United States Patent

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[54] **CARDIOSCOPE WITH VARIABLE SWEEP-TIMING MEANS INCLUDING SUPERIMPOSING RECURRING EKG COMPLEXES FOR DISPLAY**
5 Claims, 3 Drawing Figs.

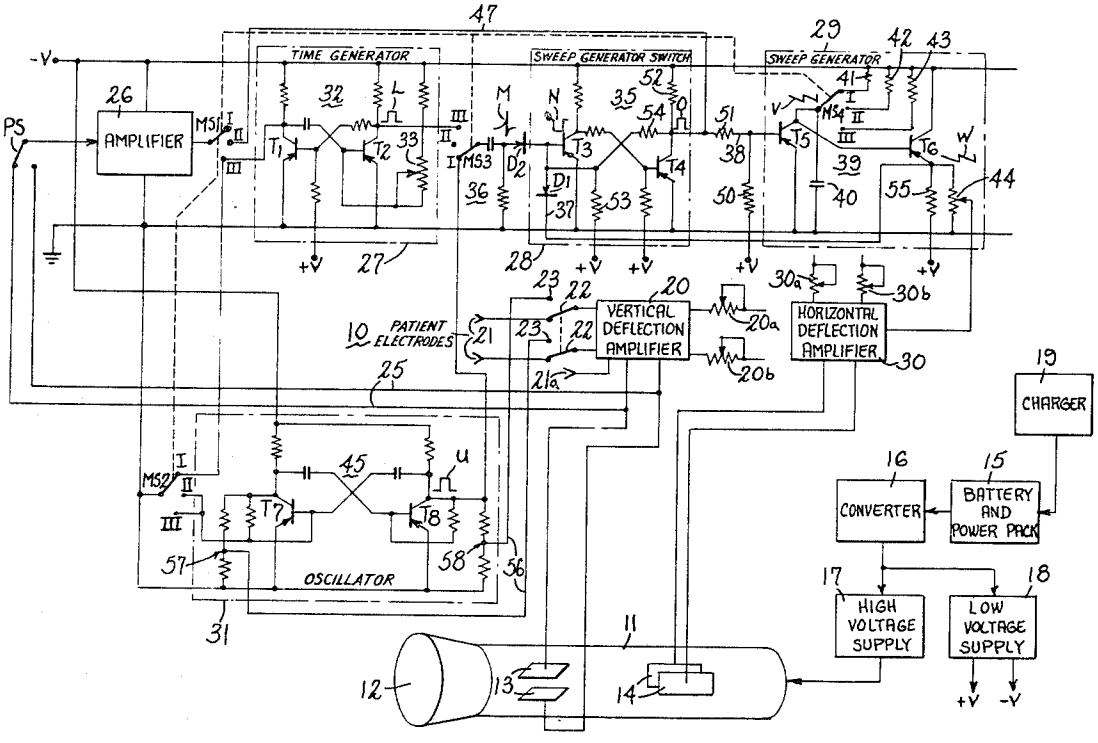
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[51] **Int. Cl.** **A61b 5/04**
[50] **Field of Search** 128/1, 2, 2.06, 2.05, 201; 315/19; 324/121

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ABSTRACT: This disclosure relates to a cardioscope including a cathode-ray tube and method for displaying superimposed succeeding groups of electrocardiac complexes. To superimpose the complexes occurrence of a first complex is detected and a timing cycle generated in response thereto and a sweep of the cathode-ray tube is initiated at the end of the timing cycle after occurrences of all the complexes of each group and before the occurrences of the first complex of the next group.

