# United States Patent [19]

**Dehnert et al.**

[11] **3,858,576**

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[54] **PORTABLE ELECTROCARDIOSCOPE**


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[52] **U.S. Cl.** ..... **128/2.06 R**, 128/2.06 B, 315/29, 328/171

[51] **Int. Cl.** ..... **A61b 5/04**

[58] **Field of Search** ..... 128/2.06 B, 2.06 G, 2.06 R; 315/29; 328/171



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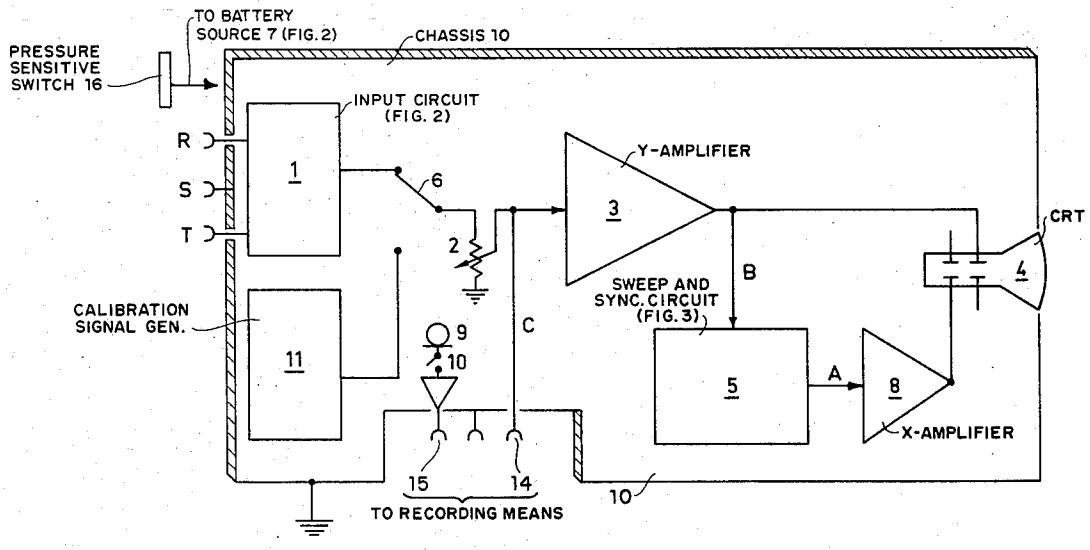
[57] **ABSTRACT**

A portable electrocardioscope is provided taking the form of a housing having a plurality of terminals at one end for direct engagement with the chest of a patient, a cathode ray tube display at its other end, and a battery-operated circuit within the housing for converting signals appearing on the terminals into a visual display on the cathode ray tube.


