VIDEO I.F. AMPLIFIERS AND VIDEO DEMODULATORS

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STUDY SCHEDULE No. 53

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.

☐ **1. Introduction .... Pages 1-7**

The basic requirements of television i.f. and demodulator circuits and a brief statement of how they are met are given in this section.

☐ **2. Getting the Desired Response .... Pages 8-14**

Here you learn how i.f. circuits are arranged to give the response needed in a TV set.

☐ **3. Typical Video I.F. Amplifiers .... Pages 15-21**

This section contains descriptions of the basic i.f. circuits and the various ways in which i.f. circuits are coupled.

☐ **4. Video Detectors .... Pages 22-28**

In this section, you learn how the output of the i.f. amplifier is demodulated to recover the video signal.

☐ **5. Answer Lesson Questions and Mail Your Answers for this Lesson to NRI for Grading.**

☐ **6. Start Studying the Next Lesson.**

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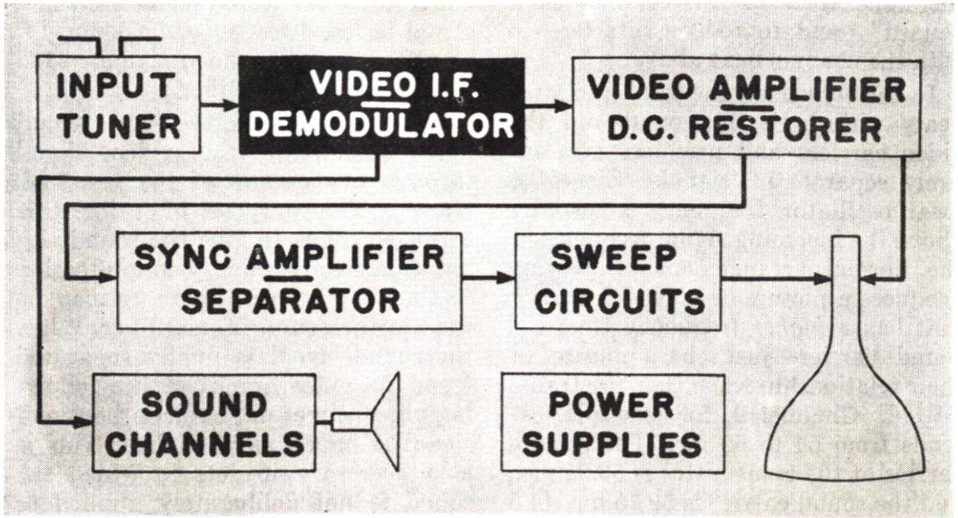


A PREVIOUS LESSON has shown you how the television input tuner selects the desired signal and, by the heterodyne process, converts it to an i.f. signal. Just as in a sound receiver, the video i.f. signal must now be passed through an i.f. amplifier to a demodulator (detector). We shall study the operation of both these sections of a TV receiver in this Lesson, starting with the video i.f. amplifier.

There are three things the video i.f. amplifier must do:

1. It must amplify the video i.f. signal. Most of the gain of a TV receiver is obtained from the i.f. amplifier, just as it is in sound receivers. Naturally, this amplification must be obtained over the band width that is desired. This presents quite a problem at the TV frequencies.

2. It must provide sufficient adjacent-channel selectivity. As we shall see later, it is not easy to get the response curve as sharp as is desired if we use the tuning methods with which we are familiar, because we have to use such low Q values to get the desired band width. In fact, it is necessary to use traps to get the selectivity needed.

3. It must get rid of the sound signal if the sound is not supposed to go through the video i.f. amplifier.

Sound and Picture Carriers. The problem of the sound signal brings up the important point that we have two separate and distinct signals for each television program. The video signal is an amplitude modulation on one carrier, and the accompanying sound signal is a frequency modulation on an entirely separate carrier. Both signal frequencies for a particular station are located within the "channel" assigned to that station, and, as shown in Fig. 1, the carrier frequencies are 4.5 mc. apart. This figure shows the arrangement of the signals for all TV stations.

As you can see from this illustration, the transmitted picture carrier is 1.25 mc. from the lower edge of the channel, and the sound carrier is 4.5 mc. higher in frequency, leaving about .25 mc. between the sound carrier and the upper end of the channel as a "guard" band to reduce interference with the channel next above.

In the converter, the local oscillator beats with both the sound and the video carriers and produces two entirely separate i.f. signals. Since the local oscillator frequency is usually above the incoming signal frequencies, the normal arrangement of beating produces a picture or video i.f. carrier that has a *higher* frequency than the sound carrier—just the opposite of their relationship when they are transmitted. Channel 2, for example, extends from 54 to 60 mc. The picture carrier at the transmitter is 55.25 mc., and the sound carrier is 59.75 mc. (4.5 mc. higher). Let's say it is picked up by a receiver that has an i.f. range of about 21-26 mc., the oscillator of which is set at, say, 81 mc. for reception of this band. The video i.f. carrier in this receiver is then 25.75 mc. (81−55.25). The sound carrier frequency is 21.5 mc. (81−59.75). Thus, the heterodyning process changes the positions of the frequencies—the one that was higher in the transmitted signal produces the lower i.f. signal.

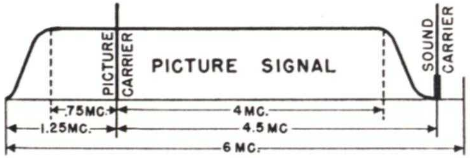


FIG. 1. This illustration shows the relative positions of the picture carrier and the sound carrier within a 6-mc. television channel. The two carriers are in these relative positions in all channels.

Since we have two entirely separate and distinct i.f. carriers at the output of the converter, it is possible to treat them as independent signals. That is just what is done in many television receivers. The two i.f. carriers are separated right at the output of the converter, from which point the sound signal is fed directly to the sound i.f. amplifier and the video signal is fed to the video i.f. amplifier.

In other receivers, the sound signal may accompany the video signal through one or two of the video i.f. stages. The purpose of using this arrangement is to give the sound signal enough preliminary amplification so that one or two less tubes may be used in the sound i.f. amplifier. When the sound signal is finally separated from the video amplifier, the following video stages must reject the sound signal as much as possible. (This is also necessary in sets in which the sound is not deliberately applied to the video i.f. amplifier.) Unless the sound i.f. signal is rejected before both signals can get to the video detector, the two carrier frequencies will beat against each other to produce a 4.5-mc. signal. This 4.5-mc. beat signal will produce an undesirable fine overall dot or grain pattern in the picture that will make it impossible to get the maximum of picture detail. Also, cross-modulation products may produce sound "bars" across the picture. To prevent such effects from occurring, receivers that have a separate sound i.f. amplifier that is tuned 4.5 mc. lower than the video i.f. use sound-rejection traps in the video i.f. amplifier beyond the point where the sound signal is taken off.

Not all sets use this kind of sound i.f. amplifier, however. Several use a system known as intermodulation for producing the sound signal. In this system (which is used chiefly because a few less tubes are needed in it than are needed in other systems), both the sound and the video signals are allowed to pass through the video i.f. amplifier and into the video detector. In the detector, the 4.5-mc. beat mentioned above is produced. This 4.5-mc. signal constitutes an i.f. carrier, frequency modulated by both the amplitude modulation of the picture and the frequency modulation of the sound.

To separate the sound from the picture signal, the modulated 4.5-mc. signal is passed through a limiter, which wipes out the amplitude variations, leaving the carrier frequency modulated by the sound. This signal is then fed into a discriminator, which demodulates it and so furnishes the desired sound signal to the audio amplifier.

Traps are used in the video amplifier to remove the 4.5-mc. beat signal from the picture signal. Traps are also used in the video i.f. to reduce the sound carrier so that it will be easier to separate the sound and picture signals after the video detector.

For now, let's ignore the problems of the sound signal (which we shall study in another Lesson) and consider the video i.f. signal by itself. Basically, the video i.f. signal is an i.f. carrier that is amplitude-modulated by frequencies ranging from about 10 cycles to about 4 mc. In this modulation are both the picture signal and the synchronizing impulses from the transmitter. If the set is to have high definition, the video i.f. must be capable of passing all these frequencies—in other words, it must pass a band of signals about 4 mc. wide. (In sets that use a 7-inch picture tube, extremely high definition is not an absolute requirement, because a watcher is not able to see fine detail in a small picture at normal viewing distances. For this reason, some of these sets have band widths of only about 3 mc.)

As you will recall, amplitude modulation produces side bands on either side of the carrier. If we use a 4-mc. modulation, therefore, we ought to need a band width of 8 mc. Obviously, it is desirable to avoid using such a band width, because it would be very difficult to cover at the i.f. frequencies: we would have to use circuits that were very low in Q—so low, in fact, that we would get very little gain from the i.f. amplifier. Let's see how we are able to avoid using an 8-mc. band.

VESTIGIAL SIDE-BANDS

When a signal is amplitude modulated, the carrier frequency is mixed with the modulating frequency in such a manner that a sum frequency and a difference frequency are produced for each frequency in the modulating signal. Let's suppose, for example, that we have a carrier of 100 mc. and that we are using a 2-mc. modulating signal. Two side frequencies will then exist, one on either side of the carrier: one will be 102 mc. (100 mc. plus 2 mc.), and the other will be 98 mc. (100 mc. minus 2 mc.). Similarly, other modulating frequencies will produce signals on either side of the carrier.

Half of the modulating energy is used to produce each of these side frequencies: that is, one-half of the modulating energy is in the upper side band, and one-half is in the lower. The modulation in each side band is identical with that in the other; if we cut off one of the side bands, therefore, the remaining one will contain all the information that was in the original modulating signal. However, we shall lose half of our power in the process. This loss of power will produce some amplitude distortion; more important, the loss will reduce the signal strength and hence cut down on the reception range.

To avoid this loss of power, it is common to use double side-band modulation in all cases where it can be used. However, if there is a wide band of signals to be passed, as in television, or if the spectrum is very crowded by signals, as in certain commercial services, it is standard practice to eliminate one of the side bands (it doesn't matter which one) and to supply more energy at the transmitter to make up for the loss of signal. At the receiver, the process of demodulation will reconstruct the modulation signal from the remaining side band and the carrier.

In television, however, there are two reasons why we do not completely suppress all of the side band we are trying to get rid of. One is that we should have to use extremely sharp filter circuits in the transmitter. Remember, we must not get rid of the carrier—it is vital that the carrier be transmitted so that we can regain our desired modulation. Therefore, if we were going to remove one side band completely, our filter would have to remove frequencies within about 10 cycles of the carrier frequency but not cut into the carrier or the desired side band.

