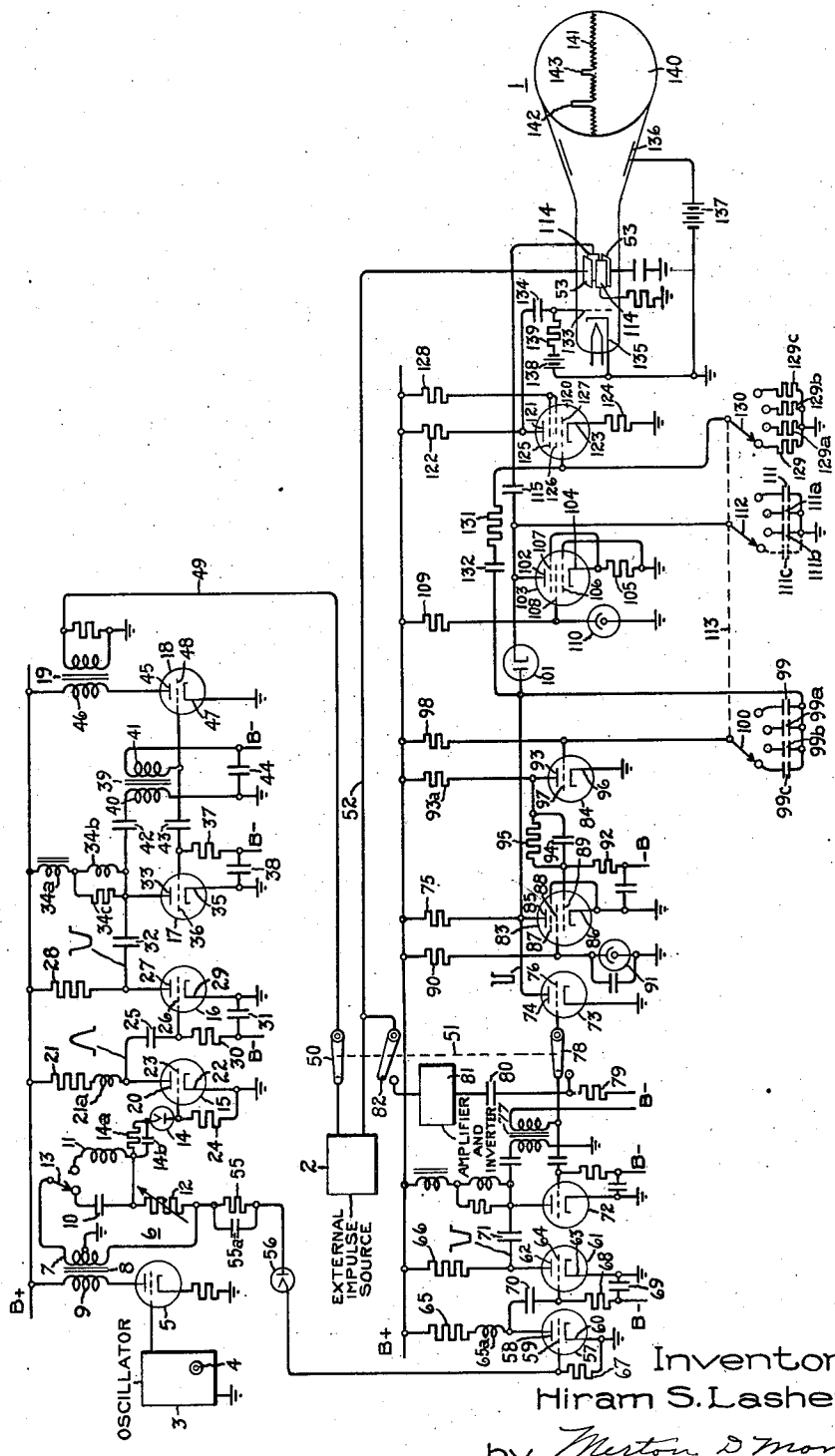
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OSCILLOGRAPH APPARATUS

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Inventor:
Hiram S. Lasher, Jr.
by Merton D. Morse
His Attorney.

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OSCILLOGRAPH APPARATUS

Hiram S. Lasher, Jr., Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

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13 Claims. (Cl. 315—24)

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My invention relates to apparatus for analyzing electric oscillations, and more particularly to cathode ray oscillographs of the type known as synchroscopes. Such instruments are commonly used for analysis of recurrent electric impulses of very short duration, such as those employed in radio detection and direction finding equipment, and the like.

It is a general object of my invention to provide a new and improved cathode ray oscillograph apparatus including means for synchronizing the operation of a source of oscillations to be observed or analyzed with the timing sweep of the electron beam.

It is a still further object of my invention to provide a new and improved cathode ray oscillograph apparatus in which a single source of timing oscillations synchronously controls the sweep of an electron beam, the intensity of the beam, and the trigger circuit controlling the source of oscillations to be analyzed.

