BASIC TV RECEIVER CIRCUITS

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STUDY SCHEDULE NO. 50

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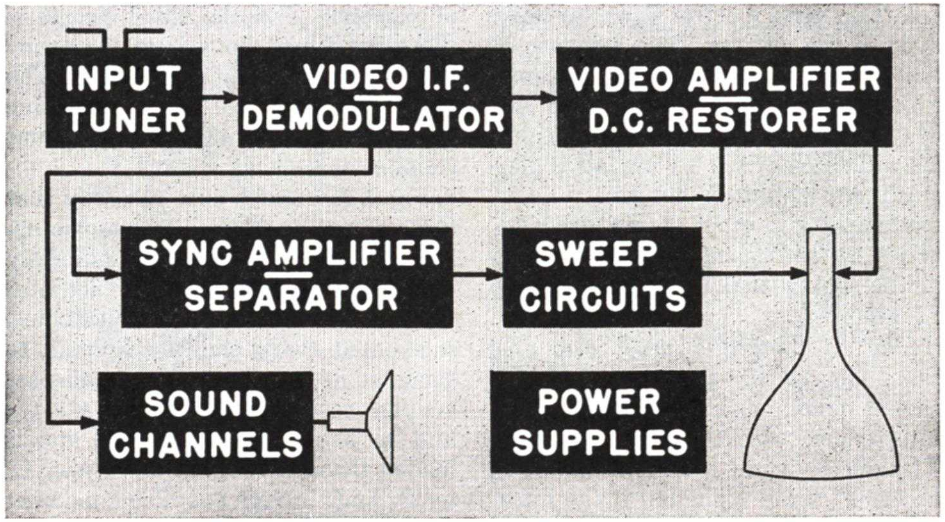

YOU HAVE previously studied in block form the various sections of a TV set and have learned something about the functions performed by the TV receiver stages and sections. In this Lesson you will get acquainted with typical TV circuits and their operation. You will not have to cover all the variations in the circuits used by different manufacturers because each section of a TV set will be treated in detail elsewhere. Now, you will build the foundation for this future study by covering only the fundamentals of television circuits.

THE INPUT TUNER

This section of a TV receiver is also commonly called the front end or head end of the receiver. It contains the r.f. amplifier and the local oscillator-mixer-first detector. The first section of the front end is the r.f. amplifier. This section increases the amplitudes of both the sound and the video r.f. signals without changing their characteristics in any way, and hence must have a pass band of at least 6 megacycles. In addition to this, the r.f. amplifier must give some rejection of carrier frequencies outside the desired channel that might cause interference.

The amplified video and sound r.f. signals are fed into the mixer-first detector section where they are combined with the unmodulated r.f. signal that is produced by the local oscillator. As a result, two i.f.-modulated carrier signals are produced; one is the sound i.f. carrier and the other is the picture i.f. carrier. Various i.f. values, ranging from 12 to 25 megacycles, have been used, but higher i.f. values in the vicinity of 40 megacycles are becoming more popular, since this gives the r.f. amplifier a better chance to reject signals that could produce image interference.

THE R.F. AMPLIFIER

The r.f. amplifier has three important functions. Since it is between the mixer and the antenna, it *reduces radiation from the local oscillator.* The local oscillator, if the r.f. stage were not used, would radiate energy from the TV antenna that might be picked up in a nearby TV set, and cause considerable interference.

The r.f. amplifier increases the signal strength on the desired TV chan-

nel. This gives a better signal-to-noise ratio in the TV set. The response of the r.f. amplifier should be broad enough so that it does not cut off any of the desired signals. However, equal amplification of the TV signals is generally not obtained, but this may be made up for in other stages of the receiver by increasing the amplification of the signals that are slighted in the r.f. amplifier.

The r.f. amplifier must also give some degree of selectivity and it should reject image signals that create interference with the desired station. The selectivity of a TV r.f. amplifier, however, is not high, and if the interfering signals are exceptionally strong, wave traps in the antenna circuit are often used to reduce the interference.

A typical TV r.f. amplifier circuit is shown in Fig. 1. Notice that the input of the r.f. amplifier is tuned. This results in better image rejection. However, many r.f. amplifiers have an aperiodic (untuned) input from the antenna system.

Also notice the band-pass r.f. coupler between the output of the r.f. amplifier and the mixer grid. This tends to improve the selectivity and to give an essentially uniform response of 6 megacycles.

To give broad-band response and to prevent oscillation, stagger-tuning is often used. Two of the resonant circuits shown in Fig. 1 are tuned to different frequencies. Two circuits alone give a deep valley between the peaks of response, and the third circuit is therefore tuned to a mid-frequency and serves to fill in the valley. The valley may also be filled in by loading the resonant circuits with low shunt resistances such as R_1 and R_5.

Fig. 1 illustrates only one way that these three tuned circuits may be arranged. Tuned circuit L_2-C_2 is tightly coupled to the antenna coil. Resistor R_1, which may be as low as 2000 ohms, is shunted across the tuned circuit to broaden its response. The band-pass coupler consisting of L_3, C_6, C_5, C_7, and L_4 has a broad response and is loaded through coupling condenser C_4 by R_4 and through coupling condenser C_8 by R_5.

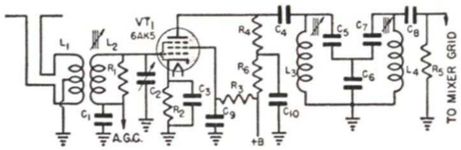

FIG. 1. Typical TV r.f. amplifier circuit. This circuit amplifies the modulated carriers for both sound and picture portions of a TV program.

The tube used in the preselector section is a pentode r.f. amplifier and may be of either the variable-mu or the sharp cut-off type. The gain in this circuit is controlled by the a.g.c. system, although in some cases a variable cathode bias resistor may be used to vary the bias of VT_1 and the tubes in the following stages.

The r.f. tube must have certain characteristics that make it suitable for amplification of very-high frequencies. Its grid-to-plate capacity must be low if feedback is to be kept at a minimum. For the same reason, the capacity between the plate and grid leads to this tube must be as low as possible. In addition to this, the grid-to-cathode and plate-to-cathode interelectrode capacities and the capacities between the leads to these

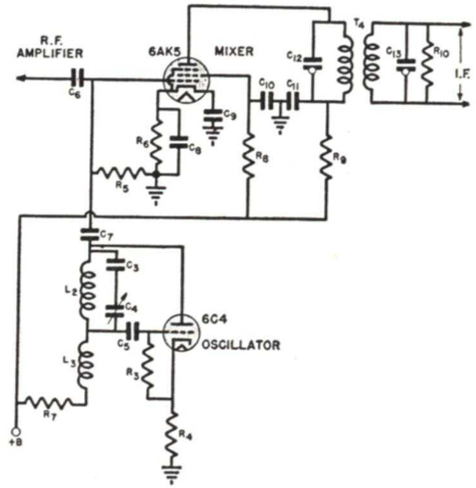

FIG. 2. A separate oscillator is used here to feed the signal into the mixer-first detector.

electrodes must be low enough so that reasonably high gain can be obtained, and so that the r.f. amplifier can be tuned to the highest desired television channel when the inductance of L_2, L_3, and L_4 are set at a minimum value.

MIXER-FIRST DETECTOR AND OSCILLATOR

The process of frequency-conversion involves the mixing of the locally generated oscillator signal with the incoming modulated carrier signal. The process is basically the same as in an ordinary broadcast superheterodyne receiver except that in a television set there are two r.f. carriers that beat with the local oscillator signal to produce two i.f. carrier frequencies.

In broadcast and f.m. receivers a pentagrid converter is generally used as a combination mixer-first-detector-oscillator tube, but this tube is inadequate for the very high frequencies employed in television, and would result in noise and low output due to degeneration and oscillator drift. In a TV set, there is a separate oscillator tube, which may be in the same envelope as the mixer.

Pentodes are commonly used in the mixer circuit, but they require a high-level signal from the r.f. amplifier if noise is to be avoided. If a low-level signal reaches the mixer input from an inefficient r.f. amplifier, or if the receiver is located in a fringe area, it has been found that a triode mixer will give as much output as a pentode and at a considerably lower noise level.

Fig. 2 shows a typical mixer-first detector-oscillator circuit. Here a 6AK5 tube is used as the mixer. This tube is biased by the drop across R_6 caused by the cathode current, and by the drop across R_5 caused by current flow through the mixer grid. This mixer-grid current flows because the oscillator output drives the grid positive. This voltage built up across R_5 charges condenser C_6 and serves to bias the tube so that it will act as a mixer.

The i.f. transformer T_4 is double-tuned and is overcoupled to provide the necessary band width. In this particular circuit both the sound and video i.f. carriers pass through the i.f. transformer and are fed to the input of the first video amplifier tube. Resistor R_{10}, which shunts the secondary of transformer T_4, loads the transformer to give a flat response.

The oscillator is a 6C4 triode tube connected as an ultra audion (modified Colpitts) using the grid-to-cathode and plate-to-cathode interelectrode capacities to maintain oscillation. Resistors R_4 and R_7 isolate the oscillator, permitting it to act as an ultra-audion on any TV channel. Choke L_3 is needed to isolate the oscillator's tuned circuits further, providing a d.c. path for the plate circuit.

The oscillator is tuned above the picture carrier by the amount of the i.f. frequency. Trimmer C_4 in the oscillator tank circuit is connected in series with C_3, so that the range of adjustment will be limited and the adjusting screw will be nearer r.f. ground potential. Even so, a well-insulated alignment tool that is designed for high frequencies is necessary when C_4 is to be adjusted. The oscillator is biased by the feedback voltage on the grid. The tube then rectifies the resulting grid current and the resistor-condenser combination R_3-C_5 is charged up to produce the operating bias. Other tubes are, of course, used as oscillators, but in practically every instance the ultra-audion circuit is used, and the tube interelectrode capacities form a portion of the tuning circuit. You will find that not all tubes will function satisfactorily as oscillators, although they may be perfectly all right in some other circuit. For this reason, servicemen always try several tubes in the oscillator stage when trouble is suspected there and thus avoid many realignment problems.

Video I. F. Amplifier and Detector

Practically all of the selectivity of any superheterodyne is in the i.f. amplifier. A TV set is no exception, and as a matter of fact the TV receiver is even more dependent on its picture i.f. amplifier for rejection of undesired signals than broadcast sets are. This is in part due to the low selectivity of the front end, which is incapable of rejecting adjacent-channel interference. The average video i.f. amplifier alone is not capable of rejecting such interference if it is designed to pass the 4-megacycle band width containing the video intelligence. A less expensive TV set having a narrower pass band in the video i.f., has sufficient selectivity to minimize adjacent-channel interference. In receivers designed to give the ultimate in definition, special traps that reject adjacent-channel interference are used in the video i.f. amplifier.