It is very difficult to make a filter that will cut off as sharply as this. Instead of attempting to do so, we use a filter that cuts off more gradually, thus taking out most but not all of the undesired side band. This is called partial suppression, since some of the undesired side band is left intact.

Phase Shift. At the receiver, there is another reason for not cutting off the frequencies too sharply. When we feed a double side-band signal through a resonant circuit, the carrier or resonant frequency undergoes no phase shift, but frequencies above and below the carrier do: frequencies on one side of resonance are forced to lead the carrier frequency, and those on the other side are forced to lag the carrier. The phase shift undergone by the side-band frequencies increases rapidly with their displacement from the carrier, reaching 90° at frequencies very close to the carrier. The phase shift of the frequencies displaced farther from the carrier remains relatively constant at about 90°.

These phase shifts are unimportant when we have both side bands, because they cancel in the process of detection. When we suppress one side band, however, all the remaining side-band frequencies are on one side of the carrier; as a result, the phase shift they undergo will not be automatically cancelled in the detector.

As you will learn later, the problem of phase shift is particularly important in television, especially at the lower modulation frequencies. Therefore, it is a good idea to let the lower frequencies in the undesired side band stay in the transmitted signal, because their phase shifts will cancel those of the equivalent frequencies in the desired side band when detection occurs. The shift in the higher frequencies will still be present, but that shift is not as troublesome.

For these reasons, the filters at the transmitter are designed to pass all frequencies in the *undesired* side band out to about .75 megacycles from the carrier, then to introduce a gradual suppression so that the undesired band is completely cut off at about 1.25 megacycles from the picture carrier. This is the relationship shown in Fig. 1, where the lower side band is the one being suppressed.

Effectively, therefore, we have double side-band transmission for frequencies within the range from about 10 cycles out to .75 mc. The amplitude of the lower side band is then systematically reduced until it reaches zero at 1.25 mc., beyond which point we have only the upper side-band frequencies. This system has two advantages: it eliminates the phase shift of the lower frequencies, and it makes it possible to use a relatively simple filter.

Since a part (a "vestige") of one side band and all of the other are transmitted, this system is known as "vestigial" side-band transmission. If we want to pass the signal in the form shown in Fig. 1, we need to pass a band only about 5 mc. wide instead of having to pass the 8-mc. band that would be needed if double side-band transmission were used. However, as we shall show, it's possible to get along with a pass band only about 4 mc. wide.

I.F. RESPONSE

We said earlier that transmitting two side bands gives double the energy that single side-band transmission offers. Since vestigial side-band transmission is actually double side-band transmission as far as the low frequencies are concerned, the detector output for low frequencies (up to .75 mc.) will be twice what it is for the higher frequencies, as shown in Fig. 2, if the transmitted signal is not modified before it is applied to the detector. The output for frequencies between .75 mc. and 1.25 mc. will gradually roll off as the one side band is suppressed; at frequencies above 1.25 mc., the detector output will remain constant out to the modulation limits around 4 mc.

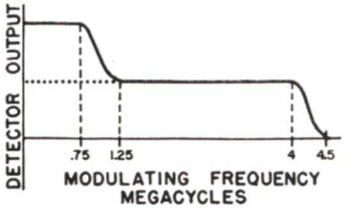


FIG. 2. The heavy line shows what the detector output would be if all the transmitted TV signal were applied to the detector. The output would be high at the low frequencies because part of the lower side band is transmitted.

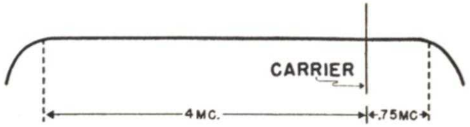


FIG. 3. A receiver would have to have an i.f. pass band of the width shown here to pass both the desired side band and the vestigial side band.

This increased detector output at the lower frequencies can be permitted; we can correct for it easily by making the low-frequency response of the following video amplifier fall off so that the over-all response will be flat. However, if we were to pass all the vestigial side band as well as all the desired one, we would need an i.f. pass band like that shown in Fig. 3. In other words, we would need a pass band of about 4.75 to 5 mc. (Remember that the "pass band" lies between the points having 70% of the maximum response, not between the points of zero response.)

Therefore, what is generally done is to arrange the video i.f. response so that the carrier frequency is on the slope of the response, as shown in Fig. 4. (Remember that the heterodyne process inverts the frequencies so that the upper side band in the transmitted signal is lower in frequency than the carrier in the i.f. stages.) If the carrier frequency is at a point where the i.f. response is 50% of the maximum response, and the curve A-B-C has the proper slope, the vestigial side band and the corresponding frequencies in the desired side band will be gradually attenuated. As a result of this attenuation, the low-frequency response will be no greater than the high-frequency response if the curve is properly shaped, even though two side bands furnish the low frequencies. The detector output will therefore be flat.

When this system is used, the increased attenuation of the lower side band means that the frequency at which phase shift will be troublesome will be somewhat lower than it would be if the whole vestigial side band were passed. However, it will still be high enough to make correction of the phase shift a relatively simple matter.

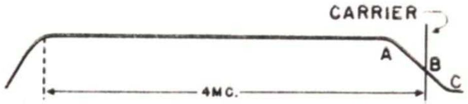


FIG. 4. Arranging the i.f. response so that the picture carrier falls at the point shown makes it possible to have a flat detector output and to pass all the desired side band with an i.f. band width of 4 mc.

The advantage of this system, aside from the fact that it can be made to give a flat detector output, is that it permits all the frequencies in the upper side band to be passed with an i.f. band width of 4 mc. (between the points at which the output is at least 70% of the maximum).

If the carrier is placed nearer point A on the A-B-C section of the curve in Fig. 4, the low-frequency response will be higher than it would be with the carrier at point B. Some manufacturers secure greater low-frequency response in this way, putting the carrier at a point where the response is 60% or 70% of the maximum instead of at the 50% point.

The "standard" i.f. response shown in Fig. 4 is also subject to other variations. It is quite possible that there may be peaks in the response to compensate for deficiencies in the input tuner or in the video amplifier. Furthermore, in those sections of the video i.f. amplifier that pass the sound carrier as well, the response must be broad enough to permit the sound carrier to go through these stages. In a set in which the intermodulation system is used, the sound carrier is passed through the entire i.f. amplifier; the band width of this amplifier must therefore be greater than 4 mc. in such a set.

VIDEO I.F. VALUES

There are several conflicting factors that engineers have to consider when they select the video i.f. carrier frequency.

The range within which the i.f. frequency may lie is limited at its upper end by the fact that the i.f. must be below the lowest channel that it is desired to tune to. The wide range of modulating frequencies used makes it impractical to have the i.f. too low. As a matter of fact, the wide frequency range makes it impossible to get much gain at a low carrier frequency, because, as you know, the band width of an i.f. stage is approximately equal to the quotient of the resonant frequency divided by the Q in the circuit. If the resonant frequency is low, the Q must also be low to create the band width necessary in a video i.f. amplifier; and a circuit having low Q has low gain also.

There is one other important factor that affects the choice of the i.f. frequency. The i.f. band should not be in a channel that is used extensively in other radio communications fields; if it is, undesired station signals at any of the i.f. frequencies may ride through the input tuner and cause serious interference.

In early television receivers, low i.f. values were used. The video i.f. carrier was about 13 mc. and the sound i.f. carrier about 8.5 mc. These values were used because it was extremely difficult to obtain high gain at higher frequencies at that time. Recently, however, wiring techniques have been refined. In addition, miniature tubes have been brought out that have very high mutual conductances and relatively low interelectrode capacities; these permit us to secure better L/C ratios and hence higher load impedances for the same Q. All these improvements combine to make it possible to obtain reasonable gain at high frequencies.

In the recent past, many manufacturers settled on frequencies somewhere in the range between 21 and 26 mc. for the i.f. pass band. However, image interference difficulties have produced a movement at the present time toward even higher frequencies, because the use of these helps the preselector in its duty of getting rid of image frequencies. (You will recall that the image frequency is twice the i.f. above the desired signal. The higher the i.f., the further removed is the image frequency from the desired one, and hence the easier it is for the preselector to tune it out.)

Some manufacturers are now using i.f. frequencies in the region around 40 mc. In the future, more manufacturers may use i.f. frequencies this high, or input tuners may be redesigned so that the image problem can be solved with the present 21-26 mc. frequency range.

Getting the Desired Response

A little consideration will show you that it is not practical to try to get the "standard" response shown in Fig. 4 with just a parallel resonant circuit. First of all, the band width is so great that even a heavily loaded single-tuned circuit could not give the desired response. Furthermore, we must use more parts than a single circuit contains to get the rather peculiarly shaped edges of the pass band shown in Fig. 4.

Let's learn a little more about the problem and then see what kinds of circuits can be used to give us the response we want.

PARALLEL RESONANT CIRCUIT RESPONSE

By itself, a parallel-resonant circuit like the one shown in Fig. 5A will have a response something like curve 1 in Fig. 5B. The height of the peak in the response of this circuit depends on the Q of the circuit: if the Q is high, the peak will be too. If we load this circuit by connecting resistances in parallel with it, we can reduce the peak and at the same time broaden the pass band, producing a response curve that is much like curve 2. You will recall that the pass band is considered to be between those points at which the output is about 70% of the peak value. Thus, for response curve 1 in Fig. 5B, the pass band has a width approximately equal to the frequency range between points A-A, whereas the band for curve 2 has broadened out to the frequency range between the points B-B.

As we increase the loading of the circuit, the peak becomes lower, and the pass band becomes wider. To produce a band width of 4 mc. with a video i.f. of about 25 mc. (which is what most TV sets have to do), the Q of a single tuned circuit would have to be about 6. Rather heavy loading would be needed to make the circuit have so low a Q.

Although it is possible to load a single circuit to this extent and thus get a broad-band response, the gain would be very low, and the curve would not have as flat a top as we want. If we were to add more stages in cascade to increase the gain, the response would become more peaked again, and the pass band would become narrower. If, for example, curve 1 in Fig. 6 represents the response of a single stage, curve 2 shows the response that two identical stages would have in cascade, and curve 3 shows the response that three stages would have. Obviously, each of these curves is far from having the ideal shape shown in Fig. 4, so there is no combination of parallel resonant circuits all tuned to the same frequency that will give us the response we want.

