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2,386,728

WAVE EXPANSION ARRANGEMENT FOR CATHODE RAY OSCILLOSCOPES

Filed Aug. 1, 1941

2 Sheets-Sheet 1

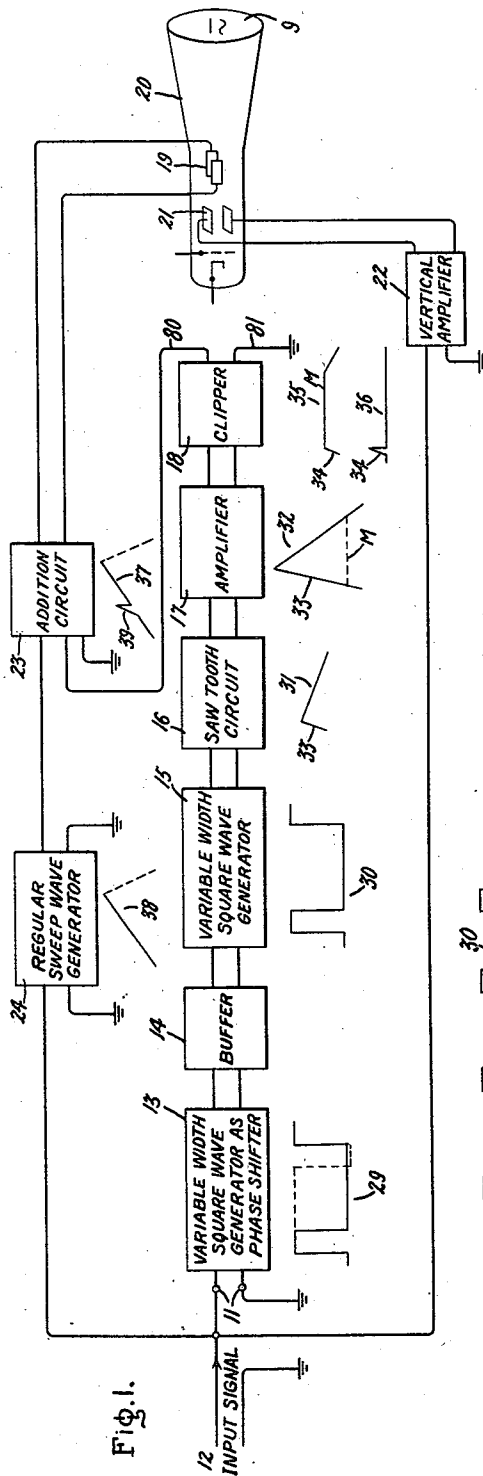


Fig. 1.

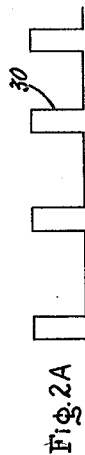


Fig. 2A

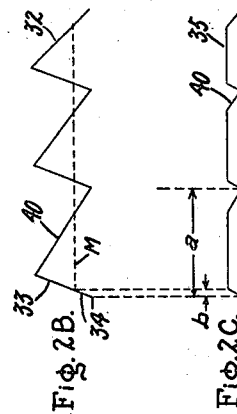


Fig. 2B

Fig. 2C

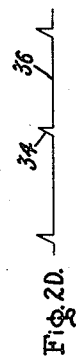


Fig. 2D

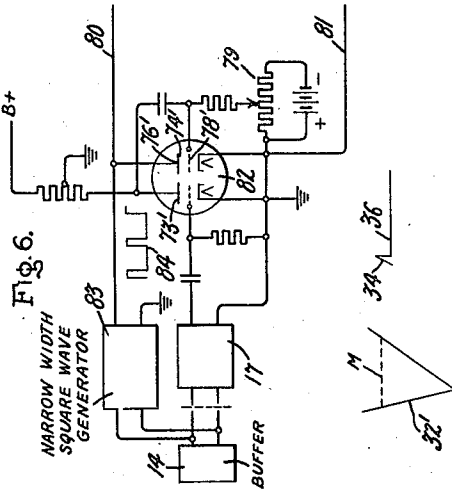
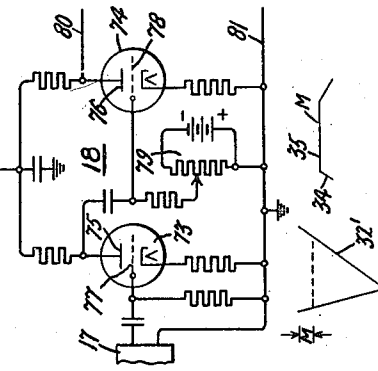


Fig. 6.

