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CARDIAC APPARATUS AND SWITCHING CIRCUIT THEREFOR

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2 Sheets-Sheet 1

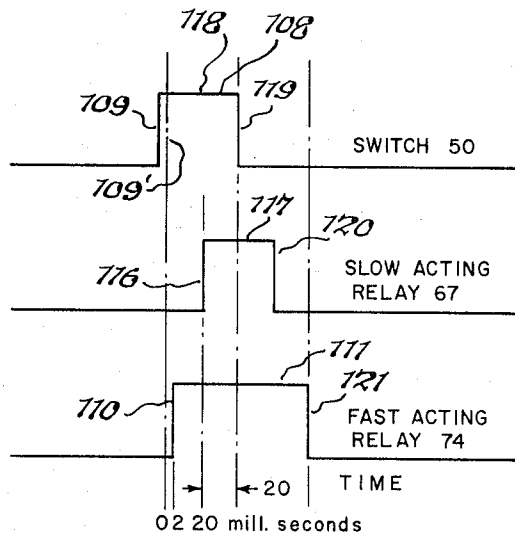


Fig. 4.

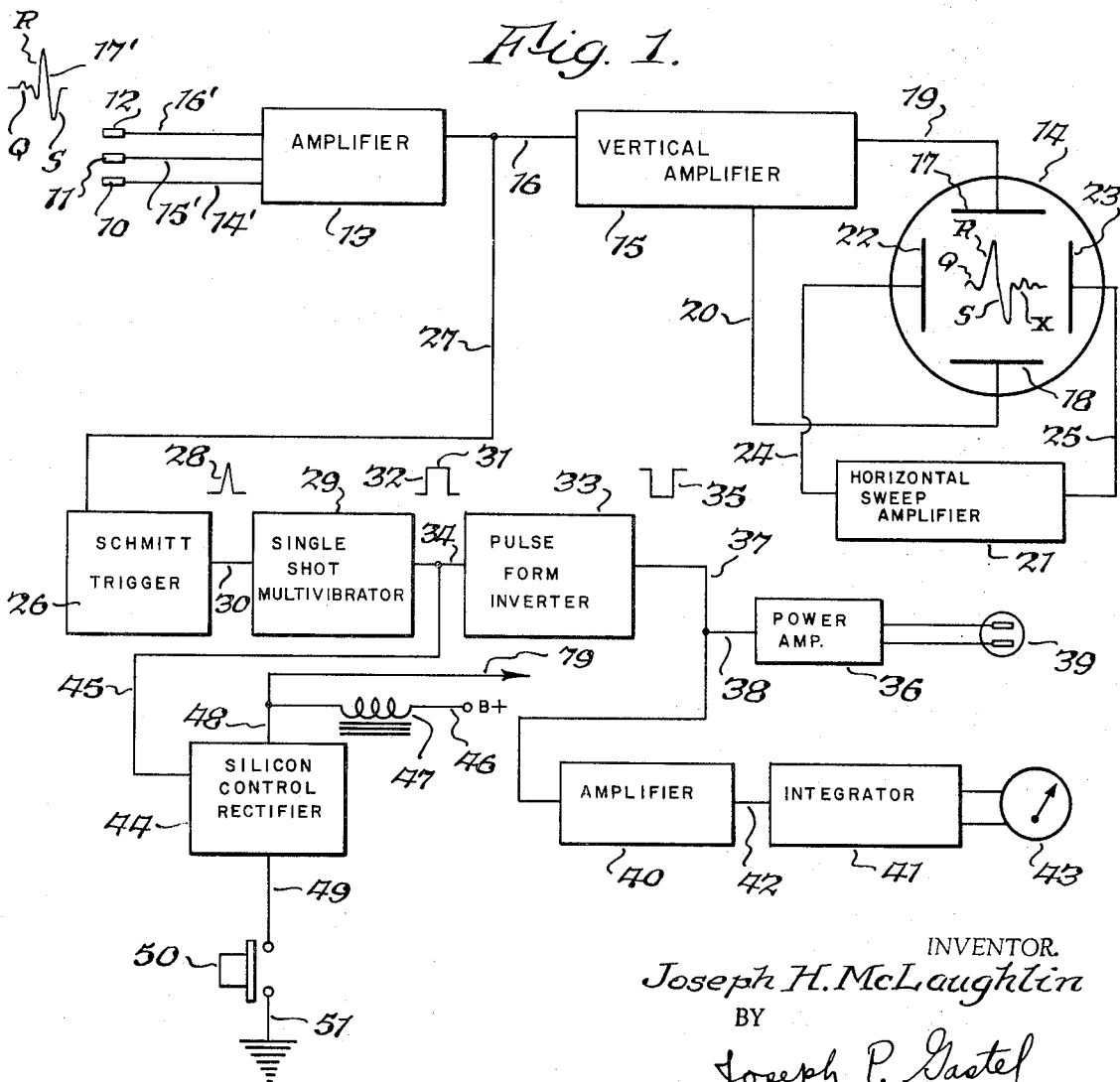


Fig. 1.