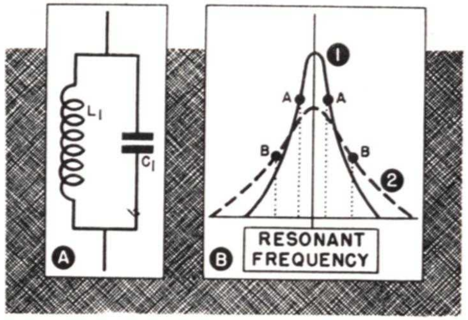


FIG. 5. Curve 1 in part B of this illustration represents the normal response of the parallel resonant circuit in part A. Curve 2 shows the effect produced on the response by connecting resistors in parallel with the circuit.

However, it is possible to get the response needed if we stagger-tune parallel resonant circuits. In fact, that is the most commonly used way of producing the desired i.f. response.

STAGGER TUNING

In a stagger-tuned system, a broad pass band and high gain are secured by connecting several resonant circuits in cascade and tuning each circuit to a different frequency. Fig. 7 shows an example of the response that can be secured in this way. If the various tuned stages in the i.f. amplifier are each tuned to different frequencies as indicated in this figure by the curves a, b, c, d, and e, and each stage has the response characteristic indicated (this can be obtained by using the right coupling and loading), the over-all i.f. response characteristic will have the shape shown by the dotted line.

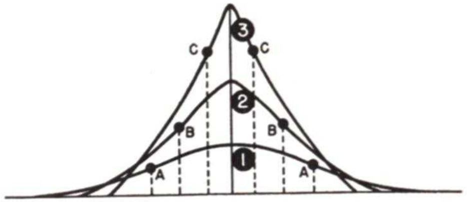


FIG. 6. These curves show the effect of connecting parallel resonant circuits in cascade. Curve 1 shows the response of a single stage, curve 2 shows that of two stages in cascade, and curve 3 shows that of three stages in cascade.

This system is called stagger tuning because the various i.f. stages are not all tuned to the same frequency but to frequencies that are staggered within the pass band desired. Of course, careful engineering is necessary to get the original responses of the several stages to fit together properly, and it is important to choose the proper loading. Some stages have rather high Q values and hence high gain; others (such as the one having the response shown by curve C) have very low Q and low gain but are nevertheless important because they fill in the over-all response to produce the desired flat-topped characteristic.

This is one of the more popular i.f. systems and offers several advantages over other types. First, since each stage is tuned to a different frequency, such an amplifier system is remarkably free from oscillation. This means that very little shielding is required. Second, since the over-all response characteristic depends upon the combined effects of several stages, it is relatively easy to vary the over-all response characteristic to obtain the best possible response by varying the responses of individual stages.

Another important advantage of this kind of i.f. section is that it can be aligned by using an ordinary signal generator and a multimeter. This is possible because it is necessary only to peak the various i.f. stages at their particular frequencies, which are given in the manufacturer's instructions, to get the desired over-all response characteristic.

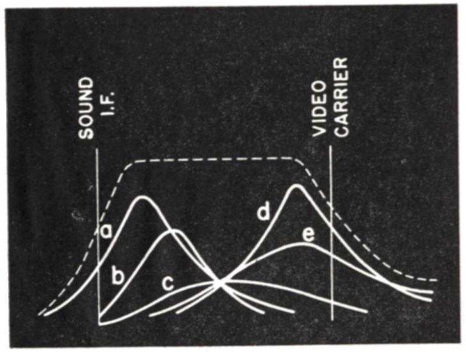


FIG. 7. If the stages in a five-stage i.f. amplifier are stagger-tuned and made to have the responses shown by the solid lines, the overall response of the amplifier will have the form shown by the dashed-line curve.

There are some disadvantages to the stagger-tuning system, but they are far out-weighed by the advantages. One disadvantage is that the over-all i.f. response will change as the gain of the individual stages is changed. As an example, if the gain of one or more of the i.f. stages should be changed by varying the bias on the stage (either by means of a.g.c. voltage or by means of the contrast control), the over-all response characteristic may change. Such a bias change will change the plate resistance and thus the loading; it may also detune the circuit, because the input capacity of a tube changes with its mu. Of course, the change in capacity will be small if pentode tubes are used. The change in loading will be relatively small, also, because the loading in a stage generally depends more on the loading resistors used than on the plate resistance of the tube in the stage. Nevertheless, it is necessary to align these circuits with the recommended bias applied, and some variations in response can be expected when any change occurs in the bias.

A practical example of the basic circuit that is used in a stagger-tuned video i.f. amplifier is shown in Fig. 8. Here we show part of one i.f. amplifier stage. The tuned circuit is made up of coil L_1, and the capacity is represented by C_3 (which is not a condenser but is a capacity that comprises the distributed capacity of the coil, the tube interelectrode capacities, and the capacities between the various components and the chassis). The circuit can be tuned to resonance by adjusting the powdered-iron core of L_1 and so changing the inductance of the coil.

The load for the VT_1 stage consists principally of the grid resistor R_1, which also serves as the d.c. grid return path for the VT_2 stage. The ohmic value of this resistor may be different in each stage, since different amounts of loading may be required for each.

In some receivers, the coil is wound of resistance wire, an arrangement that puts resistance directly in the resonant circuit. Just a few ohms here can be as effective as several thousand in the position occupied by R_1. If this method of loading is used, each coil must be specifically designed for the particular response wanted; therefore, it is not as easy to change the response of this circuit as it is to change that of the circuit in which the grid resistor acts as the load. (In the latter circuit, changing the resistance of the grid resistor will change the response.) However, circuit requirements may make the resistive coil winding desirable. You should not, therefore, assume that there is no loading if R_1 has a high resistance.

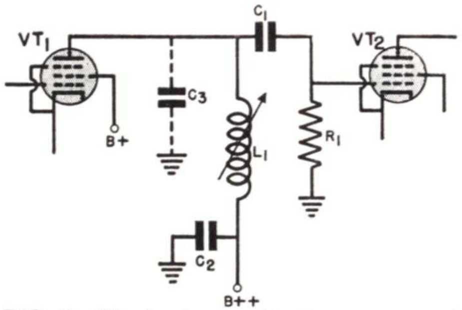


FIG. 8. The basic circuit of one stage of a stagger-tuned video i.f. amplifier. The other stages are similar.

The response of a stagger-tuned i.f. section is much more like that we want, but, as we shall show in a moment, it is necessary to add wave traps to the circuit to produce the exact response needed.

BAND-PASS COUPLING

A basic band-pass coupling circuit used in TV sets is shown in Fig. 9A. It is much like those used in sound i.f. amplifiers except that the coupling is far tighter. As you have learned, the response of such a circuit depends upon the coupling. Thus, curve 1 of Fig. 9B shows the over-all response that might be obtained with loose coupling. Curve 2 shows the effect of somewhat closer coupling—as the coupling is increased, the output will increase (up to a certain maximum) and the over-all response characteristic will tend to broaden.

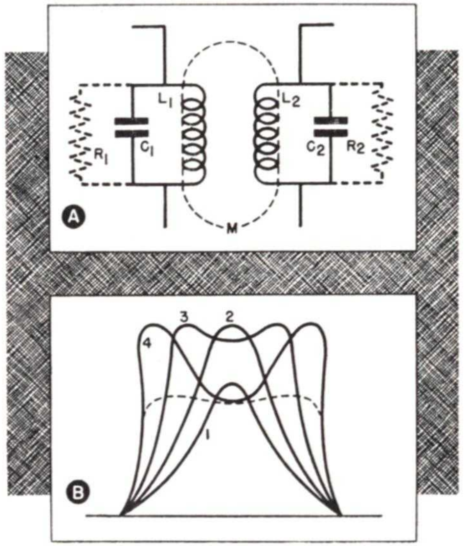


FIG. 9. Part B of this figure shows the effect of varying the coupling in the band-pass circuit shown in Part A. Curve 1 shows the response with loose coupling, curve 4 shows the response with extremely tight coupling, and the others show the response with intermediate couplings. The dashed-line curve shows the response that can be gotten by modifying curve 4 by adding resistance to each tuned circuit.

With close coupling (or "tight" coupling), we may get the over-all response characteristic shown by curve 3. This has a double-peak response, and its over-all band width is much greater.

Finally, at an extreme of coupling, we can get the very wide double-peaked response of curve 4, which has a sharp valley in the center. By loading the resonant circuits (using resistors across both the primary and secondary windings), the peaks are reduced to the values shown by the dotted lines, thus producing an over-all response that is relatively flat.

Such band-pass circuits may be connected in cascade to get greater gain. If they are overcoupled (curve 4), they may be tuned to the same frequency; if the coupling is less extreme, they may be stagger-tuned just as parallel resonant circuits are.

WAVE TRAPS

By themselves, neither the stagger-tuned parallel-resonant circuits nor the overcoupled band-pass circuits will give sufficient adjacent-channel selectivity and reject the accompanying sound signal if such rejection is wanted. The trouble is that the slopes of the "skirts" of the response are bound to be too gradual when the pass band is so broad. Fig. 10 compares the response of a stagger-tuned system (dotted lines) to the response that a receiver must have (solid lines) if the sound signal is to be led to a sound i.f. amplifier right after the

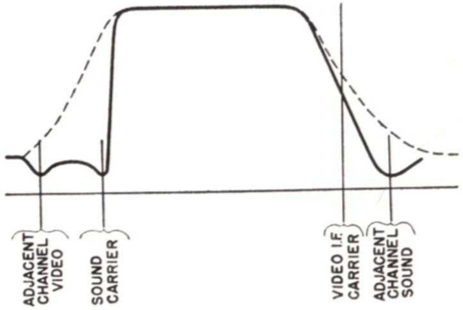


FIG. 10. As you can see, the response of a stagger-tuned system (shown by the dashed lines) is so broad that it accepts part of each adjacent channel.

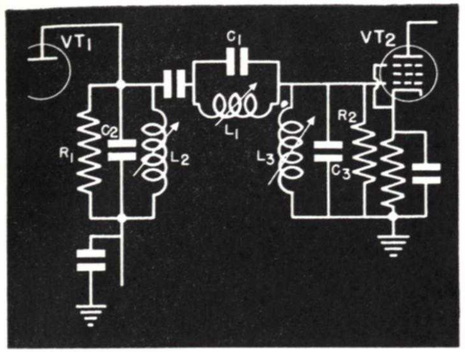


FIG. 11. The parallel resonant circuit L_1-C_1 is called a series trap because it is placed in series with the signal path.

converter, and the adjacent carriers are to be rejected.

