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H. T. FINCH ET AL
MEDICAL MONITORING SYSTEM

3,513,833

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2 Sheets-Sheet 1

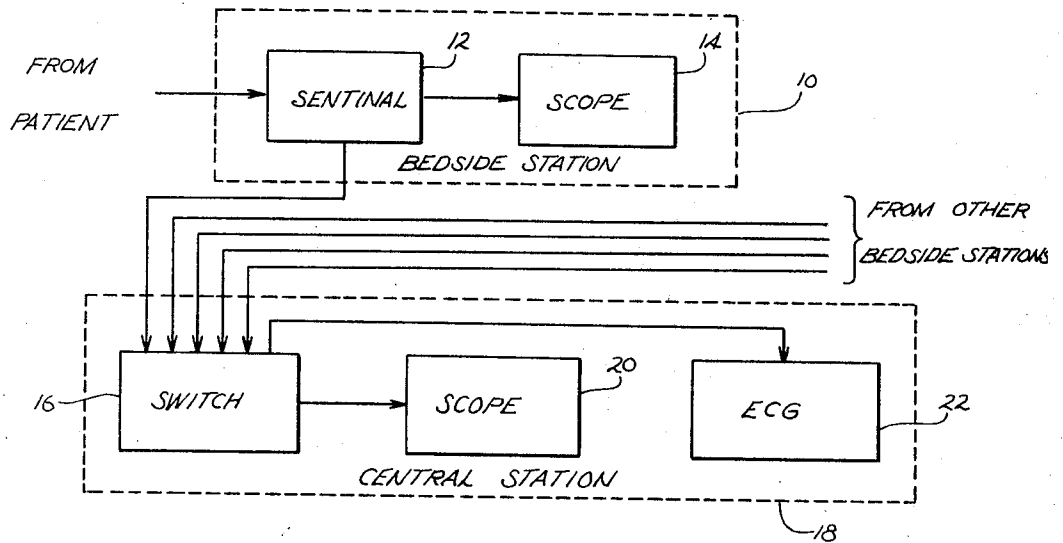


FIG. 1

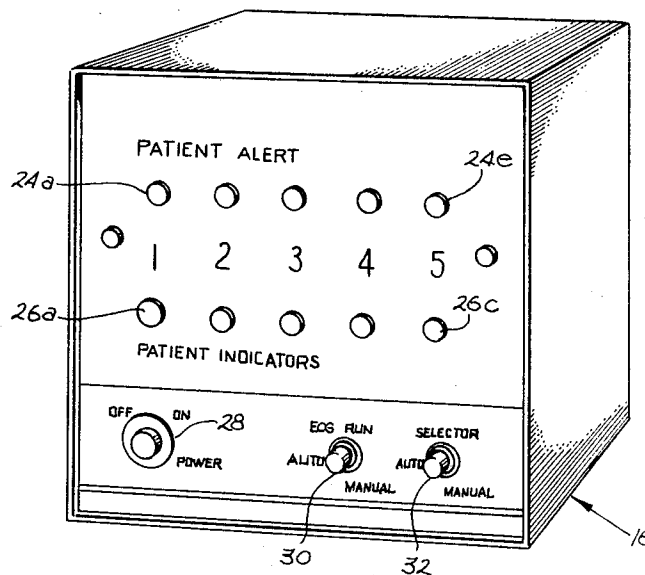


FIG. 2

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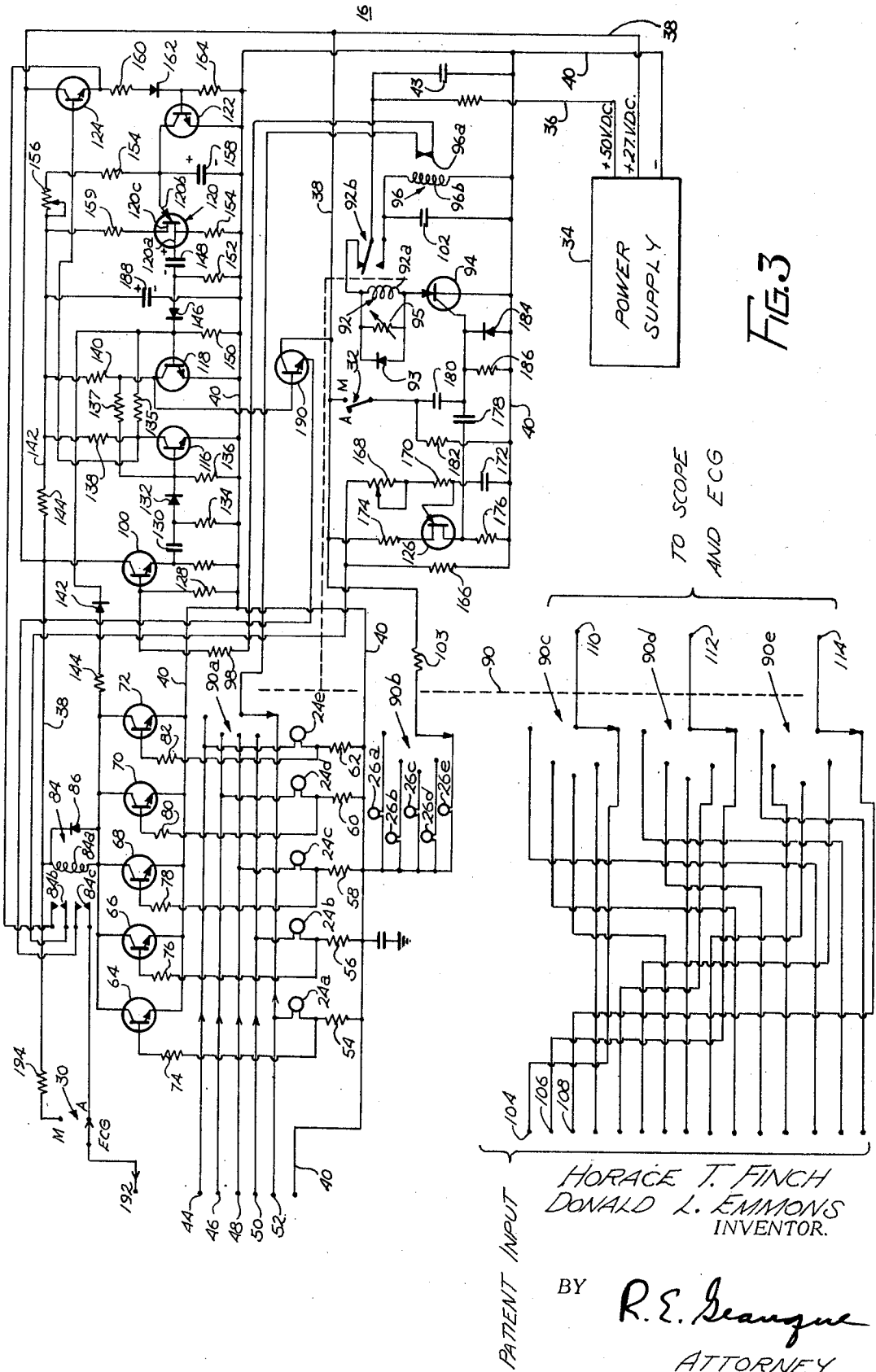
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MEDICAL MONITORING SYSTEM

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5 Claims

ABSTRACT OF THE DISCLOSURE

A bedside station continuously conveys a plurality of patients' electrocardiographic (ECG) signals to a central station and, in the event of increase or decrease in heart beat rate, transmits an "alert" signal to the central station. Monitoring instruments at the central station have facilities for manual and automatic selection of a patient from a predetermined number of patients to display the selected patient's ECG trace, activate an audible alert signal if any of the patients are in distress and an alert signal is received from the bedside station, illuminate an alert lamp that identifies the distressed patient, and render a recorded ECG trace automatically of the patient that has transmitted the alert signal.