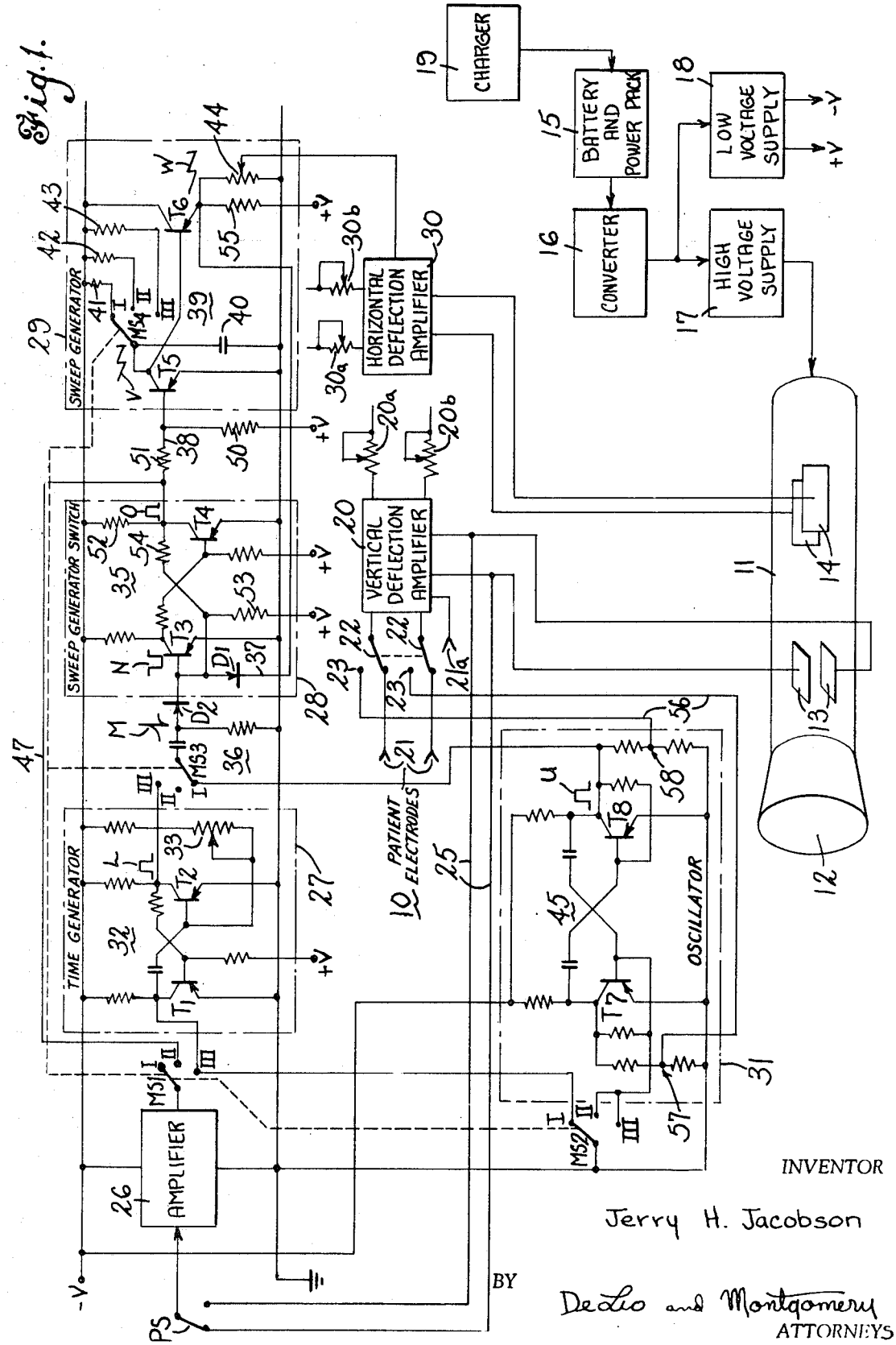


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SHEET 1 OF 2

Fig. 1.



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Fig. 2.

