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Bell et al.

[11] **3,860,009**

[45] **Jan. 14, 1975**

[54] **COMPUTER CONTROLLED DEFIBRILLATOR**

[76] Inventors: **David Bell,** 1804 N. 111th St.; **William K. Hagan,** 12418 Leavenworth St., both of Omaha, Nebr. 68154

[22] Filed: **Mar. 13, 1974**

[21] Appl. No.: **450,792**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 420,291, Nov. 29, 1973, , which is a continuation-in-part of Ser. No. 219,455, Jan. 20, 1972, Pat. No. 3,782,389.

[52] **U.S. Cl.** ..... **128/419 D**

[51] **Int. Cl.** **A61n 1/36**

[58] **Field of Search** ..... 128/419 D, 419 R, 419 P, 128/421, 422, 423, 2.1 Z

[56] **References Cited**

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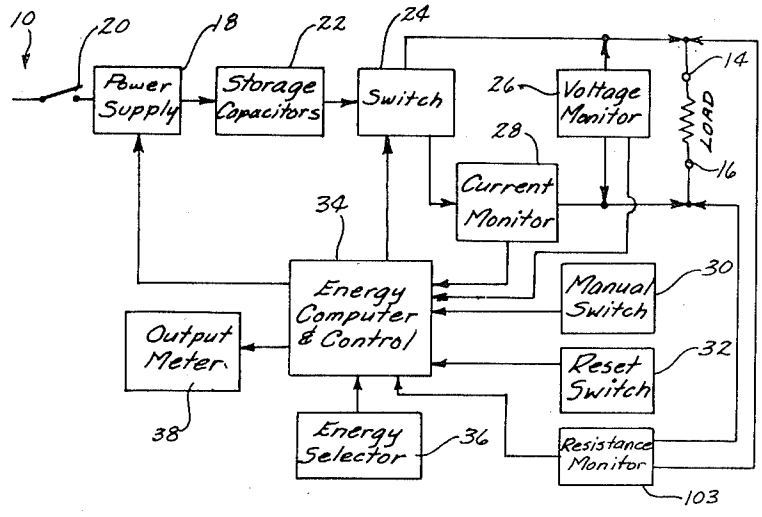
Primary Examiner—William E. Kamm

Attorney, Agent, or Firm—Zarley, McKee, Thomte & Voorhees

[57] **ABSTRACT**

A computer controlled defibrillator comprising a set of electrodes which are engageable with a patient and which are connected to a source of electrical energy by a circuit means. The circuit means comprises storage capacitors, energy selector, computer, manual and reset switches, voltage monitor, current monitor, and output meter. The computer responds to certain external inputs, automatic and manual, and controls the output delivered to the patient. The energy selector permits the selection of the energy which is desired to be delivered to the patient. The sequence is started by closing the manual reset switch which zeroes the output meter and activates the power supply (electrical energy) at a voltage which is dependent on the energy selector. The energy derived from the power supply is stored in the storage capacitors. The energy selector, which is manually set to the energy desired, also feeds an input to the computer. When the manual switch is activated, the computer causes the stored energy source to be connected to the patient through the electrodes. The current monitor and voltage monitor feed instantaneous signals to the computer which computes the energy as a continuous integration process. When the computed energy equals the selected energy, the computer causes the energy source to be disconnected from the patient. The total energy delivered to the patient is indicated as a steady reading on the output meter. A modified form of the defibrillator is also disclosed wherein the magnitude of current in the electrical circuit means may be manually or automatically selected to enable the defibrillator to compensate for the patient's body weight or body resistance.

