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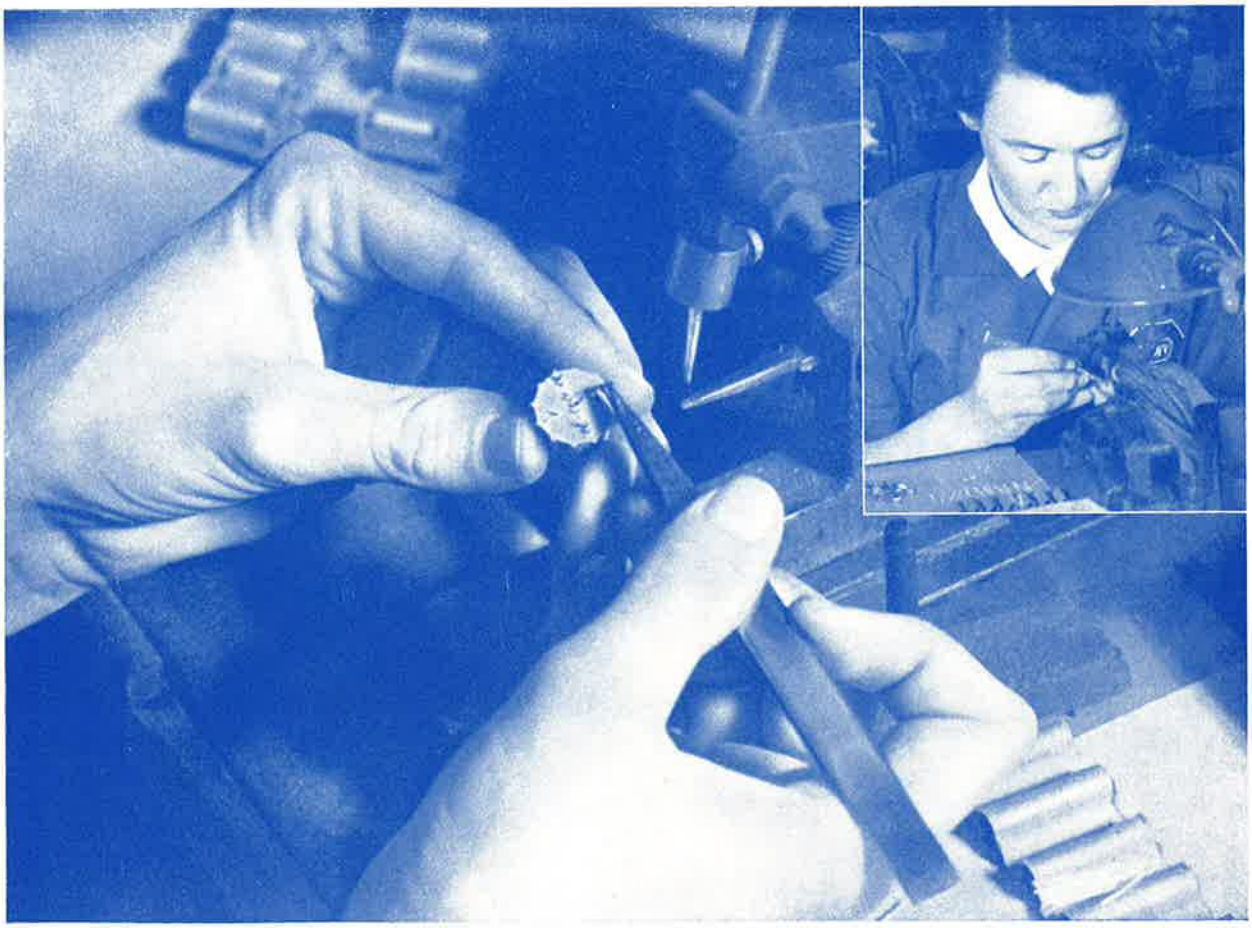
RADIOTRONICS

Volume 18 August, 1953 No. 8



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By the way—

Noted.

Correction to July, 1953, issue, page 109. Rating for AV33 Filament voltage should be changed from 4.0 volts to 4.3 max. volts.

The front cover this month shows a spot welding operation on a miniature valve assembly. It is taken from the film "Australia Makes Radio Valves by the Million" and is reproduced here by courtesy of the Australian Diary Film Unit.

Revised data on numerous popular valves such as the 6AU6, 6BA6, and others appears in the latest edition of the Radiotron Valve Data Book, now on sale at technical booksellers and trade outlets for twelve shillings and sixpence.

Included for the first time, is data on commonly used transmitting valves as well as phototubes and germanium diodes.

This new book replaces the earlier spiral bound edition, which is now obsolete.

New Zealand inquiries for the second edition should be directed to Amalgamated Wireless (Australasia) Ltd., P.O. Box 830, Wellington, or to any branch of National Electrical and Engineering Co. Ltd.

Information published herein concerning new RCA releases is intended for information only, and present or future Australian availability is not implied.

Issues of Radiotronics prior to March, 1953, are no longer available.

Editor:
Ian C. Hansen,
Member I.R.E. (U.S.A.)

CONTENTS

Page

Pulse Emission Testing 127

Television Principles & Practice

Chapter 10: Synchronization 131

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RCA Application Note* **AN-157**

A Pulse Emission Test For Field Testing Hot-Cathode Gas Tubes

Because of the particular voltage-current characteristics of gas-filled electron tubes, a single pulse test can be used in the field to detect both complete failures and "marginal" tubes. This Note describes a basic circuit for making such a test.

Voltage-current characteristic of gas tubes

Hot-cathode gas tubes, like vacuum tubes, utilize oxide-coated cathodes which emit electrons copiously. In a vacuum tube, however, some of the emitted electrons are driven back into the cathode by a field of previously emitted electrons; the emission, therefore, is said to be space-charge limited. In a gas tube, on the other hand, electrons emitted from the cathode strike gas atoms and ionize them. The ions then neutralize the space charge around the cathode and thus remove the deterrent effect of the space charge on the current. As a result, most of the emitted electrons can reach the anode under the influence of a modest voltage.

Fig. 1 shows a typical voltage-current characteristic curve for a gas-filled electron tube. The maximum voltage which can be applied to a gas tube before appreciable current flows is known as the starting or breakdown voltage, indicated in Fig. 1 as E_b. After breakdown occurs, a gas tube needs only sufficient anode voltage to produce ionization of the gas, so long as the current drawn is within the emissive capabilities of the cathode. This voltage is about 9 volts for xenon-filled tubes, and about 12 volts for mercury-filled tubes. Because the current after breakdown increases rapidly without further increase in voltage, a series resistance is necessary to limit the current. In the typical rectifier circuit, this resistance is represented by the useful load. The operating point, A, is determined by drawing through the supply voltage, E_{bb}, a line with a slope equal to the reciprocal of the load resistance. The anode voltage across the tube, E_a, at a given current, I_a, is known as the tube drop.

Causes of failure in gas tubes

Failure, or incipient failure, of gas tubes is usually evidenced by a decrease in the emissive capabilities of the cathode. The reduced emission, however, may be attributed to any one of several causes. The presence of a foreign gas such as oxygen or air in the tube may poison the cathode coating and reduce its emissive capabilities. This foreign gas, which may be introduced as a result of a leak in the glass envelope or through evolution of gas from parts within the tube, may also cause breakdown of the tubes on the inverse cycle of voltage if the ionization point of the foreign gas is lower than that of the original gas filling used in the tube.

Poor emission may also be caused by gas clean-up, which results when the cathode coating material in the tube sputters under the bombardment of the ions. The material thrown off from the cathode collects some of the gas atoms and is deposited on the tube walls. The decrease in emission results from both the damage to the cathode coating and the scarcity of ions.

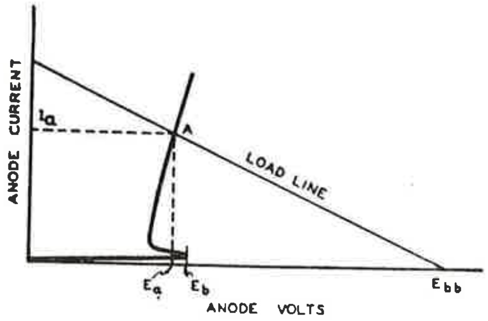

Fig. 1.—Typical voltage-current Characteristic for a gas-filled electron tube.

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*With acknowledgments to RCA.

Poor emission or a complete lack of emission may also be caused by such defects as open filaments, improperly coated cathodes, and shorts. A suitable test of emissive capability, therefore, detects these defects as well as those mentioned above.

