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M. P. SIEBAND
PORTABLE DEFIBRILLATOR HAVING SATURABLE
CORE OUTPUT TRANSFORMER

3,481,341

Filed Sept. 6, 1968

2 Sheets-Sheet 1

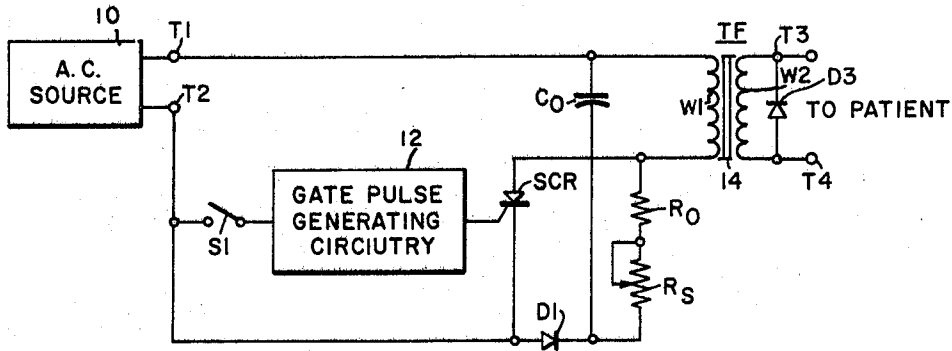


FIG. 1.

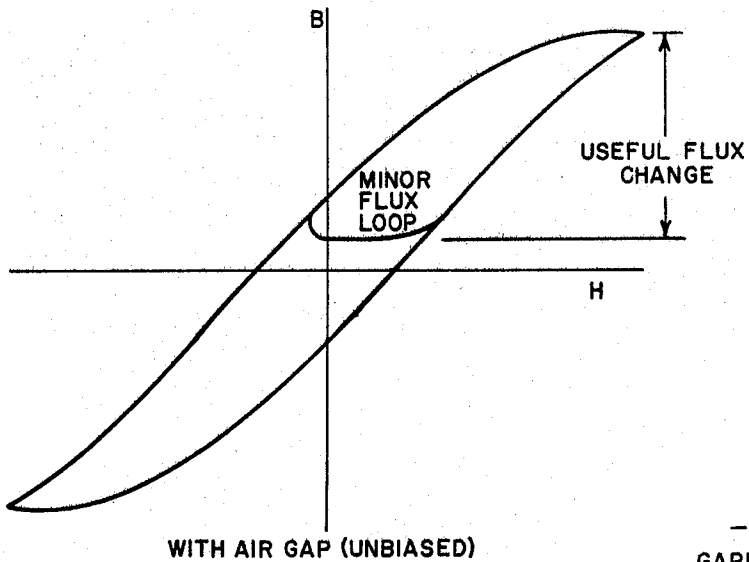


FIG. 2A.

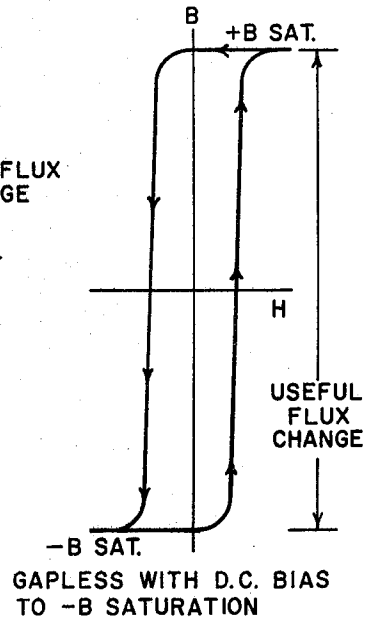


FIG. 2B.