3 Claims, 9 Drawing Figures



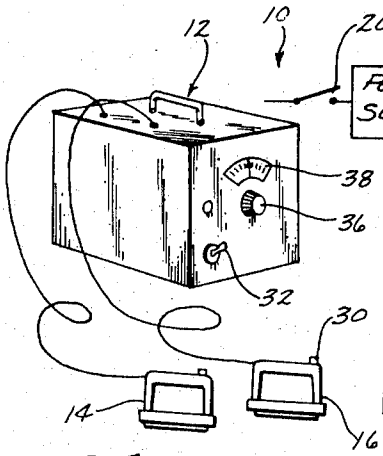


Fig. 1

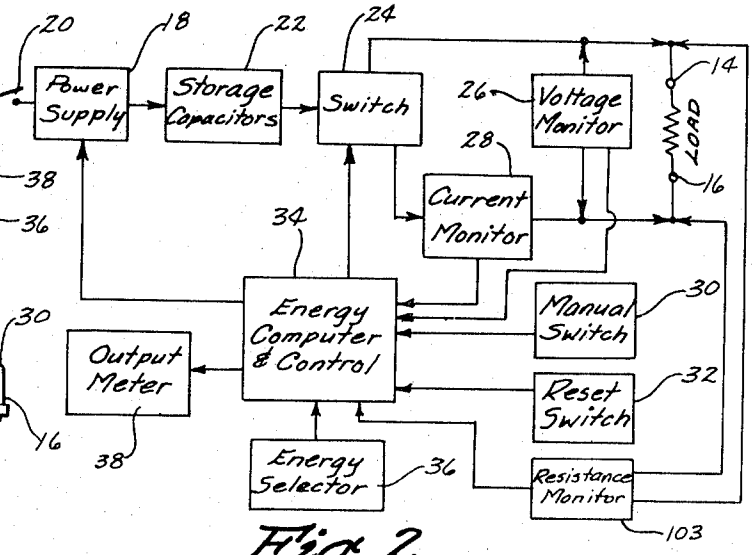


Fig. 2

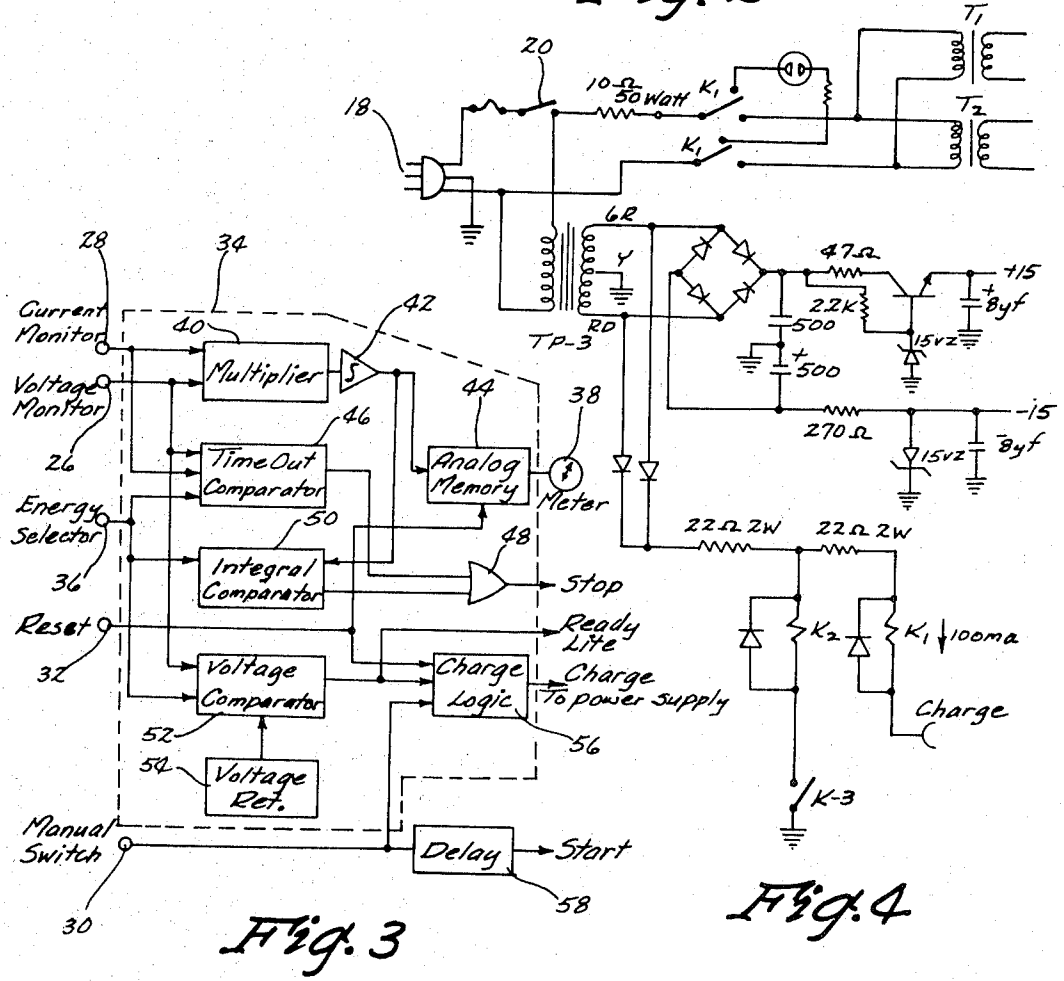


Fig. 3

Fig. 4

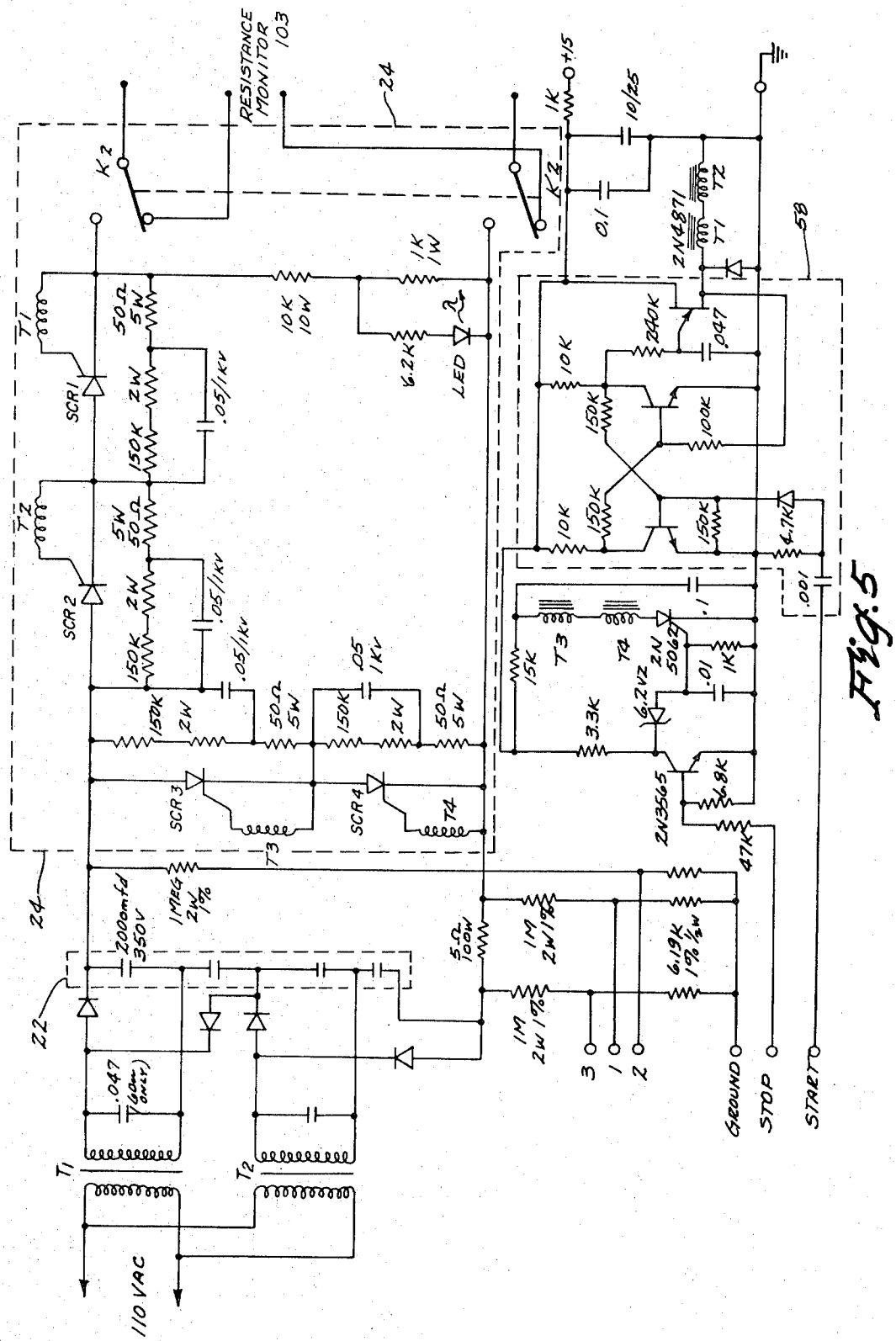

RESISTANCE MONITOR 103
24
K2
K2
1K +15
10/25
0.1
2N4871
T1
T2
58
1K 1W
10K 10W
6.2K
LED
T1
50Ω 5W
2W
150K
.05/1Kv
SCR1
T2
5W 50Ω
2W
150K
.05/1Kv
SCR2
.05/1Kv
.05 1Kv
150K 2W
50Ω 5W
150K 2W
50Ω 5W
SCR3
SCR4
T4
T3
24
200mfd 350v
1 MEG 2W 5%
22
.047 (600 ohms)
T1
T2
110 VAC
5Ω 100W
1M 2W 1%
1M 2W 1%
6.19K 1% ½W
47K
3
1
2
GROUND
STOP
START
240K
.047
10K
150K
100K
10K
150K
150K
4.7K
.001
.1
T3
T4
2N5062
15K
.01
1K
6.2V2
33K
2N3565
6.8K