The steep skirts needed to produce the latter response can be obtained by using trap circuits—high-Q resonant circuits that are tuned to the undesired frequencies. Any of the traps to be described may be used either as a sound trap or as an adjacent-channel trap. Therefore, we shall first discuss only the electrical characteristics of the trap, remembering that it might be used in any one of several ways: as an adjacent channel trap (either above or below the i.f.), as a sound i.f. trap, or simply as a "shaping" trap, tuned so as to aid in shaping the over-all response curve. We shall cover these applications later.

Series Traps. The series trap is shown in Fig. 11. Basically, it consists of a parallel-resonant circuit, L_1-C_1, that is placed in series between two i.f. tubes and is tuned to the frequency to be rejected. When a signal having the frequency to which the trap is tuned is applied to this circuit, the impedance offered by L_1-C_1 is so high in comparison to the grid-to-ground impedance of VT_2 that the trap absorbs most of the undesired signal voltage. (It acts as a voltage divider with the grid impedance.) As a result, only a negligible voltage at the trap frequency is applied to the grid of the next stage.

Most trap circuits are very sharply tuned, since they are designed to reject either one particular frequency or, at the most, a very narrow band of frequencies. For this reason, L_1-C_1 has a high Q and is not shunted with a resistance.

At all other frequencies, of course, the tuned circuit (L_1-C_1) will offer very low impedance in comparison to the grid circuit and will allow the signals to pass and be applied to the grid of the next stage.

Absorption Traps. Another popular kind of trap circuit is the absorption trap (L_1-C_1) shown in Fig. 12. This tuned circuit may be inductively coupled to a tuned circuit in the amplifier, as shown in Fig. 12A, or may be capacitively coupled, as shown in Fig. 12B. In either case, the operation is the same. At the resonant frequency of the trap circuit, it acts as a heavy load on the amplifier, absorbing the signal.

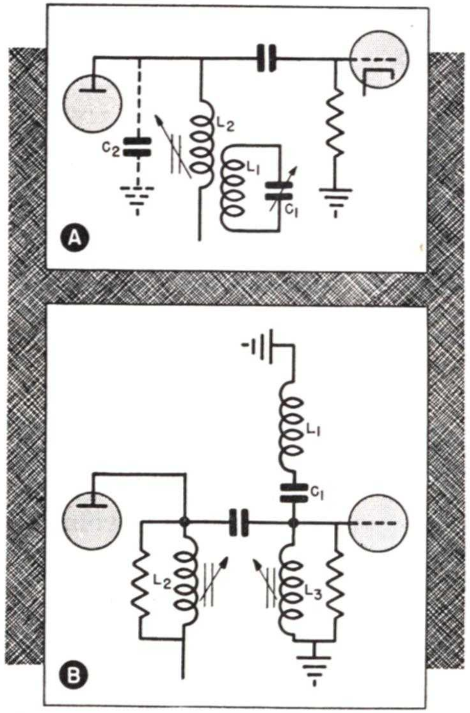


FIG. 12. Two forms of absorption trap. The one in part A of this figure is inductively coupled to the circuit; the one in part B is capacitively coupled to it.

For example, at the resonant frequency of the tank circuit L_1-C_1 in Fig. 12A, a high circulating current develops in the trap. This effectively loads the tuned circuit L_2-C_2, causing it to act as a load having an extremely low Q. As a result, the stage has practically no gain at the undesired frequency. The series trap L_1-C_1 in Fig. 12B is practically a short circuit across the load for the frequency to which it is resonant, so it, too, reduces the stage gain at this frequency.

The trap circuit may be tuned either by a variable inductance, as shown in Fig. 11, or by a variable trimmer condenser, as shown in Fig. 12A.

Cathode Traps. Occasionally a tuned trap circuit is inserted in the cathode circuit of an amplifier stage to provide degeneration at the trap frequency and thus to reduce the gain of the stage, effectively rejecting the signal. This arrangement is illustrated in Fig. 13.

The trap circuit consists of L_1 and C_1. At its resonant frequency, this circuit has a very high impedance; therefore, a very high voltage will be developed across it at this frequency.

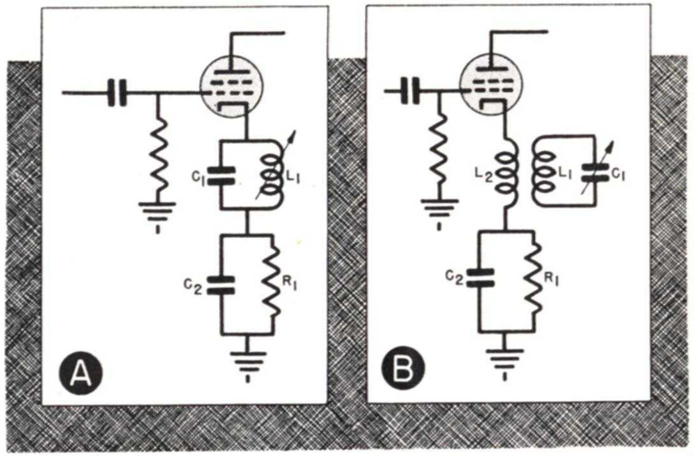


FIG. 13. This shows two ways in which a trap may be used in the cathode circuit of an amplifier stage. In each case, the trap creates degeneration at its resonant frequency and thus effectively rejects a signal of that frequency.

The voltage developed across the cathode trap at its resonant frequency is applied to the grid-cathode circuit in such a way that it is 180° out of phase with any applied signal of the same frequency; thus, for this applied signal, degeneration is produced, and little or no gain is obtained from the stage. At other frequencies, the tank is non-resonant and produces little degeneration.

A cathode trap is not always connected to the cathode circuit directly. Sometimes it is coupled to a coil in the cathode circuit, as shown in Fig. 13B; its effect when it is used in this way is the same as that of the trap in Fig. 13A.

TRAP APPLICATIONS

As many as four or five individual traps may be used in a particular i.f. amplifier—perhaps as many as two traps in a single stage. Several traps may be tuned to the same frequency to get better rejection of signals at that frequency.

When you are aligning the i.f. stages in a television receiver, you must adjust the trap circuits as well as the individual tuned circuits. In fact, in certain television sets that have broad-band stages, the trap circuits may be the only circuits you can adjust.

Now that we have discussed the various trap circuits as far as electrical characteristics are concerned, let us see how the trap circuits are used. There are two primary uses to which trap circuits are put: sound i.f. traps and adjacent-channel traps.

Sound Traps. Sound-trap circuits are placed in the i.f. amplifier to reject the sound i.f. signal so as to prevent this signal from beating with the video i.f. in the second detector stage. Therefore, these traps are tuned to the sound i.f. and have high Q values. Also, the sound trap may serve as the source of signal for the sound i.f. section, as we will show.

Adjacent-Channel Traps. If you look back at Fig. 10, you will see that the skirts of the normal response curve (dotted lines) of a channel are broad enough to permit the sound carrier of one adjacent channel and the picture carrier of the other to be passed. By using traps tuned to these frequencies, however, we can cause dips in the response curve at these unwanted carrier frequencies and thus get the final over-all response curve shown by the solid curve in Fig. 10. Notice that the response to the signals produced by the adjacent channel carriers is now so low that they cannot cause interference. A dip or "notch" in the response curve is put in at the proper frequency by each of the traps.

The solid-line curve in Fig. 10 represents the response we want for a receiver in which a separate sound i.f. channel is used. Therefore, there is a notch caused by a sound i.f. trap in this curve. The curve for a set in which the sound carrier is supposed to go through the video i.f. would not have as deep a notch at the sound i.f. frequency. A trap would probably still be used to reduce the response at this frequency, however, to reduce the strength of the 4.5-mc. beat to such a level that the traps in the video stages could remove it.

Now that we have studied the basic i.f. circuits, let's go on to complete amplifiers.

Typical Video I.F. Amplifiers

Since the video i.f. amplifier section of the television receiver contributes most of the gain for the video channel, it is customary to use tubes that give as much gain as can be secured. Tubes with a high transconductance (Gm) are used, because the gain is directly proportional to the Gm of the tube in a pentode amplifier. The miniature tubes used in modern receivers generally have low interelectrode capacities as well.

Since it is customary to vary the gain of the video i.f. amplifier either by a contrast control or by an a.g.c. circuit, tubes with remote cut-off or variable-mu characteristics are needed. Instead, however, tubes that normally have sharp cut-offs are used, because only the sharp cut-off types can be made to have very high mutual conductance. The variable-mu characteristic causes a loss in Gm because not all the grid is usable at any one voltage.

Fortunately, a sharp cut-off pentode tube can be made to act as if it had something of a remote cut-off characteristic if a series resistor is used in its screen-grid circuit. If the proper resistor is used, the d.c. voltage on the screen grid will vary with the bias on the control grid in such a way that, as the bias is increased, the screen current will drop, allowing the screen voltage to rise and partly counteract the bias change. This arrangement makes bias control reasonably effective even on sharp cut-off tubes.

Number of Stages. The number of i.f. stages needed depends on whether the receiver is intended only for areas having high signal levels or is designed for "fringe" areas where weaker signals are the rule. It takes a signal voltage of 40 to 60 volts to operate the average picture tube. The usual video amplifier (the section between the video detector and the picture tube) has a gain somewhere between 20 and 50, so the detector output must be from 1 to 2 volts to make the video amplifier output large enough to operate the picture tube.

The weakest input signal from which the set can produce a picture must be at least slightly above the noise level, which ranges from 50 to 100 microvolts on the average. Hence, a signal about 100 microvolts is the weakest that can be successfully applied to a set; reception is impossible in an area in which the signal level is lower than this, unless the noise level is exceptionally low. In strong signal areas, the signal strength may be 5000 microvolts or more.

Let's assume we are studying a set that is designed to produce a usable picture from a 100-microvolt signal. Let's say the input tuner has an overall (r.f. plus conversion) gain of 10. The tuner output from a 100-microvolt signal will then be 1000 microvolts. The i.f. amplifier must raise this to perhaps 2,000,000 microvolts (2 volts), so the gain needed may be 2,000,000 ÷ 1000, or 2000. Three stages with gains of about 13 each would give more than this if each amplified all frequencies equally well. However, with stagger tuning, not all stages have the same gain at any one frequency in the pass band. One stage may have a gain of 30 to 50 for a particular frequency, but the other stages may have very low gains for that frequency and high ones for others. As a result, it is usually necessary to have four i.f. stages to produce sufficient amplification of all frequencies in a 100-microvolt signal.

