

[54] DEFIBRILLATOR
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[51] Int. Cl. A61n 1/36
[58] Field of Search 128/419 D, 419 R

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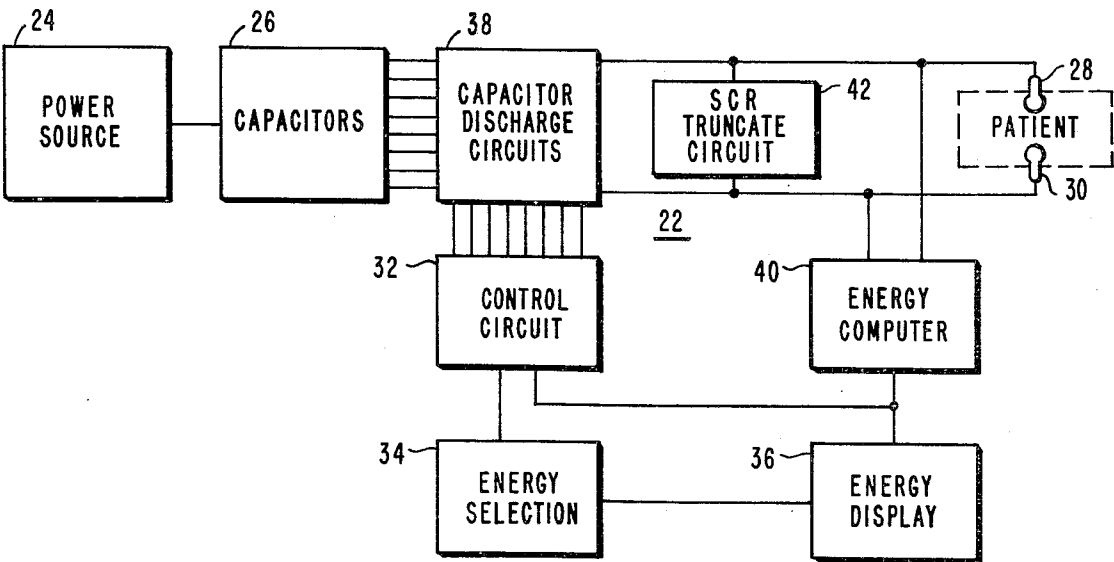
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[57] ABSTRACT

A defibrillator is disclosed which regulates the magnitude of a current pulse delivered to a patient in accordance with a selected value of current and which quickly terminates the current pulse when the measured energy delivered to the patient equals a selected value. Current regulation is accomplished by circuitry which compares current actually flowing through the patient with the selected value and which utilizes the results of such comparison to sequentially discharge a plurality of capacitors serially coupled to the patient electrodes. Further circuitry multiplies the current through the patient by the voltage measured across the patient to determine power with the resulting signal being integrated relative to time to indicate delivered energy. When the delivered energy equals the selected value of energy, the electrodes are shunted by circuitry which terminates the current pulse to the patient and which discharges all capacitors not already discharged.