A high i.f. gives the front end a better chance of rejecting image interference, but traps in the antenna circuit are often needed for complete freedom from interfering signals that are operating at image frequencies or frequencies at or near the i.f.

Separation of the sound and picture i.f. carriers may take place at the mixer output or at the output of the first or second video i.f. amplifier. In the latter case the sound i.f. will be somewhat stronger than at the mixer output, since the picture i.f. stages will be aligned to afford some gain at the sound i.f. frequency.

THE VIDEO I.F. AMPLIFIER

The coupling of the video i.f. amplifier in a TV receiver is considerably different from that of the amplifier in a sound receiver. Some TV sets, such as that shown in Fig. 2, use double-tuned i.f. transformers. Other forms of coupling will be described elsewhere, but the most common type, impedance coupling, is shown in Fig. 3. Although plain chokes are shown, often these form parallel-resonant circuits with the tube interelectrode capacities.

To obtain the necessary wide-band characteristic with adequate gain, four stages of i.f. amplification are used in the typical amplifier shown in Fig. 3.

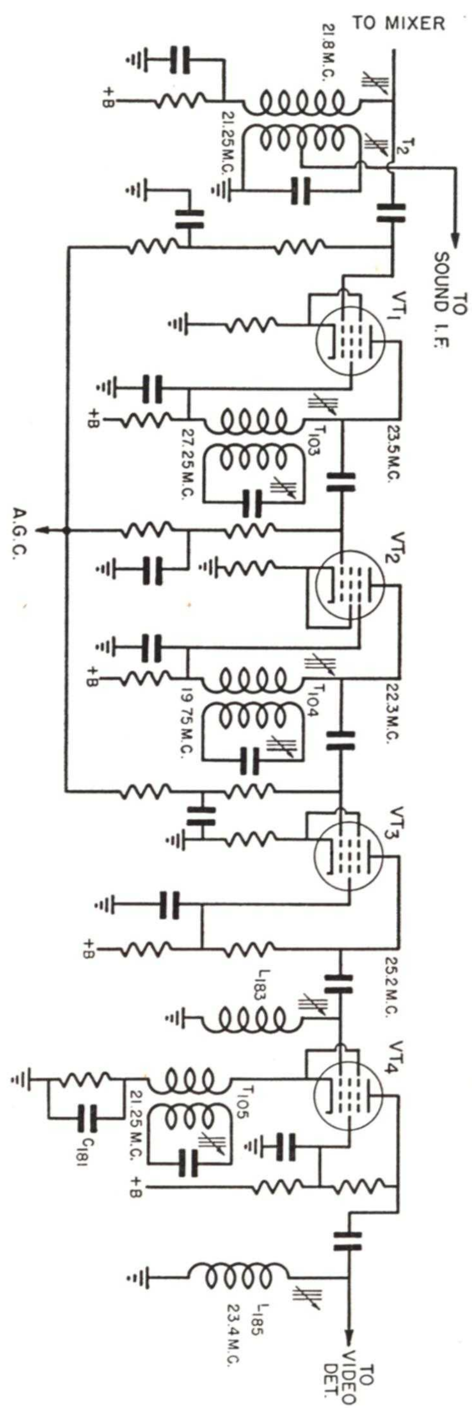

FIG. 3. A typical video i.f. section. In this example, the picture carrier is 25.75 mc. and the sound carrier is 21.25 mc.

The converter plate and the i.f. transformers each utilize only one tuned circuit, each tuned to a different frequency. The effective Q of each coil is determined by the plate resistor or the grid resistor so that the product of the responses of the total number of stages produces the desired over-all response curve. Fig. 4 shows the relative gains and selectivities of each coil and the shape of the curve of the over-all combination. This is indicated by the dotted line.

In order to obtain this band-pass characteristic, the picture i.f. transformers for this particular amplifier are tuned as follows: primary of converter transformer T_2, 21.8 megacycles; primary of first video i.f. transformer T_{103}, 25.3 megacycles; primary of second video i.f. transformer T_{104}, 22.3 megacycles; third video i.f. coil L_{183}, 25.2 megacycles; fourth video i.f. coil L_{185}, 23.4 megacycles.

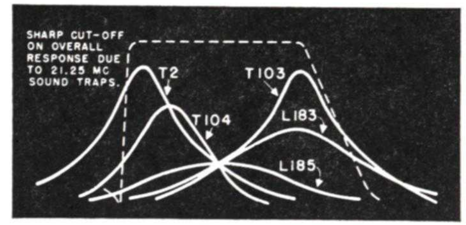

FIG. 4. Stagger-tuned i.f. response.

To align the i.f. system, the transformers are simply peaked to the specified frequencies with a signal generator. The over-all i.f. response can then be observed by use of a sweep generator and oscilloscope. The sweep generator is similar to that used to align f.m. and high-fidelity a.m. receivers, except for the fact that it operates at a much higher frequency and with a much greater sweep width. If the correct response curve cannot be obtained, the difficulty is likely to be in some part of the circuit that affects either the frequency or the Q of one or more of the i.f. transformers.

Fig. 5 shows the relative positions of the picture and sound carriers for

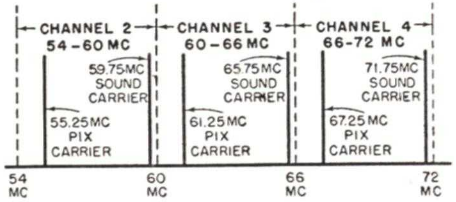

FIG. 5. Television channel frequencies.

channels 2, 3, and 4. If a station on channel 3 is transmitting a picture with video frequencies up to 4 megacycles, the picture carrier will have side-band frequencies up to 65.25 megacycles. The lower side bands, as you know, are suppressed at the transmitter. With the receiver r.f. oscillator operating at a higher frequency than the receiver channel, the i.f. frequency relation of picture-to-sound carrier is reversed as shown in Fig. 6.

Since it is necessary for the picture i.f. to pass frequencies quite close to the sound-carrier frequency, the sound carrier would produce interference in the picture. In order to prevent this interference, traps must be added to the picture i.f. amplifier to attenuate the sound carrier. If the receiver is operating on channel 3, it is possible that there will be interference from the channel 2 sound carrier and the channel 4 picture carrier. The adjacent-channel traps are provided to attenuate these unwanted frequencies. In receivers having a narrower video i.f. response, this interference is not present and such traps are not required—however, the picture definition suffers from the restricted i.f. band width.

The first three traps in Fig. 3 are absorption circuits. The first trap (T_2 secondary) is tuned to the accompanying sound i.f. frequency, the second trap (T_{103} secondary) is tuned to the adjacent-channel sound frequency, and the third trap (T_{104} secondary) is tuned to the adjacent-channel picture-carrier frequency. The fourth trap (T_{105} secondary) is in the cathode circuit of the fourth picture i.f. amplifier and is tuned to the accompanying sound-carrier i.f. frequency. The primary of T_{105} in series with C_{181} forms a series-resonant circuit at the frequency to which L_{185} is tuned (23.4 megacycles). This provides a low-impedance path in the cathode circuit at this frequency and permits the tube to operate with gain. However, at the resonant frequency of the secondary (21.25 megacycles) a high impedance is reflected into the cathode circuit and the resulting degeneration reduces the gain of the tube at this frequency. The effect of these traps on the i.f. response curve are shown in Fig. 6.

In Fig. 3, although the sound is taken directly from the output of the

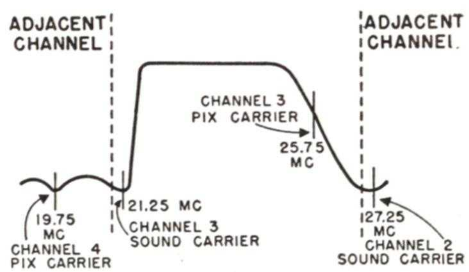

FIG. 6. Over-all picture response.

mixer, it may in some cases be taken from the output of the first or second video i.f. stages. You will note that a.g.c. in this particular case is applied to the control grids of the first, second, and third video i.f. tubes. If a.g.c. were not used, this lead would go to a manual bias control used to vary the i.f. gain.

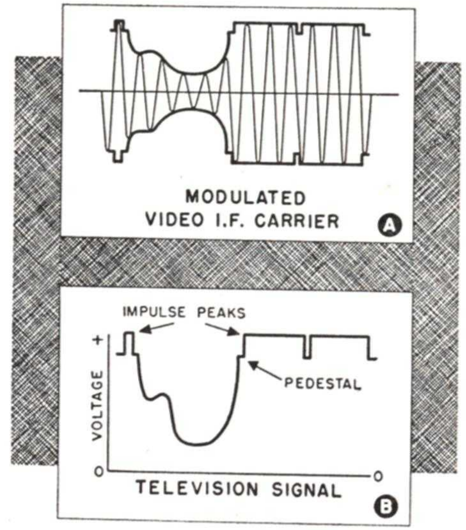

FIG. 7. The demodulated signal at B is obtained from the r.f. form at A.

THE VIDEO DETECTOR

At the output of the last video amplifier the video signal is still in its r.f. form, having both positive and negative peaks as shown in Fig. 7A. This signal must be demodulated so that it will have the form shown in Fig. 7B before it can be applied to the input of the picture tube.

To produce this demodulation, it is necessary to rectify the modulated video i.f. carrier and filter out the i.f. components. A linear detector is required for this purpose. A diode is generally used. A typical video detector circuit is shown in Fig. 8A. The video i.f. amplifier output signal existing across the final resonant circuit, consisting of L_1 and the capacity between the plate of the detector tube and ground, sends electrons through a load made up of the internal resistance of the diode detector tube, peaking coil L_2 and shunt resistor R_3, peaking coil L_3, and diode load resistor R_4, producing across the last two components a pulsating d.c. voltage. The cathode-to-filament capacity of the tube shunts to ground all a.c. components above the video range so that the video detector output voltage contains only the desired a.c. components and the d.c. component of the demodulated television signal. The pedestals for the horizontal and vertical sync pulses will now all line up at the same level.