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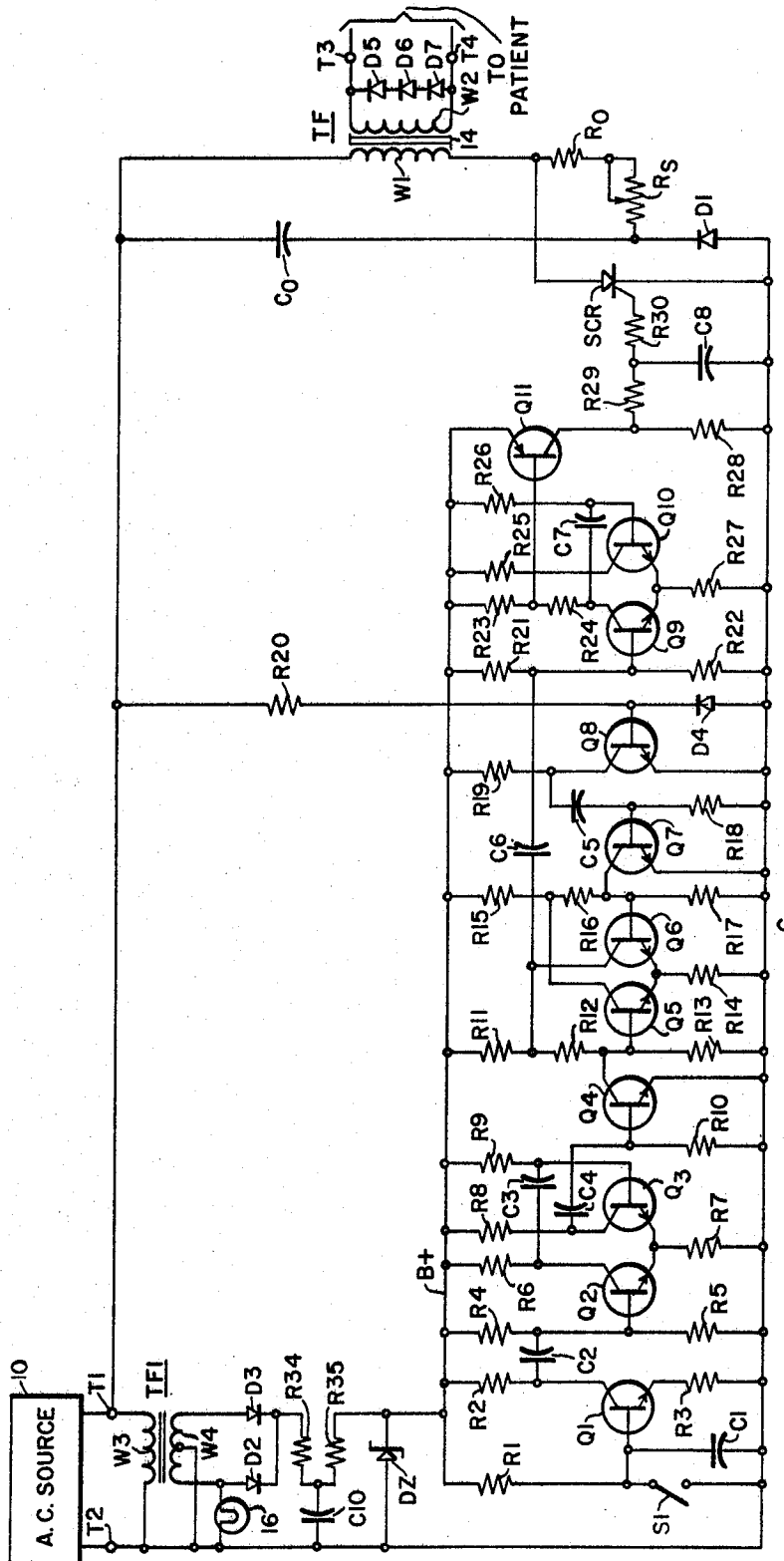


FIG. 3.