12 Claims, 4 Drawing Figures



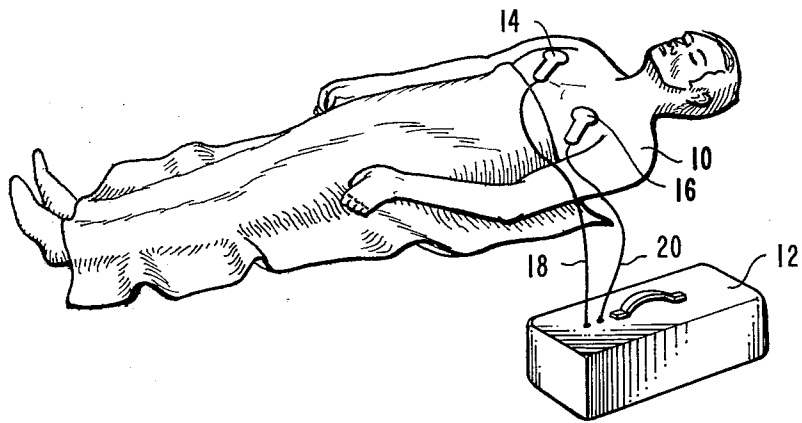


FIG.—1

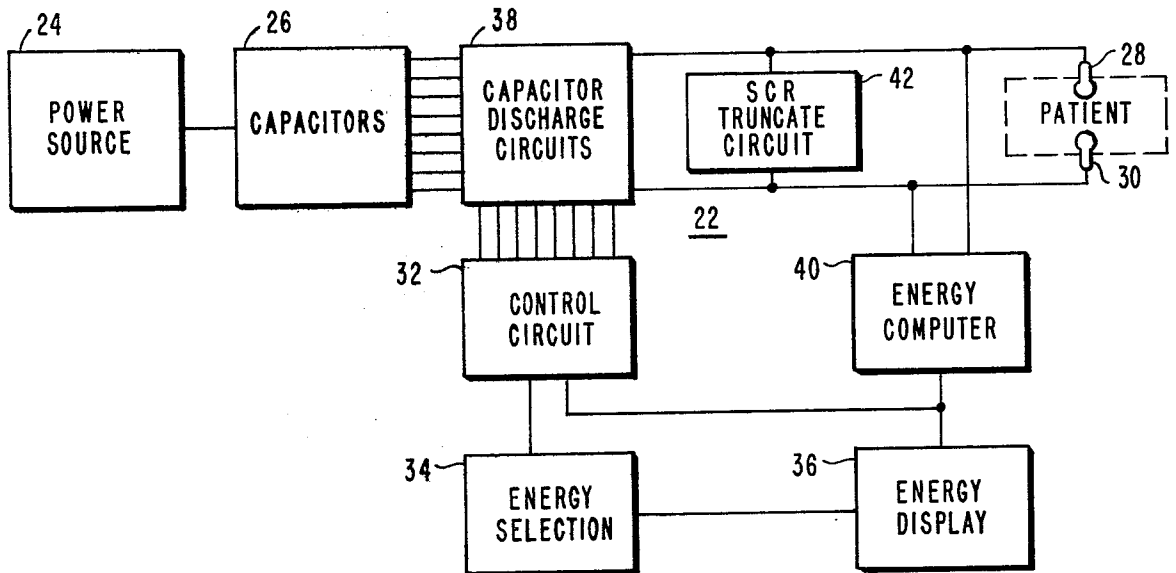


FIG.—2

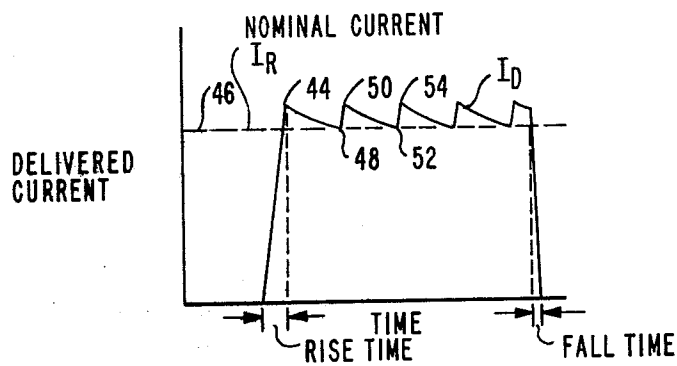


FIG.—3

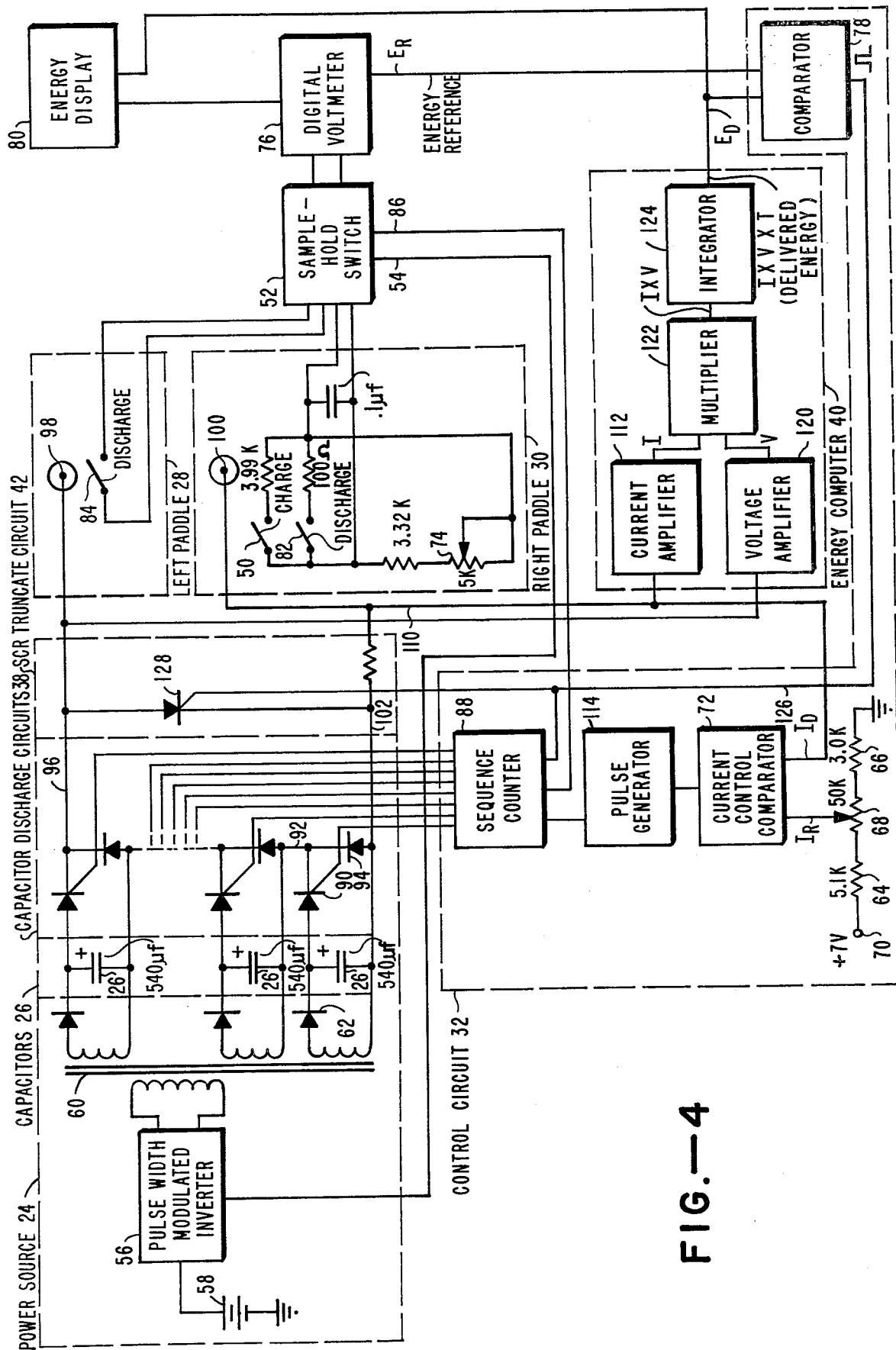


FIG.—4

DEFIBRILLATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to defibrillators of the type which apply a controlled amount of current to a patient to stop fibrillation of the patient's heart.

2. History of the Prior Art

The effects of electrical shocks on persons have been carefully studied. It has been found, for example, that shocks producing currents in the range of 2 to 50 milliamperes through the body will be felt as a tickling or other strange sensation but usually will not result in serious harm. On the other hand, currents through the body which are in the range of 50 milliamperes to 2 amperes often result in fibrillation of the person's heart. Currents greater than 2 amperes typically do not produce fibrillation, but may result in other bodily damage including eventual burning or destruction of the tissues if the current becomes too large.

Fibrillation is defined as an uncoordinated movement of the ventricular walls of the heart. It is typically caused by an electrical shock within the 50 milliampere to 2 ampere range as noted above, but also can result from a coronary heart attack. In fibrillation the blood circulation ceases, and death results if the condition is not treated promptly.

