ABSTRACT: A circuit for detecting whether an electrode has become detached from a cardiac patient or whether he is experiencing cardiac difficulty, including a first circuit for actuating a signal loss lamp in the event an electrode becomes detached, a second circuit for actuating a cardiac alarm device in the event that there is an actual cardiac difficulty, and a timing circuit for preventing application of polarizing voltage to the electrodes.
CARDIAC SIGNAL LOSS DETECTOR

BACKGROUND OF THE INVENTION

The present invention relates to an improved circuit for cardiac monitoring apparatus and more particularly to an improved circuit which will detect whether a patient is suffering from cardiac difficulty or whether an electrode has become detached from the patient, and provide an appropriate signal in each case.

In the past cardiac monitoring apparatus was incapable of detecting whether an electrode had become detached from a patient or whether the patient was experiencing cardiac difficulty. In this respect, the cardiac monitoring apparatus included a signal alarm which was energized whenever the heart rate to a monitor departed from a predeterminerange. There was this departure either when the patient's heartbeat differed from a predetermined value or when the electrode connected to the patient had become detached. Therefore, when the signal alarm was energized the nurse had to consider that a cardiac emergency had arisen and had to rush to the patient's room from a distant control monitoring station, not only to find out that an electrode had become detached to provide an erroneous signal of cardiac difficulty. This constituted a great source of unnecessary alarm and annoyance to the nurses. It is with an improved cardiac apparatus which overcomes the foregoing shortcomings that the present invention is concerned.

SUMMARY OF THE INVENTION

It is accordingly one object of the present invention to provide an improved circuit for a cardiac monitoring device which is capable of detecting whether an actual cardiac emergency has arisen or whether there has merely been a detaching of an electrode from a patient. A related object of the present invention is to provide an improved circuit which will be energized only for a relatively short time to thereby prevent the polarization of the electrodes attached to the patient. Other objects and attendant advantages of the present invention will readily be perceived hereafter.

The improved circuit of the present invention is capable of detecting whether an electrode has become detached from a patient or whether the patient is experiencing cardiac difficulty and includes electrode means for attachment to a patient, a first circuit means coupled to the electrodes for providing a first response in the event that the electrodes are coupled to the patient and the patient's heartbeat has departed from a predetermined range and second circuit means for providing a second response in the event the electrodes have become detached from the patient. The improved circuit also includes a timing circuit for preventing polarization of the electrodes in the event the circuit of the present invention is energized. The present invention will be fully understood when the following portions of the specification are read in conjunction with the accompanying drawing, which consists of a single FIG. showing schematically the circuitry of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The improved circuit of the present invention can be set to operate in the current conventional manner, namely, to give the same signal alarm whenever there is a heartbeat lower than normal, a heartbeat higher than normal, or a detaching of the electrodes from the patient. Alternatively, the circuit of the present invention can be designed to provide a first signal when there is a change in heart rate beyond a predetermined range due to a patient's experiencing cardiac difficulty, and to provide a second signal when there is merely a detaching of an electrode from the patient. It will be appreciated that when the circuit is set to operate in the conventional manner, the attending nurse does not know the reason for the signal alarm and therefore will have to treat every alarm as an emergency. The improved circuit of the present invention is capable of detecting whether there is a cardiac emergency or whether there has been a mere electrode detachment and providing an appropriate signal, to thereby permit the nurse to treat each occurrence accordingly.

When the above-described conventional mode of operation is desired, master switch 11 is set so that armatures 12 and 13 occupy the dotted line positions. This will cause a circuit to be completed from the B+ source through lead 14, alarm lamp 15, lead 16, armature 12, lead 17, switch 18 and lead 19 to ground. This will activate alarm lamp 15 to alert the nurse. Switch 18 is closed whenever heart rate meter 20 senses a heart rate which is either lower than that at which pointer 21 is set or higher than that at which pointer 22 is set, the actual heart rate being depicted at any particular time by pointer 23. When an electrode becomes detached, the heart rate meter drops to zero. Switch 18 may be a semiconductor switch which is operated by photoelectric contacts, not shown, which are energized whenever pointer 23 crosses either pointer 21 or pointer 22. Alternatively, any other type of contact may be actuated whenever there is a departure from a range of heartbeats set between pointers 21 and 22.