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PORTABLE DEFIBRILLATOR HAVING SATURABLE CORE OUTPUT TRANSFORMER

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Continuation-in-part of application Ser. No. 666,370, Sept. 8, 1967. This application Sept. 6, 1968, Ser. No. 767,027

Int. Cl. A61m 1/32; H03k 5/08

U.S. Cl. 128—421

10 Claims

ABSTRACT OF THE DISCLOSURE

The present disclosure relates to portable electronic defibrillating apparatus of the DC type wherein a full half-cycle of a sinusoidal waveform is generated and applied to a living subject to terminate the fibrillation of the heart thereof. An output transformer is provided utilizing a biased core so as to increase the flux change for a given current and thereby minimize the core material required.

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of copending application Ser. No. 666,370, filed Sept. 8, 1967 and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to electronic apparatus for the medical treatment of living subjects and, more particularly, to portable electronic defibrillating apparatus for terminating the fibrillation of the heart of a living subject.

Various defibrillating techniques and apparatus have been developed to terminate the fibrillation of the heart of a living subject. Electronic defibrillating apparatus may generally be categorized as being of the alternating current type wherein an AC current is applied to the living subject or of the DC type wherein a pulse of direct current is applied to the subject to bring about the defibrillation of the heart thereof. The effects of varying the waveshape, intensity, duration and frequency of the current applied to a patient have been investigated. It has been found that defibrillation through the use of a direct current pulse yields highly effective results particularly in cases of treating a more severely anoxic or arrhythmic heart. See for example: Nachlas, Bix, Mower and Siedband, "Observations on Defibrillators, Defibrillation, and Synchronized Countershock," Progress in Cardiovascular Diseases, vol. 9, No. 1, July 1966, pp. 64-89.

For the effective treatment of the fibrillating heart it is of course necessary that the defibrillation commence as soon as possible following fibrillation. Preferably the defibrillating apparatus should be portable so that it may be brought to the patient. Many of the prior art electronic defibrillators are not portable and therefore require that a patient be brought into the hospital for treatment. Because of the specialized voltages and currents required in such electronic defibrillators and the necessity of developing the desired operating voltages and currents within desired limits of regulation, prior art apparatus have acquired the use of output transformers weighing in the order of 30 lbs. or more. This requirement has made the overall weight of the apparatus quite high and has greatly limited the transportability of such equipment.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to

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provide a new and improved defibrillating apparatus which is highly portable.

It is a further object to provide a new and improved portable defibrillating apparatus wherein the desired wave shape of current pulse to be applied to a patient is generated in a controlled manner.

Broadly the present invention provides portable defibrillator apparatus wherein a current pulse is generated for application to a patient for the defibrillation of the heart thereof. An output transformer is utilized, and biasing circuit is provided for the magnetic core of the transformer to bias the core thereof so that a large change of magnetic flux is provided for a given current so as to minimize the amount of core material required to provide the desired voltage and current output and thereby minimize the weight of the apparatus.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a schematic-block diagram of the portable defibrillator of the present invention;

FIGS. 2A and 2B are plots of B-H-loops, respectively, utilized to demonstrate the advantages and operation of the present invention; and

FIG. 3 is a schematic diagram of circuitry suit utilized in the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, an AC source 10 is provided, which may supply, for example, 117 volt 60 cycles per second, sinusoidal output, that is typically available locally. The sinusoidal output as shown across the output terminals T1 and T2 is applied to a transformer TF which includes a primary winding W1 and a secondary W2. Primary winding W1 has one end connected to the terminal T1 of the AC source 10, and the other end connected to the anode of a silicon controlled rectifier SCR. The cathode of the controlled rectifier SCR is connected to the other terminal T2 of the AC source 10. The secondary winding W2 is selected to have the proper turns ratio to provide the desired output voltage to the patient, this output voltage being developed across the terminals T3 and T4. A diode D3 is connected across terminals T3-T4 to keep the output voltage from going negative (T3 to T4) after the output positive pulse.

