar wire acts as the primary coupling inductance, and the secondary windings are soldered to this wire at carefully calculated spacings along the wire. This circuit uses a tuned-grid pentode r.f. amplifier, which feeds into a parallel-resonant plate circuit that in turn feeds the converter.

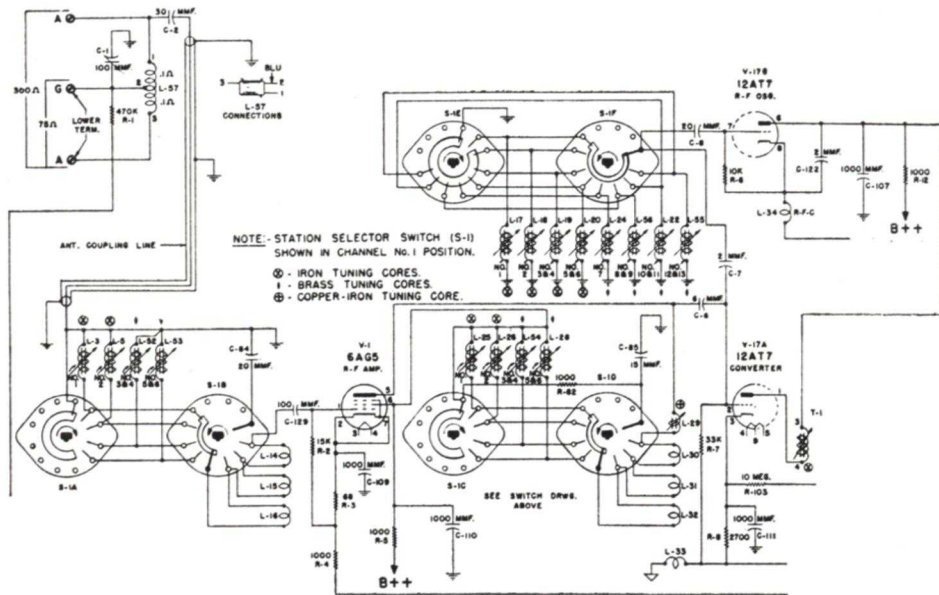The oscillator is an ultra-audion type. The switching arrangement ap-

Courtesy Motorola, Inc.

FIG. 28. The set in which this tuner is used can be tuned to only eight channels.

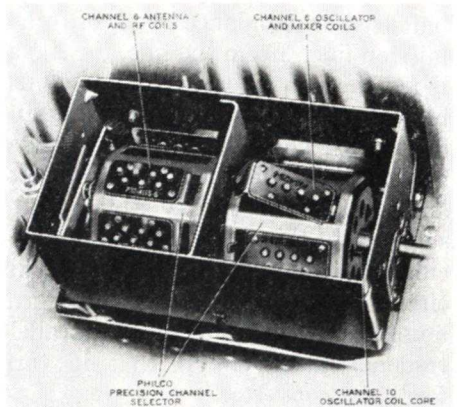FIG. 29. The schematic diagram of the tuner shown in Fig. 28.

Courtesy Motorola, Inc.

pears somewhat complex because one section of the switch connects the desired coil into the circuit and another section of the switch short-circuits all the coils that are not used, effectively removing them from the circuit.

Notice that the oscillator is somewhat unusual in that a separate coil, rather than a series-coil arrangement, is used for each of the bands.
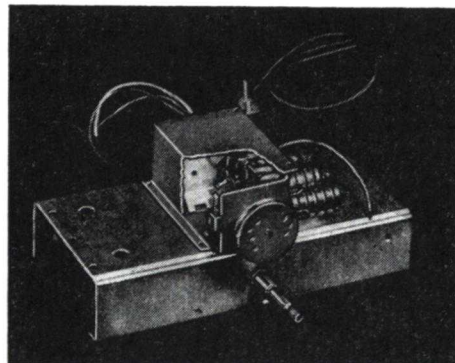

Courtesy Philco

FIG. 30. What a turret tuner looks like.

Courtesy Edwin I. Guthman and Co.

FIG. 31. Another kind of turret tuner. In this, the turret moves horizontally.

As we mentioned earlier, this particular arrangement is such that the set can be aligned to whatever seven channels are in use in any one locality.

Turret Tuner. Fig. 30 shows an example of an entirely different type of switch selector. In this one, there is a rotary turret on which several plates are mounted. Attached to each plate are the inductances needed to
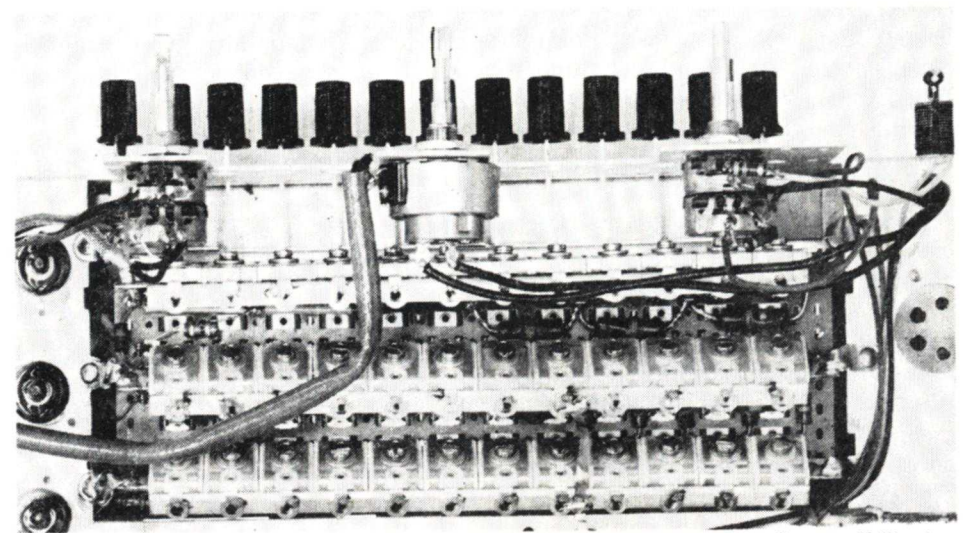