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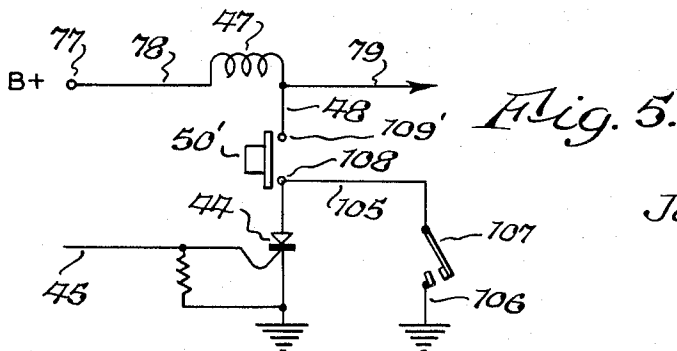
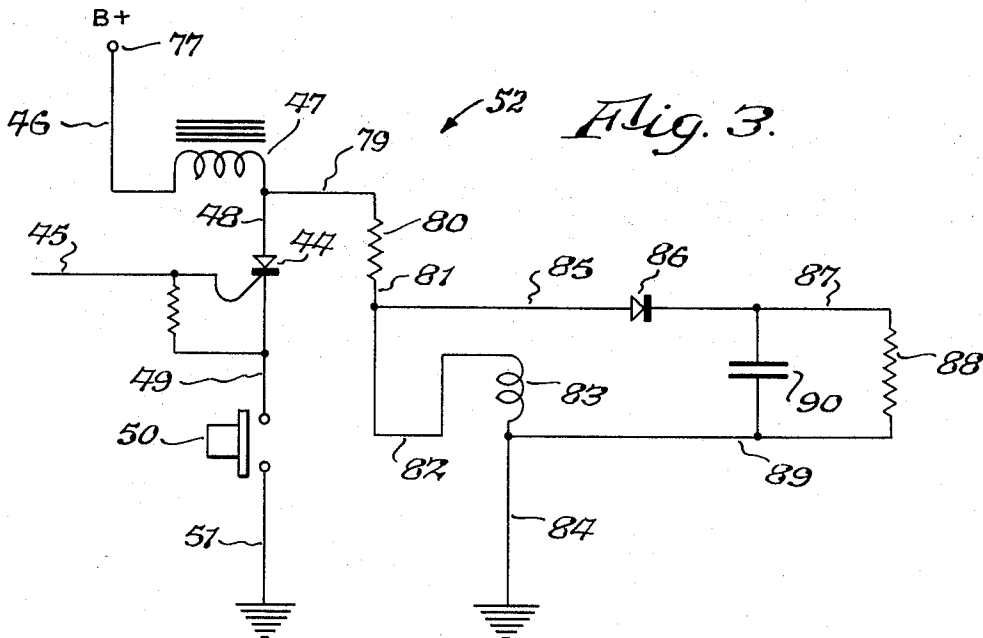
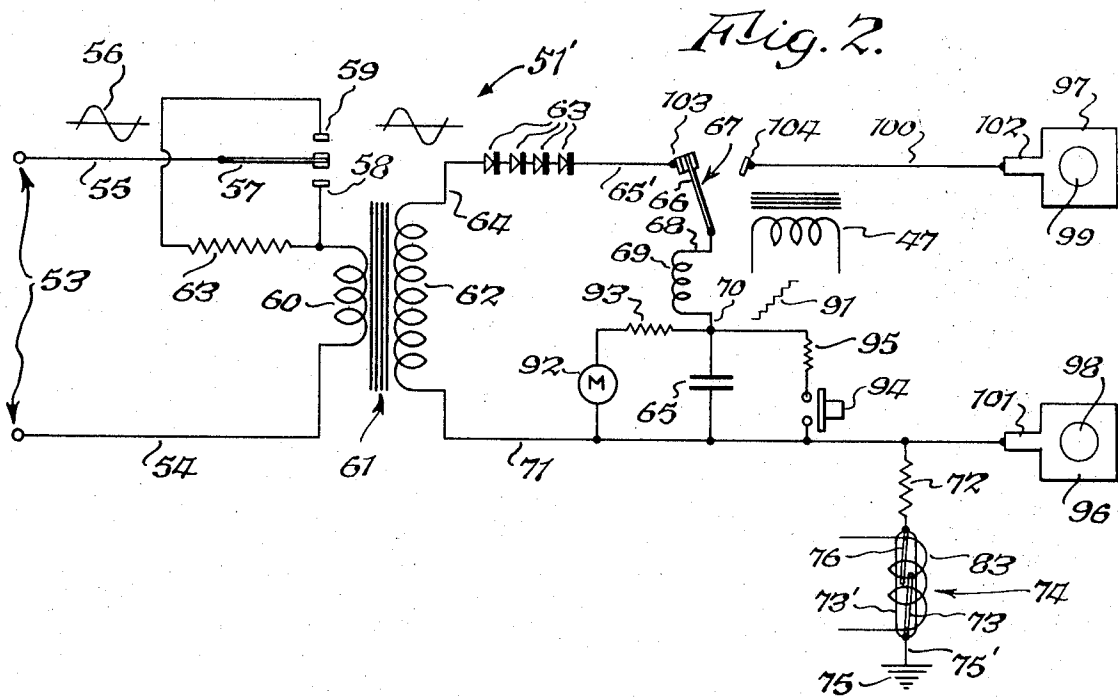
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2 Sheets-Sheet 2