Methods of test

A conventional method of testing gas tubes in the field is the measurement of breakdown voltage. This test is a fairly accurate indication of the emissive capabilities of the cathode in tubes in which the anode directly faces the cathode. In most gaseous rectifiers, however, a cathode shield employed to improve thermal efficiency breaks up the direct path between cathode and anode. This shield also acts as a grid which is made positive or negative with respect to the cathode by the action of the a.c. heater voltage and, therefore, affects the breakdown voltage of the tube. If the shield is negative with respect to the cathode when the anode swings positive, the breakdown voltage of the tube is considerably higher than if the shield and anode voltages are in phase. In such tubes, therefore, the starting voltage should not be taken as a measure of the emission.

Measurement of d.c. tube drop at rated average current is also used quite often in the field to determine the performance level of gas tubes. A gas discharge is somewhat self-compensating, however, and, therefore, an increase of a volt or two in tube drop can compensate for a considerable decrease in emission. If the cathode emits insufficient electrons to provide the current which would normally flow through the given load resistance, the tube drop increases. Because of this increased voltage drop, the positive ions strike the cathode with higher velocity, raising the cathode temperature and also increasing the secondary-emission yield, and, as a result, bringing

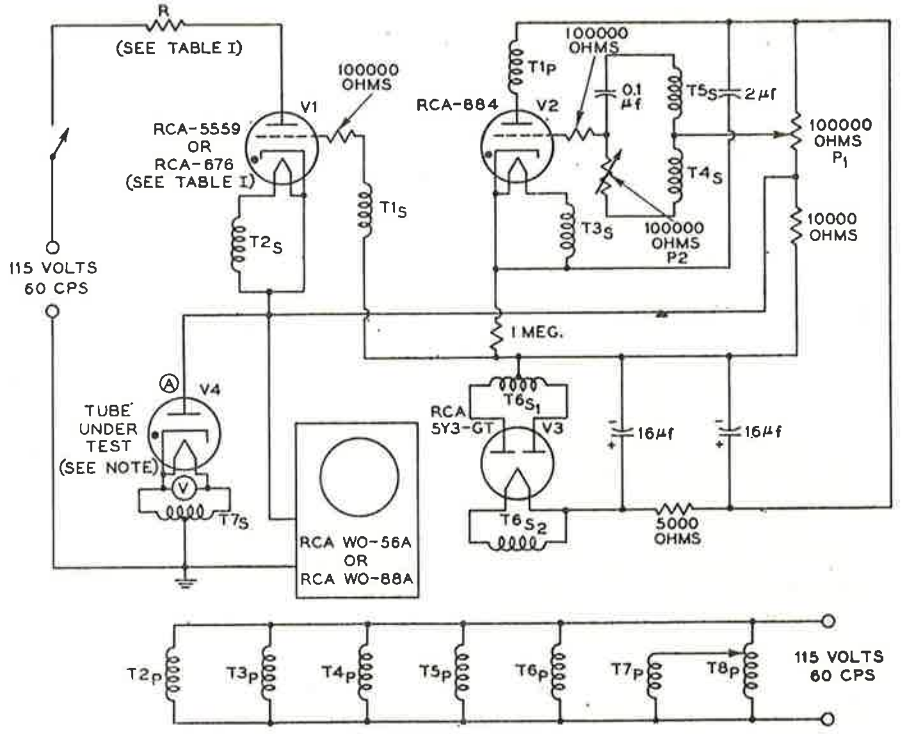

Fig. 2.—Basic circuit for making pulse emission tests on gas tubes.

T_1 = Audio transformer-turns ratio 1:1.
T_2 = Filament transformer suitable for V_1.
T_3, T_4, T_5 = Filament transformer—6.3 volts, 1 ampere.
T_6 = Power transformer — 500 volts, 60 milliamperes; 5 volts, 2 amperes.
T_7 = Filament transformer suitable for V_4.
T_8 = Variac.

NOTE: When a thyratron is being tested, the connection at A is made to grid No. 1 of the thyratron; no connection is made to the thyratron anode or grid No. 2.

the emission back to normal. Because of this compensation, little is learned about the condition of the cathode by measurement of the voltage drop with a d.c. anode supply and with average current flowing.

If, however, a gas tube under test delivers a peak current several times its rated current, the rise in peak voltage drop is appreciable and is indicative of the quantity of electrons emitted by the cathode. Such a high current cannot be drawn continuously because the anode-dissipation rating of the tube would be exceeded. The desired information can be obtained, however, when the current is drawn in short pulses and with a relatively long inter-pulse period (low duty cycle).

Pulse test circuit

A basic circuit suitable for making pulse emission tests on gas tubes in the field is shown in Fig. 2. This circuit causes the tube under test, V_4, to conduct about once a second, each conduction period lasting for only one half-cycle of the voltage from the 60-cycle supply. Such a low duty cycle permits high peak currents to be drawn without the dissipation limits of the tube being exceeded. The repetition rate is fast enough to permit observation of the tube drop on an oscilloscope.

In the circuit of Fig. 2, thyratron V_1 serves as an electronic switch to pass the test current pulse through V_4. The value of the resistor R determines the amplitude of the current pulse. Suitable values of resistance for various types of gas tubes are given in Table I. Thyratron V_2 and its associated circuit comprise a relaxation oscillator which determines the repetition rate. The output of this circuit is coupled through transformer T_1 to the grid of thyratron V_1. The repetition rate is not critical; if desired, it can be adjusted with potentiometer P_1. The low-voltage windings of transformers T_4 and T_5 are connected in series aiding so that there is 12.6 volts across the outside leads. The trigger pulse applied to the grid of V_1 should occur at the beginning of a positive half-cycle of anode voltage on V_1. Potentiometer P_2 permits adjustment of the pulse phase over 180 degrees; it may also be necessary to reverse the transformer leads of both T_4 and T_5 to obtain the desired phasing. Rectifier V_3 supplies d.c. voltage for the relaxation oscillator and for the bias of thyratron V_1. The choice of thyratron V_1 depends upon the test current to be drawn; suggested thyratrons for use with various tube types under test are given in Table I. When the tube under test, V_4, is a thyratron, the connection at A is made to the grid No. 1 of the thyratron; no connection is made to the thyratron anode or grid No. 2.

Use of pulse test

The conditions of tube operation during test should be controlled in order to assure reproducible results. The correct cathode temperature is obtained if rated heater voltage is applied for rated heating time; five minutes is adequate for all standard types. (This time should be doubled if heater transformers having poor regulation are used.) The heater voltage should be measured at the socket with a good meter; the socket and top-cap contacts should be clean and snug-fitting.

The tube drop of mercury-vapour tubes, in addition to being sensitive to heater temperature, is sensitive to changes of envelope temperature. The mercury-vapour pressure is determined by the temperature of a portion of the glass envelope half an inch long just above the base. The temperature of this portion of the envelope, sometimes called the condensed-mercury temperature, rises above the ambient temperature as the tube is operated. The rate of rise of the envelope temperature, as well as the operating temperature of the envelope, depends upon tube construction and upon the power dissipated in the heater and anode. When the condensed-mercury temperature is below 20 degrees Centigrade, the mercury pressure is less than one micron and the tube drop is so high that the cathode coating may be damaged. When the condensed-mercury temperature is 25 degrees Centigrade or higher, each additional increase of five degrees results in a decrease in tube drop of approximately two volts. Although the time required for a mercury-vapor tube to reach "equilibrium" temperature may be from 10 to 30 minutes, a warm-up time of five minutes should be sufficient to heat the cathode and to stabilize the mercury pressure before measurement of pulse emission and peak tube drop.

The oscilloscope used to measure the tube drop must be equipped to amplify dc signals so that the instrument may be calibrated with dc voltage and a convenient and stable zero voltage axis may be established. The RCA WO-56A and RCA WO-88A oscilloscopes are suitable and directly usable for this purpose. If conventional ac oscilloscopes are to be used in this application, they must be converted for dc amplification. In ac oscilloscopes having one stage of amplification, the input coupling capacitor should be shorted and the output coupling capacitor replaced with a 180-volt bias battery (isolated from ground) and a 0.5-megohm potentiometer for vertical-centering control. If there is no common connection between any two of the four deflecting electrodes, the centering may be accomplished without the internal battery by applying a suitable dc voltage from a tap on the internal supply to the vertical deflecting electrode opposite the signal electrode.

The waveforms produced on a suitable oscilloscope by the circuit of Fig. 2 are shown in Fig. 3. A single half-cycle of voltage appears across resistor R when V_1 fires. The peak current can be calculated after the peak voltage across R is measured. Because the tube drop is not sensitive to small variations in current, a fixed value of R may be used for any given tube type (see Table I). The tube drop is indicated on the oscilloscope by the perpendicular distance from the zero voltage axis to the point of the voltage wave form corresponding to maximum current flow. The value of the tube drop may be determined by substituting a dc voltage which produces the same amount of deflection on the oscilloscope.