Much experimentation has been done in the area of stopping heart fibrillation. One technique which has been found to be generally successful involves the application of electrical shocks to the patient through a pair of electrodes contained within paddles. Research in this area has involved the use of a variety of different waveforms and amplitudes. While the shock or defibrillation signals of different waveforms and amplitudes have met with varying degrees of success in many instances, it has been found that a single current pulse of generally rectangular waveform is among the most successful of the shock signals used in this type of therapy, particularly if the magnitude of the current pulse is well above 2 amperes and on the order of 10 to 20 amperes. The current pulse must also have relatively short rise and fall times. The fall of the current pulse must be particularly rapid through the 2 ampere to 50 milliampere range. Otherwise fibrillation may again set in. Discussions of the involved problems and some of the current techniques are given in a number of articles including "Transthoracic Ventricular Defibrillation with Square-wave Stimuli: One-Half Cycle, One Cycle, and Multicycle Waveforms", Schuder, Stoeckle and Dolan, *Circulation Research*, September, 1964, pp. 258-264; "Transthoracic Ventricular Defibrillation In The Dog With Truncated And Untruncated Exponential Stimuli", Schuder, Stoeckle, West and Kesar, *IEEE TRANSACTIONS ON BIO-MEDICAL ENGINEERING*, Volume BME-18, Number 6, November, 1971, pp. 410-415; "Transthoracic Ventricular Defibrillation with Triangular and Trapezoidal Waveforms", Schuder, Rahmoeller and Stoeckle, *Circulation Research*, October, 1966, pp. 689-694; and "Transthoracic Ventricular defibrillation with a very high amplitude rectangular pulses", Schuder, Rahmoeller, Nellis, Stoeckle and MacKenzie, *J. Appl. Physiol.* 22⁽⁶⁾:1110-1114, 1967.