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CARDIAC APPARATUS AND SWITCHING CIRCUIT THEREFOR

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10 Claims

ABSTRACT OF THE DISCLOSURE

Cardiac apparatus for applying a countershock voltage to the chest of a cardiac patient in timed relationship to the heartbeat including a charging circuit having a capacitor therein and a defibrillating circuit, a slow acting relay for selectively coupling the capacitor to the charging circuit or to the defibrillating circuit, a fast acting relay for selectively coupling both of the circuits to ground or removing them from ground, circuit means coupled to the relays for sensing the heartbeat of a patient, the slow acting relay being of the high voltage vacuum type and including an inherent time delay therein which causes the defibrillating voltage stored on the capacitor to be discharged through the defibrillating circuit a predetermined time after the slow acting relay is actuated by the heartbeat of the patient, the fast acting relay uncoupling both of the circuits from ground prior to the discharge of the capacitor and keeping them off of ground until the slow acting relay recouples the capacitor to the charging circuit.

The present invention relates to improved electronic cardiac apparatus for defibrillating the heart of a cardiac patient and to an improved timing and switching circuit for use in conjunction therewith.

By way of background, the heart of a cardiac patient may go into fibrillation. One type of fibrillation is known as ventricular fibrillation wherein the various groups of muscles of the heart may beat independently and without rhythm. In order to overcome ventricular fibrillation, a countershock voltage may be applied to the heart of the patient through electrodes placed in opposition to each other on the patient's back and chest to cause a current flow through the chest cavity. However, since there is no pronounced heartbeat in ventricular fibrillation, the countershock may be applied at any desired time. This countershock has in many instances caused the heart to return to a more normal rhythm.

There are also other types of fibrillation which are known as arrhythmias where there is a pronounced heartbeat which is not normal, that is, there is some degree of lack of coordination of heart muscle action. Electrical countershock is also utilized in arresting such other arrhythmias. However, the countershock must be applied in synchronized relationship to the heartbeat, that is, the countershock must not fall into what are considered the vulnerable zones of the normal heart cycle because this would of itself cause fibrillation. It is with cardiac apparatus for applying a defibrillating countershock both in ventricular fibrillation and in other arrhythmias that the present invention is concerned.

In order to provide a synchronized countershock or defibrillating voltage, a patient's heartbeat is monitored electronically. If the attending physician desires to apply a countershock voltage, he will actuate a first switch for causing a charge of a desired magnitude to be built up in a capacitive circuit. Thereafter, he will close a second switch on the apparatus which will discharge the above mentioned stored voltage across the heart in synchronized relationship to the heartbeat. The synchronization is ef-

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fectured by a timing and switching circuit which uses a part of the heartbeat as a reference point and automatically causes the countershock to be applied at that portion of the heart cycle which will avoid the vulnerable zones, noted above, thereby insuring maximum effectiveness.

In the foregoing type of apparatus the chassis is normally grounded for the purpose of preventing stray voltages from producing shocks and for making the apparatus compatible for use with other grounded apparatus, such as electrocardiographs, or the like. During the applying of countershock to a patient, the patient essentially becomes a part of the electrical circuit because current is caused to flow through his chest cavity. Therefore, if during the application of the countershock any of the attending medical personnel are both grounded and in contact with the patient or the electrode forming a part of the circuit to the patient, they will also form a part of the circuit and be subjected to some portion of the countershock voltage also.

In accordance with the present invention, a timing and switching circuit is utilized to positively obviate any possibility of the foregoing occurrence. More specifically, the circuit is normally grounded to the chassis at all times except when countershock is applied. This eliminates the possibility of shocking due to stray voltages while permitting the apparatus to be compatible with other grounded apparatus. However, the circuit is automatically removed from ground prior to the time of the application of the countershock voltage and remains in this condition until all countershock energy is dissipated. The removing of the circuit from ground and the application of the countershock are achieved automatically. In this respect, after the defibrillation switch is actuated, the heartbeat signal completes a circuit which causes a fast acting relay to disconnect the circuit from ground and simultaneously causes a slow acting relay to discharge the countershock voltage to the patient. Since the slow acting relay acts slower than the fast acting relay, the circuit is removed from ground prior to the time that the capacitive circuit can discharge its voltage across the chest of the patient. This positively prevents the defibrillating countershock, which may be of a very high magnitude, from being accidentally applied to the medical personnel. The circuit containing the fast and slow relays is set up so that a fast acting relay cannot produce an opposite switching action grounding the circuit to the chassis prior to the time that the slow acting relay has achieved its opposite switching action. This insures that the high voltage defibrillation circuit will not be coupled to the chassis when it is in a condition to discharge.