**11 Claims, 4 Drawing Figures**



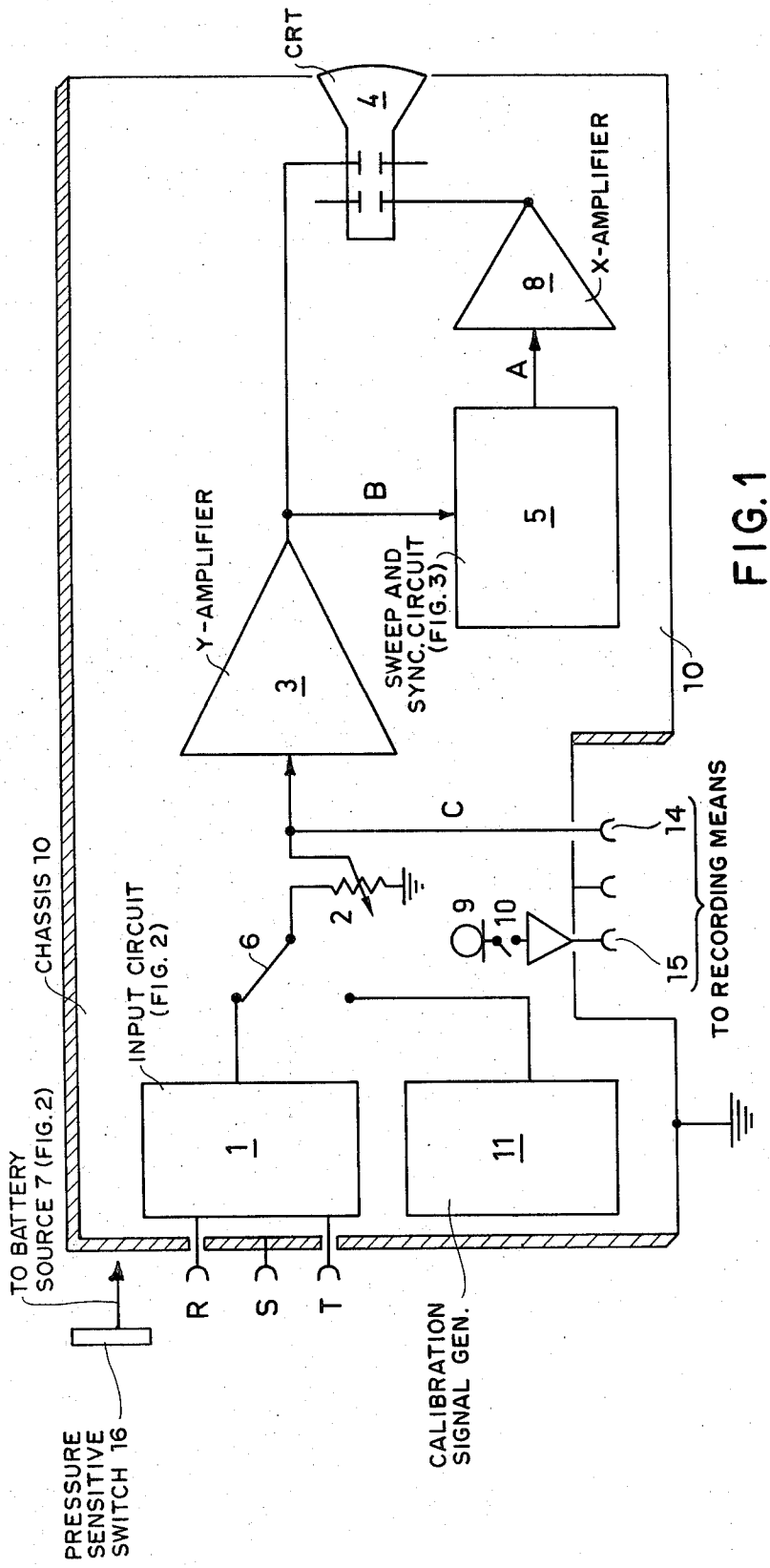

CRT
4
X-AMPLIFIER
8
A
B
5
SWEEP AND SYNC. CIRCUIT (FIG. 3)
Y-AMPLIFIER
3
10
C
14
TO RECORDING MEANS
15
CHASSIS 10
INPUT CIRCUIT (FIG. 2)
6
2
9
10
1
11
TO BATTERY SOURCE 7 (FIG. 2)
R
S
T
CALIBRATION SIGNAL GEN.
PRESSURE SENSITIVE SWITCH 16

