DEFLECTING CIRCUITS
For Television Receivers

TELEVISION receiver circuits may be divided into six parts: a) audio circuits, b) video circuits, c) decoding 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 thorough working theory of television deflection system. 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 discussed in subsequent articles.

The process of oscillation 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 30-000 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 60,000 miles per second) and the width of each strip is roughly equal to the diameter of the region in which the electrons are located. The strips over which the spot scans are located one near the other and spaced apart by a strip width. The beam of electrons is directed either back and forth or from side to side in an area designated as the picture frame. The beam is then directed again to the top of the picture to trace the next line of the picture. The electrons in the electron beam are controlled by the deflection circuits so that the image can be traced in a definite pattern.

The principle of television is based on the fact that the beam of electrons can be controlled electrically so as to produce an image on a screen. The deflection circuits are responsible for this control. The device used for deflection is called a beam deflection tube. It consists of a filament, an anode, and a grid. The filament is heated to generate electrons, which are then attracted to the anode by a strong electric field. The grid is inserted between the filament and the anode to control the flow of electrons. By varying the voltage on the grid, the electron beam can be deflected in any desired direction. This deflection is then used to scan the screen with an image of the picture.

In television parlance the strips are called lines. Each sequence of 2200 lines, from top to bottom of the picture is accomplished in 1/60 second and represents one-half frame. Between only one-half the information of the picture is scanned by each trip. On alternate trips the electrons are directed to fill exactly along lines which lie between the others (stippled 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 of information of the picture. Thus each frame consists of 2 x 2200 = 4400 individual lines, and requires 2 x 1/60 = 1/30 second for transmission.

The choice of these standards constitutes the 441 line 30 frame double interlace system of television scanning. The choice of standards is based on power line frequency, 60 cycles and sync errors. The system is a practical one which minimizes the effect of beam on picture. The interlace is a trade necessary to prevent flicker and at the same time to prevent the effect of deflection on the picture. The choice of standards is based on power line frequency, 60 cycles and sync errors. The system is a practical one which minimizes the effect of beam on picture. The interlace is a trade necessary to prevent flicker and at the same time to prevent the effect of deflection on the picture.
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 television 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 bottom right-hand edge of the picture it must be returned to the left edge for the start of the preceding line. During this return period the beam 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 the same 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 deflecting 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 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 this picture and at the completion of the 2000 line, the electron beam is cut off and the vertical field is suddenly changed so as to deflect the spot again to the top of the picture. The horizontal field has a period of 1/40000 second; that is, it takes this length of time for the direction of the horizontal field to change linearly from left to right edge of the picture and back again to left edge. The vertical field has a period of 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 of picture and back again to top of picture. Each cycle is broken into two portions: trace portion denoted in Fig. 2 by letter K, and retrace portion denoted by the letter $r$. The time of the entire cycle is treated as unity, and $r$ is always equal to one. Under RMA standards $b$ is approximately equal to 50 percent of the cycle and $r$ is approximately equal to 25 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 thedeflecting plates of the cathode ray tube on a television receiver employing electromagnetic deflection, the waveform of Fig. 2 will appear on the screen as shown in Fig. 5. The waveform in tube 5 (Fig. 3) is imposed wave form such as shown 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 is used to examine the current in a resistor in series with the deflecting coils of a television receiver employing electromagnetic scanning this waveshape 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 rise or steep portion of the wave may have exponential curvature without distorting from picture reproduction. The only important feature of the trace 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 used 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 properly linear at frequencies below 30 cycles to frequencies above 250,000 cycles, and that the phase response of the oscilloscope be properly linear at 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, resulting at 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 may be required to reproduce the frame deflecting waveform, and at least 20 harmonics of the horizontal deflecting field fundamental frequency of 15,000 cycles are required. Loss of higher harmonics will result in rounding at the points of the saw-tooth wave, and phase shift of the low-frequency components and harmonics will cause curvature of the sweep portion of the cycle.