The apparatus is also capable of providing countershock for ventricular fibrillation in direct response to the actuation of the circuit without any requirement for synchronization with any portion of the heartbeat. The present circuit automatically disconnects the circuit from ground in this type of countershock application also.

All of the foregoing circuits are integrated in a unique manner to provide accurate and dependable operation, and the various aspects of the improved cardiac apparatus for applying countershock voltage, and of the improved timing and switching circuit used in conjunction therewith will be more readily perceived hereafter.

It is accordingly one object of the present invention to provide improved electronic cardiac apparatus for applying a synchronized defibrillating countershock to patients experiencing certain types of arrhythmias, or an unsynchronized countershock to patients experiencing ventricular fibrillation, and eliminating the possibility of such countershock being applied accidentally to personnel in the immediate area of the patient. A related object is to provide improved electronic cardiac apparatus for applying countershock which includes improved circuitry

which permits the use of a chassis ground in the circuit at all times except when the countershock is being applied, thereby not only permitting the apparatus to be compatible for use with other grounded electronic apparatus and preventing stray voltages from accumulating on the chassis, but also positively preventing countershock from being applied to the personnel by removing the chassis from ground during such countershock application.

Another object of the present invention is to provide an improved timing and switching circuit which is capable of providing a plurality of switching actions in predetermined timed sequence in an extremely accurate and dependable manner. Other objects and attendant advantages of the present invention will readily be perceived hereafter when the following portion of the specification is read in conjunction with the accompanying drawings wherein:

FIG. 1 is a block diagram of a portion of the improved cardiac apparatus of the present invention;

FIG. 2 is a schematic wiring diagram of the circuit of the cardiac apparatus which is utilized for applying defibrillation voltage to a patient;

FIG. 3 is a schematic wiring diagram of a control circuit for the circuit of FIG. 2;

FIG. 4 is a diagram representing the time relationship between the defibrillation switch and the fast and slow acting relays; and

FIG. 5 is a schematic wiring diagram of a control circuit for the circuit of FIG. 2.

In FIG. 1 the improved apparatus for applying countershock for treatment of arrhythmias is shown. This apparatus includes three sensor electrodes 10, 11 and 12 which are coupled to amplifier 13 by leads 14', 15' and 16', respectively. Electrodes 10 and 11 are attached to opposite wrists of the patient and electrical contact is made by the use of a suitable electrode jelly. Electrode 12 is attached to the leg of the patient in the same manner. The heartbeat waveform 17' will thus be transmitted to amplifier 13 which effects suitable amplification thereof. The amplified heartbeat may be visually indicated on cathode-ray oscilloscope 14 by feeding the amplified signal from amplifier 13 to vertical amplifier 15 through lead 16, the output of vertical amplifier 15 being applied to plates 17 and 18 through leads 19 and 20, respectively. This signal is used to modify the trace provided by horizontal free running sweep amplifier 21 which is applied to plates 22 and 23 by leads 24 and 25, respectively. The heartbeat action comprises a QRS complex waveform including the Q portion, R portion and S portion and vulnerable area X as shown on the scope in FIG. 1. The countershock is synchronized with the heartbeat so that it does not fall in area X.

The amplified signal at lead 16 is also fed to Schmitt trigger 26 by lead 27, which produces waveform 28 which, in turn, is fed to single shot multivibrator 29 by lead 30. It is the multivibrator 29 which produces a usable signal 31 in synchronized relationship to heartbeat 17. The lead portion 32 of signal 31 is initiated when the R portion of heartbeat 17 reaches a predetermined magnitude. Waveform 31 is fed from multivibrator 29 to pulse form inverter 33 by lead 34. The output 35 of pulse form inverter 33 is conducted to power amplifier 36 through leads 37 and 38 and, in turn, power amplifier 36 is coupled to a neon lamp 39 which will ignite when a voltage of sufficient magnitude is produced by pulse form inverter 33. This will provide a visual indication that proper voltage is being applied to pulse form inverter 33; that is, that multivibrator 29 is operating satisfactorily. In addition, waveform 35 is conducted by lead 37 to amplifier 40 which, in turn, is coupled to integrator 41 by lead 42. The integrator 41 will smooth out the waveform and provide a relatively constant potential, the magnitude of which can be read on meter 43, which is directly related to the heartbeat rate.

