RADIO **SERVICE** TELEVISION

A Monthly Digest of Radio and Allied Maintenance

DEFLECTING CIRCUITS
For Television Receivers

By
Madison Cawein
In charge of
Television Receiver Development
FARNSWORTH TELEVISION & RADIO CORP.

TELEVISION receiver circuits may be divided into six parts: r-f; i-f; video; audio; deflection and power supply circuits. It is the purpose of this article to discuss the deflection circuits in order to acquaint the Service Man with a rough working theory of television deflection systems. Such a knowledge is quite necessary if he is even to approach the service problems which he will encounter. Other portions of the receiver circuit will be dicussed in subsequent articles.

The process of rectilinear scanning employed in commercial television in the United States consists of directing a beam of electricity known as the spot, to pass rapidly (at approximately 10,000 ft. per second for a 10-in. picture) across a picture from left to right, strip by strip (Fig. 1.) This beam of electricity is composed of high speed electrons (at velocities from 10,000 to 30,000 miles per second) and the width of each strip is roughly equal to the diameter of the region to which the electrons are confined. The strips over which the spot scans are located one beneath the other and spaced apart by a strip width. Two-hundred and twenty and a half strips are traced from top to bottom of the picture. The beam is then directed again to the top of the picture to trace the other set of strips which lie between those over which it passed on the first trip.

In television parlance the strips are called *lines*. Each sequence of 220½ lines from top to bottom of the picture is accomplished in 1/60 second and represents one-half *frame* because only one-half the information of the picture is scanned on each trip. On alternate trips the electrons are directed to fall exactly along lines which lie between the others (shaded in Fig. 1). This system is known as the *double interlace* system of scanning and two sets of lines from top to bottom of the picture are required for a complete frame which contains all the detail or information of the picture. Thus each frame contains $2 \times 220\frac{1}{2} = 441$ interlaced lines, and requires $2 \times 1/60 = 1/30$ second for transmission.

Choice of these standards constitutes the 441 *line, 30 frame, double interlace system of television scanning*. This choice of standards is based on power-line frequency, 60-cycles and on flicker. The system is a practical one which minimizes the effect of hum on pictures. The interlace is a trick necessary to prevent flicker and at the same time to limit the rate of projection of television pictures to a reasonable value (30 per second). Motion pictures are projected at 24 per second, but are interrupted once in each projection to give an effective flicker frequency of 48 cycles which is the limit the average eye can stand. Interlace in television corresponds to shutter interruption in motion pictures.

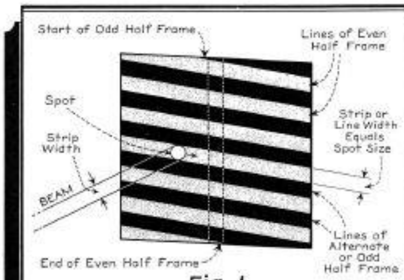


Fig. 1

The direction of the electron scanning beam is controlled by electric fields of force. No man knows exactly what an electron is, nor exactly what is the real nature of a field of force. Their practical interactions and laws of control are well understood, however. There are two kinds of electric fields of force: the electrostatic field, and the electromagnetic field. Most scientists believe these fields to be different aspects of one thing, but usually discuss them separately for simplicity.

Electrostatic fields exist between conductors of different potential, the latter expressed in volts. The fields force electrons to move toward the point of highest positive voltage, and the speed of the electrons depends upon the voltage. The electrostatic field acts in the space surrounding charged conductors to deflect a speeding beam of electrons toward the most positively charged conductor. High speed beams pass quickly through the electrostatic field of the conductors and receive less deflection than low speed beams on which the force acts for a longer time. The practical result of this is that the deflection voltage in an electrostatic system must be increased proportionally to the high voltage employed on a television picture tube anode.