The heart rate meter measures the patient's heartbeat. In this respect, a plurality of electrodes are provided, electrode 24 being attached to the right arm of a patient, electrode 25 to the left arm, and electrode 26 to the right leg. As can be seen from the diagram, electrode 24 is ultimately coupled to heart rate meter 20 via lead 27, relay armature 28, lead 29, preamplifier 30, lead 31, discriminating amplifier 32 and lead 33. Electrode 25 is also coupled to meter 20 via lead 34, relay armature 35, lead 36, preamplifier 30, lead 37, discriminating amplifier 32 and lead 33. Electrode 26 is effectively coupled to meter 20 via lead 38, preamplifier 30, lead 39, discriminating amplifier 32 and lead 33. In addition, lead 39 is coupled to ground via leads 40 and 41. It can thus be seen that whenever master switch 11 is in the dotted line position shown in the diagram, a departure of a heartbeat from the range at which pointers 21 and 22 are set will result in the closing of switch 18, and this in turn will actuate alarm lamp 15 which may be a light and a buzzer.

In the past, the above-described circuit would cause lamp 15 to become energized whenever there was an increase in heart rate due to fibrillation, a decrease due to a heart failure or stoppage, or whenever any one of electrodes 24, 25 and 26 become detached, which was a common occurrence considering the fact that the patient normally moved around sufficiently to disengage the electrodes from his limbs. A nurse would be alerted and because of the apparent emergency, she would rush from a central monitoring station to the patient's room only to find that the patient was not in a state of emergency but that the electrodes were detached.

The improved circuit of the present invention is capable of detecting whether an actual cardiac emergency is occurring or whether there has been a mere disconnection of the electrodes from the patient. If the latter is the case, then there is no need for the nurse to drop everything else and rush to the patient. She can merely take care of this occurrence in due course. On the other hand, if an actual heart emergency exists, the nurse will know that it is not a false alarm and can cope with it accordingly.

In order to set the circuit for the improved mode of operation, it is merely necessary to move master switch 11 so that the armatures 12 and 13 occupy their solid line positions. In this event there is an actual cardiac emergency and that the heart rate should depart from the range depicted by pointers 21 and 22, there will be a closing of switch 18 and an attendant completion of a circuit from B+ through lead 42, relay coil 43, lead 44, armature 13, lead 45, lead 46, switch 18 and lead 19 to ground. The energization of relay coil 43 will result in the closing of normally open contacts 47. This in turn will cause the completion of a circuit for the signal alarm lamp coupled to lead 48, now closed contacts 47, lead 49, voltage drop resistors 50 and 51, lead 52 and the parallel relay coils 53 and 54 which are connected across each other by leads 55 and 56 and are both connected to ground by lead 57.
The energization of relay coils 53 and 54 will result in the movement of armatures 28 and 35 to their dotted line positions. This movement of armatures 28 and 35 will result in the activation of left arm test circuit 58 and right arm test circuit 59. More specifically, the right arm test circuit 59 will now be completed from B+ to patient via lead 71, resistor 71', lead 62, resistor 61, lead 60, armature 28, lead 27, and electrode 24. In addition, the left arm test circuit 58 will be completed from B+ to patient via lead 71, resistor 111, resistor 65, lead 64, armature 35, lead 34 and electrode 25. Voltage drop resistors 63 and 66, which are coupled via lead 41, are also coupled to the bases of transistors 67 and 68, respectively, by leads 69 and 70, respectively, and resistors 66 and 63 are also coupled in series with resistors 111 and 71', respectively, to provide voltage dividers. It is to be noted that resistor 66 is connected between electrode 25 and ground. Resistor 63 is connected between electrode 24 and ground.

Therefore, if the electrodes 24 and 25 are in position on the patient, and electrode 26 is also in position on the patient, the patient will shunt both voltage drop resistors 66 and 63 so that there will be no voltage drop thereacross, inasmuch as electrode 26 is grounded. This in turn will cause the leads 70 and 69 leading to the bases of transistors 68 and 67, respectively, to be at substantially ground potential which will bias them negatively so that there will be no current flow therethrough.