The direction of the electron flow through diode load resistor R_4 determines whether sync pulses will make output terminal d swing in a positive direction or in a negative direction with respect to the chassis. In the circuit of Fig. 8A, electrons enter R_4 at its grounded end, making that end of the resistor negative with respect to point d. Under this condition, the

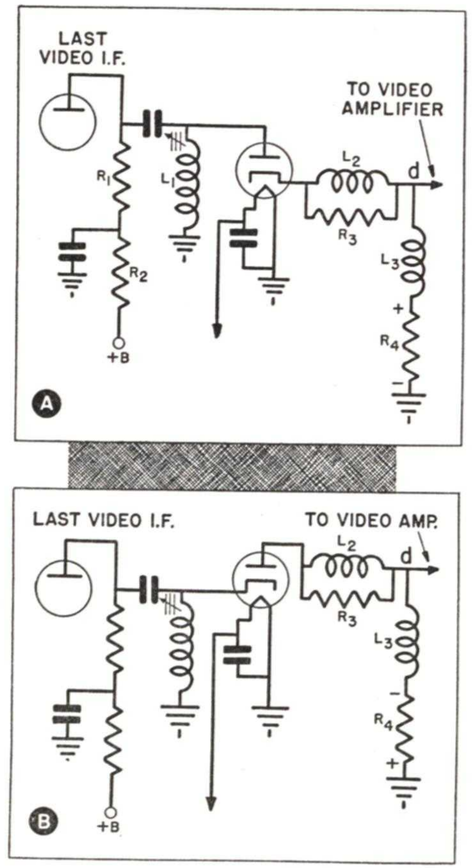

FIG. 8. Video detectors.

video detector output voltage (a modulated d.c. voltage) will vary as shown in Fig. 9A, with the sync pulses making point d swing more positive, and with the bright areas in the original scene making point d swing in a negative direction from the pedestal level.

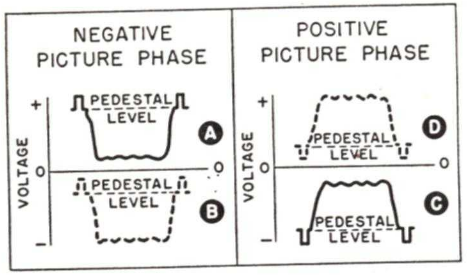

FIG. 9. When a diode video detector is connected as in Fig. 8A, the output signal has a negative picture phase (A and B); with diode connections as in Fig. 8B, the output signal has a positive picture phase (C and D).

Since this corresponds to negative modulation as at the transmitter, the modulated d.c. signal is in this case said to have a negative picture phase.

The phase of the picture signal at the output of a diode video detector can be reversed simply by reversing the connections to the diode detector tube, as is indicated in Fig. 8B. This reversal of connections makes electrons flow from the plate of the detector through the load to ground, making the take-off point from the video amplifier negative with respect to ground. In this case the video output signal is as shown in Fig. 9C. Note that bright lines now drive the signal in a positive direction from the pedestal level, giving the equivalent of positive modulation, while sync pulses drive the signal in a negative direction from the pedestal level. The modulated d.c. output signal of the video detector is in this case said to have a positive picture phase.

The addition of a d.c. bias voltage to a video-frequency TV signal has no effect upon the phase of the signal. For example, if a negative d.c. voltage is added to the signal in Fig. 9A, making the entire TV signal negative with respect to the chassis as shown in Fig. 9B, we still have the required conditions for negative picture phase (bright lines swing the signal in a negative direction from the pedestal level). Likewise, adding a positive bias to the signal in Fig. 9C may make all parts of it positive as shown in Fig. 9D, but we still have the equivalent of positive picture phase.

At this point it should be brought out that it is not necessary to use a tube as the detector. A germanium crystal, as shown in Fig. 10, makes an excellent detector, saves spaces, and eliminates the heater current of one tube. By reversing the connections to the crystal, either a positive or nega-

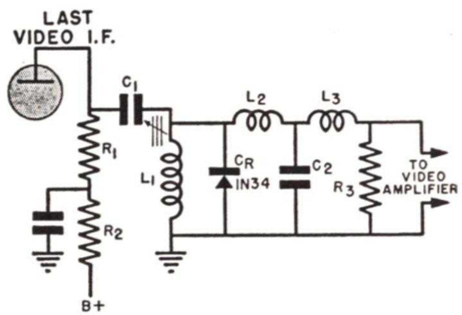

FIG. 10. A crystal video detector.

tive picture-phase signal can be obtained at the detector output. In Fig. 10, L_2 and L_3 together with C_2 form a low-pass filter that removes i.f. components and filters out i.f. harmonics. In this case the load consists entirely of resistor R_3, and the video signal across this resistor is applied to the input of the video amplifier.

Video Amplifier and D. C. Restorer

THE VIDEO AMPLIFIER

The video amplifier in a TV receiver corresponds to the audio amplifier in a broadcast set. The video amplifier drives the picture tube, swinging the bias on the picture tube to give the necessary variations in light intensity along each line of the scan.

The signal from the output of the video amplifier may be used to drive the grid, or we may hold the grid of the picture tube at a fixed voltage and drive the cathode. It is more usual to drive the grid of the tube just as in an ordinary stage of amplification, so we will consider this method here. Later the cathode drive will be studied.

If we assume for the moment that the signal level at the output of the video detector is strong enough to excite the picture tube in the receiver, which signal in Fig. 9 would we select? This question can be quickly answered by considering the E_g-B (grid voltage-brilliancy) characteristic of a picture tube as shown in Fig. 11. If we choose a signal with negative picture phase and apply it in such a way that the pedestals line up with point B on the E_g-B characteristic in Fig. 11, spot brilliancy will vary as shown by curve N. As you can see, this type of signal is incorrect, for bright portions of the scene at the transmitter would be reproduced as dark portions and the sync pulses would cause white lines to appear on the screen.

When the applied signal has a positive picture phase, and the pedestals are lined up with point A by adjusting the bias, spot brilliancy will vary as shown by curve P. In this case sync pulses will darken the spot, and increasingly bright video signals will give increasingly bright spots on the receiver screen. Since point A on the E_g-B characteristic is at the brilliancy cut-off point for the tube, the sync pulses will always drive the spot into the blacker than black region, and the video signal will always make the spot more or less brilliant, which is exactly what we want. It follows from this

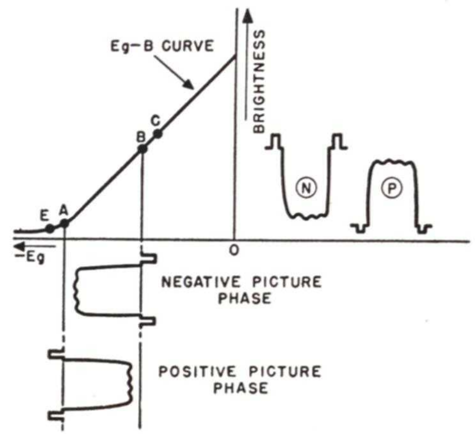

FIG. 11. Grid voltage-brilliancy (E_g-B) characteristic curve for a television picture tube.

that the picture tube in a TV set must have its grid driven with a signal having a positive picture phase, and the bias voltage must be applied in series with the signal to make the pedestals line up with the cut-off point.

In general practice, the output of the video detector is not sufficient to drive the control grid of the picture tube directly. There is seldom more than one volt output from the detector, and some tubes may require as much as 60 or 70 volts. Because of this, amplification of the signal at the output of the video detector is required. This calls for one or more video frequency (v.f.) amplifier stages between the video detector and the picture tube. These video-frequency amplifier stages introduce a number of problems, as you will see.

The video amplifier must respond more or less uniformly to signals over the entire range between 10 cycles and 4 megacycles. Furthermore, if any unequal amplification of the various frequencies takes place ahead of the video amplifier, the video amplifier response must be such that its output will be uniform. In some cases extra amplification at the high frequencies may be required, or perhaps it will be necessary to have slightly more gain in the middle register.

termined by the d.c. plate voltage and the negative C-bias voltage. For the duration of this steady-state condition, point 4 on the load resistor will be negative with respect to point 3, for electrons flow from cathode to plate, enter the resistor at 4, and flow through it to point 3.

Now suppose that we feed into the circuit the TV signal shown in Fig. 9A. This signal has a negative picture phase and makes point 2 have a varying positive potential with respect to point 1. This varying positive potential cancels out part of the fixed negative C bias, making the grid-to-cathode voltage on the tube less negative and therefore making plate cur-

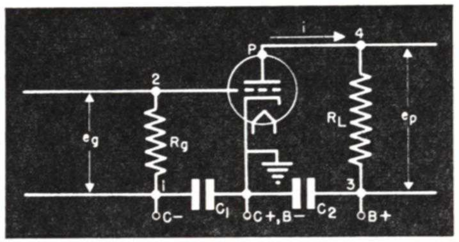

FIG. 12. Simplified video-amplifier stage.

Because of the frequency requirements resistive loads must be used. Transformer loads would be too frequency-discriminatory, and we would not be able to get a flat response.

The fact that an amplifier of any type is used introduces the problem of phase reversal, for each amplifier will reverse the phase of the picture signal. Thus, if a signal of a negative picture phase (Fig. 9A) is fed into a stage, the signal at the output of that stage will have a positive picture phase (Fig. 9C).

We can see exactly how this reversal in phase occurs by studying the action of the simplified video-amplifier stage in Fig. 12. When E_g is zero (as when no TV signal is present), a definite d.c. plate current will flow through load resistor R_L, its value being de-

rent i increase. This increase in i serves to increase the voltage drop across R_L, making point 4 more negative than before with respect to point 3. In other words, when point 2 swings positive with respect to 1, point 4 swings negative with respect to 3, thereby giving a 180-degree phase reversal. This means that if a signal having a negative picture phase (Fig. 9A) is applied to the grid of an amplifier having a resistance load like that in Fig. 12, the output signal will have a positive picture phase, as in Fig. 9C. Likewise, if the signal in Fig. 9C is applied to the grid, the output signal will be like that in Fig. 9A. A stage of video amplification thus reverses the phase of the applied signal.

Suppose we utilize the output signal between point 4 and ground in Fig. 12

instead of that between points 4 and 3. If the signal between points 4 and 3 corresponded to Fig. 9C, the resulting signal between point 4 and ground would be like that in Fig. 9D. If the signal in Fig. 9A existed between points 4 and 3, a connection between point 4 and ground would give exactly the same signal, but at a higher positive bias.

Keeping in mind that the TV signal that is feeding the control grid of the picture tube must have the equivalent of positive modulation, we can make two general conclusions as to the type of video detector circuit required:

1. If two stages of video-frequency amplification are used after the video detector in order to secure the required television signal voltage at the input of the picture tube, the video detector circuit must be of the type shown in Fig. 8B, delivering a signal with a positive picture phase.