Fig. 5

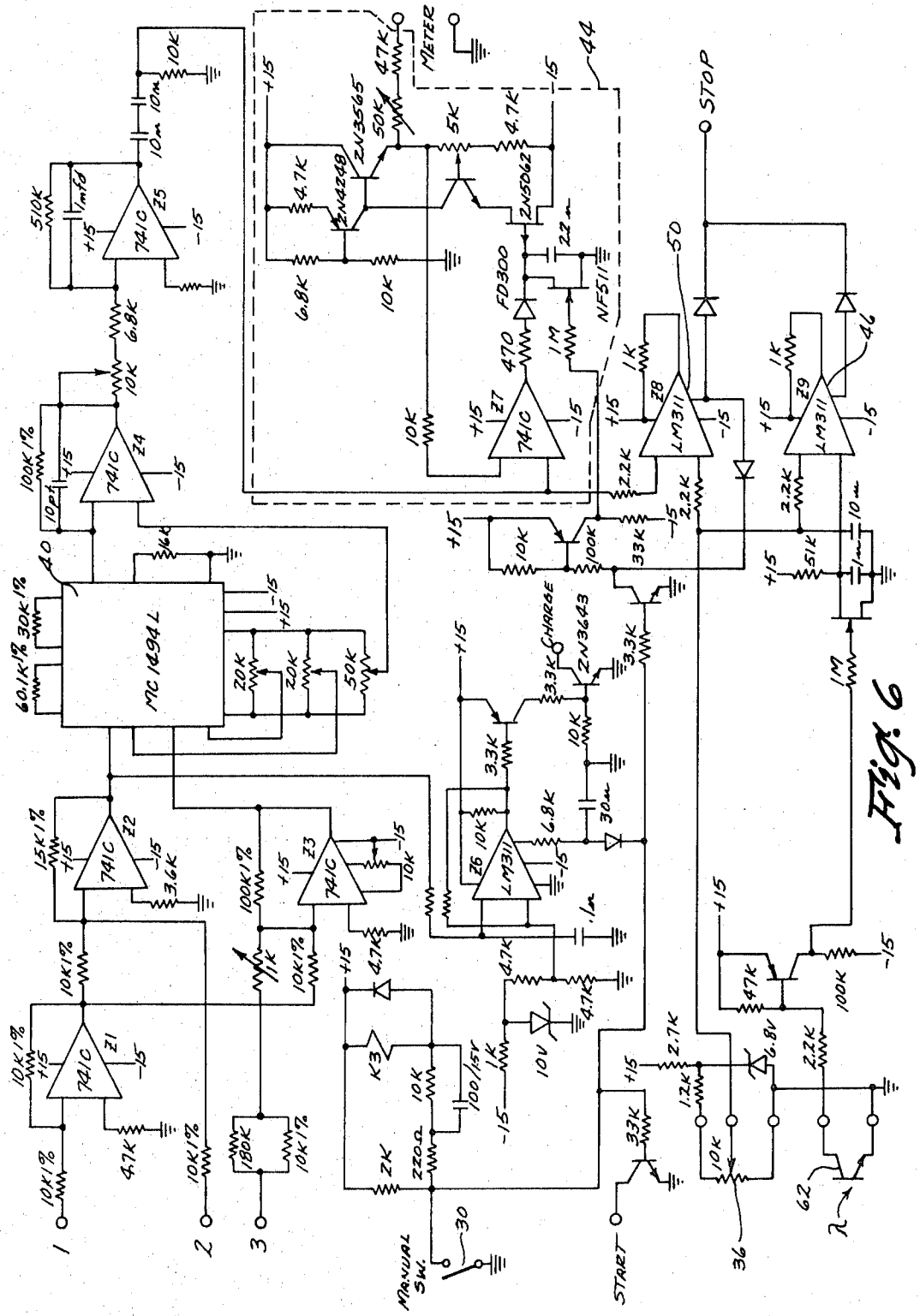

MC 14941
METER
STOP
START
MANUAL SW.
CHARGE
LM311
741C
2N3565
2N4249
2N5062
FD300
NF511
2N3643
10V
6.8V

Fig. 6

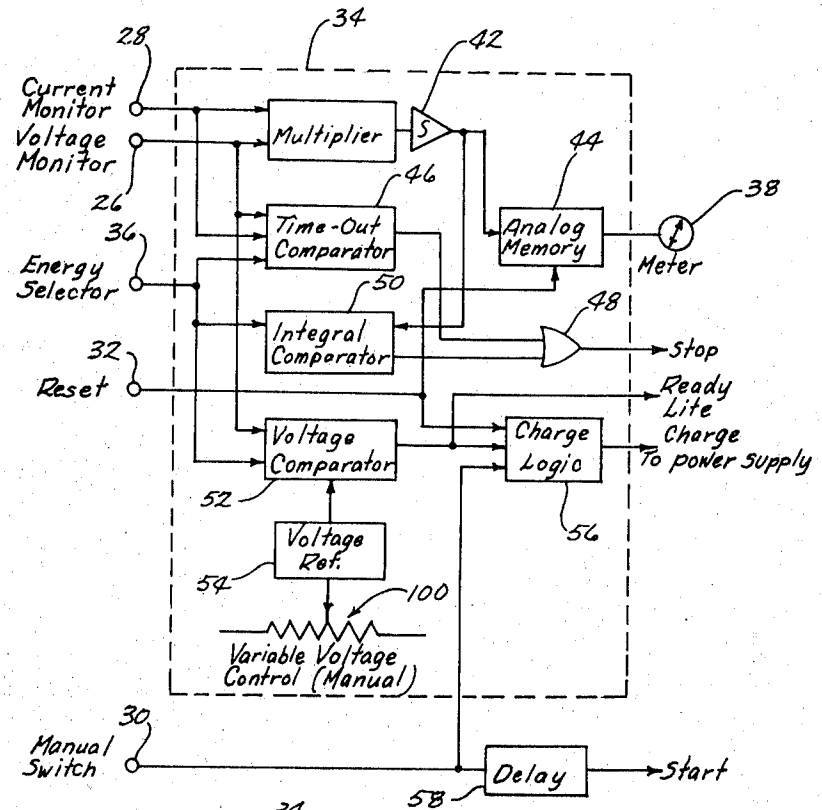

34
28
42
Current Monitor
Voltage Monitor
26
Multiplier
S
44
46
38
Time-Out Comparator
Analog Memory
Meter
36
Energy Selector
50
48
Integral Comparator
Stop
32
Reset
Ready Lite
Charge To power supply
Voltage Comparator
Charge Logic
52
56
Voltage Ref.
54
100
Variable Voltage Control (Manual)
30
Manual Switch
Delay
Start
58