It is a still further object of my invention to provide, in an apparatus of the above character, novel and simple means whereby the source of timing oscillations may be disabled and the source of observed oscillations itself used synchronously to control the beam sweep and beam intensity when the source of observed oscillations is of an inherently recurrent character.

It is a more particular object of my invention to provide, in a synchroscope of the above type, an organization of timing and synchronizing circuits having such interrelated characteristics that it is equally reliable and efficient over a very wide band of frequencies and capable of analyzing pulses of much shorter duration than have heretofore been observable with an instrument of this general type.

My invention itself, together with further objects and advantages thereof, will be more fully understood by referring now to the following detailed specification taken in conjunction with the accompanying drawing, the single figure of which is a schematic circuit diagram of a cathode ray oscillograph apparatus embodying my invention.

Referring now to the drawing, I have shown my invention applied to a synchroscope apparatus comprising a cathode ray discharge device 1, a source 2 of electric impulses or oscillations to be observed, and a source 3 of substantially constant frequency sinusoidal oscillations for controlling the sweep and intensity of the electron beam and synchronizing the operation of the source 2 with the beam sweep.

The source of sine wave voltage 3 may be an

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oscillator of any well-known type, such as a crystal or resonant circuit oscillator, and preferably includes suitable means, such as variable capacitors, inductors, or the like, controlled by a dial 4 for varying the frequency of the generated oscillations. The sine wave oscillations of selectable constant frequency from the source 3 are amplified in an electron discharge device 5 and supplied to a phase shifting circuit 6 connected to the secondary winding 7 of a transformer 8, the primary winding 9 of which is connected in the anode circuit of the amplifier 5.

The phase shifting circuit 6 comprises a capacitor 10, an inductor 11, and a variable resistor 12. A two-position selector switch 13 is arranged alternatively to connect either the capacitor 10 or the inductor 11 in series with the resistor 12 across the terminals of the transformer winding 7. The mid-point of the transformer winding 7 is connected to ground. From opposite terminals of the variable resistor 12, sine wave oscillations of controllable phase relation are derived. The phase shift results from the reactive characteristics of the reactors 10 and 11, and is controlled by the resistor 12. It will be evident that the phase of the oscillations supplied from the lower terminal of the resistor 12 is the same as that appearing at the lower terminal of the transformer winding 7, since these points are permanently and directly connected. The relative phase of the oscillations at the upper terminal of the resistor 12 is variable. It will be evident that, when the resistance of the resistor 12 is reduced substantially to zero, the oscillations at the upper terminal of the resistor are substantially in phase with those at the lower terminal. As the resistor 12 is inserted in the circuit with the capacitor 10 connected in series therewith, the oscillations at the upper resistor terminal are caused progressively to lag the fixed oscillations at the lower terminal. Similarly, if the inductor 11 is in circuit, insertion of the resistor 12 causes the oscillations at the upper resistor terminal to lead the fixed oscillations at the lower terminal. By this phase shifting circuit, it is possible to displace the relative phase of the fixed and variable oscillations over a range of substantially 180°. It will be understood, of course, that the range of phase displacement is limited at its extremities by the finite values of the circuit impedances. If desired, these end ranges of phase displacement may be covered by reversing the output connections from the upper and lower terminals of the variable resistor 12

so that substantially 360° phase shift is possible.

The fixed phase oscillations from the lower terminal of the resistor 12 are used to control a beam sweep generator and intensifier in a manner to be more fully described hereinafter. The negative half cycles of the variable phase oscillations from the upper terminal of the resistor 12 are supplied through a resistor 14a and a diode 14 in series to the input circuit of an electron discharge device 15 and are utilized to generate triggering pulses for control of the source 2 of oscillations to be observed. The resistor 14a is shunted by a capacitor 14b. The diode 14 prevents loading of the phase shifting circuit on positive half cycles and consequent unbalance of the phase shifting network. It will be understood that the normal function of the phase shifting circuit 6 is to displace in time the triggering of the source 2 with respect to the initiation of the beam sweep so that the observed phenomenon may be made to appear at any desired time on the beam sweep. In this way, the leading edge of pulses or other oscillations from the source 2 is not lost in its representation on the cathode ray screen.

The trigger circuit comprises a pair of electron discharge devices 15 and 16 for amplifying and sharpening the sine wave oscillations supplied from the variable phase terminal of the phase shifting circuit 6 and a second pair of electron discharge devices 17 and 18 connected as a blocking oscillator to supply to an output transformer 19 a series of substantially rectangular pulses of short duration having the periodicity of the timing source 3.