Electromagnetic fields exist around an electric current, the latter expressed in amperes. These fields force a speeding beam of electrons to move in a path that curls circularly around the axis of the coils through which the current flows. The electromagnetic field acts in the space surrounding coils with flowing currents to deflect a speeding beam of electrons in such direction that the space current of the beam tends to follow a parallel path to the current in the coils.

One peculiarity of the action of an electromagnetic field is that the deflecting force on the beam current increases with the speed of the electrons in the beam. There is no action on an electron which is not moving. The time that the force acts, however, is decreased with

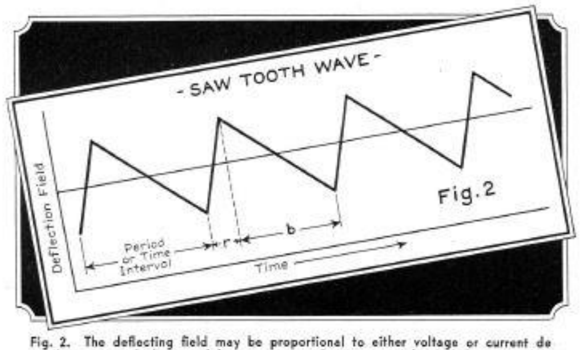


Fig. 2. The deflecting field may be proportional to either voltage or current depending upon which type (electrostatic or electromagnetic) of deflection system is used.

increased speed. The practical result of this is that the deflection current must be increased proportionally to the square-root of the high voltage employed on a television picture tube in order to maintain the proper size of picture.

• • • waveform

In rectilinear scanning, the spot must move across the picture in a linear manner: that is, the displacement from left to right must be proportional to the time. Other systems could be used but are not used because the linear system is more simple. When the spot has reached the extreme right-hand edge of the picture it must be returned to the left edge for the start of the succeeding line. During this return period the beam current is cut off during transmission; otherwise a ghost-picture would appear in the background. Actually, the beam current itself is not returned across the picture but the deflection field changes its direction during an interval of time while the beam is cut off. When the beam is turned on again the field is in such direction as to start the line at the left-hand side of the picture and slightly below the preceding line. It requires two deflecting fields to accomplish this result: namely, (1) a horizontal deflection field which deflects the spot from side to side; and (2) a vertical deflecting field which deflects the spot from top to bottom. The speed of the vertical field is much slower than the speed of the horizontal field. The vertical field directs the spot at a slow steady rate, in time, from top to bottom of the picture while the horizontal field is deflecting the spot at a fast steady rate, in time, from left to right. The net effect of these two actions is that the lines have a slight slope in relation to the edges of the picture as shown in Fig. 1. When the spot has reached the bottom of the picture and at the completion of the 220½ line, the electron beam is cut off and the vertical field is suddenly changed so as to direct the spot again to the top of the picture. The horizontal field has a period of 1/13,230 second: that is, it takes this length of time for the direction of the horizontal field to change linearly from left to right edge

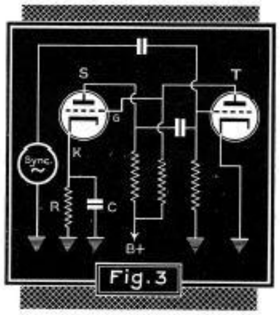


Fig. 3. The principal time controlling circuit of the saw-toothed oscillator is composed of the resistor R and capacitor C.

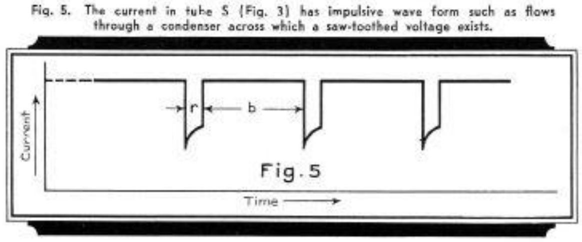
of the picture and back again to left edge. The vertical field has a period of 1/60 second: that is, it takes 1/60 second for the vertical field to change its direction from top to bottom of the picture and for it to come back to top again. It is attempted in television circuits to make the return time of the field, during the period in which the beam is cut off, as rapid as possible because this time is useless insofar as picture reproduction is concerned. Actually, the return time is approximately ten per cent of the trace time. The two portions of the deflecting cycles have been referred to in the literature as trace and retrace: trace referring to the useful portion of the cycle during which the electron current flows across the picture, and retrace referring to the useless portion of the cycle during which the electron current is cut off. Other terms for these portions of the cycle will be encountered: that is, sweep for trace and fly-back time or return-time for retrace.