Courtesy Hallicrafters

FIG. 32. A push-button tuning arrangement that can be used for all channels.

tune the preselector and oscillator to one channel. These inductances, in each case, are connected to contactor points that project through the bottom of the plate. A particular channel is tuned in by turning the turret until the plate supporting the inductances for that channel is in a position where contacting springs engage the contactor points of the plate. This connects the inductances into the circuits. Most turret tuners of this kind carry only seven or eight plates, so the proper ones must be installed for each locality.

Fig. 31 shows another type of turret unit in which the turret moves horizontally instead of rotating. Basically, this is the same as the unit we just described in that the coils or tuning circuits are movable. Unless the mechanical design prevents doing so, it is possible to use tuners of this kind with any standard circuit.

Push-Button Tuner. It is, of course, possible to use a standard push-button arrangement, as shown in Fig. 32. Here, the desired inductances, along

with their associated tuning capacitors, are switched in by an ordinary push-button arrangement much like those in a standard radio. It is possible to use a tuner of this type with any standard circuit; the push-button arrangement merely provides the mechanical means of tuning in the desired stations.

Variable-Core Tuner. Figs. 33 and 34 show a final example of a switch-type tuner. This tuner contains two
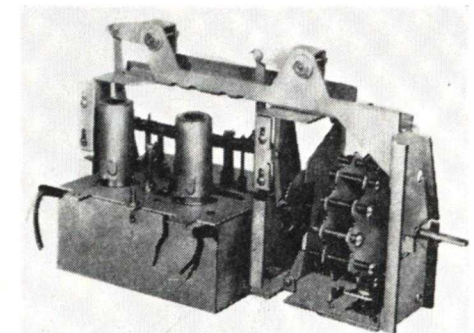
Courtesy American Steel Package Co.

FIG. 33. A switch tuner in which variable-core tuning is used.

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sets of preselector and one set of oscillator coils; each set consists of two coils, one for each band. The unit is tuned by moving the coil cores in or out in steps. The mechanical arrangement for tuning the unit consists of a rotating drum fitted with adjustment screws that bear on a plate. There are twelve of these screws, one for each channel. When the tuning shaft is rotated, the drum turns, causing a different screw to press against a movable plate C as shown in Fig. 34. The position of C governs the height of an insulated strip G to which the coil cores H are fastened. A screwdriver

adjustment makes it possible to preset the screws B for any given channel. A trip mechanism is used to switch coils for the high and low bands.
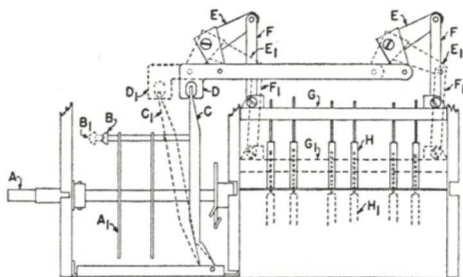

FIG. 34. The operating mechanism of the tuner shown in Fig. 33.

Lesson Questions

Be sure to number your Answer Sheet 52RH-2.

Place your Student Number on every Answer Sheet.

Send in your set of answers for this Lesson immediately after you finish them, as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.

1. Which of the following sections of a TV set is supposed to minimize adjacent-channel interference: 1, *the input tuner;* or 2, *the i.f. amplifier?*

2. What makes it difficult for the input tuner of a TV set to have good image rejection?

3. For minimum noise, should the resistances or impedances in the input circuit of an r.f. stage be: 1, *low;* or 2, *high?*

4. Why are some tubes (designed for f.m. and TV equipment) equipped with two cathode leads?

5. Name two methods of preventing oscillation when triode tubes are used as r.f. amplifiers.

6. What is the impedance between *one* outside terminal and a grounded center tap on a transformer designed for a balanced 300-ohm transmission line?

7. Where would you expect to find a wave trap designed to eliminate interference from an f.m. station: 1, *at the input of the r.f. stage;* 2, *between the r.f. and converter stages;* 3, *in the i.f. amplifier?*

8. Give two reasons why a series-resonant i.f. trap is used in the grid circuit of a *triode* TV converter.

9. Why is it frequently necessary to try several tubes when replacing the oscillator tube in a TV set.

10. In step-tuner systems, what two methods are used to get the oscillator adjusted exactly to the proper frequency?

Be sure to fill out a Lesson Label and send it along with your answers.

ALL MEN WANT TO SUCCEED

Here's a quotation I ran across the other day that made me think of several fellows I know:

"All men want to succeed. A few men want success so badly that they are willing to work for it."

Isn't it true that almost every fellow you know *wants* success, *wants* more money, *wants* security?

But how many of these men are willing to buckle down and study—work—think—to get the good things they want?

It is very true that only *comparatively few men* are willing to really work for success.

You are one of those few men. You have proved this fact by enrolling for the NRI course—by working to complete many of your Lessons. *You* are taking the first and most important step toward success.

J. E. Smith