Fig. 5.



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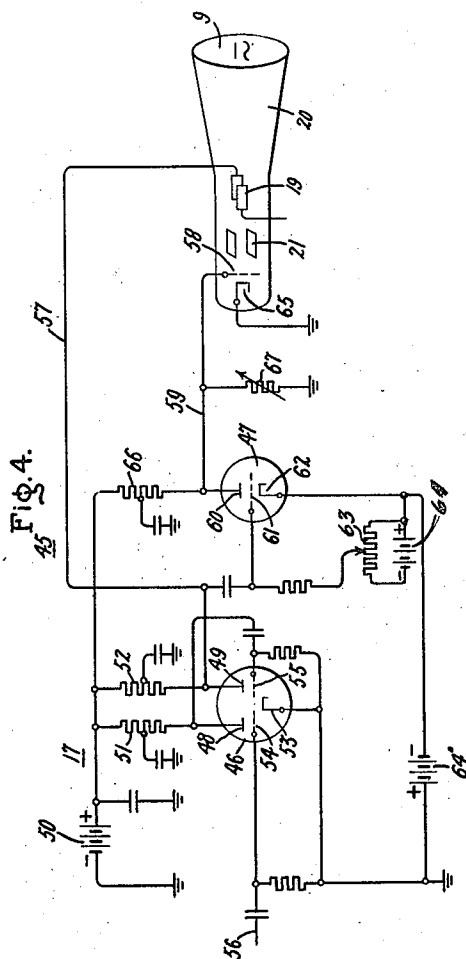
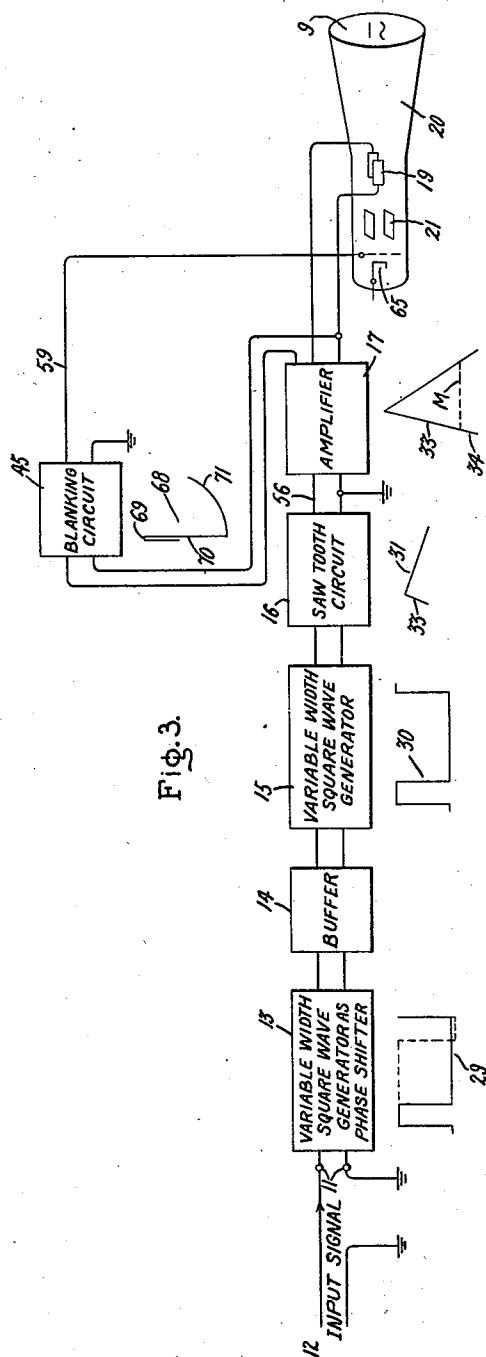
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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WAVE EXPANSION ARRANGEMENT FOR
CATHODE-RAY OSCILLOSCOPESJoseph L. Thelsen, Marblehead, Mass., assignor to
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Application August 1, 1941, Serial No. 404,967

3 Claims. (Cl. 315—22)

My invention relates to oscillographic devices of the visual or recording type and concerns particularly oscilloscopes of the type having a signal-tracing beam, such as cathode ray oscilloscopes, with means for deflecting the beam in a given plane in response to a signal wave to be examined in the oscilloscope and for deflecting the beam in a transverse plane in response to a time-axis or "sweep" wave.