This invention relates to a medical monitoring system and, in particular, to a cardiac monitoring system wherein a plurality of bedside systems continuously transmit the patients' electrocardiographic (ECG) signals to a central monitoring station, where the signals can be sequentially monitored. As each patient's signal is monitored, a white light is illuminated in the central station to identify the patient. If any patient's heart beat rate is above or below prescribed limits, a red light is automatically illuminated at the central station, and an audible alarm signal can be energized. Also, an ECG is activated at the central station to provide a permanent recording of the distressed patient's ECG trace.

If there are no alarm signals received from any of the bedside stations, the central station is in "stand-by" condition, even if it is in the automatic mode of operation, and does not cycle through the signals received from the various patients. However, if the system is in the automatic mode, receipt of an alarm signal from any one or more of the patients will cause the central station system to start cycling through all of the patients' ECG signals sequentially. Each time a distressed patient's signal is received, the red light corresponding to the patient is illuminated and his ECG signal is recorded for fifteen seconds, or some other time period, as desired. After that time period has expired, the station sequentially steps through the remaining bedside stations to determine if there are other distressed patients. If so, it will stop and monitor that bedside station for the predetermined length of time, and then move to the next station. If there are no distressed patients, the central station will then remain in stand-by until another emergency occurs.

In manual operation, an operator can manually step the central station monitoring process through the various bedside stations, and record electrocardiographic traces for any length of time desired for any of the patients. As previously noted, ECG signals are received at the central station at all times from all patients, even though they are not all recorded.

Further features and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of a system embodying the invention;

FIG. 2 is a perspective view of a central station switch for monitoring up to five patients; and

FIG. 3 is a circuit diagram of the switch shown in FIG. 2.

The system described herein is adapted to monitor the heart beats of five patients in an intensive care ward. However, the system is open-ended and may be adapted to monitor any number of patients up to a reasonable limit. Therefore, the invention is not to be considered as limited to monitoring any particular number of patients.

FIG. 1 illustrates a block diagram of a monitoring system embodying the invention. Each bedside station 10 (only one of which is shown) comprises a sentinel unit 12, which provides a signals to a bedside oscilloscope 14 and to a monitor switch 16 in a central station 18. The signals provided from the bedside station 10 are representative of a particular patient's ECG condition and, if the patient's heart beat is above or below predetermined limits, an alarm signal is also transmitted to the central station. The switch 16 in the central station provides signals to a monitor oscilloscope 20 and to an electrocardiograph 22 if desired. Of course, only one bedside station can be monitored at one time.

The sentinel 12 in each bedside station emits a continuous signal representing the particular patient's ECG and an alarm signal if the patient's heart beat rate falls below or goes above predetermined limits. Although the invention is not limited to the use of any particular unit, the Model 402 Sentinel manufactured and sold by The Birtcher Corporation, Los Angeles, Calif., is well suited to the application. That unit contains a meter, which visibly indicates the patient's heart beat rate, and also contains "high" and "low" limit switches. Along with the ECG signals, this unit provides an 18 volt signal to the central station indicating an alarm condition when the lower or upper limits of heart beat rate are exceeded, indicating a bradycardia or tachycardia condition in the patient.

The oscilloscopes 14 and 20 may, if desired, each be a Model 401 Monitroscope and the electrocardiograph 22 may be a Model 409/335 Electrocardiograph, both of which are manufactured and sold by The Birtcher Corporation of Los Angeles, Calif. However, the invention is not limited to the use of any particular oscilloscopes or electrocardiographs.