FIG. 1

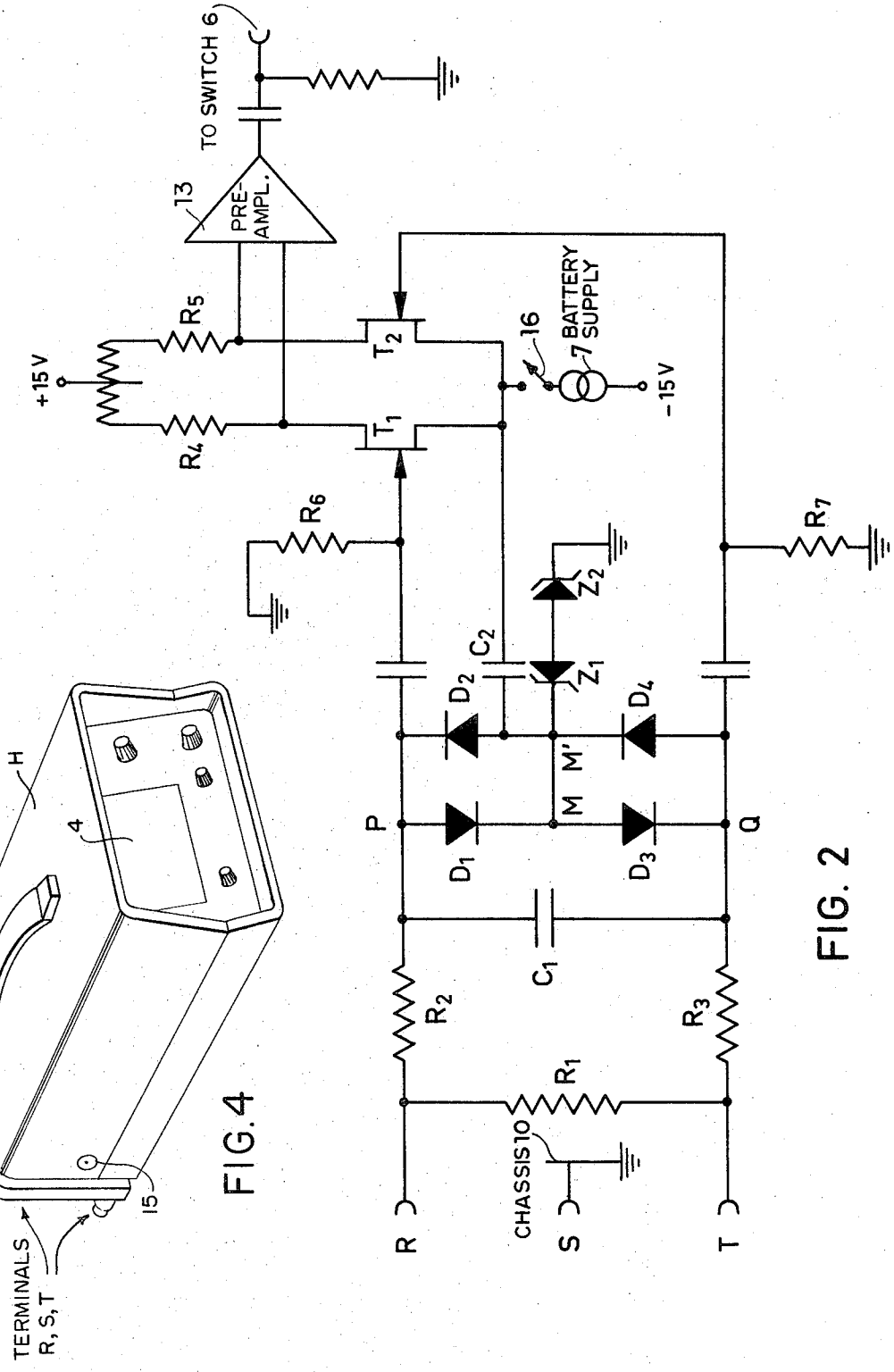

TO SWITCH 6
13
PRE-AMPL.
R5
R4
+15 V
T2
T1
16
BATTERY SUPPLY
7
-15 V
R6
R7
Z2
Z1
C2
D2
D4
M'
M
P
Q
D1
D3
C1
R2
R3
R1
CHASSIS 10
R
S
T