It is an object of my invention to provide methods and apparatus for expanding on the screen of the oscilloscope an image of a portion of the signal wave to be observed, and to select any desired portion of the signal wave for expansion.

It is a more specific object of my invention to provide methods and apparatus for modifying the shape of the "sweep" wave of the oscilloscope and to introduce a portion of greater steepness for expansion of the wave.

Other and further objects and advantages will become apparent as the description proceeds.

The sweep-wave circuits and wave expansion arrangements described in my application are modifications of those disclosed in the copending applications of Ellsworth D. Cook, Serial No. 338,360, filed June 1, 1940, and Harris A. Thompson, Serial No. 350,409, filed August 3, 1940, both assigned to the same assignee as the present application.

For convenience and simplicity the invention is described in connection with cathode ray oscilloscopes having deflection plates for electrostatic deflection of the beam. However, my invention is not limited to this particular form of apparatus.

In carrying out my invention in its preferred form I utilize discharge tube circuits for producing a sweep wave for application to the sweep deflection plates of the oscilloscope. The basic portion of the sweep-wave circuit may be similar to the basic portion of the sweep-wave circuits of the aforesaid applications. However, I produce expansion of the wave by greatly amplifying the normal triangular or sawtooth wave of the conventional sweep-wave circuit, so that but a small portion of the amplified wave represents full deflection in the direction of the time axis of the oscilloscope screen which is usually the horizontal axis. In order to prevent the cathode ray beam from striking the sides of the tube or the anode plates and thus overloading the beam energizing circuit, I provide means for suppressing the portion of the sweep wave beyond that utilized for producing full scale deflection of the cathode ray

beam. For this purpose I may either cut off the excess portion of the sweep wave or suppress the beam itself during the unwanted portions of the sweep wave. The signal wave, the shape of which is to be represented on the cathode ray screen, is applied to signal deflection producing or vertical deflection plates of the cathode ray tube. For selecting the portion of the signal wave which is to be expanded or spread across the cathode ray screen, I provide a phase-shifting circuit arranged to vary the phase relationship between the high speed sweep wave and the signal wave.

My invention will be understood more readily from the following detailed description when considered in connection with the accompanying drawings and those features of the invention which are believed to be novel and patentable are pointed out in the claims appended hereto.

In the drawings Fig. 1 is a block diagram schematically representing a sweep-wave circuit which constitutes one embodiment of my invention and which represents diagrammatically the shapes of waves appearing in various portions of the circuit; Fig. 2A is a graph representing a conventional form of square wave from which a sawtooth sweep wave may be produced, and Fig. 2B is a graph representing such a sawtooth wave; Figs. 2C and 2D are graphs representing modified sweep waves which may be obtained from the sawtooth wave of Fig. 2B in accordance with my invention for accelerating the sweep speed during a portion of the sweep-wave cycle; Fig. 3 is a block diagram in form similar to Fig. 1 representing a modified sweep-wave circuit forming another embodiment of my invention; Fig. 4 is a circuit diagram schematically representing actual electrical circuits and elements of the apparatus represented by the rectangles captioned "Amplifier" and "Blanking circuits" in Fig. 3, and Figs. 5 and 6 are circuit diagrams of two different clipper circuits which may be employed. Like reference characters are used throughout the drawings to designate like parts.