The discharge device 15 comprises an anode 20 connected to a suitable source of positive unidirectional supply B+ through an anode resistor 21 and inductor 21a, a cathode 22 connected directly to ground, and a control electrode 23 connected to the upper terminal of the phase shifting resistor 12 through the diode 14 and resistor 14a. The control electrode 23 is connected to ground through a grid resistor 24. Oscillations appearing upon the anode 20 of the discharge device 15 are supplied through a coupling capacitor 25 to a control electrode 26 of the discharge device 16. The discharge device 16 includes also an anode 27 connected to B+ through an anode resistor 28 and a cathode 29 connected directly to ground. The control electrode 26 is biased negative with respect to the cathode 29 by connection through a grid resistor 30 to a suitable source of negative unidirectional potential B—. The potential source B— is by-passed by a capacitor 31.

In operation, the blocking oscillator trigger circuit comprising the discharge devices 15 and 16 functions in the following manner. The discharge device 15 is normally conductive and the discharge device 16 is normally non-conductive. Negative half waves supplied from the phase-shifting circuit 6 to the input electrode 23 of the discharge device 15 periodically render the discharge device 15 non-conductive thereby to raise the potential of its anode 20 so that positive pulses of substantially sinusoidal configuration are supplied through the coupling capacitor 25 to the input electrode 26 of the discharge device 16. The discharge device 16, normally cut off because of its negative bias, is periodically rendered conductive and driven to saturation by the positive input pulses, so that flat-topped negative pulses appear at the anode 27 of the discharge device 16 as indicated upon the drawing. These negative pulses are supplied through a coupling capacitor 32 to a regenerative blocking oscillator comprising the discharge devices 17 and 18.

The discharge device 17 of the blocking oscillator comprises an anode 33 connected to B+ through a pair of inductors 34a and 34b, a cathode 35 connected directly to ground, and a control electrode 36 biased beyond cutoff by connection through a resistor 37 to a suitable source of negative unidirectional potential B—. The B— potential source is by-passed by a capacitor 38. The inductor 34b is shunted by a resistor 34c. The control electrode 36 is regeneratively coupled to the anode 33 and, thus, to the anode 27 of the discharge device 16 through a transformer 39 having a primary winding 40 and a secondary winding 41. One terminal of the primary winding 40 is connected to ground and the other terminal is connected through a coupling capacitor 42 to the anode 33. The secondary winding 41 is connected at one end to the control electrode 36 through a coupling capacitor 43 and at the other end to a source of negative unidirectional potential B—. The potential source B— is by-passed by a capacitor 44.

The other oscillator discharge device 18 comprises an anode 45 connected to B+ through a primary winding 46 of the output transformer 19, a cathode 47 connected directly to ground, and a control electrode 48. The control electrode 48 is connected to the control electrode 36 of the discharge device 17 through the coupling capacitor 43. Thus, by connection through the transformer winding 41, the control electrode 18 is biased negative with respect to the cathode 47 from the B— potential source.

In operation, the blocking oscillator comprising the discharge devices 17 and 18 functions in the following manner. Negative pulses from the anode of the discharge device 16 are supplied through the coupling capacitors 32 and 42 to the primary winding 40 of the transformer 39. The transformer windings are so disposed that, when the ungrounded terminal of the transformer primary winding 40 is thus driven negative, a positive voltage pulse is impressed upon the control electrodes 36 and 48 from the secondary winding 41 of the transformer. Both discharge devices 17 and 18 are normally cut off by reason of their negative bias potentials. As soon as such a positive grid pulse is impressed upon the tubes, however, both tubes become conducting. By regenerative action through the transformer 39 and the device 17, the grids 36 and 48 are rapidly driven to a high positive potential, so that both discharge devices are driven to saturation. It will be clear that, as soon as the discharge device 17 begins to conduct so that the anode 33 falls in potential, a further negative potential is impressed upon the ungrounded terminal of the transformer winding 40 so that the grids 36 and 48 are driven even further positive. Thus, once conduction has been initiated in the discharge device 17 by imposition of a negative triggering pulse upon the transformer winding 40, the grid potential of both discharge devices 17 and 18 is rapidly built up to a high positive value by regeneration through the transformer 39 and the discharge device 17. The pulse duration is determined by the time constant of a grid discharge circuit including the capacitor 43 and the grid to cathode resistance of the tube 17. As soon as the grid potential decays to a predetermined point with capacitive discharge through the grid circuit the anode current of the device 17 decreases slightly and initiates degenerative action through the discharge device 17

and the transformer 39. The degenerative action effects a very rapid termination of discharge in both the discharge devices 17 and 18. Thus, by saturation limiting, the current pulse through the discharge device 18 and the output transformer 19 is substantially rectangular in configuration. This rectangular pulse is supplied through a trigger lead 49 and a contact 50 of a control switch 51 to trigger the external source 2. While the function of the selector switch 51 will be more fully described hereinafter, it will be understood that the switch 50 is closed, as shown, only when the source 2 requires triggering for impulse generation.