2. If either one or three stages of video frequency amplification are used, the video detector circuit must be of the type shown in Fig. 8A, delivering a signal with a negative picture phase.

In high-definition reproduction of television signals it is absolutely essential that the pedestals all line up at the same constant signal level at the input of the picture tube. When this condition is achieved, it is possible to adjust the bias on the picture tube so that the sync pulses always drive the spot into the blacker than black region and the video signals always vary the spot brilliance. In other words, the pedestals must be lined up at the input of the picture tube so that we can make all the sync signals invisible and all the picture signals visible. It is a fundamental fact that the demodulated television signal (including the sync pulses along with the video signal) will retain its alignment of ped-

estals only as long as it has its d.c. component.

The only way in which we can amplify the d.c. component along with the television signal, thereby retaining the alignment of the pedestals, is by using d.c. amplifier stages in the video amplifier. This is sometimes done, but it is more usual to employ a.c. amplifiers and then to restore the d.c. component at the output of the video amplifier, as will be described later.

With only one stage of video-frequency amplification it is possible to connect the load of this stage directly to the grid-cathode of the picture tube, giving true d.c. amplification without the complications of the expensive power supply that is necessary for two or more direct-coupled stages. With two or more stages in the video amplifier, either true direct coupling or resistance-capacitance coupling can be used. When the latter system is used, the coupling condenser removes the d.c. component from the TV signal, thereby causing the pedestals to get out of line.

It is important to visualize what happens to a demodulated TV signal when it is passed through a condenser. Signal I in Fig. 13A corresponds to a line having maximum and uniform brightness, and signal II corresponds to a solid black horizontal line on the scene that is being televised. These two signals are shown as they would appear across the detector load resistor, so the pedestals all line up at a constant level with respect to the zero voltage line. Each signal is made up of an a.c. component (having equal areas on each side of the average value line for each cycle) and a d.c. component, with the average values of the a.c. components considerably out of line, and with the d.c. components of the black line considerably larger than those for the bright line.

When these TV signals are passed through a condenser, the d.c. components are blocked out, bringing the average value line down to the zero line. As a result, the average values of

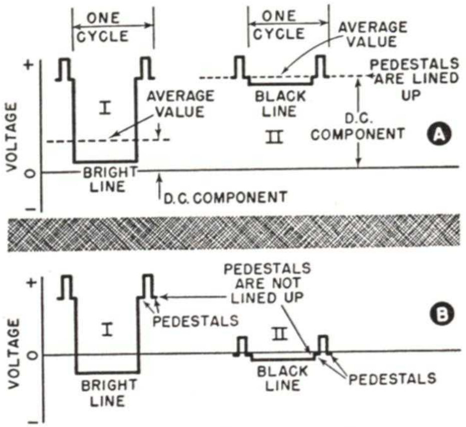

FIG. 13. Passing the demodulated television signal I in A through a condenser removes its d.c. component, giving a.c. signal I in B. Likewise, passing signal II in A through a condenser gives a.c. signal II in B.

the a.c. components line up at zero, as in Fig. 13B, after the signal has passed through the condenser. It is seen from this that the pedestals are no longer lined up.

The addition of a fixed d.c. bias voltage to the a.c. signals shown in Fig. 13B (placing the signal either entirely above or entirely below the zero voltage line) would convert them into pulsating d.c. signals, but would not get the pedestals in line again. We must add a different d.c. bias voltage value for each line if we are to make the pedestals all line up again after a TV signal has passed through a condenser.

With the pedestals in an a.c. TV signal all at different levels, it is impossible to line up all of the pedestals with the cut-off point on the picture-tube characteristic. Remember, however, that we chose two extreme line conditions in Fig. 13. When the average brightness of a line is about the same for all portions of the televised scene, the difference between pedestal levels will not be nearly as great as that shown in Fig. 13. Under this condition it is possible to secure fairly satisfactory image reproduction by adjusting the picture tube bias to correspond to the average brightness level (average pedestal level in the a.c. signal).

For high-fidelity reproduction, a d.c. restorer is essential, but on small low-priced TV receivers it is sometimes omitted. After analyzing a typical video-frequency amplifier stage, we will study the problem of realigning pedestals by properly restoring the d.c. components, as is necessary in cases where a.c. video amplifiers are employed.

Typical Video-Frequency Amplifier Stage. Assuming that we have a TV receiver that requires two video-

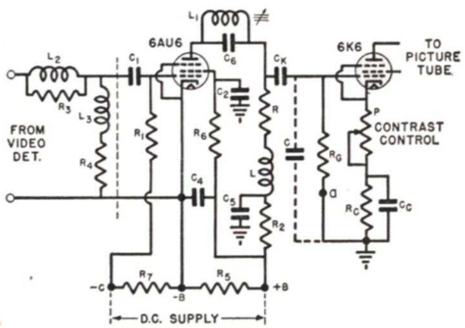

FIG. 14. Typical circuit for the first video-frequency amplifier stage in a TV receiver having two v.f. stages. Parts L_2, R_3, L_3, and R_4 are the same as in the video detector circuit of Fig. 8B.

frequency amplifier stages between the video detector circuit and the picture tube (shown in Fig. 8B), we can consider the type 6AU6 tube circuit, shown in Fig. 14, as being typical of the circuit in the first video-frequency amplifier stage. The television signal from the detector is developed across diode load L_3-R_4. Then the video signal passes through coupling condenser C_1, which strips off the d.c. component. Only the a.c. component of the television signal is thus applied to the control grid of the type 6AU6 tube. This first video-frequency amplifier tube uses fixed bias that is developed across resistor R_7 in the voltage-divider circuit, and this bias is applied to the control grid through resistor R_1.

The remainder of this video-frequency amplifier circuit is more or less conventional except for the presence of choke L in the plate load of the tube, and tuned circuit L_1-C_6. Choke L serves to boost the high-frequency response while L_1-C_6 is tuned to the 4.5-mc. beat frequency formed by the interaction of the picture and sound carriers. If this beat frequency is allowed to reach the picture tube, fine dots will appear as in a coarse-grained photograph. Thus, L_1-C_6 is called a "grain" trap.

One fundamental consideration in building a video-frequency amplifier stage like that in Fig. 14 is the value of capacity C. This capacity is shown dotted in the diagram, since it is a combination of the output capacity of the first stage, the input capacity of the second stage, and stray-lead capacity coupled together by C_K. The reactance of this capacity to ground becomes low enough at the higher video frequencies being amplified to provide a serious shunting effect. The presence of this capacity can be neutralized to a certain extent, however, by keeping plate-load resistor R low in ohmic value, somewhere around 3000 ohms. Thus, the use of a low plate load in a video amplifier stage gives wide-band response. With such a low plate-load value, a tube with a high transconductance is needed to provide the required amount of amplification.

Even more important than the attenuation of high-frequency components in the video signal is the distortion that is produced by capacity C. Coil L is introduced into the circuit for two reasons:

1. Its inductive reactance partially or totally balances out the capacitive reactance of C, thereby eliminating or at least reducing the amount of distortion.

2. If the value of coil L is properly chosen, L and C can be made to resonate at the higher video frequencies, thereby giving a broad parallel-resonant circuit that boosts or peaks the gain at the higher frequencies, and thus counteracts the shunting effect of capacity C. Coil L is called a peaking coil. In some instances you will find additional peaking coils used between the load resistor in the plate of the tube and also between the coupling condenser C_K and the control grid of the following tube. Sometimes these coils are connected in parallel with the resistors to broaden their response. Usually the coil is wound right on the resistor, which serves as a form for the coil.

You will remember that a video amplifier must handle frequencies as low as 10 cycles. At frequencies below about 60 cycles, a coupling condenser C_K of the size generally used in amplifier circuits will not allow square-top pulses or flat (constant level) video signals to pass without causing a gradual drop in the flat top. Therefore, a large coupling condenser is generally used between two video stages to increase the low-frequency response. To decrease the amount of shunting capacity C, this coupling condenser is not allowed to lie on the chassis.

In addition, some method of increasing the gain at low frequencies is incorporated in the circuit. In Fig. 14, R_2 and C_5 are inserted in the plate-load circuit as shown, to overcome the drop-off in low-frequency response. The value of C_5, which is usually an electrolytic, is chosen so that it acts as a shunt to ground for the high frequencies, but is not a complete shunt to ground at the very low frequencies. This means that at low frequencies the effect of C_5 is negligible, and R_2 then acts as a part of the plate load, increasing its resistance and thereby raising the gain.

The variable C-bias arrangement for the type 6K6 tube in Fig. 14 provides a manual contrast control. Contrast control potentiometer P is connected in series with the minimum fixed bias resistor R_C. Varying the contrast control not only changes the bias on the tube and its over-all gain, but also it introduces a certain amount of degeneration, since the contrast control is not by-passed. As the degeneration is increased by inserting more resistance in the circuit, the stage gain decreases.

There are, of course, many modifications in the video amplifiers and contrast control circuits, but we will study these in detail later.

THE D.C. RESTORER

As you have already seen, passage of the television signal through a condenser such as is used for coupling purposes in the video amplifier, will remove the d.c. component. This will leave the video signal in its a.c. form as shown in Fig. 13B. As a result, when resistive-capacitive coupling is used between the video detector and the grid of the picture tube, a d.c. restorer section must be used following the condenser to restore the d.c. component and realign the pedestals. This section adds to the a.c. television signal a d.c. voltage that varies from instant to instant in exactly the proper manner to make the pedestals line up again.

In many receivers the d.c. component of the television signal is restored in the output stage of a resistance-capacitance-coupled video amplifier. This is done simply by eliminating the fixed C bias in this last stage and allowing the sync pulses that are applied to the grid of this tube to develop their own C bias by means of a rectified grid current flow through a grid resistor of high ohmic value.