A graph of the displacement of the deflecting field in time is plotted in Fig. 2.

The field, which may be proportional to either voltage or current depending upon the use of electrostatic or electromagnetic deflection, is plotted in the vertical direction on this graph and time is plotted in the horizontal direction. The resulting waveform of Fig. 2 is known as a saw-tooth waveform. It applies to either horizontal or vertical deflection systems, for which only the value of the time element must be changed. Thus, the time intervals represent 1/13,230-second in horizontal deflecting systems and 1/60-second in vertical deflecting systems. These time intervals are the time of the cycle of the deflecting wave. Each cycle is broken into two portions: trace portion denoted in Fig. 2 by letter *b*, and retrace portion denoted by the letter *r*. If the time of the entire cycle be treated as unity, $b + r$ is always equal to one. Under RMA standards *b* is approximately equal to 93 percent of the cycle and *r* is approximately equal to 7 percent of the cycle for the vertical deflecting field, while *b* is approximately equal to 85 percent of the cycle and *r* is approximately equal to 15 percent of the cycle for the horizontal deflecting field.

When an oscilloscope is connected across the deflecting plates of the cathode ray tube on a television receiver employing electrostatic deflection, the waveform of Fig. 2 will appear on the

Fig. 5. The current in tube S (Fig. 3) has impulsive wave form such as flows through a condenser across which a saw-toothed voltage exists.



oscilloscope screen when proper synchronization of the oscilloscope with the deflecting wave is obtained; or if the oscilloscope be used to examine the current in a resistor in series with the deflecting coils of a television receiver employing electromagnetic scanning this waveform will be seen. Always the trace portion of the saw-tooth cycle must be a perfect straight line when the receiver is adjusted properly. The retrace or steep portion of the wave may have exponential curvature without detracting from picture reproduction. The only important feature of the retrace portion of the cycle is that it be accomplished rapidly, that is, during that small percentage of the cycle when the electron beam is cut off. It is important that any oscilloscope utilized to examine these waveforms have excellent fidelity over a band of frequencies to 250,000 cycles, and that the phase response of the oscilloscope be perfectly linear from frequencies below 30 cycles to frequencies above 250,000 cycles. Otherwise a true picture of the deflecting waveforms will not be obtained. Deflecting waves are made up of many frequency components, consisting of the fundamental frequency, which is the reciprocal of the time of a cycle, and all of its harmonics.

In practice, 100 harmonics of the 60-cycle fundamental of the frame deflecting field are required to reproduce the frame deflecting waveform, and at least 20 harmonics of the horizontal deflecting field fundamental frequency of 13,230 cycles are required. Loss of higher harmonics will result in rounding of the points of the saw-tooth wave, and phase shift of the low-frequency component and harmonics will cause curvature of the sweep portion of the cycle.

• • • deflection generators

It is necessary to supply deflection fields of the form of Fig. 2 in television receivers by means of either saw-tooth voltage waves or saw-tooth current waves. Some means of generating such waves is necessary. Saw-tooth generators are usually of the relaxation oscillator type. In essence, the relaxation oscillator is a violently regenerative device which may have many arrangements in practice. A simple two-tube circuit is shown in Fig. 3.