As in the apparatus described in the aforesaid Cook and Thompson applications, the sweep wave is synchronized with a signal voltage by tapping off a portion of the signal wave or a voltage proportional to it, and applying such voltage, as a synchronizing voltage, to input terminals of the sweep-wave circuit. Accordingly, a pair of synchronizing terminals 11 is provided to which is applied the input signal 12 or a voltage representing it. The basic portion of the sweep-wave circuit consists of a phase shifter 13, a synchronizing amplifier or buffer 14, a square-wave gen-

erator 15, and a sawtooth circuit 16 connected to the output of the square-wave generator 15 for converting the square wave into a triangular wave. The foregoing elements may be conventional in form, and do not in themselves constitute my invention.

In order to increase the speed of the sweep wave I provide an amplifier 17, the input of which is connected to the output side of the sawtooth circuit 16. In the embodiment of my invention illustrated in Fig. 1, a clipper circuit 18 is provided for cutting off all but the lower portion of the amplified sawtooth wave produced by the amplifier 17. In the arrangement illustrated the output of the clipper circuit 18 is applied to a pair of electrostatic deflection plates 19 of a cathode ray tube 20 and the sweep wave is a voltage wave. However, my invention is not limited to use with oscillographic devices of the type having electrostatic sweep instead of electromagnetic sweep, for example, wherein deflection coils are used carrying a current wave of corresponding wave-form. The plates 19 are those for producing deflection of the cathode ray beam along the time axis or sweep axis and are referred to for convenience as the horizontal deflection plates, since the time axis is usually horizontal. The input signal 12 is applied to vertical deflection plates 21 of the cathode ray tube 20 usually through a vertical amplifier 22. If wave expansion only is desired the output of the clipper circuit 18 is applied directly to the horizontal deflection plates 19. However, if it is desired to superimpose an image of an expanded section of the signal wave on the same cathode ray screen with an image of the complete signal wave, the high speed sweep wave from the clipper 18 may be passed through an addition circuit 23 for combination with a regular speed sweep wave provided by a regular sweep-wave generator 24 as in the case of the aforesaid Cook application.

Any suitable form of phase-shifting circuit may be employed for the phase shifter 13. It may take the form, for example, of a variable width square-wave generator including a suitable adjusting device such as a variable condenser or rheostat for changing the ratio between the time duration of the positive and negative portions of the square wave, and in which the abruptly rising portions of the wave are synchronized with the signal voltage applied at the terminals 11 and in which the abruptly falling portions of the wave serve to synchronize the wave initiated in the square-wave generator 15. The buffer 14 consists of a suitable amplifier circuit of a type well known to those skilled in the radio frequency art. The variable width square-wave generator 15 may consist of any suitable device for producing a square wave and may have a circuit similar in principle of operation to that of the phase shifter 13.

The amplifier 17 may be a vacuum tube amplifier of any suitable type and the clipper 18 may be one of several different types according to the type of wave to be produced. For producing a wave with the top portion suppressed, such as the wave 35 of Fig. 2C, the clipper circuit may take the form, for example, of a vacuum tube circuit such as illustrated in Fig. 5. If the clipper 18 is to produce a wave 36, such as that illustrated in Fig. 2D, it may take the form of the circuit illustrated in Fig. 6. The circuits mentioned by way of example or other suitable circuits for the purposes mentioned may be employed.

The clipper circuit illustrated in Fig. 5 comprises a pair of three-element vacuum tubes 73 and 74. The tubes have anodes 75 and 76 re-

spectively connected to a source of anode potential B plus through conventional anode resistors. For stability cathode resistors may also be provided. The tube 73 serves as an inverter having a control electrode 77 capacitatively coupled to the output of the amplifier 17. The tube 74, in turn, which is the clipper tube, has a control electrode 78 capacitatively coupled to the anode 75 of the tube 73. For the clipper tube 74 a vacuum tube is chosen in which the current is cut off by a negative control-electrode voltage of the value M, or the cut-off point of the clipper tube 74 may be adjusted to the desired value such as the value M, by providing an adjustable source of biasing voltage 79. Said voltage source may take the form of a potentiometer connected across a battery of cells. The tube 73 serves to invert the amplified triangular wave 32 to form an inverted wave 32', in the manner of conventional resistance-condenser coupled circuits. When the inverted, steep triangular wave 32' is applied to the control electrode 78 of the clipper tube 74 the wave is again inverted but the portion of the wave exceeding the value M is cut off because the control electrode 78 has no further control over the tube 74 when the voltage M is exceeded. Thus the discharge current in the tube 74 remains at zero and the anode voltage remains at the maximum value, representing the cutoff value M to form a wave of the shape represented by the curve 35. This voltage wave appears between the output conductors 80 and 81. The cutoff point may be adjusted by means of the bias potentiometer 79 which causes the tube 74 to clip at a lower voltage when the bias is increased and to clip at a higher voltage when the bias is decreased.