The output impulses from the external source 2 are in all cases supplied through a lead 52 to the vertical deflection plates 53 of the cathode ray discharge device 1.

Referring now to the cathode ray sweep circuit, it will be recalled that this circuit is controlled by the fixed phase oscillations derived from the lower terminal of the phase shifting resistor 12 and differing in phase with respect to the oscillations from the upper resistor terminal utilized to control the trigger circuit described above. As shown on the drawings, fixed phase oscillations are supplied from the phase shifting circuit 6 through a resistor 55 and a diode 56 to the input circuit of an electron discharge device 57. The resistor 55 is shunted by a capacitor 55*a*. The discharge device 57 comprises an anode 58, a control electrode 59, and a cathode 60, and, together with an electron discharge device 61, constitutes a blocking oscillator trigger circuit similar to that described above in connection with the discharge devices 15 and 16. Accordingly, the discharge device 61 comprises an anode 62, a cathode 63, and a control electrode 64. The anode 58 is connected to a suitable source of positive potential B+ through an anode resistor 65 and inductor 65*a*. The anode 62 is connected to B+ through a resistor 66 and the cathodes 60 and 61 are connected directly to ground. The control electrode 59 of the discharge device 57 is connected to ground by a grid resistor 67. The control electrode 64 of the discharge device 61 is biased negative with respect to the cathode by connection through a resistor 68 to a suitable source of unidirectional negative potential B—. The source B— is by-passed by a capacitor 69. The anode output of the discharge device 57 is coupled through a coupling capacitor 70 to the control electrode 64 of the discharge device 61, thereby periodically to render the discharge device 61 conductive. Accordingly, recurrent negative voltage pulses, limited in amplitude by saturation, appear upon the anode 62 in the manner heretofore described in connection with the anode 27 of the discharge device 16.

The negative pulses appearing upon the anode 62 of the discharge device 61 are supplied through a coupling capacitor 71 to trigger a blocking oscillator circuit comprising a pair of electron discharge devices 72 and 73. This blocking oscillator is similar in all respects to the regenerative blocking oscillator described above in connection with the discharge devices 17 and 18, so that a description of its operation need not be repeated. It should be noted, however, that the output discharge device 73 has its anode 74 connected to B+ through a load resistor 75 rather than a transformer, while a control electrode 76 of the device 73 is connected to the regenerative grid transformer 77 through a contact 78 on the selector switch 51. Thus, the output from the blocking

oscillator comprising the discharge devices 72 and 73 is derived directly from the anode 74 rather than through a transformer, as described in connection with the trigger circuit. It will be understood that recurrent negative voltage pulses of substantially rectangular configuration appear upon the anode 74. The contact 78 of the selector switch 51 has two alternative positions in one of which the control electrode 76 is connected to the grid transformer 77 and in the other of which the control electrode 76 is connected directly to a negative bias source B— through a resistor 79 and to the output of the external impulse source 2 through a coupling capacitor 80, an amplifier and inverter 81, and a contact 82 of the switch 51. The purpose of the switch contacts 78 and 82 in connecting the control electrode 76 to the output lead 52 from the source 2 will be described in more detail hereinafter. An inverter is used only when the observed signal is negative.

Negative output pulses from the oscillator comprising the discharge devices 72 and 73 are supplied from the anode 74 of the device 73 to trigger an aperiodic multivibrator circuit comprising a pair of electron discharge devices 83 and 84. The discharge device 83 comprises an anode 85 connected to B+ through the anode resistor 75, a cathode 86 connected directly to ground, and a plurality of control electrodes 87, 88 and 89. The control electrode 87 is a suppressor electrode connected directly to the cathode in the usual manner. The control electrode 88 is a screen electrode which is maintained at a substantially constant positive potential by means of a potential divider comprising a resistor 90 connected in series with a voltage regulating gaseous discharge tube 91 between B+ and ground, the control electrode 88 being connected to the common terminal of the resistor 90 and the voltage regulating tube 91. The control electrode 89 is connected to a negative bias source B— through a grid resistor 92 and to the anode 93 of the discharge device 84 through a coupling capacitor 94 shunted by a resistor 95. The discharge device 84 comprises also a cathode 96 connected directly to ground and a control electrode 97 which is biased positive by connection through a resistor 98 to the potential source B+. The control electrode 97 is also coupled to the anode 85 of the discharge device 83 through any desired one of a plurality of selectable coupling capacitors 99, 99*a*, 99*b*, or 99*c*. The desired capacitor 99 is selected by a switch contact 100 on a gang selector switch 113 to be more fully described hereinafter. The anode 93 of the discharge device 84 is also connected to B+ through an anode resistor 93*a*.