FIG. 2


H
4
15
TERMINALS R, S, T

FIG. 4

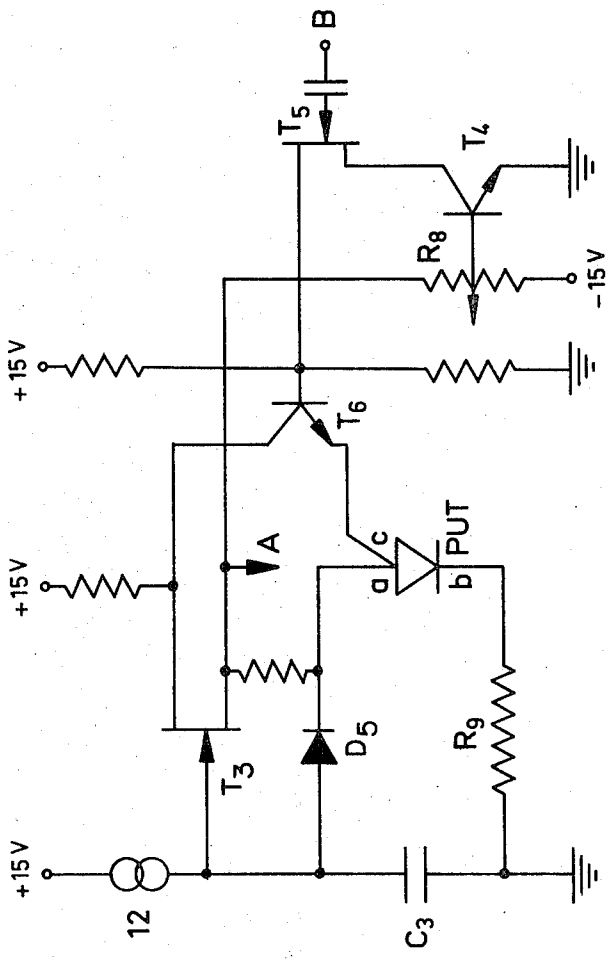



FIG. 3

# PORTABLE ELECTROCARDIOSCOPE

## BACKGROUND OF THE INVENTION

The present invention relates to electrocardioscopes and, more particularly, to a light weight, portable, battery-operated electrocardioscope adapted for use in a variety of circumstances where conventional electrocardioscopes cannot be conveniently employed.

In various emergency conditions, if the cardiac action of a patient is disturbed, the brain may suffer permanent damage within a few minutes. In such cases, it is essential to establish whether the patient is suffering from weak heart action, chamber fibrillation, or asystolia; and in the case of accident victims, or other emergency cardiac situations, this determination frequently cannot be deferred until the patient is brought to a hospital for treatment. In such cases, therefore, it may become necessary to administer appropriate treatment to the patient before he can be transported, so as to sufficiently stabilize his circulation for such transport. The type of emergency treatment which should be given will normally depend upon analysis of an appropriate electrocardiogram, but conventional electrocardiographs and electrocardioscopes suggested heretofore do not lend themselves to this type of usage since, in general, they constitute comparatively large, heavy, and delicate pieces of equipment which are energized from conventional AC power outlets.

In order to obtain an electrocardiogram quickly, and under conditions where a conventional AC outlet is unavailable, it is therefore highly desirable that an electrocardioscope be provided which is portable, light weight, and contains its own power source. It is the primary object of the present invention to provide such a portable electrocardioscope, which requires a minimal amount of operating energy.

Another object of the invention resides in the provision of an electrocardioscope which is shielded against interference voltages which may be present in the vicinity of the electrocardioscope, e.g., caused by other medical treatment devices such as defibrillators.

A further object of the invention resides in the provision of an electrocardioscope which may be associated with a recorder device operative to register changes in the patient's electrocardiogram during emergency treatment, so as to facilitate subsequent analysis of the treatment procedure.

## SUMMARY OF THE INVENTION

In accordance with the present invention, a light weight, portable, battery-operated electrocardioscope is provided which can be employed at the site of an accident, or in an ambulance, or in the emergency room, operating room, or intensive care unit of a hospital, or in other more conventional circumstances, e.g., where it is desired to examine a patient in his hospital room, or at home or in a doctor's office.

The electrocardioscope is comparatively light weight, e.g., approximately 4.5 pounds, and is comparatively small in dimension, e.g., substantially 5 inches wide, 3 inches high, and 11 inches long, and comprises a housing containing a unitary terminal tripod at one end thereof for engagement with the chest of the patient, a display taking the form of an 8 cm. cathode ray tube and associated scale at its other end, and a battery operated circuit within the housing which is responsive



to signals on said terminals for producing an electrocardioscope display on the screen of the cathode ray tube. The circuit within the housing is comparatively simple and rugged in configuration, operates with a minimum consumption of time and energy, and includes a synchronizing circuit which operates to produce a standing electrocardioscope image on the screen.

The apparatus is also preferably so arranged that it is rendered operative only when an electrocardioscope is actually being taken, thereby to keep the energy consumption in the device at a minimum. The device may, for example, include a switch mounted on the housing adjacent the terminal tripod, operative to energize the circuit only when the switch and terminals engage the chest of a patient. Alternatively, the device may be associated with a bracket in which the electrocardioscope is mounted when not in use, and the side of the electrocardioscope housing may include a switch which cooperates with the bracket to de-energize the circuit when the device is within the bracket, and which automatically energizes the circuit when the device is removed from its bracket.