One common approach to the problem of generating a defibrillation current pulse has been to employ one or a plurality of capacitors which are initially charged to

a selected level. Where a single capacitor is employed the capacitor is thereafter discharged at the selected moment to provide a current pulse through the patient. Where plural capacitors are employed, such capacitors are typically discharged simultaneously so that the effects thereof may be summed together to provide desired levels of current and voltage. Defibrillators of this type are typically relatively large, heavy and expensive, not only because of the size of the capacitor or capacitors, but also because of the presence of a large choke and vacuum relay which are frequently employed in such devices.

Perhaps of even greater importance, however, is the fact that prior art defibrillators do not regulate delivered current. The discharge of a single capacitor or the simultaneous discharge of plural capacitors provides a current pulse to the patient, the peak amplitude of which varies in accordance with the resistance of the patient's body. Since patient resistance typically varies within a range of 30 to 150 ohms, it will be appreciated that the delivered current pulse can vary substantially from one patient to the next, and even in the case of the same patient where that patient's body resistance varies for one reason or another. Consequently the capacitors must be chosen, charged and discharged so as to deliver a current pulse of optimum shape to the patient when the patient's body resistance is within an average range. The practical result is that when the body resistance is above this range, the current pulse decays slowly, particularly within the 2 ampere to 50 milliampere danger zone inviting fibrillation to again set in. On the other hand, when the body resistance is too low, the current pulse decays rapidly but tends to oscillate within the 2 ampere to 50 milliampere range, again inviting fibrillation to set in.

As a result, defibrillators of the prior art typically produce a current pulse which is more rounded than rectangular in shape and which does not have a rapid decrease at the trailing edge. Such units typically make no effort to regulate the current or to control the duration of the current pulse in terms of delivering a selected amount of electrical energy to the patient.

Accordingly, it would be desirable to provide a defibrillator which generates current pulses of generally rectangular waveform having very short rise and fall times. It would furthermore be desirable to regulate the delivered current in accordance with sensings taken from actual body current. It would furthermore be advantageous to provide a defibrillator in which the duration of each current pulse may be selected to provide a desired amount of delivered energy to the patient.

BRIEF DESCRIPTION OF THE INVENTION

The present invention provides a defibrillator in which current pulses are regulated in accordance with actual current passing through the patient so as to maintain the current substantially at a selected nominal magnitude throughout the pulse. Measured voltage across the patient is used together with measured current through the patient to compute the electrical energy delivered to the patient by each current pulse. The value of delivered energy may be used to abruptly terminate the current pulse when a selected amount of energy has been delivered.

In accordance with one aspect of the invention, the defibrillator may comprise a plurality of capacitors coupled to be charged in parallel and discharged in se-

ries. Upon commencement of a discharge cycle, one or more but not all of the capacitors are simultaneously discharged to commence generation of a current pulse. Thereafter, actual current through the patient is monitored and compared with a desired current value. The results of the comparison are used to sequentially discharge remaining ones of the capacitors to maintain the delivered current substantially at the selected value. The system thus maintains a substantially constant delivered current through the patient independent of the patient's body resistance. Defibrillators having plural capacitors utilized in this fashion are relatively compact and lightweight as well as inexpensive so as to be ideally suited for portable applications.

Energy selection is accomplished by initially adjusting controls which provide a signal representing desired energy as well as a visual display of the desired energy for confirmation by the user. Upon generation of a current pulse, the current actually flowing through the patient as sensed is multiplied by the voltage across the patient to provide a representation of delivered power. The power representation is integrated with respect to time to provide a representation of delivered energy which is then compared with the energy reference or value initially selected. At the same time the visual display is used to provide a visual indication of delivered energy. When the comparison process determines that the desired amount of energy has been delivered, the patient electrodes are shunted to terminate the current pulse to the patient. At the same time, all capacitors not already discharged are discharged through the shunt path to insure against subsequent accidental discharge through the patient.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings, in which:

FIG. 1 illustrates use of a defibrillator in accordance with the invention in conjunction with a patient;

FIG. 2 is a basic block diagram of a defibrillator in accordance with the invention;

FIG. 3 is a diagrammatic plot of a current pulse produced by the defibrillator of FIG. 2; and

FIG. 4 is a detailed block and schematic diagram of the defibrillator of FIG. 2.