In the operation of the pulse forming multivibrator comprising the discharge devices 83 and 84, the discharge device 83 is normally non-conductive by reason of the negative bias potential on the electrode 89, and the discharge device 84 is normally conductive because of the positive bias on its control electrode. Negative triggering impulses from the anode 74 of the oscillator tube 73 are impressed through the selected coupling capacitor 99 upon the control electrode 97 of the discharge device 84. Due to the regenerative characteristics of the triggering oscillator comprising the discharge devices 72 and 73, this triggering impulse has a very sharp leading edge. As soon as the control electrode 97 is thus driven negative, the discharge device 84 is cut off, so that its anode potential increases abruptly. Upon increase in the potential of the anode 93, a positive potential is impressed upon the control elec-

trode 89 of the device 83 through the coupling resistor 95 and capacitor 94. The capacitor 94, connected in shunt with the resistor 95, prevents attenuation of the sharp leading edge of the positive pulse impressed upon the control electrode 89. When the control electrode 89 is driven in a positive direction, the discharge device 83 is rendered conductive, so that its anode 85 draws a load current through the anode resistor 75 and the anode becomes less positive in potential. The reduced positive potential at the anode 85 drives the control electrode 97 of the device 84 further negative, thereby further to increase the positive potential of the control electrode 89 through the coupling resistor 95 and capacitor 94. This regenerative action now proceeds independently of the triggering pulse initiated at the anode 74 of the device 73, so that the anode 85 of the device 83 is driven rapidly to its minimum potential in a time determined by the regenerative characteristics of the multivibrator circuit. When the discharge device 83 reaches saturation, the regenerative action ceases.

The resistor 98 and the selected capacitor 99 connected in series between B+ and the anode 85 of the discharge device 83 constitute a timing circuit determining the switching time of the multivibrator tube. When regeneration in the multivibrator ceases the capacitor 99 is charged to the potential across the resistor 75 thereby gradually to increase the potential of the control electrode 97 in a positive direction along an exponential curve determined by the time constant of the circuit 98, 99. The anode 85 of the device 83 remains at its maximum negative potential until the control electrode 97 increases in potential sufficiently to render the discharge device 84 again conductive. When such conduction takes place, the anode 93 of the device 84 experiences a sudden drop in potential thereby to impress upon the control electrode 89 of the device 83 a negative potential through the coupling elements 94, 95. The negative potential upon the control electrode 89 reduces conduction of the discharge device 83, thereby to increase the potential of the anode 85 and initiate degeneration between the discharge devices 83 and 84. The negative pulse at the anode 85 is thus abruptly terminated. The initial condition is therefore re-established with the discharge device 83 nonconductive and device 84 conductive. The multivibrator circuit remains in this condition until initiation of the next triggering impulse at the oscillator tube anode 74.

It will now be observed that the combination of the regenerative triggering oscillator comprising the devices 72 and 73 with the regenerative multivibrator comprising the devices 83 and 84 produces at the anode 85 of the device 83 a negative pulse having a very sharply sloped leading edge, the shape at the initiation of the leading edge resulting from oscillator regeneration, and the higher voltage portion of the pulse being determined by the regenerative multivibrator characteristics.

The negative pulses thus appearing at the anode 85 of the multivibrator device 83 are supplied through a diode 101 to the anode 102 of a sweep generating discharge device 103. The discharge device 103 comprises, in addition to the anode 102, a cathode 104 connected to ground through a cathode bias resistor 105, a control electrode 106 connected directly to ground, a suppressor electrode 107 connected directly to the cathode 104, and a regulated screen grid electrode 108. The screen grid 108 is maintained at a substantially constant positive potential by connection to the common terminal of a resistor 109 and a voltage regulating tube 110 connected in series circuit relation as a voltage divider between B+ and ground. Thus, it will be seen that the discharge device 103 is normally connected between B+ and ground through the anode resistor 75 and the diode 101, so that the anode supply potential to the discharge device 103 is recurrently interrupted for the duration of the negative multivibrator pulses appearing upon the anode 85 of the discharge device 83.

The sweep generating discharge device 103 and cathode resistor 105 are shunted by any desired one of a plurality of selectable capacitors 111, 111a, 111b, and 111c. The desired capacitor 111 may be selected by a contact 112 on the manually operable selector switch 113. The capacitor 111c is shown in dotted lines because physically it represents only the distributed and stray capacitance of the circuits involved, the switch contact actually being left unconnected to any physically realizable circuit element.

In operation, the sweep generating discharge device 103, when connected through the diode 101 to the supply source B+, is normally conductive and impresses upon the selected capacitor 111 a charge equal to the voltage drop between the anode 102 and ground. Recurrently, and for the short duration of the recurrent multivibrator pulses, the anode supply source is removed from the discharge device 103 by reason of the fact that, for the duration of these pulses, the diode 101 is rendered non-conductive. During such periods, the charge accumulated upon the selected capacitor 111 is dissipated through the discharge device 103 thereby to form a saw-tooth wave which is utilized to control the horizontal sweep of the cathode ray beam. The saw-tooth voltage across the selected capacitor 111 is coupled to the horizontal plates 114 of the cathode ray discharge device 1 through a coupling capacitor 115. A similar sweep circuit is disclosed and claimed in copending application Serial No. 563,920, filed November 17, 1944, issued September 21, 1948, as Patent 2,449,801, by Frank J. Bias and Harold W. Lord, and assigned to the same assignee as the instant application.