A typical video output circuit that reverses the phase of the a.c. signal and at the same time restores the d.c. component in the correct manner to make the pedestals line up is shown in Fig. 15. Although this circuit employs

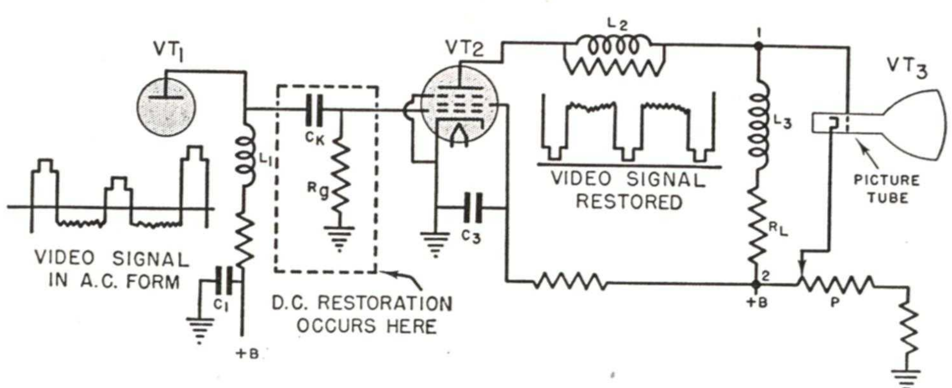

FIG. 15. One method of lining up the pedestals in a TV signal after the d.c. component has been removed by passing the signal through an a.c. amplifier.

a pentode tube, a triode tube could be used. Peaking coils L_2 and L_3 in the plate circuit of tube VT_2 are designed to give gain equalization, and resistor R_L serves its usual function as the plate load.

When an a.c. television signal of the form shown at the left in Fig. 15 (having a negative picture phase) is applied to the circuit, the output signal will be of the form shown at the right, with the pedestals all lined up to give proper restoration of the d.c. component and with the positive picture phase required by the picture tube.

Grid resistor R_g plays an important part in the d.c. restoration process. This resistor has a high ohmic value, generally between 0.5 and 1 megohm, depending upon the type of tube used for VT_2. In order to understand the action of this resistor, we must consider both the E_g-I_p and the E_g-I_g characteristic curves of a tube as shown in Fig. 16. Since there is no fixed C bias for tube VT_2 in Fig. 15, the initial application of a.c. signals I and II to the input of the tube makes the average values of these signals line up with the zero bias line in Fig. 16, and the grid of the tube is therefore driven in both a positive and a negative direction about point A on the E_g-I_g characteristic curve. Since signal I in Fig. 16 corresponds to a bright line and signal II to a black line, we can see that the amount that the grid swings positive is proportional to the brightness of the line being transmitted. These conditions hold true only at the instant of application of the a.c. signal to the grid.

Earlier in your Course you learned that a small amount of grid current flows in the tube even at negative grid-bias values, for some of the electrons that flow from the cathode to the plate under the influence of plate voltage will be trapped by the grid, then flow through the grid resistor to ground. Curve E_g-I_g in Fig. 16 shows how this grid current flow begins at a negative C-bias value corresponding to point B, and increases as the grid is driven less negative and is finally driven positive.

The application of an a.c. television signal (either I or II in Fig. 16) to the output stage will cause grid current to flow at all instants when the signal is to the right of point B. In Fig. 15, the electrons will travel from the cathode to the grid inside the tube and then through resistor R_g to the cathode again, producing across R_g a voltage drop that drives the grid negative. We thus have a negative voltage on the grid, acting in series with the applied a.c. television signal. The value of this negative voltage depends upon how much the a.c. signal swings positive from the zero bias line, and this in turn depends upon the brightness of the line that is being transmitted. We

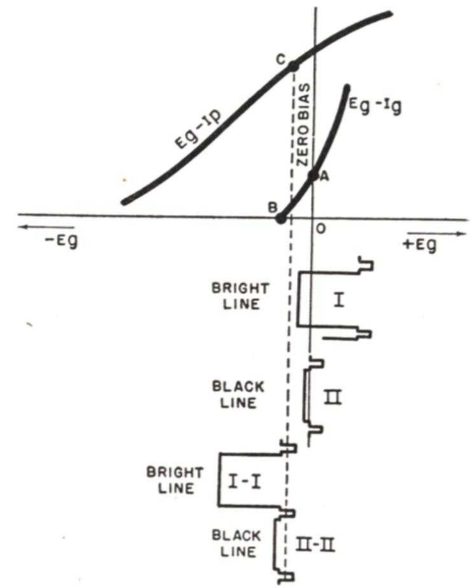

FIG. 16. Characteristic curves for a triode video output tube.

are thus applying, in series with the television signal, a d.c. voltage whose value is proportional to line brightness. If the ohmic value of R_g is made sufficiently high, the sync pulses alone will produce the grid current that is required for this form of automatic C bias and d.c. restoration action. Use of part or all of the video signal for this purpose would result in undesirable amplitude distortion.

With a negative C bias whose value is proportional to the brightness, each line of the a.c. television signal will be moved in a negative direction along the E_g-I_p characteristic curve in Fig. 16 an amount corresponding to the brightness of the line. Signal I (for a bright line) will be shifted automatically to position I-I, and signal II (corresponding to a black line) will be shifted only a small amount, to position II-II in Fig. 16. The result is an automatic alignment of the pedestals. The alignment is not exactly perfect, but it is near enough for all practical purposes. The operating C bias for the output stage will shift with each change in line brightness, but the tube will always be acting on the linear portion of the E_g-I_p characteristic (as a class A amplifier), producing an output signal which has the required phase and the required alignment of the pedestals.

The time constant of part C_K and R_g in Fig. 15 must be so chosen that it is at least equal to the time period for one line, in order to make the instantaneous grid bias dependent upon the average brightness of a line. Since average brightness ordinarily does not change rapidly from line to line, the time constant can be increased considerably; in fact, a time constant equal to the time for about 10 lines appears to be quite satisfactory.

You will notice from Fig. 15 that the picture-tube grid and cathode are connected across the plate load of the last video tube. As a result, the restored signal across this load is applied between the grid and the cathode.

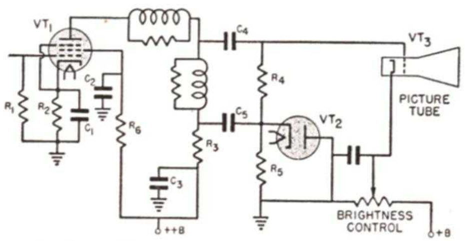

FIG. 17. Here d.c. restoration is secured in the control-grid circuit of the picture tube by means of diode rectifier VT_2. A germanium crystal is sometimes substituted for VT_2, saving space and the filament-current drain of the diode.

In some instances, however, a condenser may be inserted in series with th grid of the picture tube; this, of course, removes the d.c. component. When this is done, another method of restoring the d.c. component is used. This is illustrated in Fig. 17, where the d.c. component is reinserted in the signal at the grid of the picture tube. It will be noted here that the d.c. restorer uses a diode rectifier that could be a tube or a germanium crystal. Both types of rectifiers are widely used in modern television receivers.

Two typical conditions will serve to illustrate how the d.c. restorer in Fig. 17 operates. If the scene being televised is completely black, the amplitude of the voltage representing the picture content will be equivalent to the black level. As a result, if the d.c. component is removed, the picture signal will be at the a.c. axis and the only amplitude variations from this point will be those corresponding to the sync pulses, which will represent rather small amplitudes. If these small pulses are to drive the picture tube beyond cut-off, some means must be provided whereby the bias on the grid is automatically adjusted to cut-off.

We can assume that the initial picture tube bias is determined by the setting of the brightness control, so with no signal, the picture tube is operating at the point of cut-off. Now, if, as described in the previous paragraph, the signal voltage across the video amplifier plate load is small, only a low a.c. voltage is applied in series with the a.c. circuit represented by the plate-circuit decoupling condenser C_3, the plate load resistor R_3, condenser C_5, and the diode rectifier. When the plate is positive with respect to the cathode, the diode rectifier passes current that charges condenser C_5. During periods when the plate is negative with respect to the cathode, the diode rectifier is non-conducting, and the condenser discharges partially through resistor R_5. If the values of R_5 and condenser C_5 are correctly chosen, the charge across the condenser, and therefore the voltage from cathode to ground, will remain substantially constant during the picture interval between successive horizontal sync pulses. The effect of this circuit action is to develop across resistor R_5 a variable bias voltage that opposes the bias due to the brightness control. If part values are properly chosen, this reduction in bias will always be sufficient for sync pulses to drive the picture tube beyond cut-off.

Another analysis may be made using as an example an all-white scene. Under such a condition, the amplitude of the voltage, corresponding to the picture content, will be maximum. Consequently, after the d.c. component is removed from the signal voltage that is developed across the video detector load resistor, the voltage excursions from the a.c. axis represented by the sync pulses will represent comparatively high amplitudes. Under such conditions, the picture tube bias must be automatically reduced from its correct value for a black scene for blanking pulses to drive the tube to the cut-off point and the sync pulses beyond cut-off. An analysis of the circuit indicates that the larger voltage excursions or peak amplitudes would cause a greater amount of rectification, and therefore a correspondingly greater reduction in picture-tube bias. Thus the d.c. restorer is in reality an automatic bias control that continually adjusts the bias so that the blanking pulses always drive the picture grid to the desired cut-off point and the sync pulses drive it beyond cut-off.

Forming the Picture

THE CATHODE-RAY TUBE

The C-bias voltage for the control grid of the picture tube must have a value that will make the line-up pedestals in the television signal operate at the cut-off point on the grid voltage-brightness (E_g-B) characteristic curve for the picture tube. Let us see how this is accomplished.

When no television signal is being fed to the grid of the video output tube in Fig. 15, there is zero C bias in tube VT_2. As a result, the plate current for tube VT_2 is at its maximum value. This gives a maximum voltage drop between points 1 and 2 on the plate load, with point 1 negative with respect to point 2. If the grid of the picture tube is connected to point 1 and the cathode to point 2, as shown, the negative C bias on the picture tube for no signal will be the entire drop across R_L and L_3; this might correspond to voltage A on the E_g-B characteristic curve in Fig. 18. This voltage places the C bias for the picture tube beyond cut-off, and the screen will be dark when no station program is being received.

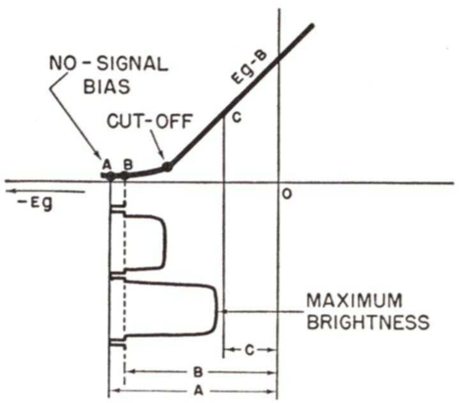

FIG. 18. Grid voltage-brightness characteristic curve for a cathode ray tube, with the television signal shown for the condition where the pedestals are not at the cut-off point.

Application of an a.c. television signal to the grid of the video output stage initiates d.c. restoration action, producing the varying negative C bias required to align the pedestals. As a result, the instantaneous voltage on the grid of the video output tube varies from nearly zero for a sync pulse to a maximum negative value corresponding to a bright line (as shown at I-I in Fig. 16). The pedestals might all line up at voltage B in this case; obviously this is not a desirable condition, for it allows part of the video signal to swing beyond brilliancy cut-off.