If the set is intended for use in an area where the signals are always considerably stronger than 100 microvolts, or if its pass band is restricted enough to permit the gain of each stage to be at least relatively high for all frequencies, only three video i.f. stages may be necessary.

Now let's turn to typical video i.f. amplifiers. You can expect to find either band-pass or stagger tuning used as the basic method of getting a pass band of sufficient width; stagger tuning is used in by far the majority of circuits. A number of traps will be found, arranged to cut out adjacent channel signals sharply and usually to cut down or to eliminate the accompanying sound signal.

The couplings between stages may be transformer, complex, or impedance coupling, or a combination of these. Let's study examples of each in video i.f. circuits.

TRANSFORMER COUPLING

Fig. 14 shows two stages of a video i.f. amplifier that uses transformer coupling. A number of signals are present in the plate circuit of the mixer stage VT_1, including the video and sound i.f.'s. These two signals are selected by tuned circuit L_1-C_1, which is broadly tuned and low in Q. The selected signals are inductively transferred to the secondary circuit L_2-C_3, which, in turn, is loaded by resistor R_2 so that it has a broadly tuned characteristic. The signal is coupled to the grid of the first amplifier through condenser C_4; resistor R_3 serves as the grid return resistor for this stage and may be connected to the a.g.c. bias voltage source.

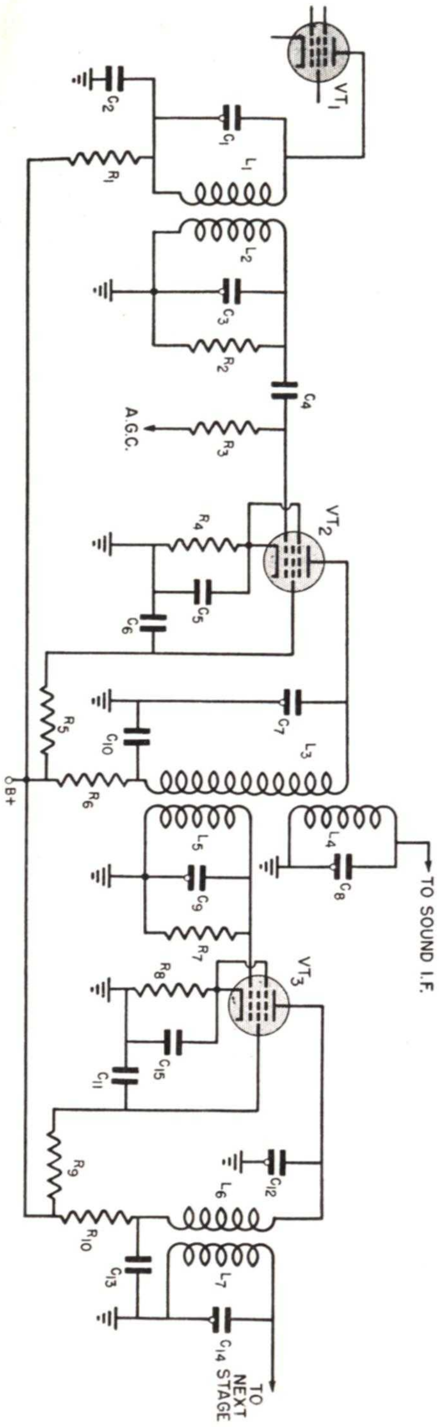


FIG. 14. This is part of the schematic diagram of the video i.f. amplifier of an actual set in which transformer coupling is used between the stages.

The R_1-C_2 combination serves as the decoupling filter for the B supply of the mixer stage.

Amplifier tube VT_2 may be either a remote-cut-off tube (since we are applying a variable bias through R_3) or a sharp-cut-off tube that exhibits remote-cut-off characteristics because of the presence of the series screen resistor R_5. Condenser C_6 acts as a screen by-pass condenser. The minimum bias for the stage (to which the a.g.c. voltage is added) is provided by R_4, which is by-passed by condenser C_5 so that there will be no degeneration caused by the presence of an i.f. voltage across R_4.

Tuned circuit L_3-C_7 is in the plate circuit of VT_2; it may be tuned to a different frequency from L_1-C_1 to provide stagger tuning, or it may be tuned to the same frequency if this is a band-pass circuit. Since the schematic will look the same for either case, you will have to consult the service manual on such a set to see which arrangement is being used.

The signal present across L_3-C_7 is coupled both to the trap L_4-C_8, which is tuned to the audio i.f., and to L_5-C_9, which is tuned either to some other frequency within the video pass band or to the same frequency as L_3-C_7. Resistor R_7 loads the L_5-C_9 circuit.

Notice that the sound trap L_4-C_8 serves two purposes. First, it reduces the sound carrier signal strength by absorbing energy and loading the primary. Also, since it has a maximum sound signal across it, the circuit acts as a signal source for the sound i.f. amplifier.

Tube VT_3 operates in much the same manner as tube VT_2. The chief difference is that a.g.c. is not applied to this stage. (This is not a universal practice: a.g.c. may be applied to any or all of the stages in a video i.f. amplifier.)

Tuned circuit L_7-C_{14}, inductively coupled to the plate tuned circuit L_6-C_{12}, is used to supply the signal to the next stage.

We see that the distinguishing feature of a transformer-coupled video i.f. amplifier is the fact that the different stages are inductively coupled—that is, there is actually a primary and a secondary winding on each i.f. "transformer." We make this distinction because the single-tuned circuits used in the impedance-coupled i.f. amplifier are often called "transformers" even though there are no specific primary and secondary circuits.

COMPLEX COUPLING

Fig. 15 shows an example of "complex" coupling. Here, the sound i.f. signal is developed across resonant circuit L_4-C_{17}, which is tuned to the sound carrier. Hence, this circuit acts both as a sound trap and as a coupling method. Notice that here we tap off the sound signal from the mixer plate circuit rather than from the plate circuit of the first video amplifier as we did in Fig. 14.

A tuned circuit consisting of inductances L_1 and L_2 in series, tuned by the distributed capacities in the circuit (including the plate-cathode capacity in the mixer tube) and loaded by resistor R_1 broadly tunes to the video i.f. or to somewhere within the video i.f. pass band. Condenser C_1, which is practically a short circuit as far as r.f. is concerned, acts in conjunction with R_2 as a decoupling network for the B supply voltage to the mixer stage.

Another tuned circuit is made up of L_2, L_3, and the distributed capacities in the circuit, including the grid-

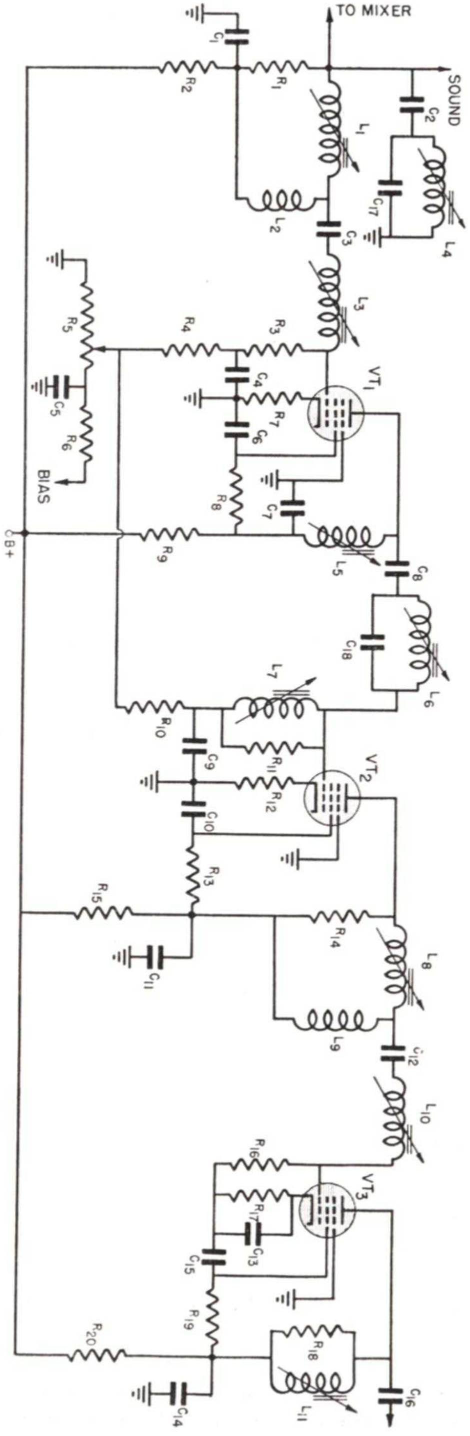


FIG. 15. This figure illustrates the use of complex coupling between the stages of the video i.f. amplifier.

cathode capacity of VT_1 and distributed wiring capacities. Condenser C_3 acts simply as a blocking condenser to prevent the B voltage from being applied to the grid of VT_1.

Notice that both tuned circuits contain L_2; the "primary" consists of L_1-L_2 plus certain capacities, and the "secondary" consists of L_3-L_2 and other capacities. Hence, this is one form of band-pass coupling. However, whether we have a stagger-tuned or a band-pass response depends on the actual coupling. If the inductance of L_2 is quite large, the circuit is probably overcoupled, which means that it has a band-pass response; otherwise, the coupling is low, and stagger tuning can be expected.

You can see one difference between this circuit and the circuit previously described—in the previous circuit, each stage was tuned by variable condensers. Here, we use variable inductances. The inductances can be made variable simply by providing each with a small powdered-iron core rod that can be screwed in or out of the coil. As the core is moved inward, the inductance increases.

Bias is provided for VT_1 and VT_2 by a combination of methods. First, the cathode resistor R_7 provides a fixed minimum bias for VT_1. R_{12} serves the same function for VT_2. An additional bias is supplied from a "bias" source across the R_6-R_5 network through R_4-R_3 to VT_1 and through R_{10}-L_7 to VT_2. The resistor-condenser combination R_4-C_4 serves simply as a decoupling filter and corresponds to the combination R_{10}-C_9 for VT_2.