FIG. 2 is a perspective view of the exterior of the central station monitor switch 16. As shown, the switch 16 embodies on its front panel a plurality of red lights 24a-24e, which, if illuminated, indicate one or more distressed patients. Its front panel also contains a plurality of white lights 26a-26e, each of which, when illuminated, indicates a particular patient being monitored. Only one of the white lights 26 can be illuminated at one time, whereas a plurality of red lights 24 can be simultaneously illuminated, if a plurality of patients are in distress. The switch 16 also has on its front panel a power on-off switch 28, an ECG run switch 30 and a selector switch 32. The functions of the latter two switches will become apparent from the description of the circuit diagram of FIGS. 3. It is sufficient for the moment to say that both the ECG run switch and the selector switch 32 are spring biased toward the "automatic" position, and can only be manually depressed to the "manual" position to cause the switch 16 to sep one position for each depression of the switch 32, regardless of how long the switch is held in the "manual" position.

Although FIG. 2 illustrates a monitor switch adapted to receive signals from five patients, as does the schematic diagram of FIG. 3, it is pointed out that the system of the invention is open-ended, and any number of input signals can be accommodated with minor modifications to the system, without departing from the invention.

FIG. 3 is a circuit diagram of the monitor switch 16. As shown, it embodies a power supply 34 that provides +50 volts direct current and +27 volts direct current on lines 36 and 38, respectively, while a line 40 serves as the return.

Connections are made from the various bedside stations 10 shown in FIG. 1 to input terminals 44, 46, 48, 50 and 52 in the monitor switch 16. These terminals receive +18 volt alert signals if one or more patients are in distress; if no patients are in distress (that is, too slow or too fast heart beat rates), no signals are present on terminals 44-52. The terminals 44-52 are respectively connected to energize the red lights 24a-24e located on the front panel of the switch 16, if signals are received from the sentinels 12 in any of the bedside stations 10. One side of each of the lights 24a-24e is connected to one of the terminals 44-52, and the other sides of the lights are respectively connected through resistors 54-62 to the return line 40.

A plurality of NPN transistors 64, 66, 68, 70 and 72, equal in number to the number of patients being monitored, are provided, with the bases of the transistors being respectively connected through resistors 74, 76, 78, 80 and 82 to the junctures of the lights 24a-24e and resistors 54-62. Thus, when any one of the lights 24a-24e is energized, the voltage on the base of the corresponding NPN transistor will rise and bias that transistor into saturation. The transistors 64-72 serve primarily as switches to energize an operating coil 84a of a two-section relay 84. The relay has two sets of contacts 84b and 84c, which are normally open when the relay is de-energized. One end of the relay coil 84a is connected to all of the collectors of the transistors 74-82, and the other end of the relay coil is connected to the power supply line 38 (+27 v.). A diode 86 is connected across the relay coil 84a. The emitters of all of the transistors 64-72 are connected to the return line 40.

One of the more important elements of the monitor switch 16 is a five-deck, five-position switch 90, having decks 90a-90e (for monitoring five patient bedside stations). The switch 90 is stepped through its five positions by a stepping relay coil 92, which is energized through a two-position section 92a, as will be hereinafter described, which is normally in position to energize the relay coil 92 from the power line 36 (+50 v.). The relay coil 92 is paralleled by a diode 93 and a varistor 95. In order for the relay coil 92 to be energized, a silicon controlled rectifier 94, connected between the bottom end of the coil and the return line 40, must be conducting. This action will be decreased later.

The input terminals 44-52 are respectively connected to the five contacts of the switch deck 90a. The rotor of the deck 90a is connected through normally-closed contacts 96a of a relay 96 and through a resistor 98 to the base of an NPN transistor 100. A capacitor 102 is connected across the coil 96b of the relay 96.

The contacts of the second deck 90b of the switch 90 are respectively connected to the return line 40 through the white lights 26a-26e, and the rotor of the section 90b is connected to the power supply line 38 through a resistor 103. As the rotor of the section 90b steps from one position to another it causes the white lights 26a-26e to be sequentially illuminated, thus indicating which patient is being monitored.