When tubes having directly heated cathodes are tested, errors due to inclusion of the filament voltage in the reading can be eliminated by making all circuit returns to the centre tap of the filament transformer. When tubes having indirectly-heated cathodes are tested, the return should be made to the cathode.

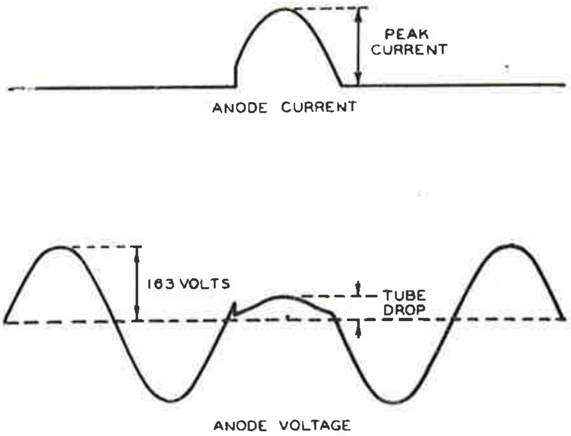

Fig. 3.—Waveform produced on oscilloscope such as RCA WO-56A by a gas tube under test in the circuit of Fig. 2.

Evaluation of test results

A major advantage of a pulse test for gas tubes in the field is the ease of locating "marginal" tubes before failure. The operational "danger zone" of tube operation, when failure may occur at any moment, can be avoided if the emission test described in this note is utilized. The tube drop of an average gas tube at the beginning of its life ranges from 8 to 16 volts, depending upon the tube type and the test current. Tube drop may decrease slightly early in the service life, but it soon settles down to a nearly constant value for the major portion of the tube life. Toward the end of life, the tube drop rises, slowly at first, but then at an increasing rate. A tube operating at 25 volts at normal current may fail at any moment. In equipment in which continuity of service is important, tubes having a drop of 25 volts under the test conditions shown in Table I should be taken out of service.

The peak test currents given in Table I are not critical; they may vary as much as ten per cent. or more for the purposes of this test. These current values, however, are in excess of the rated peak currents for the tubes and are recommended only for pulse testing.

A suggested schedule of pulse tests in the field is at 100, 500, and 1000 hours, and at 1000-hour intervals thereafter. In general, this schedule will be sufficient to prevent excessive failure in operation; a modified schedule sometimes may be necessary to suit particular requirements.

TABLE I

Tube Under Test	Auxiliary Thyratron	Peak Test Current (amperes)	Resistor R (ohms)
Rectifiers			
816	RCA 5559	2	70
866A	"	5	28
3B25	"	5	28
3B28	"	5	28
5558	"	5	28
872A	RCA 676	20	7
8008	"	20	7
4B26	"	20	7
575A	"	30	4.7
673	"	30	4.7
5561	"	30	4.7
869B	"	40	3.5
857B	"	80	1.7
Thyratrons			
5696	RCA 5559	0.2	700
884	"	1.0	140
885	"	1.0	140
2D21	"	2	70
502A	"	2	70
2050	"	2	70
629	"	1	140
5557	"	5	28
627	"	5	28
3D22	"	10	14
3C23	"	10	14
5559	"	15	9.4
5720/33	"	15	9.4
5728/67/1904	"	15	9.4
5560	RCA 676	30	4.7
672A	"	40	3.5
5563	"	30	4.7
105	"	80	1.7
172	"	80	1.7
677	"	30	4.7
676	"	80	1.7

By K. Fowler and H. Lippert.

SYNCHRONIZATION

1. Review of the synchronizing signal

In order to reproduce a true image on the screen of the picture tube, the scanning spot at the receiver must accurately trace the same pattern as the spot in the camera tube. As outlined in previous chapters, the synchronization of the scanning at the receiver with that at the transmitter is accomplished by transmitting characteristic pulses at the end of each line and at the end of each field. It might be well, at this time, for the reader to review chapter three, which covers the television signal in considerable detail, before proceeding with the following discussion on synchronization.

2. Equal height and width of pulses

As shown by the RMA Standard Television Signal, Figure 10-1, these synchronizing pulses occupy a region of signal voltages greater than that representative of black, or more precisely, the region of carrier amplitude from 75-100 per cent. of the maximum carrier. It should be noted that the synchronizing pulses for the line and field synchronizations have the same height and also that both are practically rectangular in shape. However, there is one very important difference between them and that is in their duration. The duration of the board vertical pulses making up the vertical pulse signal is 27.3 microseconds as compared to the 5.08 microsecond duration of the horizontal synchronizing pulses.

Before the adoption of the television signal of Figure 10-1, consideration was given to the use of synchronizing pulses of different height for field and line synchronization, and particularly to the possibility of having the field synchronizing pulses of greater height than the line synchronizing pulses.

However, such an arrangement has the undesirable characteristics of (1) assigning a portion of the power range of the transmitter to the sole function of field synchronization; and (2) increasing the risk of loss of the amplitude difference in an overloaded receiver. Since it is possible to obtain satisfactory results without these undesirable features, the choice of equal height but different width for the two types of pulses was made.

3. Uniform line timing during field blanking interval

It was brought out earlier that the deflection circuits of a television receiver are designed on the basis that normal line scanning will be maintained during the field or vertical retrace period. That is, the horizontal deflecting coils or plates of the picture tube must operate continuously, even though the beam is extinguished for a relatively long time (approximately 1270 μs), during the vertical blanking period. This is done so that the horizontal sweep generator will not fall out of synchronization during the field retrace period, which would result in poor interlacing.

To permit the maintenance of line synchronization during the field retrace, particularly when direct synchronization of the horizontal sweep generator is employed, suitable pulses occurring at 1 H intervals throughout the field blanking period are provided, as shown by the portion of the signal devoted to vertical synchronization and blanking in Figure 10-1.

Before considering these pulses in detail, two relevant facts should be noted:

(1) the excursion of the complete video signal from the black level to the synchronizing level is the essential line timing operation which synchronizes the line (horizontal) oscillator in the receiver;

(2) the line oscillator is insensitive to pulses occurring a substantial time in advance, for example, pulses occurring in the middle of a horizontal line.

In Figure 10-1 there are represented at the upper left of the video signal wave the last few lines of normal scanning which occur at the bottom of the picture being transmitted. It should be noted that an interval of time designated as H, equal to the horizontal scanning period of 1/15,750 second or 63.5 microseconds, elapses between the leading edge (left side) of each of these pulses. This timing is maintained during the insertion of the equalizing pulses because these include a number of pulses with a leading edge occurring at intervals of 1 H or 63.5 microseconds. The equalizing pulses have been made narrower than the regular line pulses by advancing their lagging edges while the leading edges are unaltered in position. In addition to the equalizing pulses whose leading edge occurs at one H interval, there are also equalizing pulses located just half-way between the one H spaced pulses. However, these additional equalizing pulses do not introduce any difficulties in line timing since the horizontal oscillator is insensitive to pulses occurring at double frequency. The exact function of these additional equalizing pulses ($\frac{1}{2}$ H spacing) will be described in subsequent paragraphs.

In A of Figure 10-1, the line oscillator will be synchronized by the 1st, 3rd and 5th pulses in the group of equalizing pulses preceding the serrated vertical pulses. At the end of the first group of equalizing pulses, the leading edge of the first broad serrated pulse in the vertical pulse group occurs and