The collectors of transistors 67 and 68 are connected to a B+ source, through lead 71, lead 72 and resistor 73, the collector of transistor 68 being connected to resistor 73 through lead 74 and the collector of transistor 67 being connected to resistor 73 through leads 75 and 76. Since there is no flow through transistors 68 and 67, there will be a relatively high positive potential on the base of transistor 77 which is coupled to lead 75 by lead 78. This will cause a flow of current from B+ through lead 42, lead 48, now closed contacts 47, lead 49, diode 79, lead 80 and voltage drop resistors 81 and 82 to the collector of transistor 77 and through the emitter to lead 83 which is coupled to lead 84 which in turn is coupled to lead 41 at ground through series diodes 85, 86 and 87.

In addition, the potential at the common point between resistors 81 and 82 will be applied to unjunction transistor 88 which is located in a standard memory circuit 89 which functions as an oscillator. In view of the fact that transistor 77 is conducting, it will effectively shunt capacitor 90 so that there will be no signal output and therefore silicon control rectifier 91 will not fire and therefore relay coil 92 will not be energized to close normally open contacts 93. This being the case, there can be no completion of a circuit through normally open contacts 93 from B+ through lead 94, lamp 95, lead 96, lead 97, lead 98 and lead 11 to ground. Nor can there be a completion of a circuit from B+ through lead 99, lamp 100, lead 97, contacts 93, lead 98 and lead 41 to ground.

Lead loss lamps 95 and 100 are on the monitor and on the nurse’s station, respectively, and these will light up only when one of the electrodes 24, 25 and 26 becomes disconnected from the patient. However, as noted above, this circuit cannot be completed and therefore these lamps will not light up, thereby indicating that there is no detachment of electrodes. However, the energization of the foregoing circuit will result in the energization of the alarm lamp 15 because it was a departure from a normal heartbeat rate, as sensed on meter 20, which triggered the circuit. In this respect, as noted above, there is an application of a B+ potential at the base of transistor 101 via lead 42, lead 48, contacts 47, lead 49, diode 79, lead 80, lead 49', voltage drop resistor 102, lead 103, lead 104, lead 105, capacitor 106 and lead 41 to ground, the potential at the base of transistor 101 being the same as at the junction of resistor 102 and capacitor 106, causing the base of 101 to become positive, and a circuit is completed from B+ through lead 14, alarm lamp 15, lead 16, switch armature 12, lead 104', transistor 101, diodes 105' and 106' and lead 107 to ground. The base of transistor 101 will be relatively positive because SCR 91 is not conducting and the base is biased about ground by capacitor 106 which is in series with resistor 102.

It can thus be seen that alarm lamp 15 will be energized to indicate that an emergency exists at the patient either because his heart rate has fallen below a predetermined value or has exceeded a predetermined value, these being indicative of a heart arrest or fibrillation, respectively. Also, as explained above, the signal loss lamps 95 and 100 are not energized at this time.

It will now be assumed that there has been no cardiac emergency but merely a loss of leads, that is, any one of electrodes 24, 25 and 26 has become detached from the patient. In the past, this occurred coupled to ground and this will result in the closure of contacts 47. This in turn will cause the activation of relay coils 53 and 54 as described in detail above because they are now coupled from B+ to ground via leads 42, 48, contacts 47, lead 49, voltage drop resistors 50 and 51 and lead 52. This in turn will cause armatures 28 and 35 to move to their dotted line positions.

For example, assume that electrode 24 has been detached from the patient. Therefore, the patient cannot provide a shunt circuit across resistor 63. More specifically, as can be seen, electrode 24 is connected to resistor 63 through lead 27, armature 28, lead 60, resistor 61 and lead 62. This being the case, the base of transistor 67 is not at ground potential because resistor 63 maintains it at some level above ground because resistor 63 is not shunted by the patient. This being the case, transistor 67 will conduct and when it does its collector will approach ground potential, which in turn will apply a reverse bias to the base of transistor 77 through lead 78. Therefore, transistor 77 will not conduct and a relatively high positive potential will therefore exist at the junction of resistors 81 and 82. This voltage will be applied to unjunction transistor 88 via lead 105. However, since transistor 77 is not now conducting, capacitor 90 will not be shunted and therefore the memory circuit 89, which is essentially an oscillator, will operate so that it will provide an oscillation three to four times in five-tenths of a second. The purpose for this parameter will become more apparent hereafter. When transistor 88 conducts there will be a flow of current from B+ through lead 71, unjunction transistor 88, lead 106' and resistor 107' to ground. There will therefore be a triggering pulse applied to SCR 91 via lead 108, and SCR 91, in turn, will conduct from lead 49' through relay coil 92 and lead 109 to ground. This will cause contacts 93 to close, which in turn will complete a circuit from B+ through lamps 95 and 100 to ground via lead 97, now closed contacts 93, lead 98 and lead 41. At this time, the alarm lamp 15 will not be energized because the circuit through transistor 101 is not completed. In this respect, when SCR 91 conducts, the base of transistor 101 will be relatively negative because SCR 101 being in a nonconducting state can cause an opening between leads 104' and 107 associated with lamp 15. Therefore, the nurse will know that the alarm is not a true one but is merely due to a loss of leads.