Sections 90c, 90d and 90e of the switch 90 serve to provide ECG signals from a particular bedside station to the central station. These signals are provided, for example, on terminals 104, 106 and 108 respectively to one contact on each of the sections 90c, 90d and 90e from a first patient and the rotors of those sections provide these signals to output terminals 110, 112 and 114. These signals may be provided to the oscilloscope 20 and the ECG 22 shown in FIG. 1. The switch 90, in this case, serves only as a selector and performs no other function. Of course, ECG signals from other bedside stations are

supplied to other contacts of the switch sections 90c, 90d and 90e, so that as the switch 90 is stepped through its various positions, the ECG traces of the patients are successively monitored and displayed on the oscilloscope 20 and/or permanently recorded on the ECG 22.

In automatic operation, timing of the successive monitoring of patients is controlled by the timing circuits embodying transistors 120 and 126. It, in turn, is controlled by the silicon controlled rectifier 94 and by transistors 100, 116, 118, 120, 122, 124, and 126. The transistors 100, 116, 118, 122 and 124 are NPN type, while the transistors 120 and 126 are uni-junction transistors. Of course, the particular types of transistors used are matters of design choice, and the invention is not limited to the use of any particular type or types.

The base of the transistor 100 is connected through a resistor 128 to the power supply return line 40. The collector of that transistor is connected directly to the power supply line 38 (+27 v.). The emitter of the transistor 100 is connected to the base of the transistor 116 through a capacitor 130 and a diode 132. The juncture of the capacitor 130 and the diode 132 is connected to the return line 40 through a resistor 134, and the base of the transistor 116 is connected to the return line through a resistor 136.

The transistors 116 and 118 comprise a bistable flip-flop, with the collector of the transistor 116 being connected to the base of the transistor 118 through a resistor 134 and the collector of the transistor 118 being connected to the base of the transistor 116 through a resistor 136. The collectors of the transistors 116 and 118 are respectively connected through resistors 138 and 140 to a line 142, which is connected through a resistor 144 to the power supply line 38. The emitters of the transistors 116 and 118 are connected directly to the power supply return line 40.

The base of the transistor 118 is connected to all of the collectors of the transistors 64-72 through a diode 142 connected in series with a resistor 144. The base of the transistor 118 is also connected to one terminal 120a of the uni-junction transistor 120 through a diode 146 and a capacitor 148. A resistor 150 connects the base juncture of the diode 146 and the base of the transistor 118 to the return line 40, and a resistor 152 connects the juncture of the diode 146 and the capacitor 148 to the same line. The terminal 120a is also connected to the return line 40 through a resistor 154.

The emitter 120b of the uni-junction transistor 120 is connected directly to the collector of the transistor 122, to the supply line 142 through a resistor 154 serially connected with a rheostat 156, and to the return line 40 through a capacitor 158. The resistor 154, rheostat 156 and capacitor 158 determine the rate at which the stepping relay 92 operates, as will be later described.

The emitter 120b of the uni-junction transistor 120 is also connected to the collector of the transistor 122, and its electrode 120c is connected to the line 142 through a resistor 159. The emitter of the transistor 122 is connected directly to the return line 40, and its collector is connected to the juncture of the resistor 154 and the capacitor 158 and, as stated, to the emitter of the uni-junction transistor 120.

The emitter of the transistor 124 is connected to the base of the transistor 122 through serially connected resistor 160 and diode 162 and thence to return line 40 through resistor 164. The collector of the transistor 124 is connected directly to the power supply line 38 and to the collector of the transistor 100. The base of the transistor 124 is connected directly to the collector of the transistor 116. The emitter of the transistor 124 is also connected to one contact of the section 84b of the relay 84. The other contact of the section 84b is connected through a resistor 166 to the return line 40, and through a rheostat 168 and a resistor 170 to the emitter of uni-junction transistor 126 and thence to the return line 40

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through a capacitor 172. One electrode of the transistor 126 is connected to the supply line 38 through the resistor 174, and the other electrode is connected to the return line 40 through a resistor 176. The top (as seen in FIG. 3) of the resistor 176 is connected through capacitors 178 and 180 to the pole of the "automatic-manual" switch 32. A resistor 182 is connected between the pole of the switch 32 and the return line 40. It is pointed out that the "automatic" contact on the switch 32 is unconnected, whereas the "manual" contact is connected to the supply line 38.