The SCR being connected in series with the primary winding W1 controls the output at the secondary winding W2 and at the terminals T3-T4. By gating on the control rectifier SCR at the proper time, a pulse of direct current may be developed at the output terminals T3 and T4. To control the gating of the controlled rectifier SCR, gate pulse generating circuitry, indicated by the block 12, is provided. A switch S1 is connected between the terminal T2 and input of the gate pulse generating circuitry 12. By the closing of the switch S1, a gating pulse is generated at the desired time and applied to the gate electrode of the controlled rectifier SCR to gate of this device. The turning on of the SCR completes a unidirection current path through the primary winding W1 of the transformer T1 from the AC source 10. Thus, when the terminal T1 is positive with respect to terminal T2, current will flow through the winding W1 and the anode-cathode circuit of the SCR to the terminal T2. In response to the energization of the primary winding W1, a pulse will appear in the secondary winding W2 which will be unidirectional, with the turns ratio of the transformer TF being so selected to provide the desired voltage magnitude for utilization of the defibrillation.

Assume for the time being that the biasing circuit including a diode D1, a potentiometer R_p, a resistor R_o and a capacitor C_o are not included in the circuit of

FIGURE 1. In past defibrillator designs, common practice was to utilize an output transformer having an air gap in the core thereof, with the core being unbiased. A typical B-H loop for an air gap, unbiased core transformer design is shown in FIG. 2A. Since only current in one direction would be applied to such an unbiased transformer, the operation on the B-H loop is as indicated by the arrows in FIG. 2A as a minor flux loop. As shown there is only flux change in the positive direction, with the magnetic field density B never going negative because of the unidirection current applied to the primary winding of the transformer. The useful flux change is indicated in FIG. 2A and is shown between positive saturation and a flux level above zero flux level. As can be seen the useful flux change is limited to the positive quadrants of the B-H loop. In order to minimize voltage regulation, the resistance of the windings of the transformer must be small. For the desired operation of the defibrillator apparatus, the secondary voltage applied to the patient must be as high as 1200 volts peak at 15 amps. peak. This means that the total equivalent series resistance must be made less than 16 ohms to maintain the losses below 20%. Regulation is highly important in order to keep the unloaded peak voltage to a minimum so that the patient is only subjected to the lowest possible voltage. Taking into account the transformer core and winding requirements and utilizing the best of conventional design procedures, dictates that a transformer weighing in the order of 30 lbs. must be utilized if a conventional transformer having an air gap and being unbiased and having a B-H loop as shown in FIG. 2A is to be used.

The arrangement as shown in FIG. 1 including the biasing circuit comprising the diode D1, the potentiometer R_s, the resistor R₀ and the capacitor C₀ solves the weight problem by permitting the full utilization of a B-H loop providing an increased flux change for accomplishing the desired voltage output from the transformer TF.

Referring again to FIG. 1, the transformer TF is selected to have a gapless core 14 and a relatively square B-H loop as shown in FIG. 2B. As shown in FIGURE 2B, the B-H loop is relatively narrow so that a relatively small magnetomotive force in the form of a biasing current may be utilized to place the core 14 of the transformer TF in either its positive or negative saturated state. The circuit of FIG. 1 is such that biasing current is applied to the primary winding W1 in a direction opposite to the current flow through the controlled rectifier SCR when this device is turned on. To provide the negative bias to the core 14 of the transformer TF, the diode D1 is provided which has its anode connected to the terminal T2 and its cathode connected to the tap on the potentiometer R_s. The resistor R₀ is connected between the bottom end of the primary winding W1 and the top end of the bias set potentiometer R_s. A storage capacitor C₀ is connected between the top end of the primary winding W1 and the cathode electrode of the diode D1. Thus, a bias current path is provided from the terminal T2 through the anode-cathode circuit of the diode D1, the potentiometer R_s and the resistor R₀ to the winding W1. The magnitude of this current may be adjusted through the bias set potentiometer R_s so that the core 14 of the transformer TF is maintained at its negative saturation level -B Sat. as seen in FIG. 2B whenever the controlled rectifier SCR is in its turned-off non-conducting state. Whenever the switch S1 is closed and a gating pulse generated in the gate pulse generating circuitry 12, the controlled rectifier SCR is rendered conductive to provide a positive conductive path for the primary winding W1. This relatively low impedance path through the controlled rectifier SCR causes the core 14 of the transformer TF to be driven through the B-H loop from negative saturation -B Sat. into positive saturation +B Sat. as indicated in FIG. 2B, with the sine wave of the current output from the AC source 10