Fig. 7

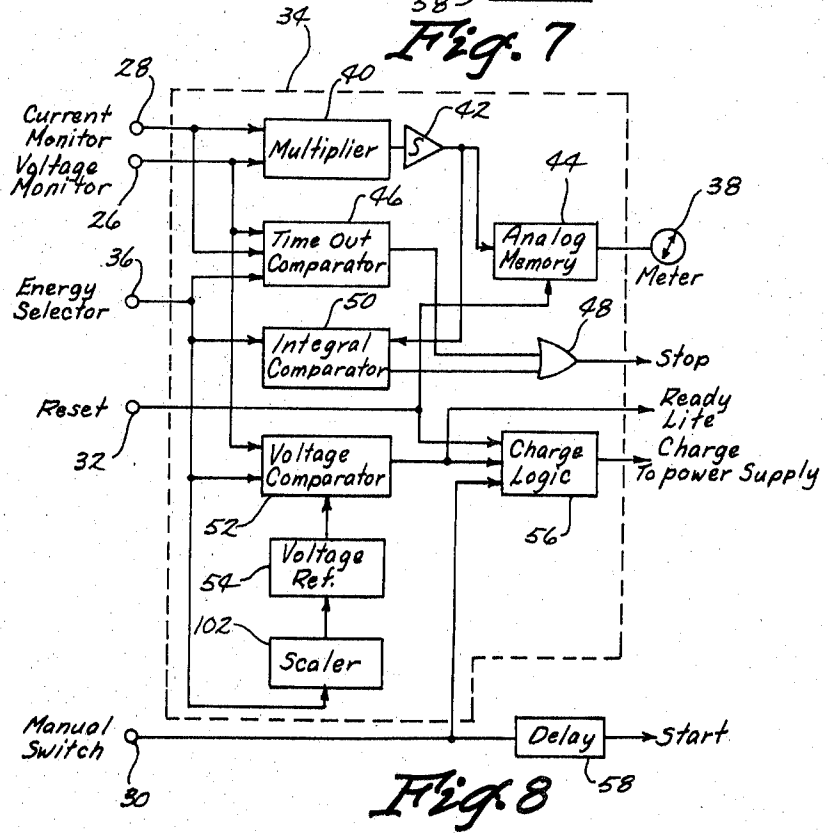

34
28
40
42
Current Monitor
Voltage Monitor
26
Multiplier
S
44
46
38
Time Out Comparator
Analog Memory
Meter
36
Energy Selector
50
48
Integral Comparator
Stop
Reset
32
Ready Lite
Charge To power Supply
Voltage Comparator
Charge Logic
52
56
Voltage Ref.
54
102
Scaler
Manual Switch
30
Delay
Start
58

Fig. 8

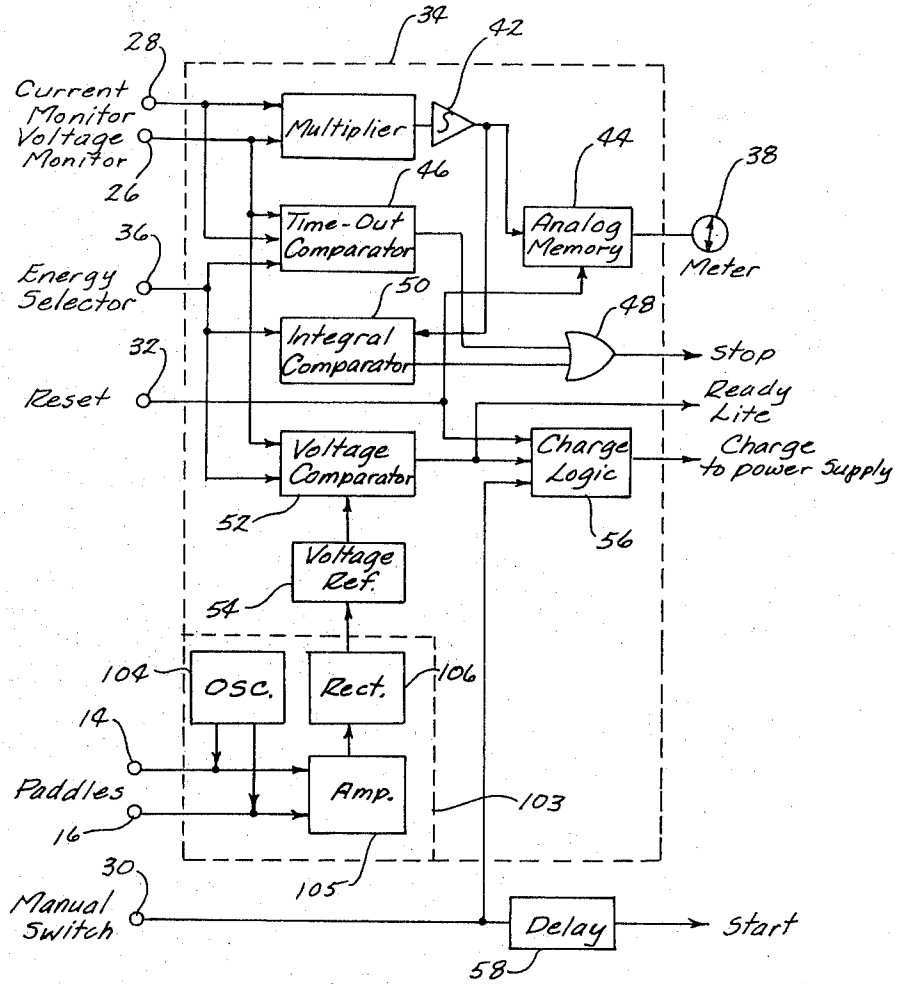

34
42
28
Current Monitor
Voltage Monitor
26
Multiplier
5
44
38
46
Time-Out Comparator
Analog Memory
Meter
36
Energy Selector
50
48
Integral Comparator
Stop
32
Reset
Ready Lite
Voltage Comparator
Charge Logic
Charge to power supply
52
56
Voltage Ref.
54
104
OSC.
Rect.
106
14
Paddles
Amp.
103
16
105
30
Manual Switch
Delay
Start
58

Fig. 9

COMPUTER CONTROLLED DEFIBRILLATOR

BACKGROUND OF THE INVENTION

This application is a continuation-in-part application of the application Ser. No. 420,291 filed Nov. 29, 1973 which was a continuation-in-part application of the application Ser. No. 219,455 filed Jan. 20, 1972, now U.S. Pat. No. 3,782,389.