The bias voltage is provided either from a fixed source (such as a bleeder resistor in the low-voltage power supply) or from a combination of a fixed source and a.g.c. The bias voltage appears across resistor R_5. This resistor is a potentiometer, so any portion of the available bias voltage can be applied to the tubes by setting the position of the slider properly. This arrangement allows the bias of these two stages to be adjusted so that the gain can be controlled. Thus, resistor R_5 serves as an i.f. gain control or a contrast control. As the slider is moved toward the right-hand side of the resistor, the bias voltage will increase, and the gain provided by stages VT_1 and VT_2 will decrease.

Notice that R_7 and R_{12} are not by-passed. By not by-passing these resistors, the designer has introduced a certain amount of degeneration. This tends to stabilize the stages and to make the tube characteristics a less critical factor in the operation of the stages. In other words, if one of the tubes goes bad and is replaced by a tube that is of the same type but has slightly different characteristics, retuning will either not be necessary or not be difficult. Also, because of the "leveling-off" effect of the un-by-passed cathode resistor, the tube replacement will cause no great change of gain as far as the particular stage is concerned.

Screen-grid voltage for VT_1 is provided through R_8; condenser C_6 serves as the screen by-pass. Similar functions are performed for VT_2 by R_{13} and C_{10}, and for VT_3 by R_{19} and C_{15}.

These tubes may be remote-cut-off tubes; alternatively, they may be sharp-cut-off tubes with R_8 and R_{13} chosen so that the tubes exhibit remote-cut-off characteristics.

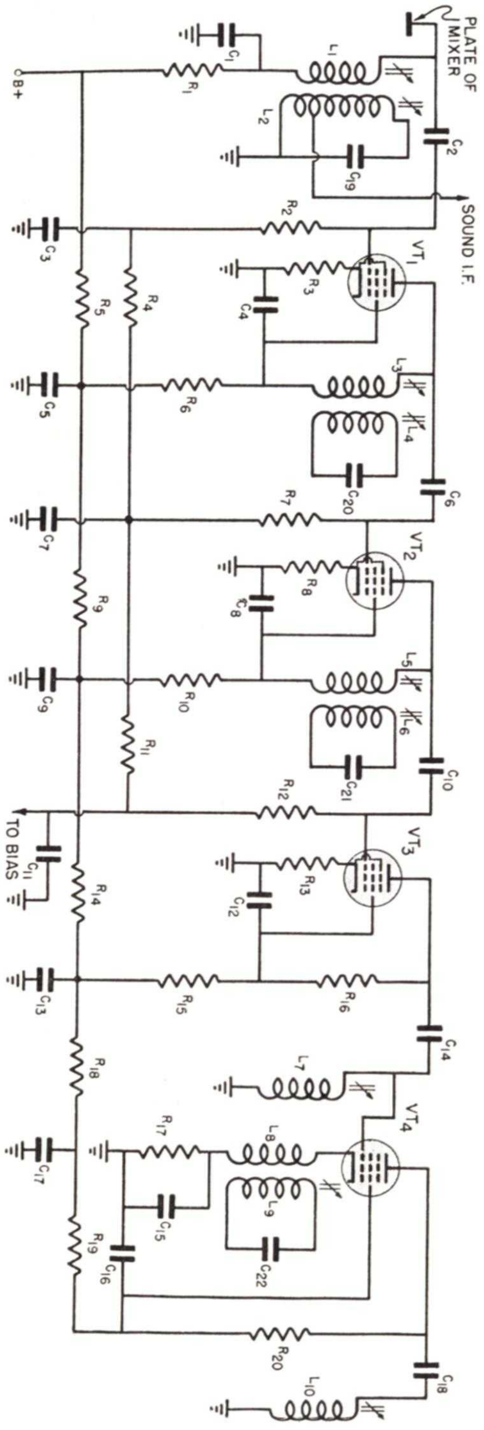
In the plate circuit of VT_1, we have a tuned circuit consisting of variable inductance L_5 plus distributed capacities, including the interelectrode capacities of VT_1. The signal appearing across this circuit is applied through coupling condenser C_8 to a series trap L_6-C_{18} and to a resonant circuit consisting of L_7 and the distributed capacities in the circuit.

The series trap L_6-C_{18} is tuned to the sound i.f. and offers a very high impedance to this frequency; therefore, most of the sound i.f. present across L_5 will be dropped across the trap and not applied to L_7. At frequencies other than the one to which it is resonant, the trap L_6-C_{18} will act simply as either an inductance or a capacity having comparatively low impedance. Thus, the trap will offer little or no opposition as far as the picture i.f. is concerned, so most of the picture i.f. will appear across L_7 and be applied to the grid of the tube. Resistor R_{11} serves as a loading resistor to broaden the response of the L_7 tuned circuit.

The coupling network between VT_2 and VT_3 is quite similar to the coupling network between the plate of the mixer and the grid of VT_1. Therefore, we shall not discuss it in detail.

A variable bias voltage is not applied to VT_3. Because of this fact, the cathode resistor R_{17} is somewhat larger than R_7 or R_{12}. You will recall that R_7 and R_{12} are not by-passed because it is desirable to have a certain amount of degeneration in the VT_1 and VT_2 stages. Because R_{17} has a relatively high resistance, however, too much degeneration would be produced if it were not by-passed. Therefore, the by-pass condenser C_{13} is used in the cathode circuit of VT_3.

A complex coupling network is not used to couple the plate of VT_3 to the detector stage. Instead, the coupling is furnished by a simple tuned circuit made up of L_{11} and the distributed



capacities in the stage, including the plate-cathode capacity of VT$_3$. This resonant circuit is loaded by R$_{18}$.

IMPEDANCE COUPLING

One of the most popular types of i.f. amplifier circuits is shown in Fig. 16. A four-stage amplifier is shown here, but the same type of circuit may be used as a three-stage amplifier. This circuit is a typical stagger-tuned, impedance-coupled i.f. amplifier. It provides good gain, good band width, and is remarkably free from any tendency to oscillate.

The plate circuit of the mixer stage is tuned by L$_1$ and the distributed capacities in the circuit.

The signal present across L$_1$ is coupled through condenser C$_2$ to the grid of amplifier tube VT$_1$. Resistor R$_2$ serves as a grid d.c. return path. A bias voltage is also applied to the grid of VT$_1$ through R$_2$. Similarly, a bias voltage is also applied to the control grids of VT$_2$ and VT$_3$ through their respective grid resistors—R$_7$ for VT$_2$ and R$_{12}$ for VT$_3$.

A trap circuit consisting of variable inductance L$_2$ and fixed condenser C$_{19}$ is coupled to coil L$_1$ in the plate circuit of the mixer. This absorption trap circuit is tuned to the sound i.f., and a tap is provided on it from which the sound i.f. is obtained.

The tuned circuit acting as the plate load of VT$_1$ consists of inductance coil L$_3$ and the distributed capacities. These distributed capacities include not only the capacities between the wiring and the chassis but also the plate-cathode capacity of VT$_1$ and the grid-cathode capacity of VT$_2$. The signal across L$_3$ is applied to the grid of VT$_2$ through blocking condenser C$_6$.

FIG. 16. The schematic diagram of a typical stagger-tuned video i.f. amplifier in which impedance coupling is used between the stages.

Coupled to L$_3$ is an absorption trap L$_4$-C$_{20}$. This may be tuned to an adjacent-channel sound carrier, for example, in which case it will serve to reject signals of this frequency.

Coil L$_5$ in the plate circuit of VT$_2$ also has an absorption type trap L$_6$-C$_{21}$ coupled to it. This trap circuit may be tuned to an adjacent-channel picture carrier.

Notice that the plates and screens of the tubes are operated at approximately the same B voltage in this amplifier circuit. This is fairly common practice when a comparatively low plate voltage is used (around 125 volts).

The plate circuit of tube VT$_3$ is different from those of the previous stages: a resistive load is used here. The tuned circuit, which consists of coil L$_7$ tuned by the distributed capacities, is placed in the grid of the next stage.

Because there is a resistor used as the load in the plate circuit, the plate voltage of VT$_3$ will be somewhat lower than the plate voltages applied to the tubes in the previous stages; as a result, not quite as much gain can be expected from this stage. The tuned circuit will also be rather heavily loaded, since the plate resistor will normally be fairly low in resistance—lower, at least, than the grid resistors that load the previous stages. For this reason, the response curve of this stage will not be as sharply tuned as those of the others discussed, nor will quite as much gain be obtained.

A coil is provided in the cathode circuit of VT$_4$ to which a tuned absorption trap L$_9$-C$_{22}$ is coupled. This trap circuit may be tuned to the sound i.f. and thus may serve to provide additional rejection of this signal.

A resistive load is also used in the plate circuit of the last video i.f. amplifier stage. The final tuned circuit consists of coil L$_{10}$ and the various distributed capacities. This last tuned circuit is loaded quite heavily, since it feeds the video detector; therefore, it will have the broadest response of all.

Notice that all the tuning in this amplifier circuit is furnished by variable inductances. This is quite common practice at high frequencies, since it permits higher L/C ratios (the only capacities are the distributed ones, so the minimum possible capacity is present; this permits a higher L value to be used).

In the stages having a variable bias supply, small un-by-passed cathode resistors furnish a small initial bias and provide some degeneration. The only bias on VT$_4$ is furnished by the cathode resistor R$_{17}$, which is by-passed. Each plate supply lead is decoupled by R-C filters.

You will notice that none of the i.f. tuned circuits we have discussed has been shown as being shielded. Sometimes the i.f. transformers (or coils) are left completely unshielded in a TV set. This is particularly true of stagger-tuned i.f. amplifiers, because there is little or no danger of oscillation between adjacent stages. When the stages are tuned to different frequencies, there is practically no feedback between stages that has sufficient amplitude and the correct phase (at a specific frequency) to cause oscillation. Thus, shielding is not always necessary.

In other sets, you may find that two or more of the i.f. tuned circuits are shielded but that the others are not shielded. In still other sets, every i.f. coil will be shielded.

Video Detectors

Once the video signal has been built up by the video i.f. amplifier, it must be passed through a detector (demodulator) if we are to regain the modulation. In this case, the modulation consists of the picture components plus synchronizing and blanking pulses. This intelligence is amplitude-modulated upon the picture carrier, so a basic rectifier type of detector will serve to demodulate the signal.

The only requirements made of the video demodulator that the detector of an a.m. radio broadcast set does not have to meet are that the polarity of its output must be considered and that more care must be taken to prevent loss of the high-frequency components of the signal. We shall investigate both of these requirements after we see how the circuit works basically.