DETAILED DESCRIPTION

FIG. 1 illustrates a patient 10 whose heart is in fibrillation due to electrical shock, coronary or other common cause. A defibrillator 12 is used to pass current pulses of selected shape and size through the patient 10 using a pair of electrodes contained within a pair of paddles 14 and 16. The paddles 14 and 16 are respectively coupled by leads 18 and 20 to the defibrillator 12. The defibrillator 12 may have to be coupled to a separate power source such as by plugging it into an electrical wall receptacle, or it may contain its own power source, typically in the form of batteries.

Defibrillators are typically relatively large and heavy units which are best located in hospital emergency rooms and similar locations where they do not have to be moved about. However the present invention provides for defibrillators which are not only more effective than prior art units, but which can be made in very

small sizes and light weights. In particular, defibrillators according to the invention can be easily made into portable units which can be carried much like a suitcase or similar piece of equipment to the patient. Such portable defibrillators are ideally suited for use by emergency personnel and rescue squads which can easily carry the defibrillator to the scene of the accident or use it in an ambulance or other means of transporting the patient to a hospital or other medical facility.

FIG. 2 illustrates a preferred form of defibrillator 22 according to the invention. In the defibrillator 22, a power source 24 is coupled to charge a plurality of capacitors 26. Charging of the capacitors 26 is initiated by a control located in one of a pair of paddles 28 and 30 as described in conjunction with FIG. 4. The optimum magnitude of the current pulse to be delivered to the patient is selected by adjusting controls within a control circuit 32. At the same time the total energy to be delivered to the patient by each current pulse is selected via energy selection circuitry 34, the controls for which are located in one of the paddles 28 and 30 as described in conjunction with FIG. 4. The energy selection circuitry 34 is coupled to an energy display 36 which provides a visual indication of the amount of energy which has been selected. The energy selection circuitry 34 also provides a reference signal representing the desired amount of energy to the control circuit 32.

A discharge cycle is begun by actuating controls within the paddles 28 and 30, thereby causing one or more of the capacitors 26 to discharge through the patient. The number of capacitors chosen to initially discharge in this fashion is determined by the known characteristics of the unit as used with average patients. The number of capacitors initially discharged is selected so as to provide a voltage across the patient sufficient to quickly establish a current flow well above 10 amperes and typically on the order of 20 amperes through the patient. Thereafter the current delivered to the patient is regulated by the control circuit 32 and a plurality of capacitor discharge circuits 38 coupled to individual ones of the capacitors 26. The control circuit 32 does this by continually comparing the current actually flowing through the patient with the current reference initially set by the user. Whenever the delivered current decreases below the reference, the control circuit 32 causes one of the capacitor discharge circuits 38 to initiate discharge of one of the capacitors 26 through the patient. This typically results in a momentary increase in the delivered current above the reference value, followed by a decrease in the current as discharge of the capacitor proceeds. Each time the delivered current falls below the reference, a new one of the capacitors 26 is discharged by the control circuit 32 via the discharge circuits 38. Accordingly during the generation of a typical current pulse, one or two of the capacitors 26 are initially discharged to begin the pulse, following which a selected number of the remaining capacitors are sequentially discharged to maintain the magnitude of the current pulse through the patient at the reference level.

During generation of the current pulse, an energy computer 40 measures the voltage across the patient as well as the current flowing through the patient. The current and voltage are multiplied, then integrated to provide a representation of the energy actually delivered to the patient. The energy computer 40 is coupled to the display 36 to provide a visual display of delivered

energy. When the delivered energy equals the reference value chosen by the energy selection circuitry 34, the energy computer 40 causes the control circuit 32 and the associated capacitor discharge circuits 38 to initiate the discharge through the SCR truncate circuit 42 of all capacitors which have not already been discharged. This is a safety feature which prevents a subsequent accidental current pulse from being generated. At the same time the SCR truncate circuit 42 terminates the current pulse by shunting the paddles 28 and 30.

If another current pulse is necessary to defibrillate the patient's heart, the above-described process is repeated with the capacitors 26 being charged by the power source, the energy being selected via the selection circuitry 34 and the current being selected within the control circuit 32. Thereafter a discharge cycle is again initiated with the control circuit 32 and associated capacitor discharge circuits 38 acting to regulate the current actually flowing through the patient while the energy computer 40 monitors the delivered energy and initiates truncation and total capacitor discharge when the selected energy has been delivered.