The gate electrode 94g of the silicon controlled rectifier 94 is connected to the juncture of the capacitors 178 and 180. It is also connected to the return line 40 through a diode 184 and a resistor 186 connected in parallel. A capacitor 188 is connected between the lines 142 and 40 to act as a filter.

An NPN transistor 190 has its base connected to the collector of the transistor 118, and its collector is connected to the supply line 38. Its emitter is connected through the contacts of relay section 84c and through switch 30 to a terminal 192. When the switch 30 is in "automatic" position, the transistor 190 will provide a voltage, at appropriate times, on the terminal 192 to energize an oscilloscope, an ECG or an audible alarm. When the switch 30 is in "manual" position, the supply line 38 is connected directly to the terminal 192 through a resistor 194.

In operation, when no alert signals are being received from the bedside stations, transistors 64, 66, 68, 70, 72, 100, 116, 120, 126 and silicon controlled rectifier (SCR) 94 are non-conducting. Thus, the coil 84a of the relay 84 is not energized and the contacts 84b and 84c are open. In this state, the transistor 124 is conducting as are the transistors 118 and 122. In this condition, the coil of stepping relay 92 is unenergized because the SCR is non-conducting. Hence, the switch 90 will remain in a fixed position.

If a +18 volt alarm signal is received on any of the terminals 44-52, it causes one of the red lights 24a-24e to light, which biases one or more of the transistors 64-72 into saturation. This energizes the coil 84a of the relay 84 and causes the contacts 84b and 84c to close. When the contacts 84b close, it supplies a bias voltage to the transistor 126, which biases the uni-junction transistor into conduction. The transistor 126, rheostat 168, resistor 170 and capacitor 172 comprise a pulse generator, which supplies pulses through the capacitor 178 to the control electrode 94g of the SCR 94. The repetition rate of the pulses is determined by the setting of the rheostat 168 and is normally set at approximately 0.4 second.

As each pulse is received by the SCR 94 from the transistor 126, the relay 92 is energized. When the relay 92 is energized it mechanically loads a spring (not shown), which moves the switch 90 one step. The relay coil 92a is energized through contacts 92b from the supply line 36. Thus, when the relay 92 is energized, the contacts 92b connect supply line 36 to the coil 96a of the relay 96.

When the normally-closed contacts 96a of the relay 96 open, they disconnect the base of the transistor 100 from the rotor of the switch section 90a and the transistor 100 remains in its non-conducting state. At this time, the contacts 92b have de-energized the coil 92a of the relay 92. The anode supply voltage for the SCR 94 is thus broken and SCR 94 is turned off. This de-energizes the coil 92a of the relay 92 and the contacts 92b return to the position shown in FIG. 3. The SCR 94 and the relay 92 are again energized when the next pulse is received from the transistor 126.

If, when the contacts 96a are closed, the base of the transistor 100 receives a positive alarm voltage from the rotor of switch section 90a, it will be biased into conduction and supply a pulse through capacitors 130 and

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diode 132 to the base of flip-flop transistor 116 to bias it into conduction. When the transistor 116 conducts, it reduces the bias on both transistors 118 and 124 and causes them to be non-conducting. When the transistor 124 is not conducting, it can no longer supply voltage to the bias network comprising transistor 126 and SCR 94 so the stepping relay coil 92 will be de-energized and the relay will remain in its last position. At this time, both a red and a white light are illuminated along with sounding an audible alarm, if desired.

When the transistor 118 is cut off, the transistor 190 is biased into conduction to supply a signal through the contacts 84c of the relay 84 to the output terminal 192 to turn on external equipment such as an ECG, oscilloscope or alarm.