If it is desired that the sweep voltage shall drop to zero after the steep portion 34 of the sweep wave to form a wave of the shape represented by the curve 36, the clipper circuit of Fig. 5 may be modified as represented by Fig. 6. By way of illustration a double triode 82 is shown having a left-hand triode element 73' and a right-hand triode element 74' corresponding to the triodes 73 and 74 of Fig. 5. The triode element 73' has its electrodes connected in the manner illustrated in Fig. 5 to form an inverter for the output of the amplifier 17. The control electrode 78' of the triode element 74' is also capacitatively connected to the anode of the triode element 73' and an adjustable bias source 79 may again be provided. In the arrangement of Fig. 6, however, the anode potential for the anode 76' is not provided by a fixed voltage source but instead by a suitable source of square-wave potential. For example, a narrow width square-wave generator 83 may be provided which is synchronized with the sweep wave by a connection to the output side of the buffer 14. The narrow width square-wave generator 83 is selected to provide a square wave of narrower width than the wave 30 provided by the generator 15, the width of the wave preferably being no greater than the length of the projection on the horizontal axis of the steep portion 34 of the sweep wave.

During the positive portion of the square wave 84 provided by the narrow width square-wave generator 83 the triode element 73' will function in the same manner as the conventional resistance-coupled amplifier to invert the triangular wave 32 and form the inverted wave 32'. The triode element 74' will likewise function as a resistance coupled amplifier to reinvert the triangular wave 32' until the cutoff point M is reached, thus tracing the steep portion 34 of the

sweep wave. Thereupon the anode voltage of the triode element 74' falls abruptly to the negative value of the square wave 84 and the sweep wave drops to a uniform negative value as represented in the curve 36. Accordingly a sweep wave of the shape represented by the curve 36 appears at the output terminals 80 and 81.

The variable width square wave produced by the phase shifter 13 is represented schematically at 29 below the phase shifter 13. The square wave produced by the square-wave generator 15 is represented schematically at 30. If it is desired to make the amount of expansion adjustable, the square-wave generator 15 will also be so constructed as to include means for adjusting the width of the wave 30. The sawtooth wave produced by the sawtooth circuit 16 is represented at 31 and will be seen to have rising and falling portions corresponding to the positive and negative portions of the rectangular wave 30. After passing through the amplifier 17 the sawtooth triangular wave 31 appears in a greatly amplified form as represented schematically at 32 in which the rising steep portion 33 of the wave 32 is greatly increased in slope for rapidly switching the cathode ray beam across the screen of the tube. It will be understood of course that the curves 31 and 32 are simply schematic and are not intended to represent the actual or most desirable ratio of amplification.

As indicated in Fig. 2B, the curve 32 is amplified to such an extent that a very small portion 34 of the entire wave, viz: that from the base line to the dotted line M represents full horizontal deflection of the cathode ray beam. In order to prevent injury to the tube or overloading which would occur from allowing the beam to be driven against the side of the tube, the portion of the wave 32 above the horizontal line M is suppressed. This is accomplished by means of the clipper 18 which simply cuts off all of the wave above the line M to form a curve of the shape represented by Fig. 2C or Fig. 2D. The ratio of expansion produced by the amplification of the triangular sweep wave 31 is represented by the ratio between the distances a and b . The period of the sweep wave as represented by a and b is the length measured in time units of the projection of the steep portion 34 of the clipped sweep wave 35 or 36.