An analogous action occurs in the event electrodes 25 becomes loosened or is disconnected from the patient. In this respect, the patient cannot provide a shunt across resistor 66. This being the case, the potential on the base of transistor 68 will be raised because lead 70 is not substantially at ground potential. It is above ground because resistors 66 and 111 act as a voltage divider between B+ and ground, via lead 71, resistor 111, resistor 66 and lead 41. When the potential at the base of transistor 68 is relatively positive, it will conduct and therefore the potential between resistor 73 and transistor 68.
will be relatively negative (approaching ground) which in turn will cause transistor 77 not to conduct because a relatively negative potential is applied at the base thereof through leads 75 and 78 which are common with the collector of transistor 68. When transistor 77 does not conduct the standard memory circuit 89 will oscillate to trigger SCR 91 which in turn will close relay contacts 93 because of the passage of current through relay coil 92, and in this manner there will be an energization of signal loss lamps 95 and 100.

A unijunction timing circuit 115 is provided for the purpose of permitting the patient to ground resistors 66 and 63 only for a relatively short period of time after switch 47 has been closed. As noted above, this switch closes to energize relay coils 53 and 54 both when there is cardiac difficulty and a detachment of electrodes. In this respect, it can readily be seen that whenever armatures 28 and 35 are in their dotted line positions, there is a flow of current across the patient from B+ via lead 71, resistor 111, resistor 65, lead 64, armature 35, lead 34 and electrode 25 because the patient is grounded. There is also a flow of current from B+ via lead 71, resistor 71', lead 62, resistor 61, lead 60, armature 28, lead 27, and electrode 24 because the patient is grounded. The flow of current will cause polarization of the electrodes 24, 25 and 26 if it continues for a time in excess of five-tenths of a second. If polarization occurs, there would be an illusion of an open circuit because the polarization would impede the acting of the patient in the above described manner as a shunt.

Accordingly, the unijunction timing circuit 115 will disconnect the flow of current through relay coils 53 and 54 after five-tenths of a second and therefore cause armatures 28 and 35 to return to their normal solid line positions. This will terminate the flow of current to the electrodes 24 and 25. More specifically, as can be seen from the diagram, whenever relay coil 43 is energized to close contacts 47, there will be a flow of current from B+ through lead 42, lead 48, contacts 47, lead 49, and lead 116 to ground through the unijunction timing circuit 115. This circuit essentially includes a unijunction transistor 117, a capacitor 118, an SCR 119, a capacitor 120 and a relay coil 121 connected in the manner shown. Since this is a standard oscillation circuit, which is well known in the art, a description thereof beyond an identification of the components will not be made. However, it is merely necessary to understand that this circuit will provide an oscillation every five-tenths of a second. Therefore, when circuit 115 is connected to B+ in the above described manner, there will be a flow of current through relay coil 121 and SCR 119 to ground, it being noted that the unijunction transistor 117 is connected to B+ via leads 71 and 122 and to ground through resistor 123 and lead 124. When a pulse is sensed at SCR 119 through lead 125 and there is a B+ potential at relay coil 121, the conduction of SCR 119 will cause energization of relay coil 121, which will remain energized thereafter as long as contacts 47 remain closed. The energization of relay coil 121 will cause the closing of normally open contacts 125 which in turn will cause both sides of relay coils 53 and 54 to be grounded inasmuch as there is now a circuit completed from ground through lead 57, relay coils 53 and 54, lead 52, diode 126, lead 127, lead 128, resistor 129, now closed contacts 125, lead 130 and lead 124 to ground. The grounding of both sides of relay coils 53 and 54 will cause relay armatures 35 and 28, respectively, to their solid line positions and this will disrupt the flow of current through electrodes 24 and 25 and thereby obviate any polarization thereof.