A typical current pulse produced by the defibrillator 22 of FIG. 2 is illustrated in FIG. 3. When a discharge cycle is initiated by discharging one or two of the capacitors, the current through the patient rises to a peak 44 which is above the selected nominal or reference value represented by a dashed line 46. As shown in FIG. 3, this provides the current pulse with a very fast rise time, which is a highly desirable feature as previously noted. The selected capacitor or capacitors discharge causing the delivered current to decrease to a point 48 at which it equals the reference current selected within the control circuit 32. The control circuit 32 responds by causing one of the capacitor discharge circuits 38 to initiate discharge of one of the capacitors 26. This causes the delivered current to increase to a point 50 from which it again decreases to a point 52. The process is again repeated with the control circuit 32 causing discharge of another one of the capacitors 26 to increase the current to a point 54 from which it again decays. The process continues with the capacitors 26 being sequentially discharged to maintain the delivered current equal to or slightly above the reference or nominal value until the energy computer 40 and the control circuit 32 determine that the selected amount of energy has been delivered. As the SCR truncate circuit 42 is activated to shunt the paddles 28 and 30, the current drops very rapidly to zero. This provides a very short fall time which is an essential feature for successful operation as previously noted.

One preferred form of a defibrillator 22 in accordance with the invention is shown in detail in FIG. 4. In this particular arrangement, the right paddle 30 is provided with a switch 50, the closure of which completes a circuit through a sample-hold switch 52 and via a lead 54 to a pulse width modulated inverter 56 within the power source 24. The pulse width modulated inverter 56 functions to increase the voltage of the power supply in the form of a battery 58 at the primary side of a transformer 60. The transformer 60 has a plurality of different secondaries, each of which is associated with a different one of the capacitors 26. In the present example eight capacitors are used, although only three of the corresponding circuits are shown for simplicity of illustration. The parallel arrangement of the trans-

former secondaries provides for the simultaneous charging of the capacitors 26. In the present example, the capacitors are 540 microfarads in value and are charged to a voltage of approximately 450 volts each. A diode 62 within each capacitor circuit insures charging of the associated capacitor in a sense as shown in FIG. 4.

Current selection is carried out within the control circuit 32 by a circuit which comprises a pair of fixed resistors 64 and 66 and a variable resistor 68, all of which are coupled between a positive supply terminal 70 and ground. The wiper arm of the variable resistor 68 is used to provide a signal representing the desired or reference current I_R to a current control comparator 72.

Energy selection is accomplished by a variable resistor 74 forming a part of a circuit within the right paddle 30. The sample-hold switch 52 remains closed during the charging cycle, causing a digital voltmeter 76 to compute and store a signal representing the energy reference or selected energy E_R . The sample-hold switch 52 may comprise a circuit sold under the designation CD4016 by Radio Corporation of America. The digital voltmeter 76 provides the energy reference signal E_R to a comparator 78 within the control circuit 32 as well as to an energy display 80. The energy display 80 includes a plurality of light-emitting diodes arranged to provide a visual display of the energy selected via the right paddle 30.

A discharge cycle is commenced by simultaneously closing a pair of discharge switches 82 and 84 within the right and left paddles 30 and 28 respectively. This completes a circuit through the sample-hold switch 52 and via a lead 86 to a sequence counter 88 within the control circuit 32. The sample-hold switch 52 is opened and remains open during the discharge cycle. The sequence counter 88 which controls the discharge of the capacitors 26 via the discharge circuits 38 causes discharge of one or more of the capacitors 26 to begin the current pulse. Each of the capacitors is coupled by a different silicon controlled rectifier 90 to a common lead 92. The lead 92 includes a plurality of diodes 94 individually coupled in parallel with different ones of the capacitors 26. Firing of any one of the silicon controlled rectifiers 90 by the sequence counter 88 causes current from the associated capacitor 26 to flow to the common lead 92 where the diodes 94 force the current to flow upwardly as seen in FIG. 4 to a common lead 96. The lead 96 is coupled to an electrode 98 for connection to the patient via the left paddle 28. An electrode 100 within the right paddle 30 connects a different portion of the patient's body to a return lead 102.

Because of the particular arrangement of the capacitors 26 and the discharge circuits 38, the capacitors 26 are effectively coupled in series across the patient. If more than one capacitor is initially discharged by the sequence counter 88, the voltages of the discharged capacitors add together in serial fashion to provide a rapid rise of current to a value at least equal to the reference current I_R . In the present example, two of the eight capacitors 26 are typically discharged upon initiation of a discharge cycle to provide a suitable current pulse for most applications.