rising from zero, reaching its maximum positive swing and then returning to zero. The bias current being supplied to the opposite direction through the winding W1 from the diode D1, the potentiometer R_s and resistor R₀, the core 14 is thus set at -B Sat. again by the biasing current so that when the SCR is gated on again it will be at the -B Sat. point on the B-H loop shown in FIG. 2B. The diode D₀ prevents a small negative output voltage induced by the bias current from appearing at terminals T3-T4.

It can be seen that the useful flux change in FIG. 2B encompasses the entire range from -B Sat. to +B Sat. as compared to the useful flux change in FIG. 2A which is much smaller. Thus, for a given quantity of current a much larger amount of flux change is produced with the B-H characteristic shown in FIG. 2B as compared to one having a B-H characteristic as shown in FIG. 2A. Therefore, a core having substantially less magnetic material may be utilized having a characteristic as shown in FIG. 2B compared to that shown in FIG. 2A and still produce the same desired voltage output as required in defibrillator apparatus. It has been found that through the utilization of a core material having a magnetic characteristic as shown in FIG. 2B as compared to that shown in FIG. 2A a weight saving of one-half to two-thirds of the magnetic material required may be obtained. The use of the magnetic characteristic as shown in FIG. 2B moreover provides the desired current and voltage outputs required for defibrillation as well as in containing the necessary regulation in the circuit. Also losses are minimized since the controlled rectifier SCR essentially shorts out the biasing circuit during the pulsing period of the defibrillator apparatus.

FIG. 3 shows the specific circuitry for the gate pulse generating circuit 12 as shown in Block form in FIG. 1. This circuit includes a power supply circuit which has an input transformer TF1. The primary winding W3 of this transformer is connected directly across the AC source 10 at terminals T1 and T2. The transformer TF1 includes secondary winding W4 which has its center tap connected to a common line G which is connected to the terminal T2 and the cathode electrode of the controlled rectifier SCR. Diodes D2 and D3 have their anode electrodes connected respectively to the ends of the secondary winding W4 and their cathode electrodes commonly connected. An indicator light 16 is connected between the top end of the secondary winding W4 and the common line G. A resistor R34 is connected between the cathode electrodes of the diodes D2 and D3 and one end of a filter capacitor C10. The other end of the filter capacitor C10 is connected to the common line G. A resistor R35 is connected between the junction of the resistor R34 and the capacitor C10 and the cathode of a Zener diode DZ. The other end of the Zener diode DZ is connected to the common line G. The voltage appearing at the cathode of the Zener diode DZ with respect to the common line G defines a DC voltage which may be utilized as operating potential for the transistor devices employed in the gate pulse generating circuitry. The direct operating voltage developed at the junction between the resistor R35 and the cathode of the Zener diode DZ is applied via a lead to a line B+. This operating voltage may for example be +12 volts.

The closing of the switch S1 instigates the generation of a gating pulse to turn on the controlled rectifier SCR thus completing a current path through the primary winding W1 so as to generate an output pulse at the terminals T3 and T4 to be applied to a patient. The momentary closing of the switch S1, which may comprise a pair of contacts of a relay, shorts a capacitor C1 which is connected across the switch S1, one end of the capacitor C1 being connected to the base of a transistor Q1 and the other end connected to the common line G. A resistor R1 is connected between the base of the transistor Q1 and the positive line B+. The transistor Q1 is normally con-