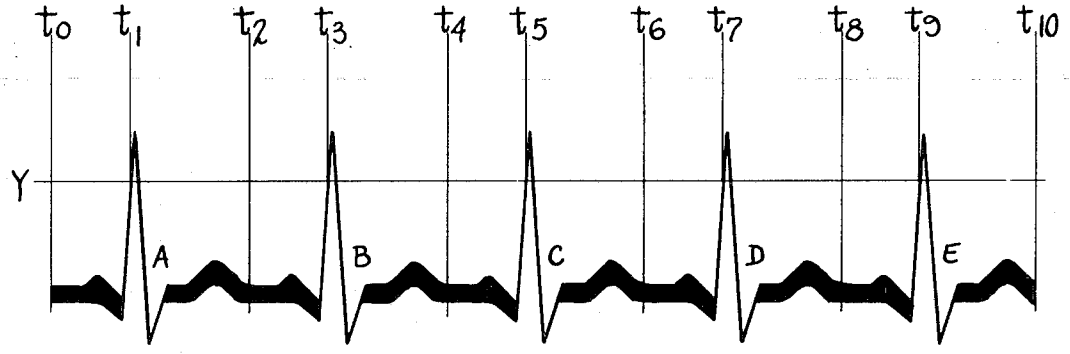
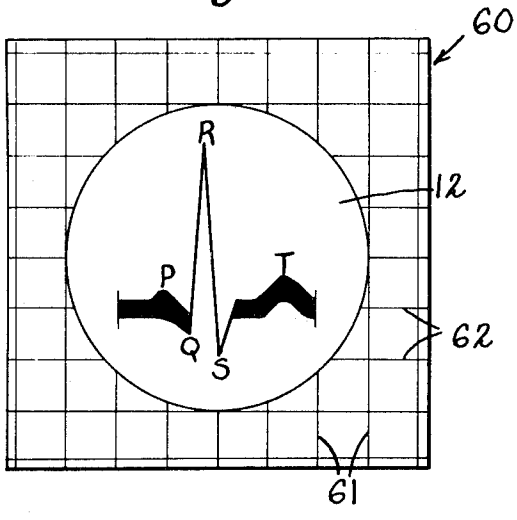


Fig. 3.



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CARDIOSCOPE WITH VARIABLE SWEEP-TIMING MEANS INCLUDING SUPERIMPOSING RECURRING EKG COMPLEXES FOR DISPLAY

This invention relates to cardioscopes, and more particularly relates to a small, portable cardioscope adapted to be carried by a physician on house calls, emergency calls and like missions.

At the present time there is no known device for monitoring the electrocardiac activity of a patient or detecting suspected unusual heart activity without bringing the patient to the location of a cardioscope, electrocardiograph, etc., such as a hospital, a clinic or, in some cases, a physician's office. Because of this, the present invention is intended to provide a small compact cardioscope which may be easily carried in a physician's handbag or separate small carrying case, and which the physician may have in his possession at all potentially necessary times.

Because of the compactness of such a unit, the viewing screen of the cathode-ray tube of the device is necessarily small, and the electrocardiac complexes which it can display are limited in number. This problem is amplified by the low frequency of electrocardiac complexes as compared to the frequency of electrical signals usually displayed on an oscilloscope. Therefore, suitable compensation and operating characteristics must be provided for the device to be useful. Due to the small size of the viewing screen, which may only be on the order of 1 to 1½inches, suitable means must be provided to present and retain low frequency signals on the small viewing screen.

Accordingly, the present invention provides new and improved means for presenting electrocardiac intelligence on a small screen. This invention provides new and improved means for viewing cardiac activity through control of the sweep time of a cathode-ray tube and the manner in which the sweep is controlled by the occurrences of electrocardiac complexes.

Briefly stated, the invention, in one form thereof, provides in a new and improved manner, a plurality of cathode-ray tube sweep modes which allow a physician to obtain an overall view of a plurality of electrocardiac complexes to indicate the regularity, amplitude and normalcy of the complexes; a more detailed examination of a lesser plurality of complexes; and, if the patient's pulse rate is fairly regular, examination in detail of a single complex display which is the result of superimposing reoccurring low frequency complexes to provide a single complex display. The last-mentioned mode is accomplished by the provision of novel sweep circuitry which is triggered by selected complexes so that succeeding complex displays are superimposed on the display screen to permit a detailed examination of a reoccurring complex, and the relationship of the modes thereof to each other.