- - deflection generators

It is necessary to supply deflection fields to deflect the electrons in the electron beam to positions on the screen. The associated circuit elements, that is, upon the products of acoustics and resistors. The principal time controlling circuit in Fig. 5 is composed of resistor and capacitor C. The product of R in ohms and C in microfarads is a constant. This constant may be increased by increasing the length of the RC time constant. This curve is known in mathematics as an exponential. When a sufficiently small portion of this curve is examined, it will tend to be approximately linear. The voltage of C which is connected to the cathode of the tube S is applied to the grid of the tube S. This voltage is known as the grid voltage of tube S. When the grid voltage of tube S is increased, the plate current of tube S is increased. This increased plate current is increased in proportion to the increased grid voltage of tube S. When the grid voltage of tube S is decreased, the plate current of tube S is decreased. This decreased plate current is decreased in proportion to the decreased grid voltage of tube S. This is known as the grid voltage control of tube S. When the grid voltage of tube S is increased, the plate current of tube S is increased. This increased plate current is increased in proportion to the increased grid voltage of tube S. When the grid voltage of tube S is decreased, the plate current of tube S is decreased. This decreased plate current is decreased in proportion to the decreased grid voltage of tube S. This is known as the grid voltage control of tube S.
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 condensors arises from the fact that their reactances have opposite signs; that is, if the reactance of an inductor be considered as positive, the resistance of a condenser 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 work in conjunction with good saw-tooth waveforms at a frequency determined by the time constant of the associated circuit and the characteristics of the tube. This frequency must be constant in a television receiver so that the receiver picture keeps exactly in step with the transmitted picture. The control is accomplished by transmission of what is known as the RMA sawtooth-syn-chronizing wave which is of impulsive form as shown in Fig. 6.

This sawtooth wave has an accurately timed wave generated at the transmission and consisting of 400 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 400 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 these pulses, as in Fig. 6, and the vertical relaxation oscillator should trigger exactly on the leading serrated pulse, as in Fig. 6. If the vertical oscillator does not trigger on the leading pulse it must trigger on identically related pulse, from one line, on each occurrence of the serrations at intervals of 1/60 second. Otherwise interaction of the receiver will not be maintained, although frame synchronization will be.

In order to insure that the horizontal and vertical relaxation oscillators trigger 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 vertical pulses is the most important physical characteristic upon which to work in obtaining successful separation. In Fig. 7 there is shown the circuit of a synchronizing separator tube.

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. 8 which have a form as shown in Fig. 6. Voltage H is applied directly to the grid of the tube T in a horizontal frequency relaxation oscillator similar to that shown in Fig. 8, 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. 8, in order to accurately time the start of the vertical saw-tooth cycle.

The waves generated at the cathode 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.

**Deflective amplifiers**

Deflection amplifiers are of two types: voltage amplifiers and current amplifiers. Voltage amplifiers are used in receivers employing electromagnetic 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 tables, 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 or combination with any size of tube. The purpose of this article is to describe for your benefit the circuits which are usually encountered.

Electronic deflection systems use simple arrangements when the electron beam velocity is relatively low, as in the cathode-ray tube 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 coupling amplification is used in this case, and a fraction of the plate voltage wave is developed and 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 200 volts, peak-to-peak, of saw-tooth voltage is required from each amplifier in order to scan a short-screen five-inch tube. Smaller voltages are required for long-screen five-inch tubes. Tubes of the double triode type, as the 6AM5, are almost always used in the electronic deflection systems. This reduces the power requirements on the receiver power supply.

The electromagnetic deflection amplifier problem is much more complex than the electronic. 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 entire or part 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 rapid collapse of scanning field so necessary in obtaining rapid recovery 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 heavy 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 saturating transformer. This reflected load must be of low impedance at all the harmonic frequencies which compose the saw-tooth wave in order that the

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Current amplifier delivers the maximum current to the deflection system. It requires in the neighborhood of 80 milliampere-peak to peak plate current in the plate circuit of a horizontal electro-magnetic scanning amplifier to produce the 0.5 microampere current in the deflection coils which is necessary to seen a picture in the cathode-ray tube or at 6000 volt plate potential. Disturbances and capacitance 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 deflection field. In such cases, the picture may be badly curved 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 methods 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 whether the coupling potential of one deflection plate or the other current through the deflection 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 even produce ghost-images. Improper adjustment of the hold controls may cause failure of interface or tearing from side to side of the lines of the picture. Overload of the horizontal 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.