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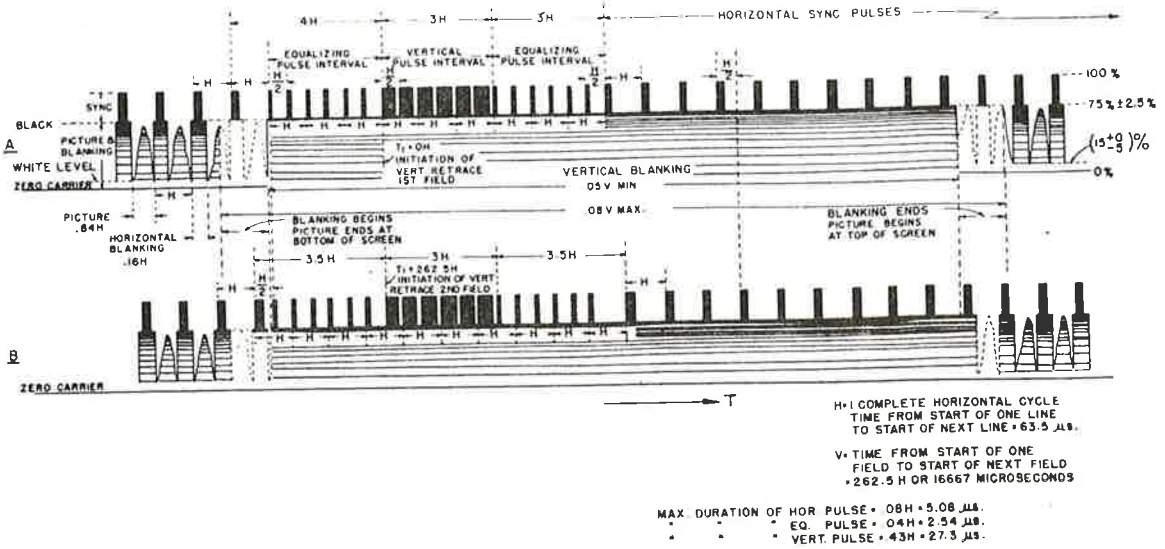

Fig. 10-1. RTMA standard television signal.

in spaced ½ H after the last equalizing pulse. Each broad vertical pulse terminates soon enough to accommodate at the next ½ H interval the leading edge of another broad synchronizing pulse. There are six broad pulses in the vertical pulse group and they are serrated so that the leading edge of every other one occurs at one H intervals, thus maintaining line synchronization. Therefore, in A of Figure 10-1 the horizontal oscillator will be tripped by the leading edge of the 1st, 3rd and 5th broad pulses in the vertical pulse group. If it were not for the maintenance of horizontal synchronization at this time, then the vertical pulse would not have to be divided (serrated) into six separate pulses but could be transmitted as a single broad pulse of approximately 190 microseconds duration.

At the termination of the vertical pulse group, there is a second group of six equalizing pulses, spaced at ½ H intervals, which serve to time the horizontal oscillator in the same manner as the equalizing pulses which precede the vertical pulse group, the horizontal oscillator being timed by the 1st, 3rd and 5th equalizing pulses of the second group.

For the other field of the frame, B of Figure 10-1, the same remarks apply as above in regard to timing the horizontal oscillator by the equalizing and vertical sync pulses during the field (vertical) blanking interval. However, in this case the line oscillator is tripped by the 2nd, 4th and 6th pulse in the vertical pulse group.

This discussion of uniform line timing during the field blanking interval may be concluded by stating the essential result that the leading edge of each equalizing and vertical pulse occurs regularly at double line frequency, thus maintaining proper synchronization of the horizontal oscillator for both fields during the field blanking intervals.

4. Equalizing pulses

As mentioned above, the equalizing pulses serve the important purpose of maintaining line synchronization during the field blanking interval, but in addition to this they satisfy another important requirement and that is to provide similarity of conditions in the vicinity of the vertical pulse interval for the two fields of each frame.

The six equalizing pulses preceding the vertical synchronizing pulses are identical for the two fields of each frame, as shown in A and B of Figure 10-1. If these equalizing pulses were not provided, the leading edge of the first broad vertical synchronizing pulse would be preceded by different conditions for successive fields. It should be noted that in A of Figure 10-1 there is a 4 H interval between the leading edge of the last regular horizontal synchronizing pulse and the leading edge of the first broad vertical synchronizing pulse, while in B there is only a 3½ H difference between the last regular horizontal pulse and the leading edge of the first broad vertical pulse. Under these circumstances, were it not for the use of equalizing pulses, the field synchronizing circuits of the integrating type would act differently for successive fields and initiate vertical retrace at different intervals. This would produce pairing of the interlace in the picture and the lines of one field would not be equi-distant from the lines of the next field but would be arranged in pairs. This is an undesirable condition since it reduces the definition of the picture. The leading set of equalizing pulses act as a buffer between the last horizontal synchronizing pulse and the first vertical synchronizing pulse of each field and prevents the difference in time intervals of 4 H for A and 3½ H for B from affecting the integrating type of field synchronizing circuit. The integrating type of field synchronizing circuit is widely used and will be discussed in detail later in this chapter. It will then be shown exactly how the leading set of equalizing pulses act as a buffer between the horizontal synchronizing pulses and the leading edge of the first vertical synchronizing pulse.

If normal line frequency pulses followed the vertical synchronizing pulse interval in A of Figure 10-1 there would be $\frac{1}{2}$ H difference between the leading edge of the last vertical pulse and the leading edge of the first horizontal pulse following the vertical pulse interval, while in B there would be a one H difference. With the integrating type of field synchronizing circuit, this difference might make the duration of the vertical retrace of successive fields different which would produce pairing of the interlace. To avoid this condition, six equalizing pulses follow the vertical pulse interval and act as a buffer between the last vertical synchronizing pulse and the regular horizontal synchronizing pulses, and allows the vertical retrace period for successive fields to have the same duration.

As shown in Figure 10-1, the lagging set of equalizing pulses are terminated before the end of the field blanking period, and the line oscillator is triggered by a number of regular horizontal synchronizing pulses before field blanking is removed.

5. Synchronizing signal separation

After the video i-f signal is demodulated by the video detector, the composite video signal corresponding to several horizontal lines will appear as in Figure 10-2. This composite signal may be divided into two sections, the portion below the blanking level which contains the actual picture impulses and the portion above the blanking level which contains the synchronizing signals. Before the synchronizing signals can be used to control the sweep generator, the synchronizing pulses must first be separated from the actual picture information which all lies below the blanking level. Then the horizontal and vertical synchronizing pulses must be separated from each other before being used to control their individual sweep generators.

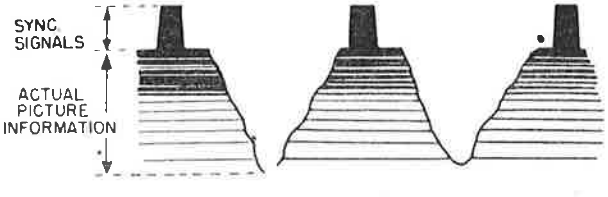

Fig. 10-2. Composite video signal.

The arrangement that is usually used to accomplish this is shown in block diagram form by Figure 10-3. It will be noted that the output of the video detector, after being amplified by the video amplifier, is fed two ways. One channel goes to the picture tube, and the other goes to a clipper stage which separates the synchronizing pulses from the actual picture information which lies below the blanking level. After separation from the picture information, the composite sync pulse signal is fed into inter-sync separating circuits where the horizontal and vertical sync pulses are separated from each other and then applied to their respective sweep generating circuits. In Figure 10-3, the pulses synchronizing the horizontal sweep circuit are shown going into the block marked A.F.C. If direct synchronization of the horizontal sweep generator were employed (which is not the case in any of the post-war GE receivers) then the block marked A.F.C. would be omitted and the sync pulses would be applied directly to the horizontal sweep generator.

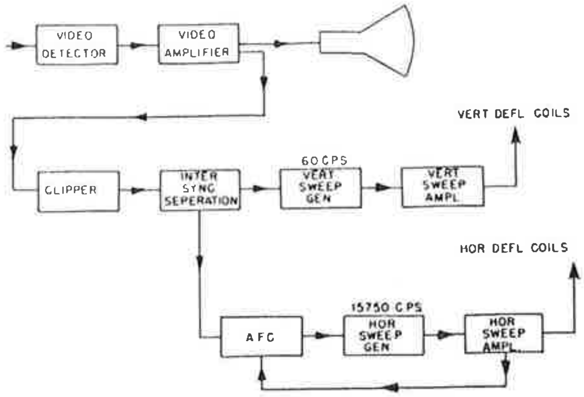

Fig. 10-3. Synchronizing signal separation.

The point at which the composite video signal is obtained for application to the clipper stage is usually in the output of the video amplifier. This signal could be obtained from the video detector but then it would be at a considerably lower level. By allowing the composite video signal to pass through the video amplifier before applying it to the clipper stage, less additional amplification is required. Also, if noise limiting is employed in the video amplifier as is the case in many receivers it will result in a cleaner signal being applied to the clipper, resulting in more stable synchronization under noise conditions. This additional amplification may precede the clipper or follow the clipper as will be discussed in detail later in this chapter.

6. Clipper circuits

The separation of the synchronizing pulses from the picture information is necessary in order to prevent the picture information from interfering with the synchronizing circuits and is usually accomplished by some form of a limiting circuit which will only pass the top 25% of the composite video signal in which the synchronizing pulses are contained. This clipping action would ideally be done just as the blanking level, but practically, it is advisable to do it at a slightly higher level in order to avoid any possibility of interference from the picture signal. If the picture signals were allowed to affect synchronization, a black portion might trigger the line oscillator ahead of time. Proper and improper separation of synchronizing signals from the picture information are shown in Figure 10-4.