The use of DC defibrillators in emergency resuscitation has become well established. Limitations due to weight have prevented more widespread use of the defibrillators. Most clinical defibrillators depend on the storage and discharge of energy through a stable RLC combination, thus requiring accurate capacitance, inductance and resistance. The conventional defibrillators employ a pair of electrodes or paddles which are placed in contact with the patient's chest. A defibrillation or electrical pulse is then applied to the patient, through the electrodes, to momentarily stop the heart so that fibrillation of the heart is stopped. Since time is critical in defibrillation techniques, it is extremely important that a sufficiently large impulse be applied to the patient during the first attempt. A majority of the prior art devices employ some means for selecting the energy to be delivered to the patient. However, it has been found that these devices generally deliver a smaller or lower output to the patient than that which was selected. A further complication is that the resistance of the patients vary greatly. Thus, the operator could possibly determine that it was necessary to apply an impulse of 200 joules to the patient. Quite often, the variances in the defibrillator and the variable resistance of the patient will result in considerably less than 200 joules being applied to the patient. If the pulse is insufficient to momentarily stop the patient's heart, the patient could possibly die.

Research has indicated that there is a possible correlation between the body weight or body resistance of the patient and the electrical current (energy doses necessary to defibrillate a fibrillating heart). In applicant's previous defibrillator, the amount of energy delivered to the patient was measured and used as a control to insure that the delivered energy is equal to the energy selected to be delivered. In applicant's previous defibrillator, the amount of current was not controlled but fixed.

Therefore, it is a principal object of this invention to provide an improved defibrillator.

A further object of this invention is to provide a defibrillator wherein the energy delivered to the patient substantially equals the selected energy.

A further object of this invention is to provide a defibrillator including a circuit means having an energy computer and control which computes the energy delivered to the patient and causes the energy source to be disconnected from the patient when the computed energy substantially equals the selected energy.

A further object of this invention is to provide a defibrillator which delivers the selected energy to the patient regardless of the resistance of the patient.

A further object of this invention is to provide a defibrillator including a resistance monitor which measures the body resistance of the patient and automatically selects the current amplitude of the energy delivered to the patient.

A further object of the invention is to provide a defibrillator wherein the magnitude of current can be manually or automatically selected.

A further object of the invention is to provide a defibrillator having means for manually or automatically selecting the magnitude of current responsive to the patient's body weight or body resistance.

A further object of the invention is to provide a method of defibrillating a fibrillating heart.

A further object of this invention is to provide a defibrillator which is economical of manufacture, durable in use and refined in appearance.

These and other objects will be apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of the defibrillator of this invention:

FIG. **2** is a block diagram of the electrical circuitry of the defibrilltor:

FIG. **3** is a block diagram illustrating the components of the energy computer and control and its relationship with other components of the device:

FIG. **4** is a schematic view of a portion of the circuitry of the invention:

FIG. **5** is a schematic view of more of the circuitry of the invention:

FIG. **6** is a schematic view of more of the electrical circuitry of the invention:

FIG. **7** is a block diagram similar to FIG. **3** except that the means for manually controlling the magnitude of current in the circuit means is illustrated:

FIG. **8** is a block diagram similar to FIGS. **3** and **7** except that an automatic means is disclosed for controlling the magnitude of current in the electrical circuit means; and

FIG. **9** is a block diagram similar to FIGS. **7** and **8** except that a resistance monitor is shown.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With respect to FIGS. **1 – 6,** the defibrillator of this invention is referred to generally by the reference numeral **10** and comprises a portable housing **12** having a pair of electrodes or paddles **14** and **16** connected to the circuitry therein as will be described in more detail hereinafter. The electrodes or paddles **14** and **16** are engageable with the patient to deliver a predetermined energy output to the patient to momentarily stop the patient's heart so that fibrillation of the heart is stopped.

The circuitry of the defibrillator is depicted in schematic form in FIG. **2** wherein the numeral **18** refers to a 110 VAC power supply having a switch **20** associated therewith. The power supply **18** is electrically connected to the storage capacitors **22** which are adapted to store energy derived from the power supply **18.** A "switch" mechanism **24** is connected to the storage capacitors **22.** Mechanism **24** is connected to the electrodes **14** and **16** as seen in FIG. **2** and to voltage monitor means **26** and current monitor means **28.** Manual switch **30** and reset switch **32** are connected to the energy computer and control means **34** as is the output meter **38.** Energy selector **36** may be comprised of a conventional rotatable dial or the like for setting the energy to be delivered to the patient.