An object of this invention is to provide a new and improved cardioscope of small size and compactness which is adapted to be carried at all times by a physician.

Another object of this invention is to provide a new and improved cardioscope having a cathode-ray tube display screen of very small size which will still permit a detailed examination of electrocardiac activity.

Another object of this invention is to provide a cardioscope of small size having a new and improved cathode-ray tube sweep circuit which permits a detailed examination of electrocardiac activity.

A further object of this invention is to provide a cardioscope having a new and improved sweep circuit which allows the superimposing of a plurality of reoccurring electrocardiac complex displays on a very small viewing screen to present to the observer a detailed examination of a complex, and allows the physician to observe the electrocardiac complexes as they occur and also in groupings of two or more complexes.

A still further object of this invention is to provide new and improved small cardioscope viewing screen, together with a grid system, for measuring time duration and amplitude.

The features of the invention which are believed to be novel are pointed out with particularity and distinctly claimed in the concluding portion of this specification. The invention, however, both as to its organization and operation, together with further objects and advantages thereof, may best be appreciated by reference to the following detailed description, taken in conjunction with the drawings, in which:

FIG. 1 is a diagram, partly schematic and partly in block form, showing the electrical network of a cardioscope embodying the invention;

FIG. 2 is a graphical representation of a series of reoccurring electrocardiac complexes; and

FIG. 3 is a view of the display of an electrocardiac complex on a cathode-ray tube of relatively small size, together with a calibration and timing means embodying the invention.

Referring now to the drawings, a cardioscope embodying the invention is generally represented by the reference numeral **10**, and includes a cathode-ray tube (CRT) **11**, having a viewing screen **12** with long persistency display coatings, vertical deflection means in the form of plates **13**, and horizontal deflection means in the form of plates **14**. CRT **11** further includes the usual grid and cathode system (not shown). Cardioscope **10** includes an integral power system which comprises a battery and power pack **15**, a voltage converter **16**, and high and low-voltage supplies **17** and **18**, respectively. The high-voltage supply **17** supplies the necessary high voltage for operation of the CRT and the low-voltage supply **18** supplies the operating voltages +V and −V for cardioscope **10**. The power system also includes a battery charger **19** adapted to recharge the battery which may have a service time of six to eight hours before requiring recharging. Charger **19** is adapted to be connected to a source of household voltage, 117 volts AC. The vertical deflection of the cathode ray beam is controlled from a vertical deflection amplifier **20** which receives an input from terminals **21** connectable to electrodes (not shown) adapted to be operative arranged on the subject's wrists. Another input terminal **21***a* receives a common signal from an electrode on a subject's ankle. Selector switch **22** is adapted to be switched between an operative position, as shown, to a source of a calibration signal. Vertical deflection amplifier **20** includes a low level amplifier with a differential amplification of about 10,000. The amplified electrocardiac signals from terminals **21** directly drive the vertical deflection system of CRT **11** and thus modulate the horizontal sweep thereof. Amplifier **20** includes vertical gain and vertical position adjusting potentiometers **20***a* and **20***b*, respectively.

The output of vertical amplifier **20** is also applied over lines **25** and through a polarity selector switch PS to an amplifier **26** in the horizontal sweep circuit. It is to be understood that, as used herein, the terms "horizontal" and "vertical" are relative and refer to one circuit being displaced 90° with respect to the other.

The horizontal sweep circuit further comprises a timing or delay generating means **27**, a sweep generator switching circuit **28**, a sweep generator **29**, a horizontal deflection amplifier **30**, and a free-running oscillator **31**. Amplifier **30** may include horizontal gain and position adjusting potentiometers **30***a* and **30***b*, respectively. The horizontal sweep may be synchronized to the input signal at terminals **21** by means of the output of vertical deflection amplifier **20** over lines **25** to amplifier **26**.