When a heart pattern is shown on scope 14 which is conductive to the use of countershock, the attending physician will close switch 50 to establish contact between leads 49 and 51. The output of multivibrator 29 is also fed to silicon control rectifier 44 by lead 45 which is connected to lead 34. The silicon control rectifier 44 will be energized whenever the lead portion 32 of wave 31 reaches a predetermined magnitude to cause current to flow from B⁺ to ground through lead 46, slow acting relay coil 47, lead 48, lead 49, defibrillation switch 50, and lead 51. Whenever the silicon control rectifier 44 is energized to complete the above circuit, relay coil 47 will also be energized. At this point it is only necessary to understand that the energization of coil 47 is synchronized with the patient's heartbeat, and that the relay associated with coil 47 actuates the circuit of FIG. 2 which supplies countershock.

Reference is now made to FIGS. 2, 3 and 4 which disclose various aspects of the timing and switching circuit which provide the countershock voltage to a patient's heart in timed relationship to the heartbeat. The circuit 51' of FIG. 2 is the actual circuit for providing the countershock and the circuit 52 of FIG. 3 is the control circuit for circuit 51'. FIG. 4 shows the time sequence of the action of various components of the circuits of FIGS. 2 and 3.

An AC source 53 is coupled across leads 54 and 55 with sine wave 56 depicting the waveform at this point. The normally centered armature 57 of switch 57' is movable to either contact 58 or 59. As can be seen, when armature 57 engages contact 58, a circuit will be completed through the primary 60 of transformer 61 which in turn will induce a voltage in the secondary 62. As will become more apparent hereafter, a charge will be placed on capacitor 65 in accordance with pattern 91. The magnitude of the charge depends on the length of time that armature 57 is held on contact 58. After armature 57 is released it will return to a neutral position, and capacitor 65 will retain a charge thereon. If it is desired to cause a lower voltage to be induced in the secondary 62, it is merely necessary to move armature 57 into engagement with contact 59 to complete a circuit to primary 60 through resistor 63.

The charge is placed on capacitor 65 through the following circuit. The output of secondary 62 is rectified by diodes 63 which are coupled to one side of secondary 62 by lead 64. Diodes 63 are coupled in series to prevent a reverse discharge thereacross after a charge is placed on capacitor 65, which is coupled in series with diodes 63 and secondary 62 through lead 65', armature 66 of slow acting relay 67, lead 68, choke coil 69, lead 70 and lead 71. At this point it is to be noted that lead 71 is grounded at 75 to the chassis of the apparatus through resistor 72, armature 73 of fast acting relay 74 and lead 75'.

Relay 74 is of the normally open type. Armature 73 of fast acting relay 74 is in engagement with contact 76 whenever there is a B⁺ voltage applied at terminal 77 of the control circuit of FIG. 3. This occurs whenever the apparatus is turned on through its master switch (not shown). Otherwise armature 73 is moved off of contact 76 and line 71 is not grounded. Whenever the B⁺ voltage is applied at terminal 77, there will be a flow of current through lead 46, the winding 47 of slow acting relay 67, lead 79, voltage drop resistor 80, lead 81, lead 82, coil 83 of fast acting relay 74, and lead 84 to ground. Because of the parameters of the circuit, relay 74 will be energized to move armature 73 to a closed position with contact or armature 76 to couple the circuit to chassis ground 75. However, there will be an insufficient flow of current through relay coil 47 to energize slow acting relay 67 and therefore armature 66 thereof will occupy the position shown in FIG. 2. There is also a small current flow from lead 81 through lead 85, diode 86, lead 87, resistor 88 and lead 89 to ground. However, there will be a delay before there is a build-up of voltage across capacitor 90,

which is coupled across leads 87 and 89, and it is only after voltage builds up on capacitor 90 that coil 83 will be energized.

The above described voltage which is applied to capacitor 65 is selectively discharged across the chest cavity of a patient to effect defibrillation. The waveform of the voltage applied to capacitor 65 approximates that shown at 91. Quantitatively, this voltage may be as high as 7,000 volts, or translated into energy, 400 joules. The magnitude of this voltage depends on the charging time through armature 57 and it can be read on meter 92 which is coupled across capacitor 65 through resistor 93. If for any reason it is desired to harmlessly discharge the voltage built up on capacitor 65, it is merely necessary to close switch 94 to thereby discharge capacitor 65 through resistor 95.

To apply the defibrillating charge to the patient, paddles 96 and 97 are electrically coupled to the opposite sides of the chest cavity of the patient by means of a suitable electrode jelly to establish good electrical contact. One paddle is mounted on the chest and the other paddle is mounted in opposition thereto on the back of the patient, with the heart being essentially located therebetween. Paddles 96 and 97 include a conductive plate 98 and 99, respectively, which are electrically connected to leads 71 and 100, respectively. The remainder of paddles 96 and 97 are made out of a suitable nonconductive plastic material to confine the electrical countershock. Paddles 96 and 97 are conveniently provided with insulating handles 101 and 102, respectively.