During the period of the beam sweep, the cathode ray is intensified by a circuit associated with the multivibrator output at the anode 85 of the discharge device 83. This circuit comprises an electron discharge device 120 having an anode 121 connected to B+ through a load resistor 122, a cathode 123 connected to ground through a cathode bias resistor 124, and a plurality of control electrodes 125, 126 and 127. The screen and suppressor electrodes 126 and 125, respectively, are connected together and to B+ through a resistor 128. The control electrode 127 is connected to ground through one of a plurality of grid resistors 129, 129a, 129b, or 129c. The connection of the resistors 129 is controlled by a contact 130 on the selector switch 113. The control electrode 127 is also coupled to the anode 85 of the multivibrator discharge device 83 through a resistor 131 and a capacitor 132.

In operation, the intensifier discharge device 120 is normally conductive by reason of the low bias on its control electrode 127. However, upon the occurrence of a negative multivibrator pulse at the anode 85, a negative impulse is transferred to the control electrode 127 of the discharge device 120 through the coupling capacitor 132. This

negative impulse cuts off the discharge device 120, thereby to increase its anode potential. The discharge device 120 remains cut off for a length of time determined by the time constant of the circuit comprising the capacitor 132, the resistor 131, and a selected resistor 129. The positive impulse appearing upon the anode 121 of the discharge device 120 is impressed upon a control electrode 133 of the cathode ray discharge device 1 through a coupling capacitor 134, thereby to intensify the cathode ray beam.

The remaining circuits of the cathode ray discharge device 1 are conventional. The discharge device 1 is provided with a cathode 135 connected directly to ground and an anode 136 coupled to the positive terminal of a battery 137, the negative terminal of which is grounded. Negative grid bias for the control electrode 133 is provided by a battery 138 connected in series with a resistor 139 between the control electrode 133 and ground.

It will be noted that the selector switch 113 is a gang switch arranged simultaneously to control the capacitors 99, the capacitors 111, and the resistors 129. This switch controls the sweep time of the cathode ray tube. It will be recalled that the capacitors 99 control the duration of the multivibrator pulse appearing upon the anode 85 of the discharge device 83. It is for the duration of this pulse, as thus determined, that anode voltage is removed from the sweep discharge device 103. Accordingly, therefore, the proper capacitor 111 is selected in accordance with the value of the desired capacitor 99 to generate a sweep pulse of the same duration as the multivibrator pulse. Similarly, the resistor 129 is selected so that the time constant of the grid intensifier circuit is so adjusted that the intensifier pulse has a duration substantially equal to the duration of the sweep.

The switch 51 is provided in order selectively to allow for either triggered operation or "servo" operation of the cathode ray apparatus. Triggered operation is used when the source 2 of oscillations or impulses to be observed is aperiodic or has no inherent repetition rate, but must be triggered to initiate each outlet pulse. The switch 51 is shown in position for the latter operation. If, however, the external source 2 is a generator of a type having an inherent repetition rate of its own, the trigger circuit coupled to the source 2 through the lead 49 cannot be used. In this case the cathode ray apparatus is operated "servo," whereby the external source 2 itself controls the sweep and intensifier circuits. For this operation, it will be observed that the contact 50 of the switch 51 disconnects the trigger lead 49 from the external source 2 and that the output of the source 2 is substituted for the blocking oscillator 72 as the sweep multivibrator trigger. This servo trigger circuit may be followed from the output lead 52 of the source 2 through the contact 82 of the switch 51, the amplifier and inverter 81, the blocking capacitor 80, and the contact 78 of the switch 51 to the control electrode 76 of the discharge device 73.

It will now be evident from the foregoing that I have provided a very versatile improved synchroscope apparatus which is operable with equal efficiency over a wide range of repetition rates and is capable of reproducing on its screen pulses of very short duration. For example, in triggered operation, I have found that my apparatus is capable of functioning with equal facility at repetition rates varying from 60 cycles per second to 140 kilocycles per second and at sweep speeds ranging from as low as about one-thirtieth microsecond per inch to as high as 6 micro-seconds per inch. Even higher sweep speeds may be secured by utilizing other high speed triggered sweep generators known to the art. It will be recalled that the pulse at anode 85 of device 83 has a very sharply sloped leading edge, so this pulse may be used directly as a very high speed sweep if desired. In any case, the system is adjusted to operate so that the necessary rapid sweep impulses are derived from the fixed phase output of the phase shifter 6 at a repetition rate determined by the selected frequency of the oscillator 3, and the intensifier circuit intensifies the cathode ray beam in exact synchronism with the sweep impulses. Also, in such operation, an aperiodic external source of oscillations 2 is controlled by a trigger impulse derived from the variable phase output of the phase shifter 6. The phase variation of the trigger pulse with respect to the initiation of the sweep is readily controllable over a wide range of phase angles, so that the triggered impulse may be made to appear at any desired point in the sweep of the beam. In actual operation, I have found that my phase shifting phase circuit 6, especially when combined with a reversing switch as heretofore suggested, is capable of varying the relative phase of sweep and trigger impulses over substantially 360°.