By way of example, and for purposes of disclosure only, the time delay generating means **27** is illustrated as comprising a one-shot multivibrator **32** having means for varying the duration of its unstable condition in the form of a potentiometer **33**. One-shot multivibrator includes two transistors T1 and T2, together with conventional circuitry. The sweep generator switching circuit **28** is shown as a bistable multivibrator or flip-flop **35**, including transistors T3 and T4 in a conventional circuit arrangement, which may be set in one stable condition through a differentiating or pulse-shaping circuit **36**. Flip-flop **35** is reset over line **37** as hereinafter described. An output signal at the right side of flip-flop **35** is applied over a line **38** to a timing circuit **39** in sweep generator **29**, which includes a transistor T5. The timing circuit **39** comprises a capacitor **40**

selectively connectable to one of a plurality of timing resistances 41, 42 and 43 to control and predetermine the horizontal sweep time or period. A transistor amplifier T6 in the form of an emitter follower is connected across capacitor 40 and furnishes, through voltage divider 44, a sweep signal to horizontal deflection amplifier 30. Transistor T6 also supplies a reset signal derived from the emitter thereof to flip-flop 35 over line 37.

Oscillator 31 is in the form of a free-running multivibrator 45 having transistors T7 and T8 in a typical Eccles-Jordan configuration. The waveform at the collector of transistor T8 may be selectively applied to flip-flop 35, as hereinafter described.

The embodiment of the invention, as disclosed, has three operational modes which will be described in specific examples. However, it is to be understood that the examples set forth are illustrative only. The three operational modes are hereinafter identified as I, II, and III, and are chosen through ganged mode selector switches MS1, MS2, MS3 and MS4, each having a contact arm adapted to selectively make contact with a terminal I, II or III corresponding to the operational mode selected.

Free-running oscillator 31 controls the sweep during operation in mode I, but during operation in modes II and III the base of transistor T7 is connected to ground through selector switch MS2 and, more specifically, terminals II or III thereof and the free-running multivibrator is disabled.

During mode II operation, free-running oscillator 31 is disabled as heretofore explained, and a synchronization signal received by amplifier 26 from amplifier 20 is applied by switch MS1 at terminal II thereof over line 47 to the collector of transistor T4, flip-flop 35, and hence by cross connection to the base of transistor T3. Such synchronization signal is effective to set flip-flop 35.

During mode III operation, the synchronization signal from amplifier 26 is applied through mode selector switch MS1 to terminal III thereof to initiate a timing cycle of the delay or timing generator 27. After a predetermined time delay, when transistor T2 switches from its unstable condition at the end of the time delay, a pulse L is applied to pulse-shaping circuit 36 through terminal III of mode selector switch MS3 to flip-flop 35 and the pulse M-shaped by circuit 36 sets flip-flop 35.

When flip-flop 35 is switched to a set condition, the signal appearing at the collector of transistor T4 is effective to turn off transistor T5 in sweep generator 29, and initiate a sweep cycle.