In operation, the electrocardioscope, which may be easily held in one hand of an operator, is placed with its terminal end directly in engagement with the patient's chest; and an electrocardiogram thereupon appears on the screen of the cathode ray tube at the other end of the device for visual examination. Additional terminals are provided for supplying signals from the electrocardioscope to a separate piece of equipment, e.g., a cassette-type magnetic recorder and/or for supplying signals from a microphone to such a recorder, to provide a permanent record of the patient's cardiac condition and the treatment being administered, for later review.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing objects, advantages, construction and operation of the present invention will become more readily apparent from the subsequent description and accompanying drawings wherein:

FIG. 1 is a schematic block diagram of the logic circuit employed in the electrocardioscope of the present invention;

FIG. 2 is a schematic of the input circuit of FIG. 1;

FIG. 3 is a schematic of the sweep and synchronization circuit of FIG. 1; and

FIG. 4 is a perspective view of an electrocardioscope constructed in accordance with the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The general nature and construction of the electrocardioscope, in respect to the housing and terminal configuration which is employed, has been described above; and this earlier description is incorporated herein by reference. More particularly, the housing H employed (see FIG. 4) includes a set of fixed electrodes R, S, T at one end thereof adapted to engage the chest (thorax) of a patient or accident victim, a cathode ray tube display 4 at its other end, and an intervening circuit for processing the electrode signals to provide a meaningful electrocardioscope display. These aspects of the invention are diagrammatically illustrated in FIG. 1.

The terminals (or electrodes) which are intended for engagement with the chest of the patient are designated

R, S, and T, and these three terminals are disposed in a tripod or triangular configuration relative to one another. Terminal S is connected to the chassis **10** of the equipment, and terminals R and T are connected as inputs to an input circuit **1**, the specific configuration of which will be more fully described hereinafter in reference to FIG. **2**. Input circuit **1** operates to impose amplitude limitations on signals passing therethrough, along with phase suppression of certain such signals, and also provides for preamplification of proper signals, as will be discussed hereinafter.

The signal appearing at the output of circuit **1** is coupled via a switch **6** and a potentiometer **2** to the input of an amplifier **3**. Amplifier **3** controls the Y-deflection of cathode ray tube (CRT) **4**; and potentiometer **2** may be adjusted to vary the height of the resultant image on the screen of CRT**4**. The signal at the output of Y-amplifier **3** is also coupled to a sweep and synchronization circuit **5** (to be described in further detail hereinafter in reference to FIG. **3**) the output of which is coupled via X-amplifier **8** to the X-deflection plates of tube **4**. By reason of this arrangement, therefore, when signals appear at the output of amplifier **3**, the X-deflection of the CRT-**4** will be synchronized with the signals applied to the Y-plates of said tube **4**, to create a stationary image representing the cardiac activity of the patient being monitored.

In order to assure that the circuit is properly operative, and to permit appropriate set-up and calibration of the equipment if necessary, a reference signal may be provided at the output of a square wave generator **11**, and this reference signal may be applied to potentiometer **2** and amplifier **3** in place of the signal appearing at the output of input circuit **1**, by manipulating the aforementioned switch.

A major problem which is often encountered in connection with the operation of electrocardioscopes involves possible distortion of the heart-generated signals being monitored as a result of the presence of interference signals generated by other sources. Such interference signals may even be generated by other electronic devices which are simultaneously being employed to treat the patient. For example it is common to use defibrillators, if the patient's condition requires such use, to supply rhythmic high-power electric pulses operative to stabilize the patient's heart action; and such pulses could, in the absence of other considerations, create voltage surges in the input circuit **1** of sufficient magnitude to actually destroy the preamplifier **13** (FIG. **2**) in that circuit. This could be avoided, of course, by interrupting the diagnostic monitoring of the patient's cardiac activity when the patient is being treated with a defibrillator or similar device; but in order to avoid the need for such interruption, the input circuit **1** is provided with means for achieving amplitude limitation and phase suppression.

More particularly, referring to FIG. **2**, it will be seen that the signal arriving at terminals R and T first pass through a frequency filter consisting of resistors $R_1$, $R_2$, and $R_3$, and a capacitor $C_1$. The signal at the output of the aforementioned filter then passes through an amplitude limiter and phase suppression circuit consisting of diodes $D_1$, $D_2$, $D_3$ and $D_4$ associated with Zener diodes $Z_1$ and $Z_2$. The signals appearing at the points P and Q in FIG. **2** are then supplied to the inputs of a differential amplifier consisting of two field effect transistors $T_1$ and $T_2$, resistors $R_4$, $R_5$ and $R_6$, $R_7$, and a DC power source **7** (i.e., a 15 volt battery disposed within the electrocardioscope housing). The output from the said differential amplifier is connected to a preamplifier **13** the output of which is coupled, as described in reference to FIG. **1**, via switch **6** and potentiometer **2** to the input of Y-amplifier **3**.