THE I.F. SIGNAL

The modulated i.f. carrier that is fed into the video detector is a signal of varying amplitude like that shown in Fig. 17A. The "envelope" of this signal represents the modulation. The partial suppression of one side band has served only to reduce the amplitude of the modulation; this has produced a certain amount of amplitude distortion by compressing the range between white and black signals, but since the eye is a very poor judge of the amount of light and of relative changes in light intensities, even fairly large amounts of amplitude distortion can be tolerated. Therefore, if the previous circuits have not introduced frequency distortion and phase delay, our signal will be entirely satisfactory.

It is standard practice in the United States to use "negative" modulation of the picture carrier: that is, the brighter the image, the less amplitude of the radiated signal. (The British system is exactly the reverse.) The maximum level is reached by the synchronizing pulses; the "black" level is the blanking pedestal height, which is about 75% of the maximum amplitude; and the "white" level is at about 15% of the peak level reached by the synchronizing pulses. This is, of course, the opposite of the method used in a.m. radio broadcasting, in which the loudest sound (corresponding to the greatest light intensity) produces the highest modulation peak; that is why this system is called negative modulation.

As you have learned, this method of modulation is used because it produces the most reliable synchronization. Since the synchronizing pulses are transmitted at the maximum amplitude, synchronization can often be maintained even if there is fairly heavy interference. Further, any noise or other interference that increases the signal amplitude will drive the picture tube dark instead of appearing as a bright flash.

To remove the modulation, it is only necessary to rectify the signal shown in Fig. 17A as shown in Fig. 18A and then to by-pass the high-frequency i.f. pulses to obtain a signal that follows the pattern of the modulation envelope. Thus, a video detector operates in exactly the same manner as the second detector used in an a.m. sound receiver. This is to be expected, of course, since the video signal is simply an amplitude-modulated signal.

PICTURE PHASE

Fig. 18 shows two ways of connecting a diode to an i.f. source L_1-C_1. It is important to choose the proper method of connection, because the polarity of the output depends upon the one we choose, and, as we shall see in a moment, this polarity must be the right one for the particular set in which the detector is used.

In either case, we apply the signal shown in Fig. 17A to the demodulator circuit. The arrangement of the circuit in Fig. 18B is such that current can flow only when point 1 on L_1 is positive with respect to point 2, since the diode plate is then positive. Therefore, the negative alternations of each cycle are rejected, and only the positive swings pass. This gives us the output shown in Fig. 17B. Since the synchronizing pulses reach the maximum in the positive direction, and the brightest portion of the picture is the least positive point in the intelligence signal, the rectified voltage produced across R_1 has a negative picture phase. This means that the signal swings in the negative direction for increases in brightness.

If we invert the diode, as shown in Fig. 18C, conduction can occur only when point 1 is negative. Therefore, this arrangement rejects the positive swings of the signal in Fig. 17A and causes the output voltage developed across R_1 to have the form pictured in Fig. 17C. Now, the brighter the picture, the more positive (or, rather, the less negative) the signal; there-

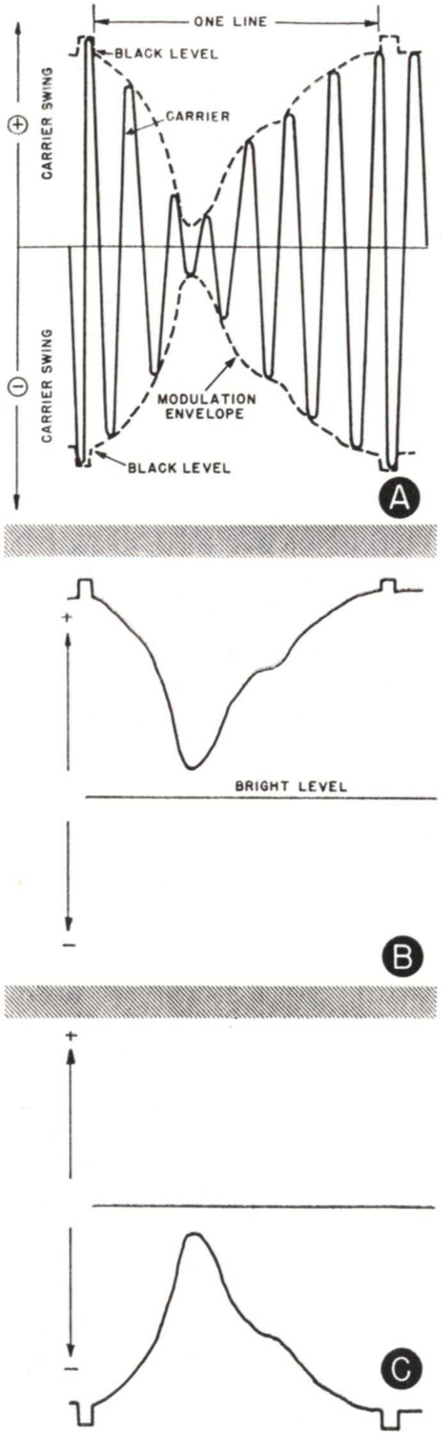


FIG. 17. Part A of this figure represents the modulated i.f. carrier that is fed into the video detector. Part B shows the form of the modulation if the detector is arranged to produce a negative picture phase. Part C shows the form of the modulation if the detector is arranged to produce a positive picture phase.

fore, the R$_1$ voltage has a positive picture phase.

This phase is important to us because it is necessary to feed the signal to the picture tube in such a way that the number of electrons in the beam will be increased when the scene calls for a brighter element. Hence, a signal that is applied to the grid of the picture tube must have a positive phase so that the grid will go more positive for increases in brightness.

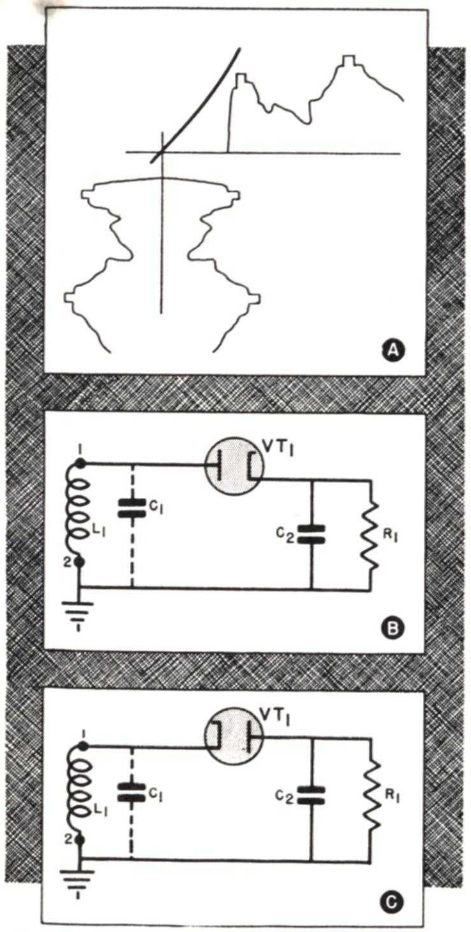


FIG. 18. The detector circuit shown in part B of this figure will produce an output having a negative picture phase. Inverting the diode as shown in Part C will give the output a positive picture phase.

Swings in the negative direction will then reduce the number of electrons in the beam and produce darker spots.

The television signal at the video detector is not sufficiently strong for direct application to the picture tube. This means that there must be a "low-frequency" amplifier (called the video amplifier) between the detector and the picture tube to raise the one- or two-volt output of the detector to the 40- to 60-volt signal that is needed to operate the picture tube. Each video amplifier stage reverses the picture phase 180°, so if we feed in a signal of positive phase to a one-stage amplifier, we will get out a negative one, and vice versa.

Now, if we are going to feed the signal to the grid of the picture tube, and if only one stage of video amplification is needed, the second detector must be connected to give a negative picture phase. The one stage of amplification will then cause a 180° reversal in the signal, and we will have a positive picture phase when the signal is applied to the grid of the cathode ray tube.

If two stages of video amplification are used, on the other hand, the video detector must be connected to give a positive picture phase. In fact, we can make the general statement that if one or three video stages are used, the output of the video detector must be connected to give a negative picture phase; if two video stages are used, the video detector must be connected to give a positive picture phase.

This statement is true if the picture signal is eventually applied to the grid of the picture tube. In some television receivers, however, the video signal is applied to the cathode rather than to the grid of the picture tube. If this is done, the video signal must have a negative picture phase when it is applied to the picture tube. It is easy to see the reason for this if you remember that driving the grid of the tube more positive (less negative) is equivalent to driving the cathode of the tube more negative (less positive) with respect to ground. In other words, it is the voltage *between* the grid and cathode that is important. If the cathode is made more positive without there being any change in the voltage applied to the grid, the voltage difference between the grid and cathode is increased, with the result that the grid is more negative with respect to the cathode. This effect is exactly the same as the one that would be produced by making the grid more negative without changing the voltage on the cathode.

Therefore, our rule about the detector polarity and number of stages must be reversed when the output of the video amplifier is applied to the cathode of the picture tube. Hence, once the manufacturer has decided whether to feed the grid of the cathode of the picture tube, and has decided on the number of video stages, the video detector must then be designed to deliver the required picture phase. In one set this may be a positive phase; in another it will be negative.

FREQUENCY DISTORTION

Like any other a.m. detector, it is necessary for the video detector stage to reject the r.f. components—that is, the high-frequency pulses contained in the rectified modulated i.f. signal must be filtered out of the load circuit in some manner. At the same time, however, all components of the modulation envelope must be reproduced with the correct amplitude, regardless of frequency. Frequency distortion can occur if the amplitude of either the higher or the lower-frequency video signals is seriously attenuated. Generally, we do not have to worry about the lower-frequency components in the video detector, because these will normally be reproduced properly.

To reproduce all the high-frequency components, however, it is necessary to avoid excessive by-passing. The basic r.f. filter in a detector circuit is a capacity across the load, such as C$_2$ in Figs. 18B and 18C. In a TV set, the distributed capacities in the wiring and the tube interelectrode capacities may well be large enough to supply all the filtering desired; in fact, they can be large enough to by-pass and thus attenuate some of the higher-frequency components of the desired signal. Hence, it is necessary to keep this capacity as small as possible or to reduce its effects.

If we make the load resistance very small, the effect of the shunting capacity will be reduced, because the impedance of the parallel combination depends more on the low resistance than on the capacitive reactance. In addition, high-frequency compensation may be used in the form of "peaking" coils in the load arrangement. Let's see how these are used by making a brief study of a few typical circuits. Much more detail on this compensation will be given in another Lesson in which you will study the video amplifier.