If mode I is selected, the input to the delay circuit 27 is grounded and delay circuit 27 is disabled, the base of transistor T7 is removed from ground, oscillator 31 will operate in its normal free-running mode, the output of amplifier 26 is open ended, and thus there is no synchronization of the sweep with the vertical deflection amplifier. Each time transistor T8 switches on and then off, a positive-going rectangular pulse U is supplied through selector switch MS3 and terminal I thereof to pulse shaping circuit 36. The shaped pulse M is then applied through diode D2 to the base of transistor T3 and flip-flop 35. Transistor T3 is normally conducting and transistor T4 normally nonconducting when flip-flop 35 is in a reset state. The positive-going pulse to the base of transistor T3 is a setting signal which turns transistor T3 off and produces a negative-going voltage N at the collector thereof. This turns transistor T4 on by the usual cross connection action and the collector thereof rises essentially to ground potential to generate a voltage 0. Therefore, the emitter base circuit of transistor T5 in sweep generator 29 is back-biased and transistor T5 is turned off. Capacitor 40 now commences to charge and the voltage at the collector of transistor T5 decreases in a linear manner. The base of transistor T6 is connected to the collector of transistor T5 and as the potential at the collector of transistor T5 linearly decreases, the potential at the emitter of transistor T6 linearly decreases to provide a ramp function and generate the sweep voltage W which is applied to horizontal deflection amplifier 30, from voltage divider 44. When the voltage at the emitter of transistor T6 decreases to a predetermined value towards −V, diode D1 will conduct current from +V through resistance 53 over line 37 and the negative-going voltage at the base of transistor T3 will turn transistor T3 on, and reset flip-flop 35. Resistance 53 is substantially greater than resistances 54, 52 and 55. By cross connection transistor T4 is turned off, and by voltage divider action of resistances 50, 51 and 52, the collector of transistor T4 and the base of transistor T5, go negative. Resistance 50 is substantially greater than resistances 51 and 52. This turns on transistor T5 and interrupts the charging of capacitor 40 and a sweep cycle is completed. Thereafter, another sweep cycle may be generated when transistor T5 is again turned off. The timing waveforms are shown at V and the output waveform of transistor T6 is shown at W. In mode I, the sweep is free-running, controlled by oscillator 31 with no external synchronization. Therefore, a number of electrocardiac complexes, as shown in FIG. 2, will appear on the screen 12, predetermined by the time of the sweep. If, for example, the sweep time is 3 seconds, and the subject has a pulse rate of 100 pulses per minute, five complexes may be displayed during each sweep.

From this, the physician may determine the pulse rate, the regularity of the pulses and the amplitude thereof. If the complexes are highly irregular, or very small in amplitude, the physician may not deem it necessary to operate the scope in modes II and III. He has, at this time, found out quite a bit of intelligence in terms of overall general assessment of the subject's clinical condition and will probably wish to have further more exhaustive tests of the patient's cardiac condition in a more controlled environment with more complex instruments, and will probably wish to run a complete electrocardiograph or vectorcardiograph on the patient.

Assume that the electrocardiac complexes are reasonably regular, then the physician may make a somewhat more detailed examination of the complexes by switching to mode II of operation. This is accomplished by moving ganged selector switches MS to terminal II. In this mode the horizontal sweep circuit is synchronized with the occurrence of the complexes through the output of the vertical deflection amplifier 20. The output of amplifier 26 is applied to terminal II of selector switch MS1 which is connected to the base of transistor T3 at the collector of transistor T4, over line 47. In this mode of operation, flip-flop 35 is set by the occurrence of an electrocardiac complex, as shown in FIG. 2, applied to the base of transistor T3 over line 47. In this mode of operation, capacitor 40 charges through resistance 42, as selected in this mode by selector switch MS4 to provide a sweep of lesser duration than in mode I, for example, 1.5 seconds. If the sweep time in mode II is selected to be 1.5 seconds, at least one complex will occur during each sweep for a pulse rate as low as 40 beats per minute and two complexes will be seen for pulse rates greater than 80 beats per minute. At the end of the fixed sweep time, flip-flop 35 is reset, as heretofore explained, and another sweep will not begin until occurrence of the next complex following the end of the sweep.

Continuing with the assumption that the pulse rate is fairly regular, the physician will now switch to mode III. In this mode, the sweep time may be fixed at a still smaller time, for example, 600 milliseconds, or less.

This sweep is also triggered by an electrocardiac complex. However, as each complex occurs, a delay or timing period is initiated. When the delay times itself out, the sweep starts. The technique involved here is to make the sweep occur during the occurrence of the next complex in time relation to occurrence of the previous complex. In this manner, each complex initiates the sweep for the succeeding complex. This process is repetitive and permits the superimposing of each succeeding complex as a single complex on the display, which may be the subject of detailed analysis. Also, by varying the delay, as hereinafter explained, one can make the complex appear to slide to the left or right of the display. In mode III operation, all selector switches MS are at terminal III, the sweep genera-