If the high speed sweep wave 36 is combined with a normal speed wave by means of the addition circuit 23, the appearance of the resultant sweep wave will be substantially as represented at 37, with the high speed wave 36 superimposed on a slow speed triangular sweep wave 38 produced by the regular sweep-wave circuit 24. The high speed portion 39 of the wave 37 corresponds to the steep portion 34 of the wave 35 or 36 and its relationship with the remainder of the wave 37 may be varied by adjustment of the phase shifter 13. Thus, in effect, the portion 39 of the sweep wave is made to move back and forth along the line 37 by adjustment of the phase shifter 13. If a high speed sweep wave or an expansion circuit only is employed, the selection of the portion to be expanded takes place in the same manner since adjustment of the phase shifter 13 changes the phase relationship between the signal wave and the steep portion 34 of the sweep wave 35 or 36. If desired the unused, less steep negative slope portion 40 of the sweep wave 35 may also be eliminated in any suitable manner as by means of a fly-back cut-off.

Whether the shape of the high speed sweep wave is such as shown in the curve 35 of Fig. 2C or in the curve 36 of Fig. 2D, expansion will take place in the same manner since the high speed portions 34 in the two shapes of sweep wave correspond.

A modified sweep-wave expansion circuit is represented in Fig. 3, employing elements 13 to 17 inclusive, which may be of the same type as the correspondingly numbered elements in the embodiment of Fig. 1. The clipper 18 of Fig. 1 is, however, omitted and instead a blanking circuit 45 is provided for the purpose of cutting off the cathode ray beam of the oscilloscope tube 20 when the sweep wave 32 reaches a voltage represented by the horizontal line M. The amplifier 17 may consist of one or more vacuum tube stages with a voltage tapped from one of the stages to operate the blanking circuit 45. The arrangement may be such as that illustrated in Fig. 4, for example, in which a double triode vacuum tube 46 is provided to serve as the last two stages of the amplifier 17. A triode vacuum tube 47 serves as the controlling element of the blanking circuit 45.

The tube 46 comprises a pair of anodes 48 and 49 to which a source of anode voltage 50 is connected through a pair of anode resistors 51 and 52, the mid-points of which are grounded through ripple-absorbing condensers. There is a common cathode 53 which is grounded, and there are grids or control electrodes 54 and 55 associated with the anodes 48 and 49 respectively. The grid 54 is capacitatively coupled to the output of the previous stage of the amplifier or, if the amplifier consists of only two stages, to the conductor 56, to which the positive output of the sawtooth circuit 16 is connected. The grid 55 is capacitatively coupled to the anode 48 in accordance with the well-known resistance capacity amplifier coupling. The amplifier output appears at the anode 49 and is applied through a conductor 57 to one of the horizontal deflection plates 19 of the cathode ray tube 20. It will be understood that the other horizontal deflection plate is either grounded or held at a fixed potential by a suitable device such as a potentiometer in accordance with the well-known cathode ray oscilloscope practice.

In order to suppress the cathode ray oscilloscope beam when the voltage of the sweep wave 32 exceeds a value corresponding to full scale deflection across the oscilloscope screen, the control electrode or grid 58 of the oscilloscope tube 20 is connected through a conductor 59 to the output of the blanking circuit 45. As shown in Fig. 4, the blanking circuit includes the tube 47 having an anode 60 to which the output conductor 59 is connected, a control electrode or grid 61, and a cathode 62.

The discharge tube 47 may advantageously be a vacuum tube of the type having a sharp upward bend in the characteristic curve representing the relationship between its anode current plotted along a vertical axis and its grid voltage plotted along a horizontal axis. The grid 61 is capacitatively coupled to the output terminal of the amplifier 17, which is the anode 49 of the tube 46. In order to cause the blanking tube 47 to operate near the bend in its characteristic curve, an adjustable negative bias is applied thereto. This may take the form of a potentiometer 63 connected across a voltage source 64 connected on the positive side to the cathode 62. In order that the blanking tube 47 may supply an adequate nega-