As noted above, the capacitor 65 which provides the defibrillating voltage discharge, is in a charged condition while relay armature 66 is in the position shown in FIG. 2. In order to cause capacitor 65 to discharge across paddles 96 and 97, armature 66 of slow acting relay 67 must move from contact 103 to contact 104. However, in the absence of opening the connection to chassis ground 75 when armature 66 engages contact 104, there is a possibility that a person in contact with the patient may form a leg of the circuit and thus receive an electrical shock. This would occur if he were grounded and touching either the patient or anything in electrical contact with him when the shock was being administered. The present circuit not only positively eliminates any possibility of such shock, but also causes the countershock, or defibrillating voltage, to be applied in perfectly synchronized relationship to the patient's heartbeat.

At this point it is to be noted that slow acting relay 67 is a high voltage vacuum relay wherein armature 66 is encased in a vacuum envelope and coil 47 is mounted in surrounding relationship to the envelope. This type of relay must be used to prevent arcing during the switching action. The fast acting relay 74 is also a high voltage vacuum relay of the type having an armature 73 within a vacuum envelope 73' and a relay coil surrounding the envelope.

In operation, the person administering the countershock closes switch 50 when he feels that countershock is necessary. Upon the closing of switch 50, both sides of fast acting relay coil 83 will be grounded, one side through lead 84 and the other side through leads 82, 81, resistor 80, lead 79, lead 48, silicon control rectifier 44, lead 49, switch 50 and lead 51. This grounding will occur only when silicon control rectifier 44 is conducting, and it does so only when a proper voltage is supplied thereto from the single shot multivibrator 29, shown in FIG. 1. In other words, the silicon control rectifier will conduct when the portion 32 of waveform 31 produced by the multivibrator 29 reaches a sufficient magnitude. It is approximately two milliseconds after this that the armature 73 will move out of engagement with contact 76, and this will disconnect the circuit from chassis ground 75.

This time sequence between the action of switch 50 and relay 74 is shown in FIG. 4 wherein waveform 108 shows the length of time that switch 50 is held closed, with portion 109 of waveform 108 indicating the time of

closing of switch 50. Portion 109' represents the time that multivibrator 29 triggers silicon control rectifier 44. Two milliseconds thereafter, armature 73 of fast acting relay 74 (FIG. 2) will move away from contact 76 as depicted by line 110 of waveform 111.

Contact between armature 73 and contact 76 must be broken to open the circuit to chassis ground 75 before armature 66 of slow acting relay 67 reaches contact 104 to thereby insure that the attendant cannot be subjected to the countershock voltage. Slow acting relay 67 requires approximately twenty milliseconds to reach contact 104 after leaving contact 103. When armature 66 reaches contact 104, capacitor 65, which has the countershock voltage stored thereon will discharge through choke coil 69, armature 66 and leads 100 and 71 across paddles 96 and 97, thereby establishing an electric circuit through the chest of the patient. The choke coil 69 causes the discharge to extend over a period of approximately two and one half milliseconds (.0025 second). The initiation of the discharge of capacitor 65 is indicated at portion 116 of waveform 117. Portion 116 occurs approximately twenty milliseconds after silicon control rectifier 44 is triggered, or approximately eighteen milliseconds after the deenergization of fast acting relay 74. The countershock voltage will be synchronized with the heartbeat and fall between the R and S waves, and therefore not in the vulnerable zone X.

The armature 66 of slow acting relay 67 will remain in engagement with contact 104 for as long as defibrillation switch 50 remains closed after contact is made because once the silicon control rectifier 44 has been triggered by waveform 31, it will continue to conduct. This is represented by the portion 118 of waveform 108 in FIG. 4. Capacitor 65 provides only a single discharge each time switch 50 is closed. In other words, the attendant may maintain the defibrillation switch 50 closed for as long as he desires but he will get only a single shot of defibrillating voltage. Another shot can be obtained only after the capacitor 65 is again charged up in the manner described in detail above.

After switch 50 has been released, it returns to the position shown in FIG. 3 and this time is depicted by portion 119 of waveform 108. The slow acting relay will therefore have armature 66 thereof move from contact 104 to contact 103 and this will take approximately twenty milliseconds, this delay being inherent in the relay. This occurs because the opening of switch 50 (FIG. 3) terminates the flow of current through slow acting relay coil 47.

However, it is important that the armature 73 of fast acting relay 77 does not return to contact 76 before armature 66 of slow acting relay 67 leaves contact 104, to insure that an undesired countershock cannot be applied to either the patient or the attendant through ground. The circuit containing capacitor 90 achieves this function. More specifically, after both sides of fast acting relay coil 83 were grounded by switch 50 incidental to initiating countershock, capacitor 90 also discharged across resistor 88. However, after switch 50 is opened, relay coil 83 will not be energized until after capacitor 90 becomes energized, and this takes a period of time depending on the time constant of the circuit consisting of capacitor 90 and resistor 80. This is shown in FIG. 4. As can be seen, the armature 66 of slow acting relay 67 returns to contact 103 at time 120, and as noted above, it takes approximately twenty milliseconds for the switching action to be completed. However, the switching action effected by fast acting relay 74 cannot be completed until time 121, which is greater than twenty milliseconds, because of the action of capacitor 90. This insures that the fast acting relay 74 will not close until after the armature 66 of slow acting relay 67 is no longer in contact with contact 104.