It is to be noted at this point that the standard memory circuit 89 described above provided oscillations three to four times in five-tenths of a second. This insures that this circuit will operate to energize the signal loss lamps 95 and 100 or alarm 102. As above described contacts 125 close to permanently ground relay coils 53 and 54 to prevent polarization. However, the appropriate lamps 95, 100 or 15 will remain energized notwithstanding the grounding of both sides of relay coils 53 and 54.

While preferred embodiments of the present invention have been described it will be appreciated that it is not limited thereto but may be otherwise embodied within the scope of the following claims.

I claim:

1. A circuit for detecting whether an electrode has become detached from a cardiac patient or whether said patient is experiencing cardiac difficulty comprising electrode means for attachment to said patient, means coupled to said electrode means for providing a first indication if the heartbeat rate of the patient is within a predetermined range and a second indication that the heartbeat rate is outside of said predetermined range, first circuit means for providing a first response in the event said second indication is obtained and said electrode means are coupled to said patient thereby indicating that said patient is experiencing cardiac difficulty, second circuit means for providing a second response in the event said second indication is obtained because said electrode means are uncoupled from said patient thereby indicating that said electrode means are uncoupled from said patient, first circuit means including third circuit means coupled across said patient through said electrode means when said patient is experiencing cardiac difficulty, and third circuit means when said electrode means are coupled to said patient, fourth circuit means responsive to said shunting relationship for conditioning said first circuit means to produce said first response, means included in said first and second circuit means capable of applying a polarization voltage across said electrode means, and fifth circuit means for maintaining said first and second circuit means energized for a predetermined period of time only to thereby prevent polarization of said electrode means.

2. A circuit for detecting whether an electrode has become detached from a cardiac patient or whether said patient is experiencing cardiac difficulty comprising electrode means for attachment to said patient, means coupled to said electrode means for providing a first indication if the heartbeat rate of the patient is within a predetermined range and a second indication that the heartbeat rate is outside of said predetermined range, first circuit means for providing a first response in the event said second indication is obtained and said electrode means are coupled to said patient thereby indicating that said patient is experiencing cardiac difficulty, second circuit means for providing a second response in the event said second indication is obtained because said electrode means are uncoupled from said patient thereby indicating that said electrode means are uncoupled from said patient, first circuit means including third circuit means coupled across said patient through said electrode means when said patient is experiencing cardiac difficulty, and third circuit means when said electrode means are coupled to said patient, fourth circuit means responsive to said shunting relationship for conditioning said first circuit means to produce said first response, means included in said first and second circuit means capable of applying a polarization voltage across said electrode means, and fifth circuit means for maintaining said first and second circuit means energized for a predetermined period of time only to thereby prevent polarization of said electrode means.
means for providing a first indication if the heartbeat rate of
the patient is within a predetermined range and a second indi-
cation that the heartbeat rate is outside of said predetermined
range, first circuit means for providing a first response in the
event said second indication is obtained and said electrode
means are coupled to said patient thereby indicating that said
patient is experiencing cardiac difficulty, second circuit means
for providing a second response in the event said second indi-
cation is obtained because said electrode means are uncou-
pled from said patient thereby indicating that said electrode
means are uncoupled from said patient, said first and second
circuit means including test circuit means comprising a source
of voltage, voltage divider means coupling said voltage source
to ground, and relay means for selectively coupling said volt-
age divider means in parallel relationship across said patient
through said electrode means upon the obtaining of said
second indication, said first circuit means including first signal
means which produce said first response when said patient
shunts said voltage divider means, said second circuit means
including second signal means which produce said second
response when said patient cannot shunt said voltage divider
means because said electrode means are disconnected.

5. A circuit as set forth in claim 4 including third circuit
means for limiting the length of time said relay means remains
energized, to thereby avoid polarization due to prolonged
coupling of said electrode means to said voltage source.