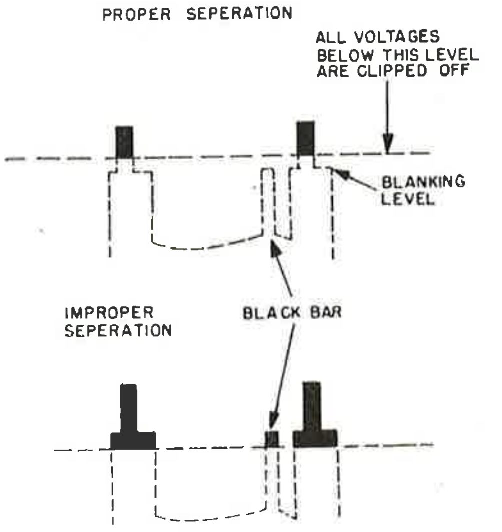

Fig. 10-4. Proper and improper separation of synchronizing signals.

In the lower diagram it can be seen that a black bar in the picture information might by improper separation have the same effect as a horizontal synchronizing pulse in timing the line oscillator.

There are several methods of separating or clipping the synchronizing signal from the picture information. Basically this is accomplished by applying the composite video signal to a tube, which may be a diode, triode or a pentode, and biasing it so that no current can flow through it except when the composite video signal is above the blanking level. Usually a clipper tube is operated with a negative bias of such value that when the composite video signal is applied to its input terminals, in a polarity such that the tips of the sync pulses represent the most positive portion of the signal (sync pulses up), current will flow only during the time that the signal is above the blanking level. Therefore, since the actual picture information is all below the blanking level, the plate current will consist only of sync pulses which are free from the actual picture information.

The biased diode method of sync separation shown in Figure 10-5 is probably the simplest. In this circuit the diode will conduct when the input signal is positive and if the time constant of R and C is sufficiently great, the diode current drawn will charge the capacitor to the peak value of the input signal and establish a bias across capacitor C, which is sufficient to keep the diode from conducting except during the positive peaks of the composite video input signal as indicated in Figure 10-5. However, when the diode does conduct during the peaks of the synchronizing signal, a voltage will appear across R_2 proportional to the synchronizing pulses. The values of R_1 and C must be of such value as to prevent diode current flow except during the intervals when the signal is in excess of the blanking level. This system is satisfactory except that the output is relatively small, and some video signal is coupled to the output circuit by the diode's plate-cathode capacitance. It should be noted that since the diode conducts during the peaks of the sync pulses it acts as a clamper so that the peak of each recurring sync pulse is lined up at the same level.

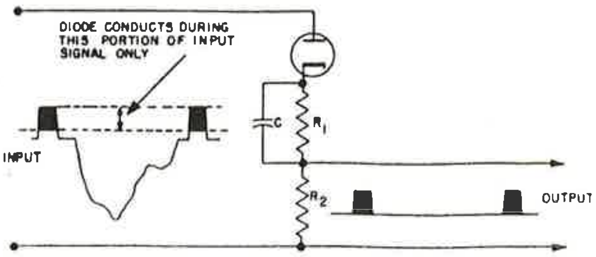

Fig. 10-5. Biased diode clipper.

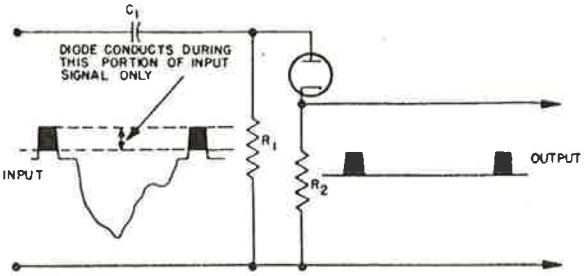

Fig. 10-6. Diode type clipper.

A second type of clipper which makes use of a diode is that shown in Figure 10-6. In this circuit the time constant of C_1 and R_1 is such as to maintain a high average bias between the plate and cathode. Capacitor C_1 is charged up to the peak value of the input signal during the positive peaks of the input signal and if the time constant is of the proper value, a high average bias will be maintained between the plate and cathode and the only time current will flow through R_2 is during the time that the input signal is above the black level.

A third type of separator or "clipper" and one which is widely used is that shown in Figure 10-7. This type of clipper makes use of a triode operated at a low plate potential so that its cut-off bias will be quite low, as shown by the characteristic curve in Figure 10-7. In this circuit, when the grid becomes positive with respect to the cathode, it conducts and rapidly charges the capacitor C_g to the peak potential of the input signal. In the interval between synchronizing peaks, if the time constant of the grid resistance R_g and coupling capacitor C_g is sufficiently long, the capacitor will

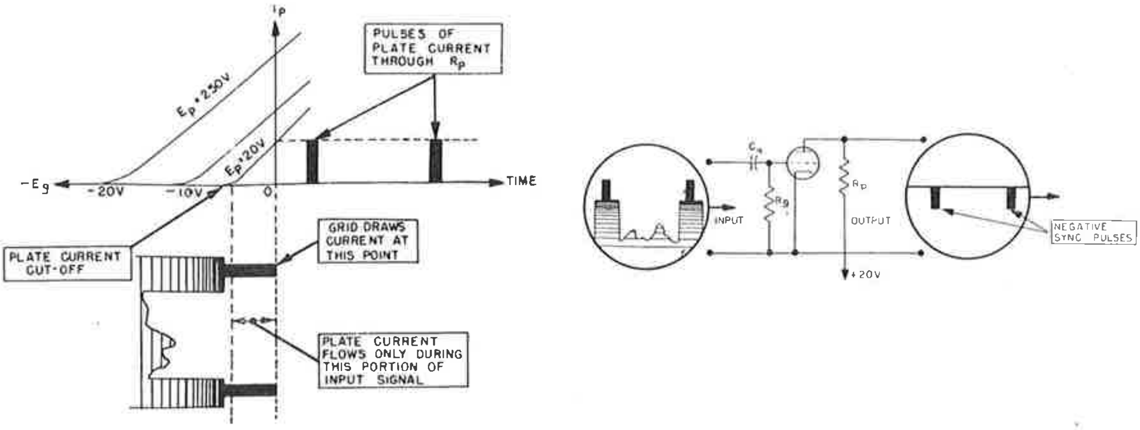

Fig. 10-7. Triode type clipper circuit.

discharge relatively slowly through R_g, which is a much higher resistance than the cathode-to-grid resistance when the grid is positive and will, therefore, maintain a bias on the tube which is just equal to the peak potential of the input signal. What little charge leaks off (between synchronizing peaks) will be replaced once each cycle when the tips of the pulses draw grid current. Since the plate potential on the tube is very low, its plate current will be cut off shortly after the input signal falls below the value of the synchronizing pulse peaks and none of the signal appearing below the blanking level of the composite video input signal will appear in the plate circuit. The plate circuit, therefore, responds only to that portion of the input signal which lies above the blanking level, as indicated on Figure 10-7. The sync peaks are clamped or "lined up" to the same level by DC reinsertion which is accomplished by the grid current charging the capacitor C_g to a potential where only the tips of the sync pulses draw grid current. It should be noted that in the clipper circuits just discussed, the composite video signal is applied to the input terminal in such a polarity that the tips of the sync pulses represent the most positive portion of the signal (sync pulses up).

The triode circuit has the advantage of providing considerably more output than the simple diode type of clipper. If a higher output than that provided by a triode is desired a pentode may be used instead. This also has the further advantage of lower grid to plate capacitance, which means that very little picture information will be coupled to the output circuit due to capacity of the tube.

7. Inter-sync separation

After the portion of the signal lying in the synchronizing region has been separated from the picture information, the horizontal and vertical synchronizing pulses must be separated and applied to their respective sweep generators. As mentioned earlier, the waveform method of separation is used. The composite synchronizing signal after coming from the clipper is fed two ways: One way is through a low-pass filter or integrating circuit which separates the long duration or low frequency vertical pulses from the short duration or high-frequency horizontal pulses; and the other is through a high-pass filter or differentiating circuit which converts the leading edge of every synchronizing pulse, whether it is a horizontal, equalizing, or vertical pulse, into voltage pulses which will properly time the horizontal oscillator.