SERIES PEAKING

A typical video detector circuit arranged to deliver a negative picture phase is shown in Fig. 19. The modulated i.f. signal is applied to the plate of the video detector VT$_1$ from i.f. transformer L$_1$. Tube VT$_1$ will conduct only on positive peaks, so the signal appearing across diode load resistor R_2 will have negative picture phase. (That is, if a modulated i.f. carrier signal like that shown in Fig. 17A is applied, the lower half will be stripped away, and the signal reproduced across R_2 will have the form shown in Fig. 17B.) An odd number of video frequency amplifier stages will follow this detector if the signal is to be applied to the grid of the picture tube.

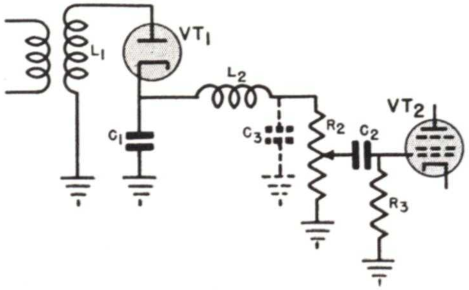


FIG. 19. A typical video detector circuit. Its output has a negative picture phase.

Condenser C_1 represents part of the distributed capacity, and includes such items as the cathode-filament capacity of VT_1. To increase its size and get proper filtering of the i.f. pulses, a small by-pass condenser may be used here in addition.

The rest of the distributed capacity (in particular, the input capacity of video stage VT_2) is represented by C_3.

Coil L_2 serves three purposes. It separates the capacities C_1 and C_3, reducing their shunting effect across the load R_2. If its size has been properly chosen, it forms a low-pass filter that further removes the i.f. pulses. Finally, it can also act as a series resonant circuit with C_3 and can thus be used to boost the higher video frequencies. That is, if we consider that L_2 and C_3 form a series resonant circuit at a frequency somewhat higher than the highest video signal, we know that there will be a boost in signals around this frequency because of resonance step-up. Diode load resistor R_2 acts to load this resonant circuit and thus to broaden its peaking action. When the coil is used in this manner, it is called a "series peaking coil."

COMBINATION PEAKING

Fig. 20 shows another typical circuit, arranged this time to produce a positive picture phase.

Coil L_1 may be the last tuned circuit in the i.f. amplifier of the television receiver. The modulated i.f. carrier signal will appear across this coil and will be applied to the cathode of VT_1.

Tube VT_1 will conduct only when the cathode is made negative with respect to the plate. Thus, the tube is connected to give a positive picture phase. (In this case, if a modulated carrier like that shown in Fig. 17A is applied to the detector, the upper half will be stripped away, and the envelope from the lower half of the signal will appear across the load as a signal having the form shown in Fig. 17C.)

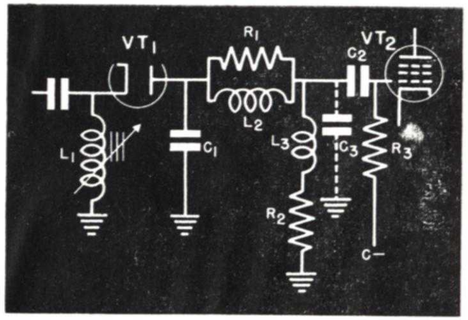


FIG. 20. This video detector circuit produces a positive picture phase. Coil L_2 acts as a series peaking coil, and coil L_3 acts as a shunt peaking coil.

Condenser C_1 charges on the peaks of the rectified i.f. pulses and discharges in the valleys between the pulses, thus smoothing out the rectified i.f. signal and producing the video signal. Acting in this manner, it bypasses the high-frequency i.f. pulses. Since the i.f. frequencies are quite high, this condenser has a fairly small value—usually something on the order of 10 mmf. It acts in conjunction with other distributed capacities in the circuit.

Coil L_2 is a series peaking coil that serves to split the distributed capacities, to filter the i.f., and to increase the strength of the higher video frequencies by resonance step-up. Resistor R_1 loads coil L_2 and acts to prevent transient oscillation. This latter function is needed because coil L_2 may resonate with various capacities in the circuit at some particular frequency and tend to set up a damped oscillation at this frequency when a pulse is received. If we load the circuit with R_1, however, such transient oscillation can be avoided.

Coil L_3 is chosen to resonate with the distributed capacities in the circuit (including not only wiring capacities but also the grid-cathode capacity of tube VT_2) near the highest-frequency video signal to be transmitted. Hence, it forms a parallel-resonant circuit that is part of the load across which the signal is developed. Maximum voltage will appear across this resonant circuit at its resonant frequency, so it tends to boost the signal at the higher frequencies and thus to make up for any loss of high frequencies due to distributed capacities in other parts of the circuit. It is a resonant circuit with a low Q, however, because of the loading effect of R_2, so a sharp peak is not produced—instead, the circuit boosts a rather wide range of frequencies near the upper limit to be transmitted.

Because of this action, coil L_3 is called a peaking coil. Since it is connected in parallel with the distributed capacities in the circuit, it is called a shunt peaking coil.

Since this detector circuit is connected to produce a demodulated signal having a positive phase, it must be followed by an even number of video amplifiers to obtain the proper positive picture phase for driving the grid of the picture tube, or by an odd number if the signal is eventually applied to the cathode of the picture tube.

DETECTOR VARIATIONS

An unusual video detector circuit is shown in Fig. 21. Diode VT_1 in this circuit has a low ohmic resistance when it is conducting current; when it is not conducting, it acts simply as a low capicity. When the video i.f. voltage makes point 1 positive with respect to point 2, diode VT_1 will conduct and will have a much lower resistance than R_1. The signal voltage will then be divided in such a way that practically all of it will be dropped across R_1 and practically none across VT_1; as a result, only a negligibly low i.f. signal voltage will be applied to the grid of the first video-frequency amplifier tube.

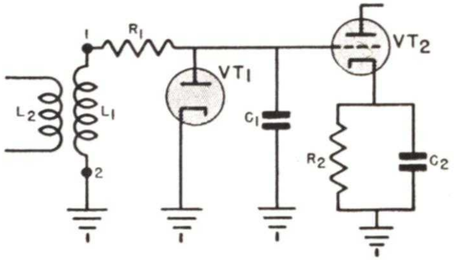


FIG. 21. Another form of video detector.

However, when point 1 is negative with respect to point 2, diode VT_1 will be an open circuit, and the complete negative half-cycle of the video i.f. signal across L_1 will be applied

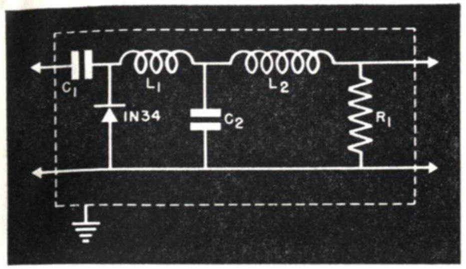


FIG. 22. A video detector circuit in which a germanium crystal is used instead of a diode.

through R_1 between the grid and cathode of VT_2. Thus, only the negative alternations will act upon the grid of the video amplifier tube; this means that we shall obtain a positive picture phase from the video detector.

When the negative alternation of the i.f. signal is applied to the grid of the video amplifier tube, the combined capacity between this tube and ground (the capacity of C_1 in parallel with the plate-cathode capacity of diode VT_1 and the grid-cathode capacity of the first video amplifier tube) is charged and discharged through R_1. This action makes the net voltage on the grid of the video tube follow the desired modulation envelope, and at the same time removes i.f. components more or less completely. Resistor R_1 also serves to limit the current through diode VT_1 to a safe value during the half-cycles on which VT_1 conducts.

Crystal Detector. Still another video detector circuit is shown in Fig. 22. Here, the diode detector tube has been replaced by a germanium crystal (type 1N34). A germanium crystal will allow current to pass better in one direction than in the opposite direction. Because of this action, it can be used as a rectifier and thus as a second detector. It occupies less space than a vacuum tube and does not require heater current.

When a germanium diode is used as a detector, it is customary to build the entire second detector circuit (including the peaking and filtering coils L_1 and L_2 as well as condensers C_1 and C_2 and the diode load resistor R_1) inside a shielded can. Therefore, if you encounter a television set that appears to have no video demodulator, careful investigation may well prove that the entire second-detector stage has been built into a small shield can from which only the output and input leads project beneath the chassis.

In the circuit shown in Fig. 22, condenser C_1 acts as a blocking condenser to prevent the application of d.c. to the 1N34 crystal. Resistor R_1 is the diode load resistor, and the detected video signal appears across its terminals.

Lesson Questions

Be sure to number your Answer Sheet 53RH-3.

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. Are the sound and the picture signals from a TV station on the same carrier or are they on separate carriers?
2. When a TV set does not use an intermodulation sound system, why is it desirable to eliminate the sound carrier in the video i.f. amplifier before the carrier can reach the video detector?
3. If the i.f. carrier is located on the slope of the i.f. response at a point higher than that giving 50% carrier response, will the over-all low-frequency response be: *higher than; lower than; the same as;* that for other frequencies in the pass band?
4. Name the two basic ways of getting the broad-band i.f. response needed in a video i.f. amplifier.
5. What happens to the response when resistors are used to load both the primary and the secondary of an overcoupled band-pass video i.f. transformer?
6. How are the steep slopes on the response curves of the video i.f. section obtained?
7. In addition to reducing the response (to the sound carrier) of a video i.f. section, what other use frequently is made of the sound trap?
8. How is a remote-cutoff characteristic obtained when sharp cutoff pentode tubes are used in the video i.f. amplifier?
9. If the signal is to be applied to the grid of the picture tube, and there are two video stages, what must be the phase of the signal at the output of the video detector—positive or negative?
10. Why is it necessary to use a low capacity as the r.f. by-pass across the diode load in the video detector?

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

GET ALONG WITH PEOPLE

In a recent study covering the activities of several hundred successful men, this question was asked:

"What single ability is most essential to success?"

The almost unanimous answer was:

THE ABILITY TO GET ALONG WITH PEOPLE.

You will agree with this, I am sure.

The successful technician—engineer — business-man—must *get along with* other people, if he is to gain the greatest success, and earn the greatest profit from his technical abilities.

Keep this in mind in your everyday life. *Practice getting along with* people. We can all improve on our abilities in this "art"—and will profit by doing so.

J. E. Smith