Diodes $D_1$ and $D_3$ are disposed in series with one another across the input signal, i.e., across the output from the aforementioned filter. Similarly, diodes $D_2$ and $D_4$ are connected in series with one another, but in opposite polarity to the $D_1$–$D_3$ circuit, across the same signal source. The mid-points of these two series-connected diode arrangements are interconnected to one another at the points designated M, M′, and this interconnected mid-point is coupled via capacitor $C_2$ to the source electrodes of the two transistors $T_1$, $T_2$.

By reason of this arrangement, it becomes impossible for the voltage between the points P and Q to exceed the sum of the threshold voltages of diodes $D_1$ and $D_3$, or of diodes $D_2$ and $D_4$, respectively. Accordingly, it is impossible for the voltage between the points P and M, or between the points Q and M, respectively (in other words, the voltage between the source and gate electrodes of the transistors $T_1$ and $T_2$) to exceed the threshold voltage of one of the diodes $D_1$, $D_2$, $D_3$ and $D_4$. The differential amplifier is thus effectively protected against excessive input voltage signals.

There is, of course, the possibility that both of the terminals R and T may be at a high potential relative to the potential of the chassis, i.e., the potential on terminal S. This condition could similarly lead to destruction of transistor $T_1$ and/or $T_2$. In order to prevent this from occurring, the common mid-point M, M′ described previously is connected to the chassis via the two Zener diodes $Z_1$ and $Z_2$. This arrangement accordingly limits the maximum voltage on terminals R and T, when said voltages are in phase relative to the chassis, to the equivalent of the sum of the Zener voltage of diode $Z_1$ or $Z_2$, and the threshold voltage of one of the diodes $D_1$–$D_4$. The overall circuit thus provides amplitude limitation and phase suppression which protects transistors $T_1$ and $T_2$ against damage due to signal surges at the input leads R, S and T. These protective features of the input circuit **1** similarly protect the operation of the Y-amplifier **3**.

In order to assure proper operation of the electrocardioscope, it is necessary to assure that the X-deflection of CRT **4** is achieved reliably and in proper relation to the Y-deflection. More particularly, in order to obtain a stationary image on the screen of CRT **4**, it is necessary to synchronize the X-deflection with the input signal from the patient's heart, appearing at the output of amplifier **3**. When such synchronization is achieved, a meaningful electrocardiogram will appear on the screen of CRT **4** which can be interpreted and analyzed in conjunction with appropriate calibration scales extending in the X direction of said screen, to permit a direct reading of the patient's pulse rate.

Synchronization circuits capable of achieving this type of operation are already known in conjunction with conventional oscilloscopes. However in order to provide the portable apparatus of the present invention, it was found necessary to use a particularly simple and robust type of synchronization circuit which would operate in the desired fashion, without any noticeable time delay, and with a minimum of energy consumption. This sweep and synchronization circuit (desig-

nated 5 in FIG. 1) will now be described in detail by reference to FIG. 3.

The X-deflection signal is generated, in conventional fashion, by charging and discharging a capacitor $C_3$. Capacitor $C_3$ is charged from a constant current source 12 (e.g., of the transistor type) which is in turn energized by the battery supply within the electrocardioscope housing. Capacitor $C_3$ is selectively discharged by a programmable unijunction transistor (PUT) via a diode $D_5$, electrodes *a*, *b* of PUT, and resistor $R_9$ when the voltage across capacitor $C_3$ reaches a predetermined level, e.g., 9.5 volts (provided that no synchronization signal is applied to PUT, as will be described hereinafter). After the capacitor $C_3$ has discharged, PUT is blocked, and the sequence of operation described repeats itself to produce a saw-tooth voltage having a regular repetition rate. The saw-tooth voltage thus produced is coupled via a field effect transistor $T_3$, acting as an impedance converter, to terminal A which constitutes the input of X-deflection amplifier 8 (see FIG. 1).