tive potential at proper times, its cathode 62 is held negative with respect to the cathode 65 of the cathode ray oscilloscope tube 20. The cathode 62, for example, may be connected to a negative side of the voltage source 64, grounded on the positive side, the oscilloscope cathode 65 being grounded. The blanking-tube anode 60 is connected to the positive side of a source of anode voltage, such as the source 50, through an anode resistor 66 which also has its mid-point bypassed through a ripple-absorbing condenser connected to ground. The constants of the circuits, the characteristics of the tube 47 and the bias voltage provided by the grid bias potentiometer 63 are so chosen as to cause the blanking tube 47 to become strongly conducting, when the voltage of the wave 32 appearing at the amplifier anode 49 reaches the value represented by the horizontal line M. Since the tube 47 is one having the aforesaid sharp bend characteristic, as long as the sweep-wave voltage remains below the value M, the anode current of the tube 47 is negligible and a positive voltage is maintained on the cathode ray oscilloscope grid 58. However, when the sweep-wave voltage exceeds the value M, the bend in the characteristic curve of the tube 47 is passed and a relatively heavy discharge current flows through the tube 47 causing a large voltage drop in the anode resistor 66, depressing the voltage of the oscilloscope grid 58 below that of the oscilloscope cathode 65 and cutting off the cathode ray beam to suppress the wave traced on the screen.

It will be understood that suitable means, adjustable if desired, are ordinarily provided for normally maintaining the potential of the oscilloscope grid 58 at the value which produces the most satisfactory operation. This may take the form of a voltage divider, for example. Such a voltage divider is represented in Fig. 4 by the anode resistor 66 and a rheostat 67 of suitable value connected between the anode 60 and ground. Thus normally the potential of the oscilloscope grid 58 is fixed by the ratio between the resistance of the rheostat 67 and the resistance 66 which are connected in series to the voltage source 50. However, when the blanking tube 47 becomes strongly conducting it draws current of such magnitude through the anode resistor 66 as to depress the grid voltage of the oscilloscope 58. The approximate shape of the voltage wave applied to the grid 58 is represented by the curve 68 as shown below the rectangle representing the blanking circuit 45. It will be observed that for the time duration of the steep portion 34 of the curve 32, the curve 68 remains positive as represented by the positive loop 69. However, when the sweep-wave voltage exceeds the value M the anode voltage of the blanking tube 47 drops abruptly along the line 70 but remains strongly negative with respect to the oscilloscope 65 until the sweep voltage falls again to the value M. The exact shape of the negative portion 71 of the curve 68 will of course depend on the characteristics of the tube 47.

I have herein shown and partially described certain embodiments of my invention and certain methods of operation embraced therein for

the purpose of explaining its practice and showing its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and I aim therefore to cover all such modifications as fall within the scope of my invention which are defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A signal wave expansion arrangement for a sweep-wave circuit of an oscillographic device having a signal-tracing beam comprising in combination with a sawtooth wave generator for producing a sweep wave for deflecting a signal-tracing beam along a sweep axis of the oscillographic device and spreading an image of the signal wave on the screen of the oscillographic device, an amplifier for increasing the amplitude of the sweep wave and thus increasing its slope to increase the speed of sweep, and a device responsive to the sweep wave at a value thereof exceeding the amplitude required to produce full scale deflection along the sweep axis of the oscilloscope for interrupting further sweep of the signal-tracing beam, whereby an expansion of the traced signal wave is produced by the uninterrupted portion of the amplified sweep wave.

2. An oscilloscope sweep-wave generator for an oscillographic device comprising a sawtooth wave generator for producing a triangular wave for application to one of the deflection circuits of an oscillographic device but of a greater value than required for full scale deflection, a clipper circuit connected to said sawtooth wave generator for cutting off the portion of the sweep wave which would otherwise have an amplitude greater than that required to produce a deflection the full length of the desired sweep axis of the device whereby the slope of the used portion of the sweep wave is caused to be relatively great to produce high speed sweep and expansion of a signal wave to be examined in the device during a portion of the cycle of the signal wave to be examined.

3. An oscilloscope sweep-wave generator comprising generating means for producing a triangular wave for application to one of the deflection circuits of a cathode ray oscilloscope but of greater peak value than required for full scale deflection, said oscilloscope being of the type having a control electrode or grid circuit, a blanking circuit responsive to the magnitude of the sweep wave having output terminals for connection to the control electrode or grid circuit of the oscilloscope for applying a negative voltage therein of sufficient value to cut off the cathode ray beam whenever the sweep wave exceeds the amplitude required to sweep the cathode ray beam the full desired length of the sweep axis of the oscilloscope, whereby the slope of the used portion of the sweep wave is relatively great to produce high speed sweep and the signal wave existing during only a portion of the cycle is expanded to the full length of the sweep axis of the oscilloscope.

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