8. Differentiating circuits

The high-pass filter or differentiating circuit which causes the leading edge of every synchronizing pulse to properly time the horizontal oscillator will be considered first. A differentiating circuit is a circuit whose output depends on the rate of change of the input voltage rather than on the duration of the voltage applied to the input of the circuit. A simple type of differentiating circuit that is widely used consists of a capacitor and resistor as shown in Figure 10-8. The composite sync signal marked input wave is applied across the combination with the output, marked differentiated output wave, appearing across the resistor. The output voltage of the differentiator circuit is proportional to the current through the resistance leg of the circuit. The current flowing through the resistance leg is the charging current of the capacitor. If the capacitor is made relatively small, its charging current will very closely follow the rate of change in the potential applied to the input and, therefore, current will only flow through the resistor when the input waveform rises from zero to maximum (leading edge) and when the input waveform drops from maximum to minimum (lagging edge). Between these points no current will flow through the resistor and the duration of the input voltage will have no effect on the output waveform. The pulses in the output waveform above the line are produced by the leading edge of the input waveform when the capacitor rapidly charges, while the pulses below the line are produced by the lagging edge of the input waveform when the capacitor discharges and the current through the resistor is reversed.

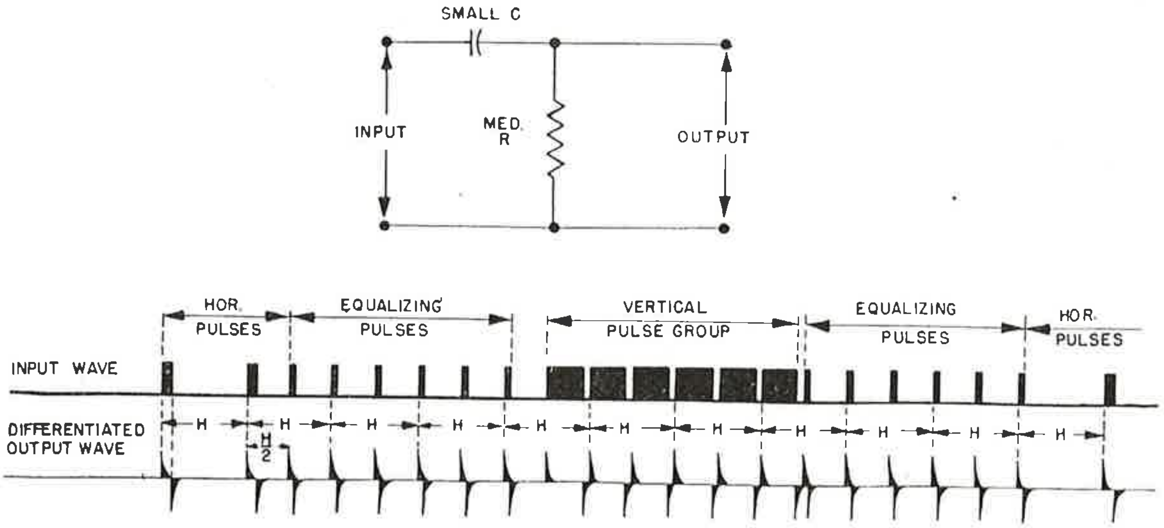

Fig. 10-8. Differentiating circuit.

It should be noted in Figure 10-8 that the leading edge of every horizontal equalizing and vertical pulse in the composite input waveform produces corresponding upward excursions in the output which have the same timing between pulses as that between leading edges of the pulses in the input. Also, that the amplitude and shape of each pulse in the output is identical regardless of whether it corresponds to a horizontal, vertical or equalizing pulse. When these pulses are properly applied to the horizontal generator, the pulses in the differentiated output which correspond to the leading edge of the pulses applied to the input will be the only ones to affect the sweep generator. In the case of Figure 10-8 these are the pulses occurring above the line. Those appearing below the line (produced by the lagging edge of the pulses applied to the input) can be neglected because horizontal retrace will have already been initiated by the leading pulses and the sweep generator will not be susceptible to pulses occurring during this period.

As brought out earlier, the horizontal sweep generator is not susceptible to synchronizing pulses occurring during the mid-range of the sweep cycle and thus the sweep generator will synchronize only on the proper alternate vertical and equalizing pulses at one H intervals, as indicated by the letter H between pulses in the differentiated output.

The composite sync pulses from the clipper can also be differentiated by inductive means as shown in Figure 10-9. By applying the composite synchronizing signal to the input of the tube, which functions as an amplifier, the current through the primary winding L_1 will have a waveform consisting of steep slopes corresponding to rapid changes of current. The voltage appearing across L_2 will be proportional to the rate of current change through L_1, and the leading and trailing edge of each sync pulse of the input wave applied to the grid of the tube will produce a corresponding pulse of voltage across L_2 as indicated in Figure 10-9.

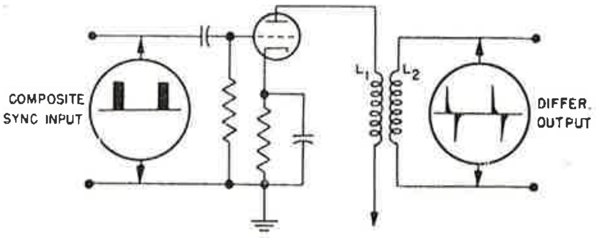

Fig. 10-9. Inductive differentiating circuit.

The output from this type of differentiating circuit is essentially the same as that obtained from the R-C differentiating circuit shown in Fig. 10-8.

9. Integrating circuits

The composite synchronizing signal from the clipper is also applied to a low-pass filter or integrating circuit for obtaining the necessary timing pulses for the vertical sweep generator. This type of circuit is shown in Figure 10-10 (A) and is just opposite from the differentiating circuit just discussed. It has a very slight response to the short duration horizontal and equalizing pulses. When short duration pulses are applied to the input of this type of circuit the output voltage is of sawtooth waveshape, having an amplitude of only a few percent of the input wave. However, when the broader vertical synchronizing pulses are applied, the integrator output builds up rapidly. This condition is shown in B of Figure 10-10. The resistance in series with the capacitor is sufficiently large to prevent the capacitor (which is relatively large) from charging up to the full input potential

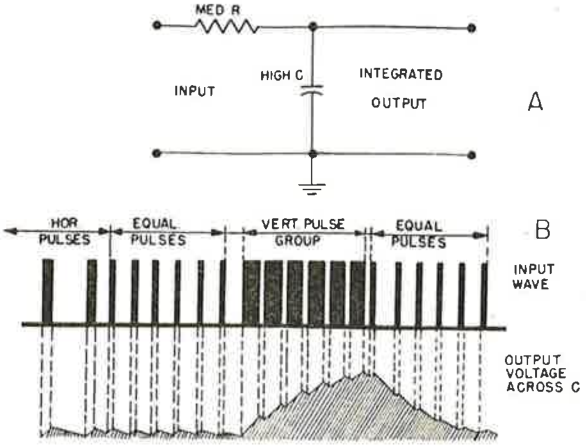

Fig. 10-10. Integrating circuit.

on any one pulse in the input. Therefore, the charge on the capacitor will continue to rise for the duration of the pulses. The output voltage which is taken off from across the capacitor is proportional to the amount of charge on the capacitor. The output of the integrator will continue to rise only if the duration of the pulse itself is greater than the interval between pulses. If the duration of the pulse is small compared to the interval between pulses, as in the case of the horizontal and equalizing pulses, the output will tend to rise momentarily (for the duration of the pulse), but will rapidly drop to its original value between pulses as indicated in B of Figure 10-10. However, if the duration of the pulse is greater than the interval between pulses, as in the case of the six vertical pulses, then the charge on the capacitor will continue to rise as indicated in Figure 10-10. Although the charge drops slightly between vertical pulses, this is more than compensated for by the additional charge produced by the following vertical pulse. After passage of the broad vertical pulses, the output of the integrator will again drop to a very low value compared to the amplitude of the input signal and will remain there until the next group of vertical pulses comes along.

The output wave of an integrating circuit, which is really a low-pass filter, approximates the area under the input wave as indicated in B, Figure 10-10. In other words, the output of an integrating circuit depends on the duration of the input voltage rather than on its rate of change. Several integrating circuits are usually used in cascade to provide for a sharper pulse to synchronize the vertical sweep generator.

10. Use of equalizing pulses

As mentioned previously, the output of the integrating circuit must be identical for each field in order to maintain proper interlace. In order to accomplish this, the slope of the leading and lagging edge of the pulse in the output of the integrating circuit is made exactly the same for each succeeding field by the insertion of equalizing pulses which precede and follow the vertical pulse group. This causes equivalent amounts of charge to be produced on the capacitor in the integrator output during succeeding fields.