Summarizing, the heartbeat consists of the QRS complex and includes a vulnerable zone x. The single shot

multivibrator is triggered whenever portion R of the heartbeat reaches a predetermined value and relay coil 47 is thereafter energized to cause armature 66 of relay 67 to close onto contact 104 approximately twenty milliseconds after this portion of the heartbeat complex has triggered multivibrator 29. It is in this manner that the countershock or defibrillating voltage is applied in synchronization with the heartbeat, automatically and without the possibility of providing a shock to the medical attendant because the timing and switching circuit of the present invention automatically disconnects the circuit from chassis ground prior to the time that the defibrillating voltage is discharged onto the patient and does not again couple the circuit to chassis ground until after the countershock circuit cannot discharge.

The foregoing description was directed mainly to the application of a synchronized countershock in cases of arrhythmias having a pronounced pulse. However, the circuit of FIGS. 1 and 2, when modified, can also be used to apply countershock in cases of ventricular fibrillation where there is no pronounced pulse. This modified circuit is shown in FIG. 5. Except for the relocating of defibrillator switch 50' ahead of silicon control rectifier 44 and the coupling of terminal 108 to ground through leads 105 and 106 and switch 107, the remainder of the control circuit of FIG. 5 is the same as the control circuit of FIG. 3. More specifically, in cases of ventricular fibrillation, switch 107 is closed to ground both sides of silicon control rectifier 44. Thereafter, any time that countershock is required, assuming that a charge already exists on capacitor 65, it is merely necessary to close switch 50' across terminals 108 and 109' to discharge capacitor 65. The countershock is applied simultaneously with the closing of switch 50'. It is to be especially noted that any signal applied to silicon control rectifier 44 from lead 45 will under no circumstances be able to trigger the countershock discharge. It will be appreciated, of course, that when switch 107 is open, the circuit of FIG. 5 functions in an identical manner to that of FIG. 3, the only difference being in the physical location of the defibrillator switches 50 and 50'.

While the present switching and timing circuit has been specifically described with respect to cardiac apparatus, as used for defibrillation, it will be understood that the timing and switching circuit is capable of providing accurately gauged switching and timing in any predetermined sequence for use in other applications and this is achieved in a highly reliable, efficient and accurate manner. It will also be appreciated that the timing circuit can be utilized in general applications having a plurality of relays of the foregoing type with different actuation times to provide a positive sequence of switching actions which is not necessarily limited to two switching actions, but may comprise any desired number. Furthermore, it will be appreciated that by incorporating delay circuits with any of the relays, the opening or closing of fast acting relays may be delayed to cause them to open or close at a later time than slow acting relays, as described in detail above relative to relays 67 and 74.

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

I claim:

1. Cardiac apparatus for applying a countershock voltage to the chest of a cardiac patient comprising first circuit means for producing a countershock voltage, second circuit means for selectively coupling said first circuit means to the chest of said cardiac patient, third circuit means for grounding said first circuit means, first switch means for actuating said second circuit means to apply said countershock voltage to said patient, fourth circuit means including second switch means for removing said first circuit means from ground by opening said third circuit means in response to the actuation of said first

switch means to thereby prevent application of countershock voltage outside of said second circuit means, said first circuit means including a charging source and capacitor means coupled to said charging source for storing said countershock voltage thereon, and third switch means for effectively alternately coupling said capacitor means to said charging source during the producing of said countershock voltage by the charging of said capacitor means and coupling said capacitor means to said second circuit means for effecting the discharging thereof to apply said countershock voltage to the chest of said patient, said second switch means comprising a fast acting relay and said third switch means comprising a slow acting relay to thereby cause said first circuit means to be removed from ground prior to the time that said capacitor means are coupled to said second circuit means, said third circuit means also coupling said second circuit means to ground, and said opening of said third circuit means also disconnecting said second circuit means from ground.

2. Cardiac apparatus for applying a countershock voltage to the chest of a cardiac patient comprising first circuit means for producing a countershock voltage, second circuit means for selectively coupling said first circuit means to the chest of said cardiac patient, third circuit means for grounding said first circuit means, first switch means for actuating said second circuit means to apply said countershock voltage to said patient, fourth circuit means including second switch means for removing said first circuit means from ground by opening said third circuit means in response to the actuation of said first switch means to thereby prevent application of countershock voltage outside of said second circuit means, said first circuit means including a charging source and capacitor means coupled to said charging source for storing said countershock voltage thereon, third switch means for effectively alternately coupling said capacitor means to said charging source during the producing of said countershock voltage by the charging of said capacitor means and coupling said capacitor means to said second circuit means for effecting the discharging thereof to apply said countershock voltage to the chest of said patient, and a time delay circuit coupled to said second switch means for delaying the coupling of said first circuit means to ground until after said third switch means no longer completes said second circuit means.