A lead 110 couples the electrode 100 to provide a representation of the actual delivered current or current flowing through the patient's body I_D to the current control comparator 72 within the control circuit 32 as well as to a current amplifier 112 within the energy

computer 40. The current control comparator 72 which may comprise a circuit sold under the numerical designation 5556 by Signetics Corporation compares I_D with I_R . If I_D becomes less than I_R , the comparator 72 initiates the generation of a pulse by a pulse generator 114 which may comprise a circuit sold under the designation CD4011 by Radio Corporation of America. The resulting pulse generated by the generator 114 causes the sequence counter 88 which may comprise a circuit sold under the designation CD4017 by Radio Corporation of America to sequence to the next step and cause discharge of one of the capacitors 26. Each time I_D starts to fall below I_R as determined by the comparator 72, a pulse is provided by the pulse generator 114 to step the sequence counter 88 to the next position and cause discharge of another one of the capacitors 26.

Accordingly, current delivered to the patient is completely independent of the patient's body resistance or variations thereof. The current actually delivered to the patient is monitored and is compared with a reference value to insure it is maintained at or slightly above the reference value through the sequential discharge of the capacitors 26.

As previously noted, a representation of the delivered current I_D is provided by the lead 110 to the current amplifier 112. At the same time, the actual voltage across the patient at the electrodes 98 and 100 is sensed, then amplified by a voltage amplifier 120. The voltage is amplified in the amplifier 120 to provide a voltage V to a multiplier 122. A current I as amplified by the current amplifier 112 in response to I_D is also provided to the multiplier 122. The multiplier 122 effectively multiplies I by V to provide a representation of the actual power delivered to the patient. This representation is integrated with respect to time in an integrator 124 to provide a representation of delivered energy E_D . The current amplifier 112, the voltage amplifier 120 and the multiplier 122 may together comprise a circuit sold under the designation MC1595 by Motorola Radio Corporation. The integrator 124 may comprise a circuit sold under the designation N5556 by Signetics Corporation. The signal representing the delivered energy E_D is applied to the comparator 78 as well as to the energy display 80 to provide a visual display of the energy actually being delivered to the patient.

The comparator 78 which may comprise a circuit sold under the numerical designation 5556 by Signetics Corporation compares the delivered energy E_D with the selected or reference energy E_R . When E_D becomes equal to E_R , indicating that the desired amount of energy has been delivered, the comparator 78 provides a pulse via a lead 126 to the sequence counter 88 and to a silicon controlled rectifier 128 comprising the SCR truncate circuit 42. The pulse fires the silicon-controlled rectifier 128 to provide a temporary shunt path bypassing the patient. This rapidly terminates the current pulse as seen in FIG. 3. At the same time, the pulse from the comparator 78 causes the sequence counter 88 to sequence through all remaining positions so as to discharge all of the capacitors 26 not yet discharged. This is a safety feature which prevents inadvertent delivery of an unwanted current pulse to a patient at a later time.

Accordingly, the energy computer 40 responds to the actual delivered current and voltage at the patient and computes the delivered energy E_D during each current pulse. The control circuit 32 and the SCR truncate cir-

cuit 42 in turn respond when E_D is equal to the desired energy E_R by truncating or shunting the current pulse away from the patient while at the same time insuring that all capacitors are discharged.

It has been found that when a nominal current I_R of approximately 20 amperes is selected, the duration of the current pulse is typically on the order of about 10 milliseconds so as to supply an amount of energy typically selected. The particular circuit of FIG. 4 has been found to provide a rise time in the current pulse in the order of 100 microseconds and a fall time on the order of 10 microseconds.

Use of plural capacitors in accordance with the invention provides for a defibrillator which is very compact and light in weight. A portable defibrillator utilizing the circuit of FIG. 4 weighs approximately 15 pounds compared with weights on the order of 30 pounds and greater in most prior art defibrillators. In the particular circuit of FIG. 4, the delivered energy is continuously adjustable up to 300 watt-seconds, the delivered current is made adjustable up to 40 amperes so as to maintain a constant current independent of the patient's skin impedance over a range of 30 to 120 ohms, and a peak delivered voltage of 3 kilovolts is made available. The 10 D size batteries used will last through at least 50 different 300 watt-second discharges before requiring recharging.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A defibrillator for delivering electrical current to a plurality of patient electrodes comprising:
 - a plurality of electrodes;
 - a plurality of capacitors coupled to the electrodes;
 - means coupled to the capacitors and including a power source for charging the capacitors;
 - means coupled to the capacitors for initiating discharge of at least one of the capacitors to initiate generation of a current pulse; and
 - means coupled to the capacitors and responsive to the initiating of discharge of at least one of the capacitors for subsequently discharging at least one other capacitor during the discharge of said at least one of the capacitors to continue the generation of the current pulse.
2. The invention defined in claim 1, wherein the means for subsequently discharging at least one other capacitor during the discharge cycle comprises means for initiating discharge of said at least one other capacitor when the magnitude of the current pulse as provided by discharge of said at least one of the capacitors decreases to a predetermined minimum value.
3. The invention defined in claim 1, further including means for monitoring delivered electrical energy at the electrodes, a shunt lead coupled in parallel with the electrodes and means coupled to the monitoring means for discharging all capacitors not already discharged through the shunt lead whenever the delivered electrical energy reaches a selected value.
4. A defibrillator for delivering electrical current to a plurality of patient electrodes comprising:
 - a plurality of electrodes;
 - a plurality of capacitors coupled to the electrodes;