With the transistor 122 non-conducting because of lack of base bias, the capacitor 158 will charge at a rate determined by the values of the rheostat 156, the resistor 154 and its own impedance value. After a predetermined length of time, as set by the time constant of the circuit, transistor 120 will conduct and transmit a pulse to the flip-flop transistor 118. This length of time is preferably set at about 15 seconds. When the transistor 118 is biased into conduction by the pulse from transistor 120, its collector voltage drops, thus causing transistor 116 to become non-conducting. As the collector voltage of transistor 116 rises, it biases the transistor 124 into conduction. Conduction of the transistor 124 also supplied bias to the transistor 126 through rheostat 168, resistor 170 and capacitor 117, if the relay 84 is energized and the contacts 84b close. This means that no alert signals are being received and no red lights are illuminated; thus, the stepping relay 92 will not again be actuated until an alarm is received or until the system is put into manual operation.

To place the system in the manual mode of operation, the switch 30 is moved to the manual position, which connects the power supply line 38 through the resistor 194 to the output terminal 192. Thus, power is continuously supplied to the terminal 192 to energize an ECG or other external display device. In order to monitor one patient after another, the switch 32 is repetitively closed, which causes a pulse to be transmitted from the supply line 38 through the capacitor 180 and resistor 186 to the gate electrode 94g of the SCR 94. This causes the relay 92 to step the switch 90 one step for each closure of the switch 32. Maintaining the switch 32 closed does not cause the relay 92 to be repeatedly actuated. However, the switch 90 will remain in its previous position and the external device energized (so long as the switch 30 is held in the manual position) to monitor a particular patient until the switch 32 is again actuated or the system is returned to manual operation, or is over-ridden by an alarm signal.

If, while the system is in the manual mode of operation, an alarm signal is received on one of the input terminals 44-52, the system returns to its automatic mode of operation and over-rides the manual mode. Thus, the cycle of operation previously described goes into effect.

Although an embodiment of the invention has been described in detail, it is apparent that many modifications may be made therein by one skilled in the art without departing from the true spirit and scope of the invention.

What is claimed is:

1. A medical monitoring system for monitoring a plurality of patients comprising:

a plurality of bedside systems in communication with each patient being monitored, each system having electrocardiograph means;

a central monitoring means coupled to each bedside system for sequentially receiving and monitoring each patient's electrocardiographic signals, said monitoring means including means responsive to the sequentially received signals for indicating which of said plurality of bedside systems is being monitored;

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means responsive to the electrocardiographic signals to indicate an abnormal electrocardiographic signal; means responsive to the abnormal signal for causing the sequential monitoring of said central monitoring means to dwell at the bedside system of the abnormal received electrocardiograph; and means responsive to the received electrocardiographic signals for recording a permanent record of the abnormal patient's electrocardiogram.

2. The monitoring system as defined in claim 1, and further including means for initiating the sequential monitoring of each bed system after a predetermined dwell at the bedside system receiving the abnormal electrocardiographic signal.

3. A cardiac monitoring system comprising a plurality of bedside stations for providing a patient's heartbeat rate signals, means provided in each bedside station for transmitting an alert signal when said heartbeat rate falls below or rises above a predetermined limit;

a central monitoring station adapted to receive the transmitted patient's heartbeat rate signal when said heartbeat rate falls below or rises about predetermined limits;

said central station including switching means for successively monitoring all bedside stations when an alert signal is received from at least one of said bedside station;

means for causing said transmitting means to dwell

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for a predetermined length of time on a station from which an alert signal is received;

means for stepping through the remainder of said stations and returning to said dwell for said predetermined length of time at said alerting bedside stations; and

visible means included in said central station and being responsive to reception of an alert signal to identify a patient which is transmitting said alert signal.

4. The system as defined in claim 3 and further including means for manually stepping said switching means to its monitoring position in the absence of an alert signal being received at said central station.

5. The system as defined in claim 4, wherein said means for stepping said switching means automatically includes means for overriding said means for manually stepping said switching means when an alert signal is received at said central station.

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WILLIAM E. KAMM, Primary Examiner