To make the pedestals line up at the cut-off voltage, it is necessary to introduce in the grid circuit of the picture tube a positive voltage of the proper value. This can be done as shown in Fig. 15 where the cathode of the picture tube is connected to the movable arm of potentiometer P, a part of the voltage divider connected between B+ and chassis. As the slider of potentiometer P in Fig. 15 is moved toward the right, the negative voltage on the control grid of the picture tube is reduced, and increased brilliancy results. Moving the potentiometer toward the left as shown in Fig. 15 results in increased bias and a darker over-all picture.

Although the brightness control shown in Fig. 15 is entirely satisfactory and is widely used, there is some danger of damaging the picture tube if the video output tube burns out. In this case no plate current would be drawn by the video output tube and point 1 would be of the same potential as point 2. If the slider of potentiometer P is turned toward the right, the cathode of the picture tube will be negative with respect to the control grid—in other words, a positive voltage will be applied to the control grid. Usually this will not damage the screen of the picture tube, but the cathode of the tube could be harmed.

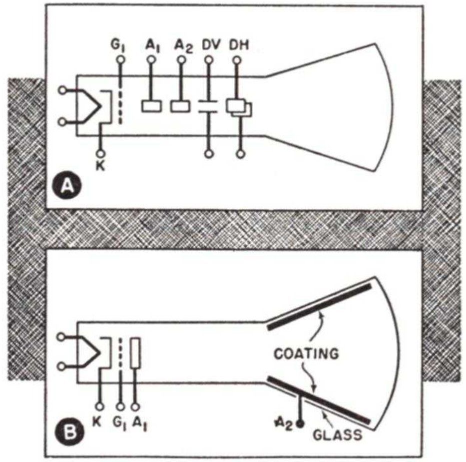

FIG. 19. The electrodes found in electrostatic and electromagnetic picture tubes.

If the brightness control shown in Fig. 17 is used, the bias on the picture tube is entirely independent of the last video amplifier, and unless leakage should develop in condenser C_4 or C_5 nothing would occur that would drive the picture tube grid positive. These are obscure complaints, however, that seldom occur and are not a great problem.

PICTURE-TUBE ELECTRODES

The important electrodes in an electrostatic picture tube are shown in schematic form in Fig. 19A. In addition to the heater (filament), the cathode, and the control electrode G_1 (the control grid), there are two anodes marked A_1 and A_2. These anodes are positive with respect to the cathode, and provide acceleration of the electrons. Anode A_2 is higher in potential than anode A_1. The difference in potential between these two anodes serves to produce an electric field that makes the electrons focus to a point on the screen. Finally, there are electrostatic deflecting plates DV and DH that serve to sweep the beam horizontally and vertically across the screen.

In Fig. 19B the electrodes of an electromagnetic picture tube are shown schematically. Again we have the heater, the cathode, the control grid, and anode A_1 which serves as an accelerating anode. Further acceleration is obtained by means of anode A_2 which consists of a coating on the inside of the glass envelope of the tube. In the metal tubes, the entire metal shell serves as the second anode. A very high voltage is applied to the second anode, and a relatively low voltage, about 300 volts, is applied to the first anode. In these tubes, focusing is accomplished by means of a magnetic field produced by direct current through a focusing coil; other coils carry the currents used to provide magnetic fields for the vertical and horizontal sweeps.

SWEEP CIRCUITS

In both the electromagnetic and the electrostatic picture tube, a saw-tooth sweep is used to move the electron beam back and forth and up and down across the face of the tube. In the electrostatic tube, a saw-tooth voltage is applied to the deflecting plates; in the electromagnetic tube, a saw-tooth current is produced in the deflecting coils that surround the neck of the picture tube.

The sweep circuits used for the electromagnetic and electrostatic tubes are quite similar, although there are a few differences. First, we will consider the sweep circuits for the electrostatic tubes.

In the electrostatic tube each pair of deflecting plates must be fed with a saw-tooth voltage of the correct frequency. The voltage applied to a pair of deflecting plates should have the form shown at C in Fig. 20, which is an a.c. voltage having a saw-tooth wave form.

The circuit shown in Fig. 20 will produce a saw-tooth pulsating a.c. voltage if its grid is controlled by pulses of constant amplitude and duration, so this circuit is satisfactory for a television receiver. The circuit uses an ordinary high-vacuum triode tube, with plate voltage applied through resistor R_L. A bias voltage applied through resistor R_g makes the grid sufficiently negative to give plate-current cut-off, there is no plate current, and condenser C becomes charged to the full plate-cathode voltage of the tube.

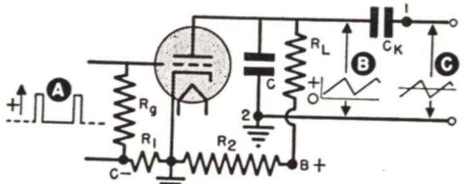

FIG. 20. Saw-tooth sweep circuit.

Each time a positive sync pulse (A) reaches the grid of this tube, the pulse overcomes the negative grid bias and makes the tube conductive for the duration of the pulse. Condenser C then discharges through the tube, which has a definite resistance when conductive. At the end of a sync pulse, plate current flow stops, and condenser C charges up again through R_L. Since the tube when conductive has a considerably lower resistance than R_L, the discharge is far more rapid than the charge. We thus have a gradual build-up in the voltage across C until a pulse arrives, then a sudden drop in voltage during the pulse interval, this process repeating itself for each sync pulse. The voltage across C will be a d.c. voltage having the saw-tooth wave shape shown at B in Fig. 20. When this voltage is applied through condenser C_K, the d.c. component is removed, giving the a.c. saw-tooth wave shape shown at C in Fig. 20.

The saw-tooth generator circuit shown in Fig. 20 cannot be driven directly by the received sync pulses, because the shape of its saw-tooth output wave depends upon both the amplitude and the duration of the pulses fed into it. Under practical receiving conditions, the sync pulses are not constant in amplitude and duration. If they were used to drive a saw-tooth generator, therefore, the shape and frequency of the saw-tooth output would not be constant. Instead, each saw-tooth generator circuit must be driven by an oscillator that will produce pulses of constant amplitude and the correct duration. This will make the saw-tooth generator circuit produce a constant and correct saw-tooth sweep voltage at all times.

An oscillator that is controlled by the TV sync pulses but disregards any variation in their amplitude or duration is used as the driving unit for the saw-tooth generator. Furthermore, each oscillator circuit produces positive pulses at a rate slightly lower than the correct frequency for the generator, and is so designed that the frequency of the oscillator will increase to the correct value automatically when fed with the sync pulses that are associated with the TV signal.

An oscillator circuit that meets these requirements is shown in Fig. 21. It is known as a self-blocking oscillator, commonly called a blocking oscillator, and is used for both electromagnetic and electrostatic sweep systems.

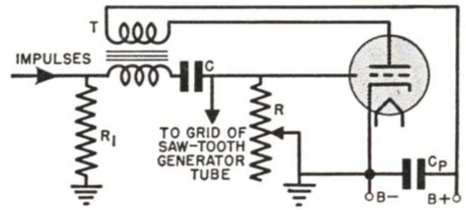

FIG. 21. Self-blocking oscillator circuit which can be controlled by synchronizing impulses.

Transformer T in this circuit provides feedback from the plate circuit to the grid circuit. The transformer connections are such that when the circuit is in operation, the feedback voltage drives the grid positive, just as in a conventional oscillator. The resulting flow of grid current through R produces a voltage drop across R which drives the grid highly negative and at the same time charges condenser C. This charging action lasts for only a brief interval equal to the time required for the negative grid to stop all electron flow in the entire circuit. Condenser C then begins discharging through resistor R at a rate determined by the values of C and R. Both R_1 and the grid winding of transformer T have a low resistance, and consequently the terminal of the winding to which R_1 connects can be considered as connected to ground during this discharge process. When the charge on condenser C has leaked off enough to lower the negative C bias on the grid sufficiently to allow plate current to flow again, feedback then takes place, driving the grid positive, and causing a repetition of the entire cycle.

The frequency of the blocking oscillator circuit in Fig. 21 is controlled by variable resistor R, because it controls the time constant of C and R. The natural frequency of blocking should always be lower than the frequency of the sync pulse that is fed into the circuit, because then the sync pulse will arrive just before the oscillator can unblock by itself and will therefore control the unblocking action. (If the pulse were to arrive after the oscillator had unblocked, it would have no effect on the frequency of operation.) The sync pulse controls the unblocking action because it swings the grid positive almost instantly, starting a new cycle. The same form of sync pulse is produced by this blocking oscillator regardless of the amplitude and duration of the TV signal sync pulses (provided their amplitude is sufficient to swing the grid positive). Sync pulses thus determine the exact frequency of the controlled pulses that are fed to the saw-tooth generator, and these new pulses always have the correct amplitude and duration to control the saw-tooth generator so it will produce the desired sweep voltage.

In actual use, resistor R may be mounted on the front panel so that the customer can make readjustments as necessary, or it may be of a semi-adjustable type mounted on the rear chassis apron. In the latter case, R is adjusted by the technician (at the time of installation) to a compromise setting which gives maximum sensitivity to weak pulses and at the same time insures that the pulses will control the frequency of blocking under all normal receiving conditions.

The grid of the blocking oscillator in Fig. 21, being highly negative with respect to the chassis except for the duration of each pulse, may be connected directly to the grid of the saw-tooth generator circuit in Fig. 20. With this connection, no separate negative bias is needed for the saw-tooth generator grid, and parts R_g and R_1 in Fig. 20 may be omitted. Usually the generator tube and the oscillator

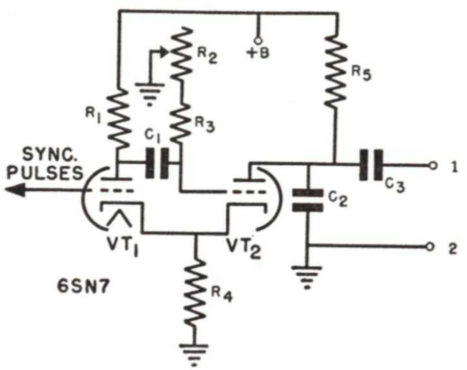

FIG. 22. Saw-tooth generator of the mutivibrator type.

tube are in a single envelope. A double triode such as the 6SN7 is used. One double triode with its blocking oscillator and saw-tooth generator circuit must be provided for the horizontal sweep and another similar system for the vertical sweep, each circuit being adjusted to give the proper sweep frequency.