means coupled to the capacitors including a power source for charging the capacitors;
 means coupled to the capacitors for initiating discharge of at least one of the capacitors to initiate a discharge cycle;
 means coupled to the capacitors and responsive to the initiating of a discharge cycle and the initiating of discharge of at least one of the capacitors for subsequently discharging at least one of the capacitors during the discharge cycle to provide a controlled amount of electrical current to the electrodes;
 means for monitoring electrical current at the electrodes;
 means for providing a reference;
 and means for comparing the monitored electrical current with the reference to provide a current deficiency signal, the means for subsequently discharging at least one other capacitor during the discharge cycle performing discharge of at least one other capacitor in response to the current deficiency signal.

5. A defibrillator comprising:
 chargeable means;
 means for selectively charging the chargeable means;
 means for selectively initiating discharge of the chargeable means to provide a current to a patient;
 means for measuring current flowing through the patient;
 means for providing a reference signal representing a desired value of current through the patient;
 means responsive to the measured current flowing through the patient and to the reference signal for generating a control signal representing differences between the measured current flowing through the patient and the reference signal; and
 means responsive to the control signal for controlling discharge of the chargeable means in accordance with the control signal to regulate the current flowing through the patient.

6. The invention defined in claim 5, wherein the chargeable means comprises a plurality of capacitors and the means for controlling discharge comprises means responsive to the control signal for generating pulses representing the difference between the measured current flowing through the patient and the reference signal and means responsive to the generated pulses for sequentially discharging the capacitors in accordance with the number of pulses generated.

7. A defibrillator for delivering current pulses to a patient via a pair of electrodes comprising:
 a pair of electrodes;
 a plurality of capacitors coupled to the electrodes;
 means for selectively charging the capacitors;
 means for discharging at least one capacitor to initiate the delivery of a current pulse to the patient;
 means for measuring the magnitude of the current pulse delivered to the patient;
 means for providing a desired value of current magni-

tude;
 means for comparing the measured magnitude of the current pulse with the desired value of current magnitude to provide a current error signal representing the difference therebetween;
 means responsive to the current error signal and coupled to the capacitors for selectively discharging the capacitors in accordance with the value of the current error signal to maintain the magnitude of the current pulse substantially equal to the desired value of current magnitude;
 means for measuring the electrical energy delivered to the patient via the current pulse;
 means for comparing the measured electrical energy with the desired value of energy to provide a pulse termination signal whenever the measured electrical energy is substantially equal to the desired value of energy; and
 means responsive to the pulse termination signal for terminating the current pulse at the electrodes.

8. The invention defined in claim 7, wherein the means for selectively discharging the capacitors includes a plurality of silicon controlled rectifiers, means for coupling each of the silicon controlled rectifiers between a different one of the capacitors and one of the electrodes, and means for selectively gating each of the silicon controlled rectifiers.

9. The invention defined in claim 8, further including a plurality of serially coupled diodes coupled between the electrodes, and wherein each of the capacitors is coupled in parallel with a different one of the plurality of serially coupled diodes and the means for selectively discharging the capacitors includes a plurality of silicon controlled rectifiers, each of the silicon controlled rectifiers being coupled between a different one of the capacitors and an associated one of the diodes, and means coupled to selectively bias the silicon controlled rectifiers into conduction in response to the current error signal.

10. The invention defined in claim 7, wherein the means for selectively discharging the capacitors includes means for generating a plurality of discharge signals, the number of which is dependent upon the value of the current error signal, and means responsive to the discharge signals for discharging a different capacitor in response to each separate discharge signal.

11. The invention defined in claim 7, wherein the means for measuring the electrical energy delivered to the patient includes means for measuring the voltage across the electrodes, means responsive to the measured voltage and the measured current for computing measured power, and means responsive to the measured power for computing measured energy.

12. The invention defined in claim 7, further including means responsive to the desired value of energy for providing a visual display thereof, said visual display means also being responsive to the measured electrical energy for providing a visual display thereof.

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