tor is synchronized with the input at the vertical deflection amplifier. Reference is made to FIG. 2 which shows a substantially uniform train of electrocardiac complexes, A, B, C, D, E, commencing at time t_0. At time t_1, when the QR portion of complex A has risen to a value y, it actuates the delay means here exemplified as one-shot multivibrator **32** which is set to an unstable condition. Then the delay times out at time t_2, transistor T2 turns on and a positive-going voltage L is applied to pulse-shaping circuit **36** to set flip-flop **35**. Thereafter, the operation of flip-flop **35** and sweep circuit **29** is as heretofore described with the exception that capacitor **40** charges through resistance **43** to provide a predetermined sweep time, shown in FIG. 2, as t_4—t_2 to display complex B. During the interval t_2 to t_4, and while complex B is being displayed, as shown in FIG. 3, portion QR of complex B at amplitude y and time t_3 triggers delay circuit **37** to initiate another sweep at time t_4. This display of each complex and the use of each complex to set a delay, and then at the end of such delay, trigger the sweep circuit before occurrence of the next complex reoccurs continuously while the scope is in mode III operation. This results in the superimposing of a single complex, as shown on the face **12** of the scope in FIG. 3. This technique permits a continuous display of a very low frequency recurring signal.

To follow through with the description of FIG. 2, at time t_4, the delay times out and the sweep circuit is triggered to display complex C. At time t_5, complex C, initiates another delay which times out at time t_6. Then complex D is superimposed on complex C during the next sweep from t_8—t_{10}.

It will be noted that the delay times t_2—t_1; t_4—t_3; t_6—t_5; and t_8—t_7 are of lesser time than the sweep time, exemplified as t_2—t_4; t_4—t_6; t_6—t_8; and t_8—t_{10}.

If in mode III operation, the sweep time is chosen to be, say, 600 milliseconds, the face plate **60** surrounding the face **12** of the CRT may be calibrated into a predetermined number of graduations, each of which would indicate a time interval. If, for example, there were six vertical graduations **61**, each would indicate an interval of 100 milliseconds. Thus the spaces between the graduations would be an integral factor of the sweep time of the CRT. With this information, the physician may determine the time between the various nodes or other parts of the complex; for example, the time between the T and Q nodes, the time between the Q and S nodes, etc. Moreover, by varying the delay as by adjusting potentiometer **33** in one-shot multivibrator **32**, the physician may move any portion of the complex displayed on the face **12** to coincide with a calibration which may be used as a base to time its relation with other portions of the complex. In this manner, any point of the complex may be used as a base to time the other portions relative thereto. Similarly, the horizontal position may be varied so that the amplitudes of the nodes may be compared with the horizontal graduations **62**.

To calibrate the amplitude of the input waveform, and also as a check on the battery voltage, the essentially rectangular output waveform of free-running multivibrator **45** is applied over lines **56** to terminals **23** of calibration switch **22**. The calibration signal is taken from similar voltage dividers **57** and **58** connected across the collector and emitter of each of transistors T7 and T8, respectively. Prior to using the scope, the physician, without an input signal on terminals **21**, may move calibration switch **22** to terminals **23** and observe the waveform of the output of multivibrator **45**. Then, by the vertical positioning adjustment, this waveform may be displayed in a desired position on the face **12** of the CRT **11** in predetermined relationship with horizontal graduations **62**. Additionally, the failure of such signal to reach a predetermined amplitude upon adjustment of the gain control will indicate that the batteries require recharging.

It will be understood that the timing of the delay and the sweep may be such as to present every succeeding pair of complexes superimposed. Assume, for example, that the sweep time is 1.2 milliseconds, and the delay was set to be effective from time t_1 to time t_4, then a sweep would be initiated at time t_4 and would last until time t_8 and display complexes C and D. During this display period, from time t_1 to t_8 and, specifically, at time t_5, complex C would trigger the delay circuit and time out at time t_8 to commence a sweep which would display complex E and the succeeding complex. During this sweep and at time t_9, complex E would again trigger the delay. In this manner, the delay and the sweep time may be so arranged as to superposition each succeeding pair of complexes on the preceding pair of complexes. In a similar manner, the sweep time may be decreased to display only a portion of a complex for more detailed study. It will be understood that the various sweep times are set forth only for purposes of illustration. Moreover, the modes of operation may be so chosen that both modes I and II display superimposed succeeding complexes or portions thereof.