The circuit of FIG. 3 includes provision for rendering PUT conductive at selected times, even though the voltage across $C_3$ has not reached the predetermined potential described earlier. This mode of operation is accomplished by applying a synchronization signal to electrode *c* of PUT when it is desired to render PUT conductive. Such a synchronization signal is generated when the following two conditions occur simultaneously:

*a*. The X-deflection has caused the beam in CRT 4 to be deflected completely across the screen and beyond its right-hand edge (the potential then present on capacitor $C_3$ nevertheless being less than the potential required to effect its discharge); and

*b*. The sweep circuit 5 receives a signal of predetermined minimal amplitude, via connection B, from the output of the Y-deflection amplifier 3 (i.e., a meaningful signal is present which would not be observable since the CRT beam has been deflected beyond the visible area of the screen).

When the above two conditions occur simultaneously, it is necessary, in order to obtain a stationary image which makes use of the entire width of the CRT screen, to start a new sweep immediately, i.e., to discharge capacitor $C_3$ even though the potential across the capacitor has not yet reached the aforementioned discharge potential, e.g., 9.5 volts. This mode of operation is accomplished by the arrangement shown in FIG. 3 comprising transistors $T_4$, $T_5$, $T_6$ and resistor $R_8$.

Transistors $T_4$ and $T_5$ are in series with one another. The Y-deflection signal appearing at terminal B can only be amplified by field effect transistor $T_5$, and transferred via transistor $T_6$ to electrode *c* of PUT, when transistor $T_4$ is conductive. The base of transistor $T_4$, however, is biased by the sweep voltage through an intermediate trimming potentiometer $R_8$. Potentiometer $R_8$ is set to provide a potential which causes transistor $T_4$ to be rendered conductive when the CRT beam passes beyond the right-hand edge of the CRT screen.

When transistor $T_4$ is triggered for conduction, transistor $T_5$ is able to amplify any signal which appears at terminal B. If such a signal should appear at terminal B, the resultant output signal from transistor $T_5$ is coupled via transistor $T_6$ to electrode *c* to render the unijunction transistor PUT conductive; and the capacitor $C_3$ is accordingly immediately discharged to initiate a new X-deflection of the electron beam. Appropriate synchronization operative to produce the stationary image is therefore assured.

It is sometimes of considerable importance to have a permanent record of the patient's cardiac condition during treatment, and the nature of the treatment and procedures which were employed, since such a record makes it possible to conduct a later review of the treatment, and a more deliberate analysis of the patient's condition. In order to provide such a record, the electrocardioscope of the present invention includes a terminal 14 connected via lead C (see FIG. 1) to the input of amplifier 3, to permit signals to be supplied to a separate magnetic recording device, e.g., a cassette-tape recorder, for storage and later retrieval. The electrocardioscope may also include a further terminal 15 associated with a microphone 9, which can, for example, be permanently installed in the face of the equipment adjacent the CRT display, and which is associated with a selectively operable switch 10, to permit contemporaneous oral comments to be recorded as well. These terminals 14, 15 act as both input and output terminals, i.e., if a permanent record has been made, it is entirely possible to replay the cardiac signals via connection C to produce a viewable image on the CRT screen, and to simultaneously replay the oral information through the microphone which then acts as a speaker.

As discussed earlier, the terminals or electrodes R, S, T are mounted in unitary fashion on the end of the housing opposite to the face of cathode ray tube 4, so that by placing that end of the housing and said electrodes directly on the patient's chest, a viewable electrocardioscope will be produced. In order to assure that the battery supply is not unnecessarily drained, it can be associated with a pressure-sensitive switch 16 mounted on the housing directly adjacent the three electrodes (see FIG. 1), with said switch 16 being arranged to close only when the electrodes are in engagement with the patient's body thereby to energize the circuit of the present invention. In this way, when the electrocardioscope is not in actual use, it is automatically de-energized. A similar result can be achieved, if the electrocardioscope is intended to be stored in a bracket when not in use, by providing such a pressure-sensitive switch on a portion of the housing which would engage the bracket when the electrocardioscope is not being used. In this form of the invention, depression of the switch, due to storage of the device, should be arranged to de-energize the circuit, so that removal of the device from its storage location automatically energizes the circuit to place the device in condition for monitoring the cardiac action of a patient.