In this circuit the plate current varies between negative cutoff and positive overload alternately in the two tubes. The frequency of the current waves is dependent upon the time constants of the associated circuit elements, that is, upon the products of capacitors and resistors. The principal time controlling circuit in Fig. 3 is composed of resistor R and capacitor C. The product of R in ohms and C in farads has the dimensions of time. Thus, if R is one (1) megohm and C is 0.1 microfarad the product is 10^6 ohms $\times$ 10^{-7} farads = 0.1 seconds. This product is known as the time constant of the RC circuit and should in general be larger than the period of a cycle of the saw-tooth wave: in general 1/10 second is sufficient time constant to produce linear waves of frame frequency, that is at 60 cycles. Condenser C charges up from tube S until the cathode potential of S, is so great that the plate current is cut off. Since tube T has no bias, the plate of R which is connected to the grid of S will be much lower in potential than the cathode of S, and will thus keep the plate current of S at zero. C discharges through R in a manner indicated by the solid line in the graph of Fig. 4: This curve is known in mathematics as an exponential. When a sufficiently small portion of this curve is examined, it will be found to be approximately linear. When the voltage of C which is connected to the cathode of tube S approaches the grid voltage of tube S shown in dotted line G of Fig. 4, the current again begins to flow.

This flow of current reduces the bias of tube T allowing its plate voltage to rise, and regenerating the flow of current in tube S so that condenser C is very rapidly charged from the B+ source to the potential K of Fig. 4, where the tube S again cuts off. This process continues indefinitely and the cathode potential of tube S follows the solid line variation shown in Fig. 4 which is an exponential saw-tooth wave that is almost linear. The greater the amplitude of this wave the more curvature it will exhibit. In practice it is attempted to keep the amplitude of the generated saw-tooth wave low, in order to obtain good linearity. The wave form of the plate current in tube S is shown in Fig. 5.

This wave is known as the impulsive wave and represents the form of the current which flows through a con-

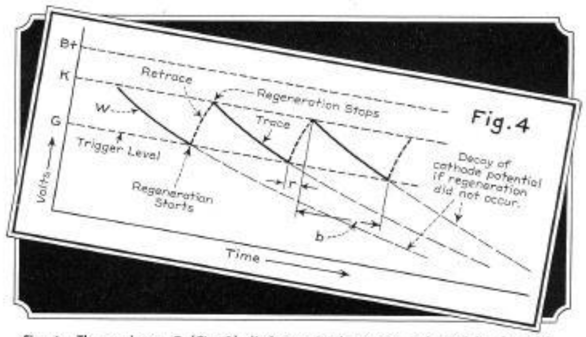


Fig. 4. The condenser C (Fig. 3) discharges in the manner indicated by the solid line. This curve is known as an exponential.

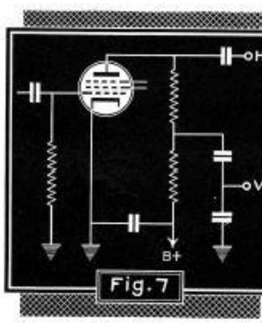
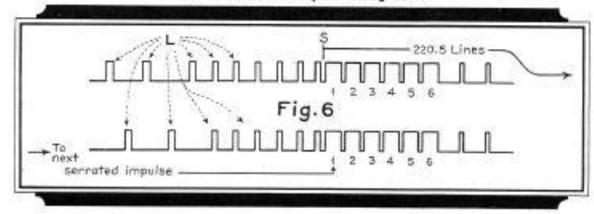


Fig. 7. A special tube is used to separate the synchronizing pulses for the H and V circuits.

Fig. 6. The saw-toothed frequency is controlled by transmission of what is termed the RMA standard synchronizing wave.



denser across which saw-tooth voltage exists. It also represents the form of the voltage which exists across electromagnetic coils through which saw-tooth current flows. The physical reason for this inverse relationship of voltage and current in coils and condensers arises from the fact that their reactances have opposite signs: that is, if the reactance of an inductor be considered as positive, the reactance of a capacitor must be considered as negative. The relationship between currents and voltages in capacitors and inductors will be found helpful in trouble-shooting television receivers.