The expected range of times of an electrocardiac complex as measured between nodes (FIG. 3) is

P to Q	.070—.120 milliseconds
P to R	.120—.200 milliseconds
Q to S	.050—.100 milliseconds
Q to T	.260—.450 milliseconds

If the physician wishes to view and investigate only a portion of a complex, a sweep time of, say, 300 milliseconds might be selected. As related to this, the duration of a complex might be close to 600 milliseconds. For example, the delay commencing at amplitude y of any complex may be set in relation to the sweep time, or vice versa, to time out subsequent to the succeeding P and Q nodes on the QR wave to display only the R, S, and T nodes of the complex. Alternatively, the delay may be set in relation to the sweep time, or vice versa, such that only the PQR nodes were displayed.

It may thus be seen that the objects of the invention set forth above as well as those made apparent from the preceding description are efficiently attained, and while a preferred embodiment of the invention has been set forth for purposes of disclosure, other embodiments to the invention as well as modifications to the disclosed embodiments thereto may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments of the invention and modifications thereof which do not depart from the spirit and scope of the invention.

I claim:

1. In a cardioscope including a cathode-ray tube having a viewing screen for displaying an electrocardiac complex, means for controlling and timing the sweep of the cathode-ray tube and means for modulating the sweep of the cathode-ray tube with electrocardiac complexes; timing means responsive to occurrences of a complex for initiating a timing cycle, means responsive to the end of said timing cycles to initiate a sweep a predetermined time after occurrence of each complex and prior to occurrence of the next complex so as to superimpose such complex display on the preceding complex displays, a platelike member having edges defining an aperture adapted to surround the viewing screen, said member having calibration marks, said marks being of such number that each space defined therebetween is an integral factor of the sweep time of the cathode-ray tube.

2. A cardioscope including a cathode-ray tube having a viewing screen for displaying an electrocardiac complex or portion thereof, means for controlling and timing the sweep of the tube to display an electrocardiac complex or portion thereof, a platelike member having edges defining an aperture adapted to surround the viewing screen, said member having calibration marks, said marks being of such number that each space defined therebetween is an integral factor of the sweep time of the cathode-ray tube.

3. A cardioscope including a cathode-ray tube having a viewing screen adapted to display electrocardiac complexes, said cathode-ray tube having horizontal and vertical deflection means, a sweep circuit operatively connected to one of said deflection means, means for applying electrocardiac signals to the other of said deflection means, circuit means for synchronizing said sweep generator to occurrence of elec-

trocardiac complexes, time delay means, said time delay means being responsive to occurrence of a complex for actuating said sweep generator a predetermined time before or during occurrences of the next complex, and selection means for actuating said sweep generator either through said delay means or directly upon occurrence of complexes, said selection means being operative to predetermine the timing of the sweep generator in response to the mode of operation selected.

4. The cardioscope of claim 3 further including means for varying the delay of said time delay means.

5. A cardioscope including a cathode-ray tube having a viewing screen, vertical and horizontal deflection means, means for controlling one of said deflection means to produce a sweep of the cathode-ray beam across the viewing screen, and means for applying electrocardiac complexes to the other of said deflection means to modulate the sweep of said cathode-ray beam and display the complex, comprising a

sweep generator connected to said first of the deflection means, said sweep generator having selection means effective to predetermine the time to sweep of the cathode-ray beam across said viewing screen, resettable switching means effective to trigger said sweep generator and produce a sweep, said switching means being responsive to completion of the sweep to be reset, first and second means for actuating said switching means and selection means for choosing said first or second means, said first means comprising a free-running oscillator effective to repetitively set said switching means and produce sweeps at a first time rate, said second means being effective upon selection thereof to set said switching means upon occurrence of a complex, delay means, and means for actuating said delay means in response to occurrence of a complex, said delay means being connectable to said switching means to set said switching means at the expiration of the delay provided by said delay means.