In some instances, particularly in receivers using electrostatic tubes, the self-blocking oscillator in Fig. 21 and the discharge tube in Fig. 20 may be replaced by a multivibrator like that shown in Fig. 22. This saw-tooth generator uses a type 6SN7 tube as a conventional cathode-coupled multivibrator. The multivibrator can be easily adjusted with the hold control R_2 to oscillate slightly below the correct frequency. The pulses that are applied to the grid of VT_1 will increase the multivibrator frequency automatically to the correct value. Tube VT_2 acts as a discharge tube across condenser C_2 to give a saw-tooth output. The values of C_2 and R_5 are chosen to permit use of the linear portion of the charging curve.

SWEEP AMPLIFIERS

The output of a sweep generator is never sufficient to bend the beam in a picture tube. For this reason, amplification of the sweep generator output is always required.

In the electromagnetic picture tube, the current that passes through the deflection coils is used to produce the magnetic field that bends the beam. A power amplifier between the sweep generator output and deflection coils is required.

In Fig. 23 you will find a typical voltage amplifier for an electrostatic picture tube. Notice that push-pull operation is used because it reduces the total amount of sweep voltage required. The saw-tooth voltage is developed across discharge condenser C_1 in Fig. 23 and is applied through coupling condenser C_2 to the input of tube VT_2. Resistor R_2 controls the

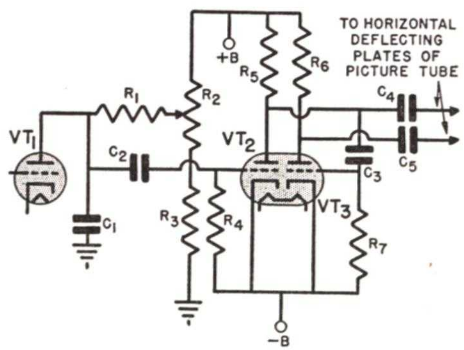

FIG. 23. Push-pull horizontal sweep amplifier for an electrostatic picture tube.

amplitude of the saw-tooth sweep. The signal across grid resistor R_4 is amplified by VT_2 and appears across plate load resistor R_5. This saw-tooth voltage is passed through coupling condenser C_4 directly to one of the horizontal deflection plates of the picture tube. Some of the voltage at the

output of tube VT_2 is tapped off through condenser C_3 and develops a saw-tooth voltage of the correct amplitude across grid resistor R_7 of tube VT_3. This tube amplifies the signal, which is 180 degrees out of phase with the signal that is fed to the input of

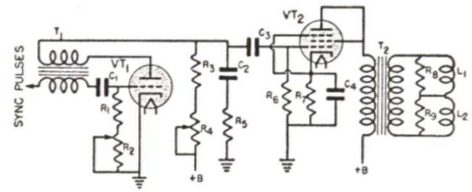

FIG. 24. Single-ended amplifier typical of those used in vertical sweep circuits of electromagnetic picture tubes.

VT_2, and the amplified signal appears across the plate load R_6. Coupling condenser C_5 serves to impress this voltage on the other horizontal deflection plate.

There is practically no difference between the horizontal- and vertical-sweep amplifiers used in electrostatic receivers, with the exception of part value variations. Coupling condensers C_4 and C_5 for the vertical sweep must be far larger in capacity than those for the horizontal sweep, since the vertical sweep operates at 60 cycles, and the horizontal sweep operates at 15,750 cycles.

Fig. 24 is a typical vertical-sweep amplifier circuit used with an electromagnetic picture tube. A conventional blocking oscillator is used, and resistor R_2 is used to vary the sweep-frequency rate. The blocking oscillator also acts as the sweep generator. The amplitude of the generated sweep signal is determined by the setting of resistor R_4. Condenser C_2 and resistor R_5 serve to produce the correct sweep wave shape, which is applied through condenser C_3 to the input of vertical-amplifier tube VT_2. This tube is a pentode but you will note that it is connected as a triode, with the plate and screen tied together. An output transformer that will permit maximum power to be delivered to the vertical deflecting coils marked L_1 and L_2 is used. Resistors R_8 and R_9, in parallel with the vertical deflection coils, are used to damp out any tendency toward self oscillation in this circuit. The currents through L_1 and L_2 have a saw-tooth wave shape, although they are produced by a voltage that differs considerably from a saw-tooth. The reason for this will be explained in greater detail when we study sweep circuits in another Lesson.

There is considerable difference between the horizontal and vertical amplifiers in an electromagnetic picture tube. A horizontal-amplifier circuit is shown in Fig. 25. A high-power tube is used here. The plate generally comes out to the top-cap connection. (You should never make the mistake of touching a top cap of a horizontal output tube since several thousand volts may be present as a result of the high value of inductance in the plate circuit.)

The sweep signal is applied to the input of this tube across resistor R_1 in the usual manner, and the amplified

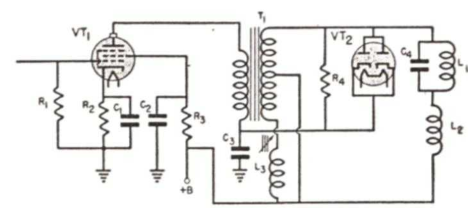

FIG. 25. Horizontal amplifier and deflection coils showing damper tube used to prevent fold-over in the raster.

signal across the primary of T_1 is transferred to the secondary. The current flowing in the secondary circuit and through deflecting coils L_1 and L_2 can be limited by adjustable inductance L_3. This inductance is therefore the horizontal-width control.

The Damping Tube. The linear rise of current through the horizontal deflection coils moves the electron beam from the left to the right side of the picture in approximately 53 microseconds. The current must then return to its starting value at approximately 7 microseconds to produce the

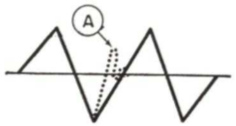

FIG. 26. Current through horizontal deflection coil and oscillation removed by damping tube.

retrace. This sudden collapse of current through an inductance produces an oscillatory condition, shown at A in Fig. 26, that would destroy the linearity of the sweep and must be removed by the damping tube. This tube is VT_2 in Fig. 25. When the plate of the damping tube becomes more positive than its cathode, conduction occurs, heavily loading the circuit, and preventing the undesirable oscillation. As a result of this conduction, a d.c. potential of approximately 100 volts is developed and stored in condenser C_3. This voltage is added to the normal plate voltage of the horizontal amplifier and makes its potential considerably higher than that from the power supply of the receiver alone. Unless this salvaged energy is used, there will be considerable loss in efficiency.

Damping-tube actions will be described in greater detail elsewhere in the Course, but you will be interested to see in Fig. 27 the effect of a burned-out damping tube. Notice how the horizontal-sweep linearity is destroyed so that overlapping or "fold-over" occurs at the left of the test pattern.

SPOT-CENTERING CONTROLS

It is not economically practical to build a gun in a cathode-ray tube that will produce a spot in the exact center of the screen when there are no deflecting voltages applied to the plates of an electrostatic tube, or when there is no current flowing through the deflecting coils of an electromagnetic tube. Some adjustment must be provided that will move the spot to the exact center of the screen and thereby center the reproduced image on the screen.

In Fig. 23, the required sweep voltage exists at the output of condensers C_4 and C_5 and must be applied to a pair of deflecting plates in the picture tube as shown in Fig. 28. Condensers C_4 and C_5 are coupling condensers (like the ones shown in Fig. 23), and resistors R_1 and R_2 complete the return circuit for deflecting plates 1 and 2 and also serve as the signal load for the sweep voltage supplied through condensers C_4 and C_5. Notice that plate No. 1 connects to point b on the voltage divider. Plate No. 2 connects

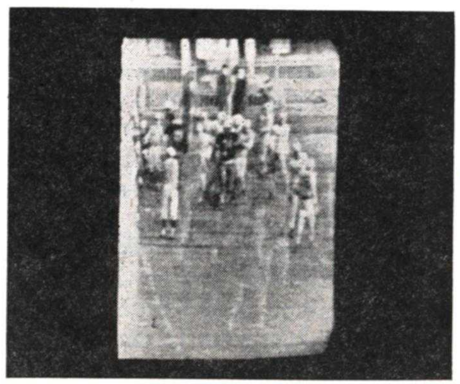

FIG. 27. Fold-over in raster due to defective damper tube in horizontal sweep.

to the slider of potentiometer R_6. Moving the slider toward point a makes plate 2 more positive than plate 1, and the beam is bent toward plate 2 while being repelled by plate 1. Moving the slider toward point c makes plate 2 negative with respect to plate 1, and the beam is repelled from plate 2 and attracted toward

plate 1. By properly adjusting R_6 the beam can be exactly centered. A similar system is used for the other pair of deflection plates.

It is also necessary to center the beam in an electromagnetic tube using a sweep system such as that shown in Fig. 24. In this figure, no means is provided for centering the beam; centering is done by moving the focus coil. This will be taken up in detail later. In many sets, an actual adjustment is often used for centering purposes in an electromagnetic picture tube. A typical system is shown in Fig. 29. Here we have a low-resistance tapped potentiometer in the B-supply circuit. Notice that the secondary of the sweep transformer connects directly to point 2 and through deflecting coils L_1 and L_2 to the slider of the potentiometer.

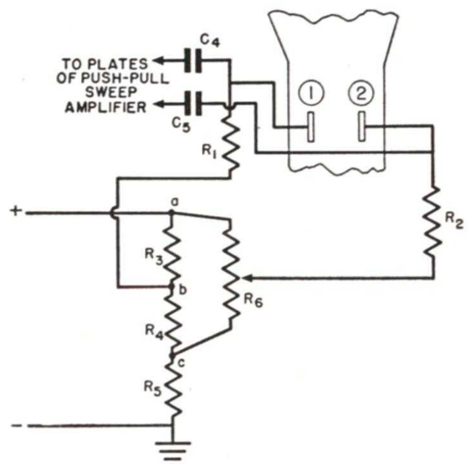

FIG. 28. Electrostatic centering control.