• • • synchronization

Deflection generators in general will oscillate with good saw-tooth waveform at a frequency determined by the time constant of the associated circuits and the characteristics of the tube. This frequency must be controlled in a television receiver in order that the receiver picture keep exactly in step with the transmitted picture. The control is accomplished by transmission of what is known as the RMA standard synchronizing wave which is of impulsive form as shown in Fig. 6.

This synchronizing wave has an accurately timed wave generated at the transmitter and consisting of 441 equally spaced line impulses at each 1/30 second and two equally spaced series of serrated vertical synchronizing pulses spaced at 1/60 second. Because of the odd-number relationship between 441 and 60 there is always one half-line extra between each series of six vertical synchronizing serrated pulses. The horizontal relaxation oscillator must trigger exactly at the start of each of the pulses L in Fig. 6, and the vertical relaxation oscillator should trip exactly on the leading serrated pulse S in Fig. 6. If the vertical oscillator does not trigger on the leading pulses S it must trigger on identically related pulses, from one to six, on each occurrence of the serrations at intervals of 1/60 second. Otherwise interlace of the receiver will not be maintained, although frame synchronization will be.

In order to insure that the horizontal and vertical relaxation oscillators trip exactly in time with the transmitted signal it is necessary to separate the horizontal synchronizing pulses from the vertical serrated synchronizing pulses. There are many ways in which to accomplish this. Fundamentally the difference in the duration between the horizontal pulses and the serrated pulses is the most important physical characteristic upon which to work to obtain successful separation. In Fig. 7 there is shown the circuit of a synchronizing separator tube.

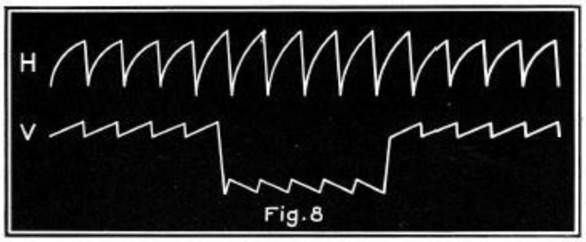


Fig. 8. The voltage pulses of Fig. 6 applied to the grid of the tube of Fig. 7 will produce the pulses indicated at H and V of Fig. 7.

The separation accomplished by this tube is dependent only upon the time constant of the associated RC circuits. The voltage pulses of Fig. 6 applied to the grid of the tube of Fig. 7 will produce voltage pulses at H and V of Fig. 7 which have a form as shown in Fig. 8.

Voltage H is applied directly to the grid of tube T in a horizontal frequency relaxation oscillator similar to that shown in Fig. 3, and serves to accurately start each horizontal deflection cycle at the proper time. The voltage V is applied to the grid of tube T in a vertical frequency relaxation oscillator similar to that shown in Fig. 3 in order to accurately time the start of the vertical saw-tooth cycle.

The waves generated at the cathodes K (see Fig. 3) of the horizontal and vertical deflection oscillators are of saw-tooth form and may be utilized to excite either voltage or current amplifiers for the purpose of deflecting the electron beam of a cathode ray tube in a television receiver.

• • • deflection amplifiers

Deflection amplifiers are of two types: voltage amplifiers and current amplifiers. Voltage amplifiers are used in receivers employing electrostatic deflection. Current amplifiers are used in receivers employing electromagnetic deflection. Voltage amplifiers are in general much less complex than current amplifiers. They will be encountered in receivers employing small cathode-ray tubes, that is, from three to seven inches in diameter. Current amplifiers will be encountered in receivers employing large cathode-ray tubes, that is, from seven to fifteen inches in diameter. It is possible to use either system of deflection with any size of tube. The purpose of this article, however, is to describe for your benefit, the circuits which are usually encountered.