The various terminals R, S, and T can be arranged to receive elongated flexible leads terminating in electrodes adapted for attachment to a patient's chest, to permit the unit to be placed on a table or the like beside the patient when the device is being used under non-emergency conditions.

Having thus described our invention we claim:

1. An electrocardioscope comprising a plurality of input terminals adapted to receive cardiac signals representing the cardiac action of a patient, display means, and a control circuit disposed between said terminals and said display means for processing said cardiac signals to produce output signals which are coupled to

said display means to produce a visual representation of said cardiac action, said control circuit comprising means connected across a pair of said terminals and responsive to said received cardiac signals for producing an input signal, a first pair of diodes connected in series with one another across said pair of terminals, a second pair of diodes connected in series with one another and in parallel with said first pair of diodes, said first pair of diodes being poled oppositely to said second pair of diodes, means coupling said input signal across said parallel-connected pairs of diodes, a differential amplifier comprising first and second interconnected transistors, capacitor means coupling the opposing ends of said parallel-connected diode pairs to said first and second transistors respectively, means connecting the mid-junction of said first pair of diodes to the mid-junction of said second pair of diodes, further capacitor means coupling the interconnected mid-junctions of said pairs of diodes to said first and second transistors respectively, means defining a point of reference potential, a pair of oppositely poled zener diodes connected in series with one another between the interconnected mid-junctions of said diode pairs and said point of reference potential, and output means coupling the output of said differential amplifier to said display means.

**2.** The combination of claim **1** including a dc battery connected to said differential amplifier to energize said amplifier.

**3.** The combination of claim **1** wherein said control circuit is mounted on a chassis, said point of reference potential comprising said chassis, said input terminals including a terminal connected to said chassis.

**4.** The combination of claim **1** wherein said display means comprises a cathode ray tube having means for deflecting the beam of said tube in X and Y directions, said output means including a Y-amplifier coupled to the output of said differential amplifier, the output of said Y-amplifier being connected to said Y-deflecting means for controlling the Y-deflection of said cathode ray tube, and means for generating a sweep signal for controlling the X-deflecting means of said cathode ray tube.

**5.** The combination of claim **4** including means for recording signals, and terminal means connected to the input of said Y-amplifier for coupling signals to and from said recording means.

**6.** The combination of claim **4** wherein said means for generating said sweep signal includes a storage capacitor, a dc current source for charging said storage capacitor, a discharge circuit connected across said capacitor for selectively discharging said storage capacitor, said discharge circuit including means connecting said capacitor to a normally nonconductive programmable unijunction transistor for rendering said transistor conductive when the charge potential across said storage capacitor reaches a predetermined level, third and fourth transistors connected in series with one another to render the conductivity of said third transistor dependent upon the conductivity of said fourth transistor, means coupling the output of said Y-deflection amplifier to said third transistor, means responsive to the X-deflection of the cathode ray tube beam for controlling the conductivity of said fourth transistor, and means coupling a signal from said third transistor to said programmable unijunction transistor for rendering said programmable unijunction transistor conductive to discharge said storage capacitor in response to conduction of said third transistor due to the occurrence of a signal in excess of a predetermined minimum amplitude at the output of said Y-deflection amplifier concurrent with conduction of said fourth transistor due to deflection of the beam in an X-direction beyond a predetermined position on the screen of said cathode ray tube.

**7.** The combination of claim **4** wherein said electrocardioscope includes an elongated, portable housing containing said control circuit and also containing a battery supply for said control circuit, said housing having said terminals mounted on one end thereof for direct engagement with the chest of a patient to provide said cardiac signals, said cathode ray tube being mounted in said housing with its screen exposed to view through the other end of said housing.

**8.** The combination of claim **7** including pressure sensitive switch means mounted on said housing for automatically controlling the energization of said circuit from said battery supply.

**9.** The combination of claim **8** wherein said switch means is mounted adjacent said terminals, said switch means being operative to effect energization of said circuit only when said switch means and electrodes are in engagement with the chest of a patient.

**10.** The combination of claim **7** including recording means, a microphone, and a terminal on said housing connected to said microphone for coupling audio signals to and from said recording means.

**11.** The combination of claim **1** wherein said means for producing said input signal comprises a frequency filter connected between said pair of terminals and said parallel-connected pairs of diodes.

* * * * *