When the slider is placed at point 2, no d.c. flows through the deflecting coils. When the slider is moved toward point 1, electrons will flow from point 2, through the secondary of output transformer T_1 and through L_1

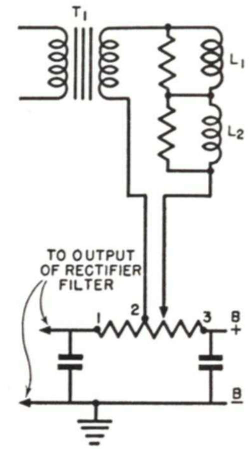

FIG. 29. Electromagnetic centering control.

and L_2 back to the slider. This will bend the beam in a given direction. When the slider is moved toward point 3 it reverses the direction of current flow, and the electrons now travel from the slider, through L_2 and L_1, the secondary of T_1, and back to point 2. This moves the beam in the opposite direction. Proper adjustment of the slider gives exact centering of the beam, and hence centering of the reproduced picture on the screen. The same method can be used for either the horizontal or vertical sweeps in electromagnetic picture tubes.

Sync-Separating and A. G. C.

SYNC-SEPARATING CIRCUIT

Before the synchronizing pulses that accompany the video signal can be made to control the horizontal and vertical sweep circuits, the sync pulses must be separated from the video signal, and the horizontal sync pulses must be separated from the vertical sync pulses.

Either a triode or a pentode tube that is negatively biased to plate current cut-off or a diode tube will separate the sync pulses from the video signal, provided that only the pulses cause plate current to flow. The television signal that is fed into the sync separator circuit can have either a positive or a negative picture phase, but in either case *the pedestals must be lined up.* Alignment of the pedestals makes the use of a negative picture phase more desirable, as you will shortly see.

If the sync separator is to be connected to a point in the video amplifier where pedestals are not lined up (where only the a.c. component of the television signal is present), *the pedestals must be lined up by properly restoring the d.c. component* before the signal can be fed into the sync-separator tube.

The sync separator will have a loading effect upon any stage to which it is connected, even though the separator tube is negatively biased, for the separator circuit has an input capacity that can affect the high-frequency response of the video amplifier. There is one point in a television receiver to which this input capacity can be connected without affecting high-frequency response. Referring to Fig. 30, you will see that one half of a duo diode is used as a video detector. The other half of the tube may be used as the sync separator or clipper. This is section VT_1 of the 6AL5 shown in Fig. 30. Section VT_1 rectifies the video signal applied to it through condenser C_1, the path of electron flow being through R_2, VT_1, and R_1. The input time constant, which is governed by the values of C_1 and R_1, is such that VT_1 holds its bias just above black level and delivers separated sync pulses to sync amplifier VT_3. The pi filter composed

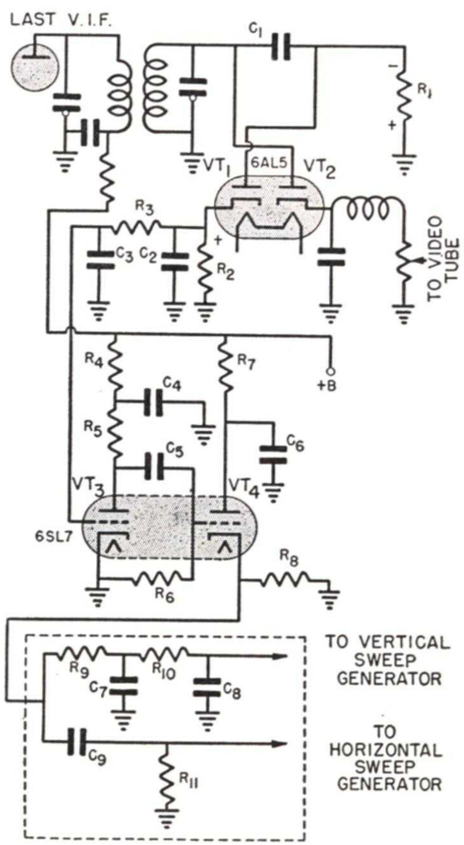

FIG. 30. Here are shown the detector, the sync separator and amplifier, and the sync limiter, which delivers noise-free, constant amplitude pulses to the sweep generator. That portion of the circuit shown in the dotted lines separates the horizontal and vertical pulses.

of resistor R_3 and condensers C_2 and C_3 separates the video i.f. frequency and hash from the sync pulses.

The sync amplifier VT_3, and the sync limiter VT_4, frequently precede saw-tooth generators of the multivibrator type shown in Fig. 22. VT_3 and VT_4 share a type 6SL7 tube and VT_3 amplifies both the horizontal and vertical pulses obtained from VT_1. Section VT_4 acts as a limiting cathode follower which clips off the noise peaks and supplies constant amplitude sync pulses to the saw-tooth generator circuits.

The grid of sync amplifier VT_3 is d.c. coupled to the cathode of VT_1. Resistor R_4 drops the voltage applied to the sync amplifier with R_5 as the short intensity, as they are for the horizontal sync pulses and the horizontal equalizing sync pulses (serrations) in Fig. 31, C_9 charges and discharges through R_{11}, producing the required horizontal timing pulses for the horizontal saw-tooth generator. This is due to the short time constant of C_9 and R_{11} which enables the condenser-charging current to follow faithfully the voltage variations shown in Fig. 31. Thus, horizontal sync pulses are obtained even during the vertical synchronizing periods, as is required.

With no sync signals being received, C_8 in the vertical separator circuit is charged up to the same voltage as appears across R_8. The time constant of

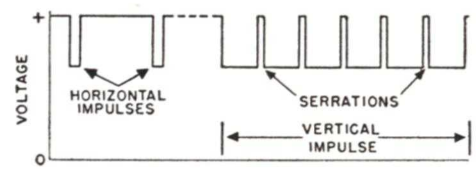

FIG. 31. Wave forms of impulses at the output of the amplitude-separator section.

plate load resistor. Resistor R_7 and condenser C_6 supply low d.c. voltage to the plate of the cathode follower. When a sync pulse is rectified by VT_1, it causes the cathode end of R_2 to become positive, thus applying a positive voltage pulse to the grid-cathode of VT_3 and increasing its plate current. The voltage drop across R_5 increases, which reduces the plate voltage of VT_3, allowing C_5 to discharge through R_6 and VT_3. Electrons flow from C_5 through R_6 to the chassis, making the grid of VT_4 negative and decreasing its plate current. This reduces the voltage across R_8. When picture signals are being transmitted, no signal reaches the grid of VT_4 and the voltage across R_8 has a constant value. Sync signals cause this voltage to decrease.

When the voltage variations are of this circuit is slow, and C_8 does not have time to discharge on the widely separated horizontal sync pulses. When the vertical sync pulses arrive, C_8 will gradually discharge, being relatively unaffected by the short duration serrations, and the decrease in voltage across C_8 at this time is used to control the vertical saw-tooth generator.

AUTOMATIC GAIN CONTROL

The final television receiver section to be considered is that which provides the automatic gain control voltage. In this section, again, it is best to use the television signal in its d.c. form with pedestals lined up. The voltage for the a.g.c. circuit should be obtained across a load resistor which is shunted by a large condenser, in order to give a time constant so long that the voltage will follow the sync pulse peaks. Doing this insures that the a.g.c. voltage will depend upon carrier level (or its equivalent, the level of the sync pulse peaks), rather than upon line brightness.

Tube VT_1 in Fig. 30 produces across

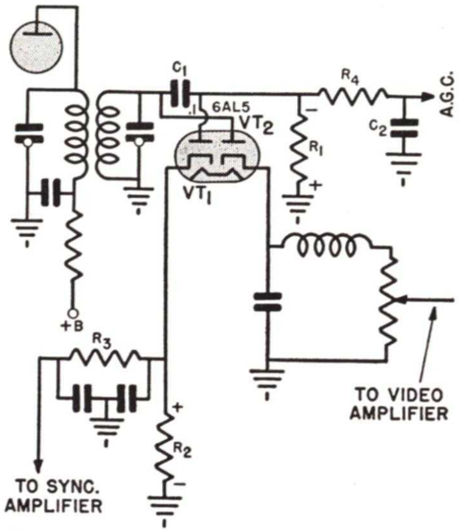

FIG. 32. By filtering the voltage across R_1, and a.g.c. voltage is obtained across C_2.

R_1 a voltage that follows the sync pulse peaks and has the correct polarity for a.g.c. purposes. It is only necessary to add an R-C filter composed of C_2 and R_4, as shown in Fig. 32, to complete the a.g.c. system. The a.g.c. voltage appears across C_2 and will follow at all times the level of the sync peaks. If for any reason the carrier fades, the a.g.c. voltage will be reduced and the receiver gain will increase. An increase in carrier level increases the a.g.c. voltage, which in turn will reduce the receiver sensitivity.

In this manner the 6AL5 tube shown in Fig. 32 serves three purposes; acting as the video detector, the amplitude separator, and the a.g.c. This is a very simple a.g.c. system. Some sets use complicated circuits. These will be described in detail in another Lesson.

REVIEW OF LESSON

In reviewing this Lesson, try to visualize the frequency conversions that occur and the new frequencies developed as the television signal progresses through the receiver. Learn the frequency ranges that are handled by each stage and section, and above all, try to visualize the characteristics of the television signal at each stage or section. Furthermore, keep in mind that in television the terms *picture signal, video signal, image signal,* and *sight signal* are used interchangeably. The terms *sound* and *audio* are likewise used interchangeably.

Lesson Questions

Be sure to number your Answer Sheet 50RH-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. If a signal having a positive picture phase is fed to the grid of a video amplifier, what will be the picture phase of the amplified signal in the plate circuit of the stage?
2. Why does passage of a video TV signal through a condenser cause misalignment of the pedestals?
3. Why cannot the sync pulses in the TV signal be used to drive a sweep saw-tooth generator?
4. Why should the natural frequency of a sweep oscillator be lower than the frequency of the sync pulses?
5. How may the phase of the picture signal at the output of the diode video detector be reversed?
6. Why must the pedestals of a video signal all be lined up at the same constant level at the input of the picture tube?
7. Why are video amplifier stages operated with low plate loads?
8. Why is a large capacitor usually used as the coupling condenser between two video stages?
9. What is the purpose of the resistors connected in parallel with the vertical deflection coils in an electromagnetic sweep circuit?
10. What is the purpose of the sync separator or clipper?

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

PAY ATTENTION TO LITTLE THINGS

It is the close observation of *little things* that is the secret of success in business, science, and every pursuit in life. Human knowledge is only an accumulation of small facts.

You may come across some facts and observations in your NRI course that may seem to be unimportant. But keep in mind that all will have their eventual uses and will fit into their proper places.

When Franklin made his discovery of the identity of lightning and electricity, people asked, "Of what use is it?" Franklin replied, "What is the use of a child? It may become a man!"

When Galvani discovered that a frog's legs twitched when put in contact with different metals, his observation did not seem important. But this observation was the "germ" of the telegraph.

Yes—it is well worth-while to *pay attention* to little things. When added up and used properly, great things may result.