To illustrate this, suppose that no equalizing pulses were inserted between the regular horizontal pulses and the start of the vertical pulse group and that the regular horizontal pulses continued right up to the beginning of the first vertical pulse. In this case, at the start of one field, the first vertical pulse would be separated from the last regular horizontal pulse by a spacing of one H, or one line as indicated in A of Figure 10-11. At the start of the next field, 262½ lines later, the first vertical pulse would be separated from the last horizontal pulse by a distance of only half a line, or ½ H as indicated in B of Figure 10-11. It should be noted that in A, the charge on the capacitor in the integrator output, at the start of the first vertical pulse, is at the level marked x. Also that the charge on the capacitor at the start of the first vertical pulse in the following field is somewhat higher, as indicated by the level marked x plus in B of Figure 10-11. This condition is due to the fact that the charge on the capacitor produced by the horizontal pulse just preceding the first vertical pulse has more time to leak off to a lower level in A than in B, because of the longer time interval (1 H as compared to ½ H) between the last horizontal pulse and the first vertical pulse in A. Therefore, since the level of charge on the capacitor is higher at the start of the first vertical pulse in the field associated with B, than with the field associated with A, the leading edge of the pulse in the integrated output would reach the synchronizing level of the vertical sweep generator earlier for field B than for field A, as indicated in Figure 10-11. If this condition were permitted, it would cause pairing of the interlace which would result in a picture having poor quality.

A similar condition would exist in connection with the lagging edge of the pulse in the integrated output if no equalizing pulses were inserted between the end of the vertical pulse group and the regular horizontal pulses as indicated by A and B of Figure 10-11.

In order to correct this undesirable condition, six pulses (which are narrower than the horizontal pulses) occurring at twice the frequency of the regular horizontal pulses are inserted before the vertical pulse group and six similar pulses are inserted after the vertical pulse group.

The relative spacing of these are shown in A and B, Figure 10-11, by the pulses in dashed lines. It should be noted that the spacing between the leading edges of these pulses is only ½ H or half a line, as compared to the spacing of 1 H or one line between the leading edges of the regular horizontal pulses.

These pulses are called equalizing pulses because they act as a buffer between the regular horizontal synchronizing pulses and the vertical pulse group, thus equalizing or greatly reducing the effect of the $\frac{1}{2}$ H difference between successive fields. By the insertion of these equalizing pulses, nearly identical conditions are established immediately preceding the following vertical synchronizing pulses and the charge on the capacitor in the output of the integrator circuit will be practically the same for succeeding fields.

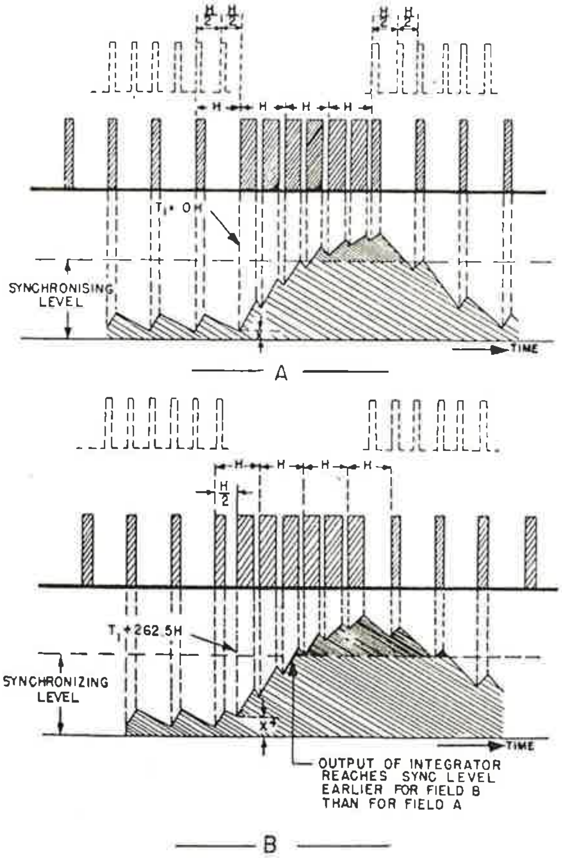

Fig. 10-11. *Output of integrating circuit in the absence of equalizing pulses.*

It was brought out several times before that the vertical pulse group consists of six separate pulses and that if vertical synchronization were the only consideration then only one broad pulse could be used instead of dividing the vertical pulse interval into six separate pulses. However, in order to maintain horizontal synchronization during the vertical retrace period, the vertical pulse is serrated or broken up into separate pulses having $\frac{1}{2}$ H spacing between leading edges so that the horizontal oscillator will be timed or synchronized on the proper alternate vertical pulses which occur at 1 H intervals.

There are many variations in the circuits used for separating the horizontal pulses from the vertical, but since the only difference between the various synchronizing pulses is the duration or width of the pulse, the circuits can usually be analyzed by considering the time constants involved. It should be kept in mind that the duration of each broad vertical pulse is 27.3 microseconds, while that of each horizontal and equalizing pulse is 5.08 microseconds and 2.54 microseconds respectively.

11. Typical circuits

A circuit using a pentode as the clipper, with amplification of the synchronizing pulses following the clipper, is shown in Figure 10-12.

The composite video signal is obtained from the output of the video amplifier and its polarity is such that the sync pulses are positive going (sync pulses up). The 10K resistor R_1, between the output of the video amplifier and the input to the clipper, is used to prevent the clipper circuit from loading the video amplifier and affecting its frequency response.

The pentode clipper tube V_1 is operated at very low screen and plate voltages, with bias for the tube being derived by grid rectification of the positive going signal in the grid circuit as discussed previously. Consequently, the clipper tube will conduct only during the sync pulse interval which is the most positive portion of the composite video signal, leaving only the composite sync pulses in its output.

The negative going composite sync pulses in the output of the clipper are fed two ways. One path feeds into a three section integrating circuit, through C_3, which accepts the wide vertical pulses while rejecting the narrow horizontal pulses. This integrating circuit consists of R_7 - C_4, R_8 - C_5 and R_9 - C_6, and provides a much cleaner and sharper pulse for application to the vertical sweep generator than a single section integrating circuit. The output of the integrating circuit is applied to the grid of a triode, V_3, where it is amplified before being used to synchronize the vertical sweep generator. The sync appearing in the output of the vertical pulse amplifier is positive going, which is the correct polarity for controlling the blocking oscillator used as the vertical sweep generator in this particular receiver.

The other path taken by the composite sync signal is through C_7 to the grid of a triode, V_2, used as a horizontal sync amplifier. Some differentiating of the composite sync signal is obtained by means of the small capacitor C_7 and resistor R_6 in the grid circuit. The synchronizing pulses are further differentiated by inductive means as explained earlier, with the leading and lagging edge of each synchronizing pulse appearing in the secondary of the transformer, T_1, as indicated in Figure 10-12. In this particular receiver the differentiated synchronizing pulses are not applied directly to the horizontal sweep generator, but instead they synchronize the sweep generator indirectly by means of an automatic frequency control circuit which will be discussed in the next chapter.

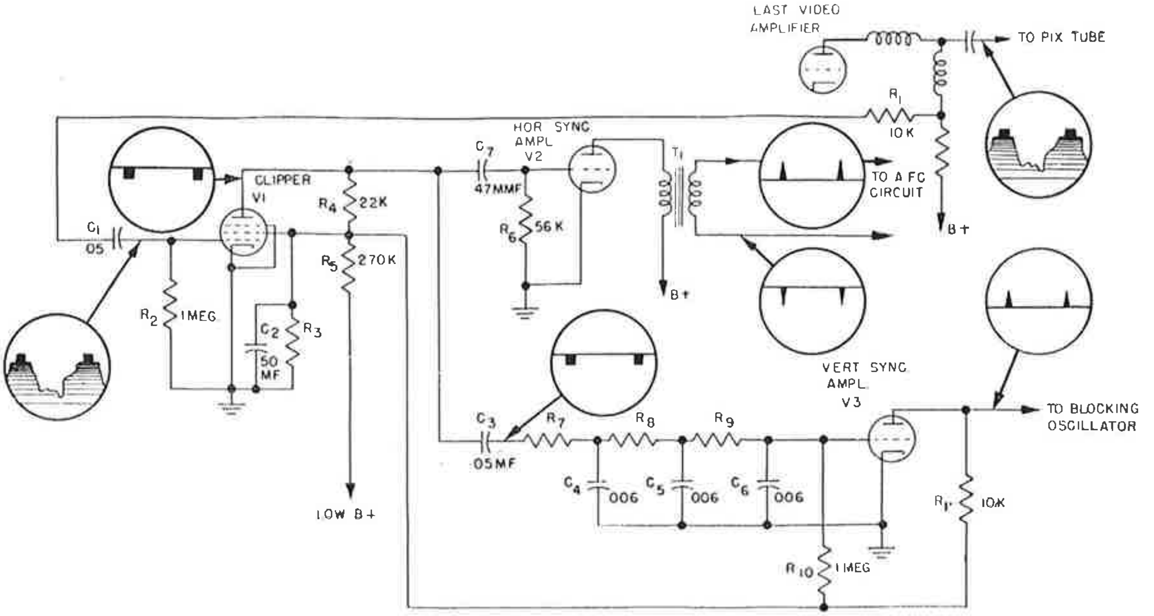

Fig. 10-12. Pentode clipper and inter-sync separating circuit.