By way of illustration of one application of my invention, I have shown upon a fluorescent screen 140 associated with the cathode ray tube 1 a typical picture which may appear in the event that the oscillation source 2 is a radio direction and range finding apparatus of the type comprising a pulse transmitter and a receiver of echo or reflected pulses. In accordance with my invention, the cathode ray beam is turned on once per cycle of the oscillations from the timing source 3. The horizontal sweep of the beam traces a line 141 upon the fluorescent screen 140. Synchronously with the initiation of the beam sweep and in fixed time delay relation with respect thereto, as determined by the phase shifting circuit 6, triggering impulses are supplied to the source 2 through the triggering circuit terminating in the lead 49, thereby to render the transmitter operative. Upon triggering of the transmitter, a transmitted pulse 142 appears upon the fluorescent screen 140 by operation of the source 2 and the vertical deflection plates 53. In the event that the pulse 142 encounters a detected object and is reflected back to the receiver of the source 2, a reflected pulse 143 will appear upon the fluorescent screen 140 a predetermined time after the pulse 142, as determined by the distance between the source 2 and the reflecting object. In this manner, the range of a reflecting object may be determined.

Certain features of the synchronizing system herein described are claimed in their broader aspects in the foregoing application of Bias and Lord, Serial No. 563,920, filed November 17, 1944.

While I have shown and described only a preferred embodiment of my invention, many modifications will occur to those skilled in the art and I therefore wish to have it understood that I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

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

1. An apparatus for analyzing electric oscilla-

tions comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of timing oscillations, a source of observed oscillations connected to one of said deflecting elements, phase shifting means for deriving from said timing source fixed and variable phase electric oscillations, means utilizing said fixed phase oscillations and the other of said deflecting elements recurrently to sweep said beam across said surface, and means utilizing said variable phase oscillations synchronously to control said source of observed oscillations.

2. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of timing oscillations, a source of observed oscillations connected to one of said deflecting elements, phase shifting means for deriving from said timing source fixed and variable phase electric oscillations, a pair of similar regenerative pulse forming means for deriving from said fixed and variable phase oscillations substantially rectangular voltage impulses of fixed and variable phase relation respectively, means utilizing said variable phase impulses recurrently to render said source of observed oscillations operative, and means including the other of said deflecting elements for utilizing said fixed phase impulses recurrently to deflect said beam across said surface in synchronism with oscillations supplied to said first deflecting element from said source of observed oscillations.

3. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of timing oscillations, a source of observed oscillations connected to one of said deflecting elements, phase shifting means for deriving from said timing source fixed and variable phase electric oscillations, a pair of similar regenerative means for deriving from said fixed and variable phase oscillations substantially rectangular recurrent voltage impulses of fixed and variable phase relation respectively, means utilizing said variable phase impulses to control said source of observed oscillations, means for deriving from said fixed phase impulses substantially saw-tooth voltage impulses of like duration, and means for impressing said saw-tooth impulses upon the other of said deflecting elements recurrently to sweep said beam across said screen synchronously with the control of said source of observed oscillations.

4. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of oscillations to be observed and a source of substantially saw-tooth sweep impulses connected to said coordinate deflecting elements respectively, a source of substantially sinusoidal timing oscillations, phase shifting means for deriving from said timing source electric oscillations in fixed and variable time phase relation respectively, separate regenerative pulse forming means utilizing said fixed and variable phase oscillations to provide series of substantially rectangular recurrent electric impulses of fixed and variable time phase relation respectively, means utilizing said fixed phase impulses to control said source of sweep oscillations, and means utilizing said variable phase impulses synchronously to control said source of observed oscillations.

5. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of oscillations to be observed and a source of substantially saw-tooth sweep impulses connected to said coordinate deflecting elements respectively, a source of timing oscillations, phase shifting means for deriving from said timing source electric oscillations in fixed and variable time phase relation respectively, separate regenerative pulse forming means utilizing said fixed and variable phase oscillations to provide series of substantially rectangular periodic electric impulses of approximately equal duration and of fixed and variable time phase relation respectively, means utilizing said fixed phase impulses to determine the periodicity of said sweep impulses, means utilizing said fixed phase impulses to intensify said beam during the sweep intervals, and means utilizing said variable phase impulses periodically to render said source of observed oscillations operable to deflect said beam synchronously with the beam sweep.

6. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of oscillations to be observed and a source of substantially saw-tooth sweep impulses connected to said coordinate deflecting elements respectively, a source of timing oscillations, phase shifting means for deriving from said timing oscillations electric oscillations in fixed and variable time phase relation respectively, a pair of similar regenerative pulse forming means utilizing said fixed and variable phase oscillations to provide series of substantially rectangular periodic electric impulses of approximately equal duration and of fixed and variable time phase relation respectively, means utilizing said fixed phase impulses to determine the periodicity of said sweep impulses, pulse forming means utilizing said fixed phase impulses to intensify said beam synchronously with the beam sweep, means utilizing said variable phase impulses periodically to render said source of observed oscillations operable to deflect said beam synchronously with the beam sweep, and interdependent means for adjusting the duration of said fixed phase impulses, said sweep impulses and said intensifier impulses.

7. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of recurrent impulses to be observed and a source of substantially saw-tooth sweep impulses connected to said coordinate deflecting elements respectively, an aperiodic regenerative pulse forming circuit coupled to said source of observed impulses and arranged to generate a series of substantially rectangular electric impulses having a predetermined duration, means utilizing said electric impulses to determine the periodicity of said sweep impulses, pulse forming means utilizing said electric impulses to intensify said beam synchronously with the beam sweep, and interdependent means for adjusting the duration of said electric impulses, said sweep impulses and said intensifier impulses.

8. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of observed oscillations connected to one of said deflecting elements, regenerative pulse forming means utilizing said observed oscillations to generate a series of substantially rectangular recurrent voltage impulses, and separate pulse forming means utilizing said voltage impulses recurrently to intensify said beam and synchronously to sweep said beam across said surface.

9. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of timing oscillations, a source of observed oscillations, a pulse forming network, and means for selectively connecting said timing source and said source of observed oscillations to trigger said pulse forming network thereby to generate a series of substantially rectangular recurrent voltage impulses, and separate pulse forming means utilizing said voltage impulses recurrently to intensify said beam and synchronously to sweep said beam across said surface.

10. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of timing oscillations, a source of observed impulses, an aperiodic pulse forming network, capacitive discharge means triggered by said pulse forming network and connected to one of said deflecting elements recurrently to sweep said beam across said surface, separate pulse forming means triggered by said network and arranged recurrently to intensify said beam synchronously with said beam sweep, and switching means arranged selectively to connect said timing source to trigger said pulse forming network and control said source of observed impulses and to disable said timing source and connect said source of observed impulses to trigger said network.

11. An apparatus for analyzing electric oscillations comprising means for projecting an electron beam against a sensitive surface, a pair of coordinate deflecting elements for controlling said beam, a source of timing oscillations, a source of observed oscillations connected to one of said deflecting means, phase shifting means for deriving from said timing source fixed and variable phase electric oscillations, similar regenerative pulse forming networks for deriving from said fixed and variable phase oscillations substantially rectangular periodic voltage impulses of fixed and variable phase relation respectively, a regenerative time element pulse forming network, switching means arranged selectively to supply said fixed phase impulses and impulses from said source of observed oscillations to trigger said time element network, said switching means supplying said variable phase impulses to trigger said source of observed oscillations whenever said fixed phase impulses trigger said time element network, and means coupled to said time element network synchronously to intensify said beam and to sweep said beam across said surface.

12. A saw-tooth wave generator comprising a source of electric current supply, a normally-conductive electron discharge device including an anode and a cathode connected in circuit with said supply source through a normally-conductive unilateral conducting device and through a load resistor in series circuit relation, a timing capacitor connected in parallel circuit relation with said discharge device, means for suddenly reversing the voltage across said unilateral conducting device to permit discharge of said capacitor through said discharge device, said means comprising a second, normally-non-conductive electron discharge device including an anode and a cathode connected in circuit with said source through said resistor and also including a control electrode, and means for impressing a voltage pulse on said control electrode in a polarity to render said second discharge device conductive for a predetermined pulse interval.

13. A saw-tooth wave generator comprising a source of electric current supply, a normally-conductive electron discharge device having an anode and a cathode connected in circuit with supply source through a normally-conductive unilateral conducting device and through a load resistor in series circuit relation, a timing capacitor connected in parallel circuit relation with said discharge device, means for suddenly reversing the voltage across said unilateral conducting device to permit discharge of said capacitor through said discharge device, said means comprising a second, normally-non-conductive electron discharge device including an anode and a cathode connected to said source through said resistor and also including control electrode, means for abruptly impressing a pulse on said control electrode to initiate conduction in said second discharge device, and regenerative time element means for controlling and terminating said conduction, thereby to form across said resistor a substantially rectangular negative voltage pulse of predetermined duration.

HIRAM S. LASHER, JR.

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