The energy computer and control means **34** is illustrated in schematic form in FIG. **3.** In FIG. **3,** it can be seen that the current monitor **28** and voltage monitor **26** are electrically connected to the Multiplier **40** and that the Multiplier **40** is connected to an Integrator **42.** Integrator **42** is connected to an Analog Memory **44** which is connected to the meter **38.** The current monitor **28** and the voltage monitor **26** are also connected to a Time Out Comparator **46** which is connected to the OR gate **48.** The energy selector **36** is connected to the Time Out Comparator **46,** Integral Comparator **50** and Voltage Comparator **52.** The Integral Comparator **50** is connected to the OR gate **48** and to the Integrator **42** as depicted in FIG. **3.** Voltage Comparator **52** is connected to the Voltage Reference **54** and to the Charge Logic **56.** The Multiplier **40** is also connected to the Voltage Comparator **52.**

The reset switch **32** is electrically connected to the Analog Memory **44** and to the Charge Logic **56** which the manual switch **30** is connected to the Delay-Start **58** and to the Charge Logic **56.**

The heart of the control mechanism in the defibrillator is the energy computer and control **34** which responds to certain external inputs, manual and automatic, and controls the output delivered to the patient. In operation, the manual reset **32** starts the sequence by zeroing the output meter **38** and activating the power supply **18** at a voltage which is dependent on the energy selector **36.** Thus, if it were desired to deliver an impulse of 200 joules to the patient, the energy selector **36** would be set at 200 joules. The energy derived from the power supply **18** is stored in the storage capacitors **22.** The energy selector **36,** which is manually set to the energy desired, also feeds an input to the energy computer and control **34.** The electrodes or paddles **14** and **16** are then placed into contact with the patient and the manual switch **30,** located on either or both of the paddles **14** and **16,** is activated.

When the manual switch **30** is activated, the energy computer and control **34** causes the stored energy source to be connected to the patient. The current monitor **28** and voltage monitor **26** feed instantaneous signals to the energy computer and control **34** which computes the energy as a continuous integration process. When the computed energy equals the selected energy, the energy computer and control **34** causes the energy source to be disconnected from the patient. The total energy delivered to the patient is indicated as a steady reading on the output meter **38.**

More specifically, the circuitry of FIGS. **4, 5** and **6** operates as follows. The circuit of FIG. **4** is basically the power supply for the device. TP3 transformer feeds a full wave bridge rectifier to generate plus and minus DC voltage. The transistor and zener diodes regulate the DC to ± 15 v. and are of conventional design. The second set of diodes leading to the coils of K1 and K2 supply power to operate these relays. Contact K3 operates coil K2. K2 operates the contacts on FIG. **5.** K3 is operated off the control circuit illustrated in FIG. **6.** These devices, K2 and K3, control the main discharge from the firing circuit to the patient. K2 connects the patient to the measuring circuit during the time that the defibrillator is not being fired.

K1 which is controlled by the voltage comparator **52** and charge logic **56** switches **110** VAC to transformers T1 and T2. This circuit supplies power to the capacitor bank **22** in FIG. **5** as required to maintain 1,400 VDC.

The four rectifiers between T1 and T2 in FIG. **4** and the four capacitors **22** in FIG. **5** form two full wave voltage double circuits in cascade to generate 1,400 v. About 500 joules of energy are then stored in the capacitor bank. Initially all four silicone controlled rectifiers SCR are not conducting. The 150 K resistors around the SCRs are used to balance the off leakage current. The 0.05 mfd– 50 ohm networks around each SCR are to suppress switching transcients.

Terminals **1, 2** and **3** are the monitor points. The voltage between **1** and **2** is proportional to the stored voltage and the voltage to the load. The voltage between **1** and **3** is proportional to the current in the load. The 5 ohm, 100 watt resistor serves the dual function of current shunt and crow-bar protection.

The remainder of this circuit can be best explained by a typical operating sequence. Initially the capacitors are charged and all SCRs are off. The cycle starts with the start input going to a positive 15 v. This starts the 0.030 sec. timer **58.** At the same time K2 relay begins to close. The timer delay is to allow K2 to close completely. When the unijunction transistor in the timer fires, a large current pulse is fed to trigger transformers T1 and T2. These pulses turn on SCR **1** and **2** applying power to the load. The LED is turned on by the applied voltage and is optically coupled to the photo transistor in FIG. **6.** This transistor starts timeout comparator Z9. When the comparator circuit determines the required energy has been delivered, a positive voltage is applied to the stop terminal. This fires the small 2N5062 SCR generating a high current pulse in T3 and T4. This pulse fires SCR **3** and **4** which crow-bars the remaining energy in the capacitor bank.

With respect to FIG. **6,** amplifiers Z1, Z2 and Z3 form two DC differential amplifiers. These amplifiers convert the essential floating inputs **1, 2** and **3** to ground referenced signals. The two outputs are $v(t)$ from Z2 and $i(t)$ from Z3. These signals are fed to **40** which together with Z4 form an analog multiplier. The output of Z3 in mathematical terms is $V(t) \times i(t)/K$.

This signal is proportional to the power being delivered to the load at any instant of time. Z5 is an integrator which integrates power with time to give energy. The AC coupling network on the output of Z3 removes the long term DC drift. The output at this point is approximately an increasing ramp voltage. This ramp is compared to the setting of the potentiometer **36,** by comparator **50.** When these are equal, the comparator sends the stop output high. The peak value of the ramp is stored on the 0.22 mfd capacitor in analog storage circuit **44.** The four transistor amplifier has a gain of +1. This allows the energy delivered to be displayed on the meter.

Comparator Z9 (**46**) performs a similar function to **50** except it compares the potentiometer **36** setting with time. In this way the output pulse width is limited to a maximum value for any given setting. This circuit does not affect operation for loads of less than **150** ohms.

Comparator Z6 controls the charging of the capacitor bank. Z6 compares the output of amplifier Z2 which is proportional to the bank voltage to a zener diode. A certain amount of positive feedback is used as controlled hysteresis to prevent chatter of relay K1.