A clipper and sync separating circuit that is somewhat different from that just described is shown in Figure 10-13. This is the circuit used in a pre-war receiver, the model 226. A triode, V_1, is used as the clipper, with the composite picture signal being applied to its grid with the sync pulses up (positive going). The sync pulses are separated from the picture information due to the bias developed in the grid circuit and the low plate voltage which causes the tube to cut off for all voltages below the blanking level. The composite sync signal appearing in the plate circuit of the clipper tube is coupled to the grid of the sync signal amplifier V_2 through C_1. It should be noted that the polarity of the signal has been reversed and that the composite sync pulses applied to the grid of V_2 are negative going.

The composite sync pulses appearing in the cathode circuit of V_2 are applied to a differentiating circuit consisting of C_2 and R_2. The short time constant of C_2 and R_2 differentiates the composite sync signal and allows only the leading and lagging edges of the sync pulses to appear across R_2, as indicated in Figure 10-13. In this case, the pulses in the output (across R_2) which correspond to the leading edge of the sync pulses at the input are all negative (below the axis), since the polarity of the composite sync pulses is negative when applied to the input of the differentiating circuit. The differentiated output appearing across R_2 is applied to the horizontal sweep generator in the polarity shown, which causes it to be synchronized by the negative pulses corresponding to the leading edge of the synchronizing pulses.

The composite synchronizing signal appearing in the plate of V_2 is coupled to the grid of a cathode follower V_3, through C_3. Capacitor C_4 and R_4 in the grid circuit of V_3 form an integrating circuit and, due to the long time constant of this circuit, integration of the composite synchronizing pulses takes place. The time constant of C_4 and R_4 is so chosen as to allow C_4 to develop a cumulative charge during the vertical pulse interval that is sufficient to produce a pulse of current through the cathode resistor of V_3. However, during the horizontal and equalizing pulses the time constant of C_4 and R_4 prevents C_4 from accumulating a sufficient charge to produce a pulse of current through the cathode resistor of V_3. The plate voltage of V_3 is quite low, which also contributes to the integration of the synchronizing pulses. The vertical synchronizing pulses appearing across the cathode resistor, R_5, are injected into the grid circuit of the vertical sweep generator, which is a blocking oscillator. It will be noted that the synchronizing pulses taken off R_5 are positive-going, which is the correct polarity to inject into the grid circuit of a blocking oscillator.

Another version of the clipper and sync separating circuits is that shown in Figure 10-14. The composite video signal is obtained from the output of the video amplifier and is a negative going signal of fairly high level at the input to tube V_1. The tube V_1 performs two functions and is used to amplify and invert the composite video signal applied to its grid and also to limit transient noise that may be riding on the composite video signal. Noise limiting is accomplished by the fairly high bias developed at the grid of V_1, due to grid current flow on the positive peaks of the picture signal and the fact that the sync pulses are negative going at the grid. This causes plate current cut-off when the signal on the grid of V_1 becomes slightly more negative than the tips of the sync pulses, thus limiting transient noise in the manner shown in

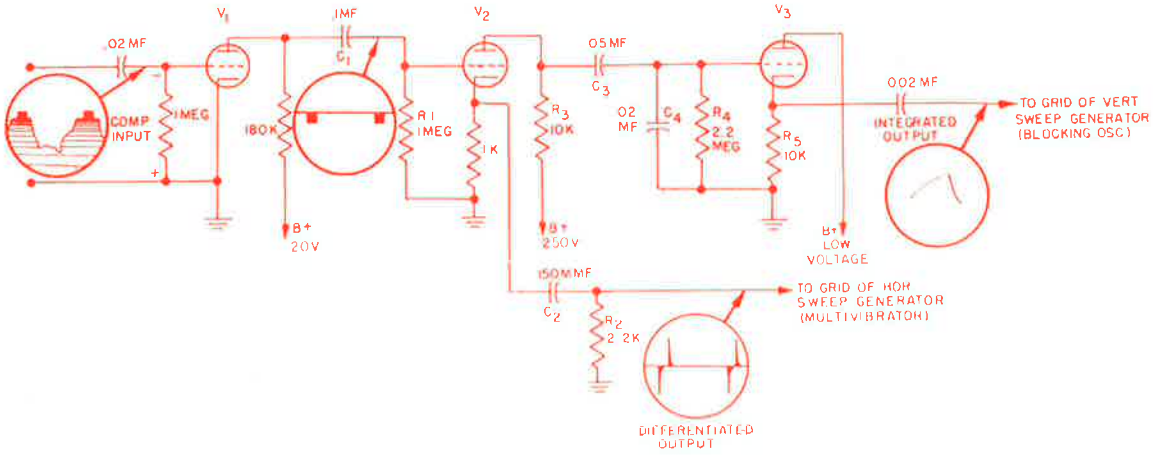

Fig. 10-15. Triode clipper and inter-sync separating circuits.

Figure 10-14. The amplified signal in the plate of V_1 is positive going, that is, the sync pulses are the most positive portion of the composite video signal. This positive going signal when applied to the diode, V_2, causes the diode to conduct and charge C_2 in proportion to the amplitude of the sync pulses. Electrons flow from the diode cathode to plate and into C_2, making the diode side of C_2 negative. This negative charge on C_2 in conjunction with R_4 establishes a bias on the clipper tube, V_3. The diode, in addition to charging C_2 during conduction, also clamps the most positive portion of the composite signal at the potential of the diode cathode (ground potential) so that the tip of each recurring pulse is at the same voltage level as indicated.

Due to the bias developed on the grid of the clipper tube V_3 and the comparatively low voltage on its plate, the clamped composite video signal in its grid circuit will cause plate current to flow in the clipper tube only during the portion of the composite signal that is above the blanking level. Therefore, only the composite sync pulses minus the actual picture information will appear in the output of the clipper.

The composite sync signal appearing across the clipper plate resistor R_6 is applied to an integrating network consisting of C_3, R_7, C_4, R_8 and C_5. The negative-going output of the integrating network is then applied to the proper point in the vertical sweep generator.

The positive-going composite sync signal appearing across the clipper cathode resistor R_5 is passed into the horizontal A.F.C. circuit. No differentiating circuit is used in this case, since the particular type of horizontal A.F.C. used in this receiver does not require a differentiated sync signal.

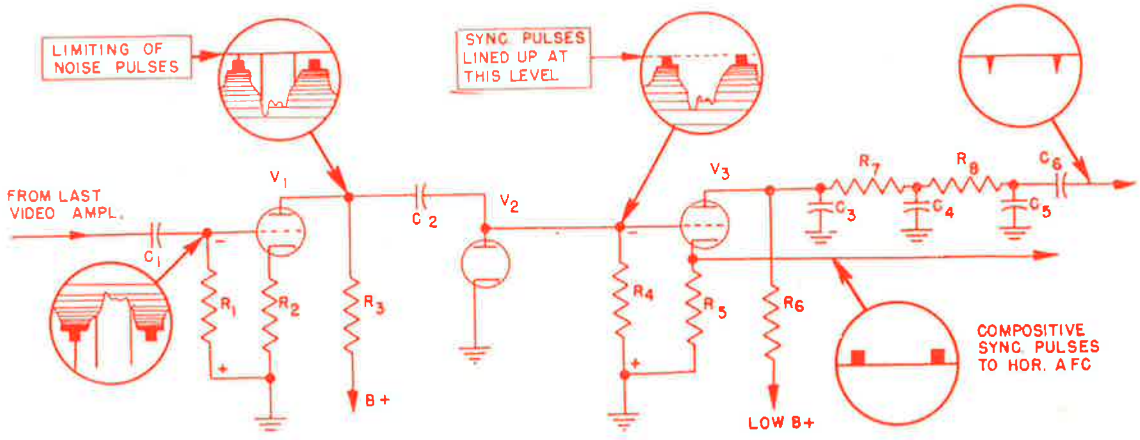

Fig. 10-14. Clipper and inter-sync separating circuits with noise limiting.