Electrostatic deflection systems are simple arrangements when the electron beam velocity is relatively low, as in the cathode-ray tubes employing less than 2,000 volts of plate potential. In such receivers the oscillator voltage waveform W of Fig. 4 is applied directly to the grid of a triode amplifier. Resistance coupled amplification is used in this case and a fraction of the plate voltage wave developed is applied to the grid of a second triode amplifier having a large plate resistance, the output of which will be in the inverse polarity to that of the first triode amplifier. These two outputs are then applied via high-voltage blocking condensers directly to either the vertical or horizontal deflecting plates of the cathode-ray picture tube. Approximately 250 volts, peak-to-peak, of saw-tooth voltage is required from each amplifier in order to scan a short-necked five-inch tube. Smaller voltages are required for long-necked five-inch tubes. Tubes of the double triode type, as the 6F8G, are usually sufficient in the electrostatic deflection systems. They impose relatively low power requirements on the receiver power supply.

The electromagnetic deflection amplifier problem is much more complex than the electrostatic. For one thing, the polarity of the wave shown in Fig. 4 is incorrect for application to the grid of a saw-tooth current amplifier. It is extremely important that the retrace or steep portion of the saw-tooth wave occur in a negative rather than a positive direction, otherwise the inertia effect of the electromagnetic scanning coils in the plate circuit of the scanning power tube will prevent the rapid collapse of scanning field so necessary in obtaining rapid retrace during the period in which the cathode-ray beam is cut off.

There are relaxation oscillators which will generate the wave of Fig. 4 in reverse polarity. The reverse polarity wave may be applied directly to the grid, preferably of a beam power tube of the type 6L6, or of higher rating. The plate circuit of this tube contains a reactive load composed of the reflected reactance of scanning coils through a scanning transformer. This reflected load must be of low impedance at all the harmonic frequencies which compose the saw-tooth wave in order that the

(Continued on page 300)

DEFLECTING CIRCUITS

(*Continued from page 274*)

current amplifier deliver the maximum current to the deflection system. It requires in the neighborhood of 80 milliamperes peak-to-peak saw-tooth current in the plate circuit of a horizontal electromagnetic scanning amplifier to produce the 0.5 ampere current in the deflection coils which is necessary to scan a nine or twelve-inch cathode-ray tube at 6000 volts plate potential. Distributed capacitances in the plate circuit of the amplifier or across the scanning coils will short-circuit the high frequency components of the deflecting saw-tooth wave and cause non-linearity of the picture and insufficiently rapid return time of the deflecting field. In such cases, the picture may be badly crowded from one side to the other and even a partial ghost-image may be produced in the background.

In servicing television receivers these points must be kept constantly in mind.

• • • adjustments

Commercial television receivers employ various numbers of controls for adjusting the scanning pattern of the receiver. In general, the more expensive the receiver the more controls will be employed. In present day practice, it is usual to provide at least six scanning controls. These are: the vertical hold control which controls the synchronization of the picture framing; picture height control which controls the amplitude of the vertical deflection; picture centering control which controls either the d-c potential on one deflecting plate or a d-c current through the deflecting coils to take care of misalignment of the cathode-ray beam at the center of the picture tube; horizontal hold control, which controls the horizontal synchronization; picture width control, which controls the amplitude of the horizontal deflection; and horizontal centering control.

Too great an amplitude of scanning and too great an amplitude of deflection may result in an overload of deflection amplifiers which will produce curvature and crowding in the picture and also may produce ghost-images. Improper adjustment of the hold controls may cause failure of interlace, or *tearing* from side to side of the lines of the picture. Overload of the contrast control can also cause these troubles. It must be emphasized that usually three or four different misadjustments may all contribute to the same effect of distortion in the received picture. For this reason a Service Man must become well versed in the theory of television scanning.

For this purpose it is suggested that he acquire and read all available current articles appearing on this subject. No general trouble-shooting information on all the troubles to be encountered can be given here.