The remaining transistors are used as switches to turn on or off certain functions when the manual switch **30** is closed. For example, the voltage comparator Z6 is

turned off and comparators **56** and **50** and analog memory **44** are turned on.

FIGS. **7, 8** and **9** are block diagrams similar to FIG. **3** except that means for controlling the magnitude of current in the circuit means is illustrated. With respect to FIG. **7,** the numeral **100** refers to a variable voltage control of the manual type which is electrically connected to the voltage reference **54.** The variable voltage control **100** may be a manually controlled adjustable resistor, switch or the like. The circuitry of FIG. **7** operates in the same manner as the circuitry illustrated in FIG. **3** except that the control **100** is provided for manually controlling the amount of current in the defibrillator. The operation of the circuitry of FIG. **7** is as follows. The operator would initially determine the amount of energy to be delivered to the patient and would determine the approximate body weight of the patient. The variable voltage control **100** would then be manually adjusted in response to the approximate body weight of the patient. In the circuitry of FIG. **3,** it was only necessary to determine the energy to be delivered to the patient since the current in the circuitry of FIG. **3** is not variable but is fixed. The manual reset **32** starts the sequence by zeroing the output meter **38** and activating the power supply **18** at a voltage which is dependent upon the energy selector **36.** Thus, if it had been determined that it was desirable to deliver an impulse of 200 joules to the patient, the energy selector **36** would be set at 200 joules. The energy derived from the power supply **18** is stored in the storage capacitors **22.** The energy selector **36,** which is manually set to the energy desired, also feeds an input to the energy computer and control **34.** The electrodes or paddles **14** and **16** are then placed into contact with the patient and the manual switch **30,** located on either or both of the paddles **14** and **16,** is activated.

When manual switch **30** is activated, the energy computer and control **34** causes the stored energy source to be connected to the patient. The current monitor **28** and voltage monitor **26** feed instantaneous signals to the energy computer and control **34** which computes the energy as a continuous integration process. When the computer energy equals the selected energy, the energy computer and control **34** causes the energy source to be disconnected from the patient. The total energy delivered to the patient is indicated as a steady reading on the output meter **38.**

As previously stated, the voltage reference **54** is variable which results in the output of the voltage comparator **52** and charge logic **56** to result in a variable charge voltage on the energy storage capacitors **22** in FIG. **2.** Since the amount of current is proportional to the voltage, the desired current can be selected by manually selecting the reference voltage **54** by means causes a suitable variable voltage control which may be a switch or variable resistor.

It is also possible to control the reference voltage with the energy selector **36** through a proper scaler such as seen in FIG. **8** so that as higher energy levels are selected, corresponding higher values of current are supplied automatically. FIG. **8** is identical to FIG. **7** except that a scaler **102** has been substituted for the variable voltage control and is electrically connected to the energy selector **36** in conventional fashion as seen in FIG. **8.** Scaler **102** may comprise an amplifier having a gain of A which may be greater than or less than **1.** Thus, the reference voltage **54** is controlled with the energy selector **36** through an amplifier or proper scaler so that as higher energy levels are selected, corresponding higher values of current are supplied automatically to the system.

The circuitry illustrated in FIGS. **7** and **8** may be substituted for the circuitry of FIG. **3** in the defibrillator so that the magnitude of current therein can be manually or automatically selected since there appears to be a correlation between the patient's body weight and the current-energy doses necessary to defibrillate a defibrillating heart.

It is also possible to control the reference voltage with the resistance monitor **103** as seen in FIG. **9** so that as the patient's body resistance increases, the corresponding higher values of current are supplied automatically. FIG. **9** is identical to FIG. **7** except that a resistance monitor **103** has been substituted for the variable voltage control.

The resistance monitor comprises a high impedance oscillator **104** which supplies a source of signal at a frequence of approximately 100K Hz to the patient load through the paddles **14** and **16.** The signal that is supplied is a conventional high impedance, constant current source such that the signal current through the patient is constant and is not effected by the variation of patient body resistance. Since the current is constant, the voltage across the patient load is directly proportional to the resistance of the patient. The amplifier **105** increases the level of the signal so that it can be rectified in **106.** The resultant DC signal will be directly proportional to the body resistance. Thus the reference voltage **54** is controlled by the resistance monitor **103** so that as the body resistance increases, corresponding higher values of current are supplied automatically to the system.

Thus it can be seen that the defibrillator accomplishes at least all of its stated objectives.

We claim:

1. A defibrillator comprising in combination,

an electrical power source,

a set of electrodes engageable with a patient,

circuit means connecting said power source to said set of electrodes comprising, a computer means, a storage capacitor means for storing energy derived from said power source, an energy selector means for selecting the energy to be delivered to the patient, said energy selector means also feeding an input to said computer means, a switch means for causing the stored energy to be connected to the patient, said switch means being operatively electrically connected to said computer means, a power monitor means for feeding signals to said computer means when said stored energy is delivered to the patient, said computer means computing the energy delivered to the patient and causing the delivery of energy to the patient to be discontinued when the computed energy substantially equals the selected energy,

said circuit means also comprising means for selecting the magnitude of current delivered to the patient responsive to the body resistance of the patient.

2. The defibrillator of claim **1** wherein said means for selecting the magnitude of current comprises a resistance monitor means.

3. The defibrillator of claim **2** wherein said electrical circuit means includes a reference voltage means and wherein said resistance monitor means is electrically connected to said reference voltage means and to said set of electrodes.

* * * * *