3. Cardiac apparatus as set forth in claim 2 wherein said second switch means comprises a fast acting relay and wherein said third switch means comprises a slow acting relay to thereby cause said first circuit means to be removed from ground prior to the time that said capacitor means are coupled to said second circuit means.

4. Cardiac apparatus as set forth in claim 3 wherein said third switch means comprises a high voltage vacuum relay.

5. Cardiac apparatus as set forth in claim 4 wherein said second switch means comprises a high voltage vacuum relay.

6. Cardiac apparatus for applying a countershock voltage to the chest of a cardiac patient comprising first circuit means for producing a countershock voltage, second circuit means for selectively coupling said first circuit means to the chest of said cardiac patient, third circuit means for grounding said first circuit means, first switch means for actuating said second circuit means to apply said countershock voltage to said patient, fourth circuit means including second switch means for removing said first circuit means from ground by opening said third circuit means in response to the actuation of said first switch means to thereby prevent application of countershock voltage outside of said second circuit means, said first circuit means including a charging source and capacitor means coupled to said charging source for storing said countershock voltage thereon, third switch means for effectively alternately coupling said capacitor means to said charging source during the producing of said countershock voltage by the charging of said capacitor means

and coupling said capacitor means to said second circuit means for effecting the discharging thereof to apply said countershock voltage to the chest of said patient, said second switch means comprising a fast acting relay and said third switch means comprising a slow acting relay to thereby cause said first circuit means to be removed from ground prior to the time that said capacitor means are coupled to said second circuit means, means for sensing the heartbeat of a patient, and means for effectively coupling said capacitor means to said second circuit means in synchronized relationship to said heartbeat for effecting the discharge of said capacitor means to said patient in said synchronized relationship including said slow acting relay having inherent therein a predetermined time delay for moving between a first position wherein it couples said capacitor means to said first circuit means and a second position wherein it couples said capacitor means to said second circuit means to apply said countershock voltage, said third circuit means also coupling said second circuit means to ground, and said opening of said third circuit means also disconnecting said second circuit means from ground.

7. Cardiac apparatus for applying a countershock voltage to the chest of a cardiac patient comprising first circuit means for producing a countershock voltage, second circuit means for selectively coupling said first circuit means to the chest of said cardiac patient, third circuit means for grounding said first circuit means, first switch means for actuating said second circuit means to apply said countershock voltage to said patient, fourth circuit means including second switch means for removing said first circuit means from ground by opening said third circuit means in response to the actuation of said first switch means to thereby prevent application of countershock voltage outside of said second circuit means, said first circuit means including a charging source and capacitor means coupled to said charging source for storing said countershock voltage thereon, third switch means for effectively alternately coupling said capacitor means to said charging source during the producing of said countershock voltage by the charging of said capacitor means and coupling said capacitor means to said second circuit means for effecting the discharging thereof to apply said countershock voltage to the chest of said patient, means for sensing the heartbeat of said patient, fifth circuit means for effectively coupling said capacitor means to said second circuit means in synchronized relationship to said heartbeat for effecting the discharge of said capacitor means to said patient in said synchronized relationship, and a time delay circuit coupled to said second switch means for delaying the coupling of said first circuit means to ground until after said third switch means no longer completes said second circuit means.

8. Cardiac apparatus as set forth in claim 7 wherein said second switch means comprises a fast acting relay and wherein said third switch means comprises a slow acting relay to thereby cause said first circuit means to be removed from ground prior to the time that said capacitor means are coupled to said second circuit means.

9. A timing and switching circuit for providing a plurality of switching actions in a predetermined sequence comprising a source of current, fast acting high voltage vacuum relay means including a first coil and a first armature normally occupying a first position and movable to a second position, slow acting high voltage vacuum relay means including a second coil and a second armature normally occupying a third position and movable to a fourth position, first circuit means coupling said first and second coils, switch means in said first circuit means for selectively initiating and terminating the flow of current from said source to said first and second coils through said first circuit means to thereby cause said first armature of said fast acting relay to move from said first position to said second position in a first predetermined time and to cause said second armature of said slow acting relay to move from said third position to said fourth position in a second predetermined time which is greater than said first predetermined time when said switch means are actuated to thereby insure that the switching action produced by said first armature is completed before the switching action produced by said second armature, output means coupled to said second armatures and second circuit means coupled to said first coil of said fast acting relay means to delay movement of said first armature from said second position to said first position for a third predetermined time after said flow of current is terminated by said switch means with said third predetermined time being greater than the time required for said second armature to move away from said fourth position toward said third position and thereafter permit said first armature to move from said second position to said first position, to thereby insure that said slow acting relay means moves away from said fourth position toward said third position before said fast acting relay means completes its movement from its second position to its first position after the termination of flow of current by said switch means.

10. A timing and switching circuit as set forth in claim 9 wherein said second circuit means comprises a delay circuit having a high time constant for delaying the energization of said first coil upon the initiation of flow of current therethrough.

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WILLIAM E. KAMM, Primary Examiner

U.S. Cl. X.R.

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