ductive with the switch S1 open. When the switch S1 is closed, the transistor Q1 is turned off. A resistor R2 is connected between the collector of the transistor Q1 and the B+ line, and the emitter of the transistor Q1 is connected through a resistor R3 to the common line G. The turning off of the transistor Q1 causes a positive going signal to be coupled through a capacitor C2 connected between the collector of the transistor Q1 and the base of a transistor Q2 which turns on the normally turned off transistor Q2. The transistor Q2 and a transistor Q3 comprise the active elements of a monostable multivibrator. The emitter electrodes of the transistors Q2 and Q3 are commonly connected, with a resistor R7 connecting the emitters to the common line G. The base of the transistor Q2 is connected to a junction of a pair of resistors R4 and R5 which are connected in series between the B+ line and the common line G. The collectors of the transistors Q2 and Q3 are, respectively, connected via resistors R6 and R8 at the B+ line. A capacitor C3 connects the base and collector electrodes of the transistors Q3 and Q2, respectively. The base of the transistor Q3 is connected to resistor R9 to the B+ line. The turning on of the transistor Q2 of the monostable multivibrator turns off the normally turned on transistor Q3 which causes a signal to be coupled through a capacitor C4 which is connected between the collector of the transistor Q3 and the base of a transistor Q4 which comprises the active element of a trigger amplifier. The base of the transistor Q4 is connected through a resistor R10 to the common line G, and the emitter thereof is connected directly to the common line. The trigger transistor Q4 is normally non-conductive and is rendered conductive in response to the turning off of the transistor Q3. The time constant of the monostable multivibrator including the transistors Q2 and Q3 is selected to have a switched time of approximately one second before reverting to its monostable stage. Thus the transistor Q3 once switched will remain in its non-conductive condition for at least one second before it may return to its normally non-conductive state. The one second switched time of the monostable circuit Q2-Q3 prevents more than one triggering signal per second from reaching the trigger amplifier Q4.

The collector of the transistor Q4 is connected to the base of a transistor Q5. The transistor Q5 and a transistor Q6 forms the active elements of a bi-stable multivibrator. The emitters of the transistors Q5 and Q6 are commonly connected, with a resistor R14 connecting the emitters to the common line G. A resistor R13 and a resistor R17 connect the base electrodes, respectively, of the transistors Q5 and Q6 to the common line G. The collector of the transistor Q5 is connected between the junction of resistors R15 and R16 which are connected between the base of the transistor Q6 and the B+ line. The collector of the transistor Q6 is connected between the junction of a resistor R11 and a resistor R12 which are connected between the base of the transistor Q5 and the B+ line. The transistor Q5 is normally in the conductive state and is turned off in response to the trigger amplifier transistor Q4 being turned on. The transistor Q6 of the bi-stable multivibrator is normally nonconductive but is turned on in response to the turning off of the transistor Q5. The bi-stable circuit including the transistors Q5 and Q6 remains in the switched state until the transistor Q6 is turned off in response to the activation of a line trigger circuit including a transistor Q7 and a transistor Q8.

The transistors Q7 and Q8 are responsive to the polarity of the line voltage received from the AC source 10. During the half cycle when the terminal T1 is positive with respect to the terminal T2, the transistor Q8 is conductive and the transistor Q7 is nonconductive. A resistor R20 is connected between the terminal T1 and the base of the transistor Q8, and the emitter electrode thereof is connected to the common line G. The collector of the transistor Q8 is connected through a resistor R19 to the

B+ line. A diode D4 is connected between the emitter and base electrodes of the transistor Q8 with the anode thereof connected to the emitter and the cathode thereof connected to the base. Thus, during the negative half-cycle of the input waveform from the AC source 10 with the terminal T2 positive with respect to the terminal T1, a conductive path is provided through the diode D4 to turn off the transistor Q8. The turning off of the transistor Q8 couples a signal to the base of transistor Q7 via a capacitor C5 connected between the cathode electrode of the transistor Q8 and the base electrode of the transistor Q7. A resistor R18 is connected between the junction of the capacitor C5 and the base of the transistor Q7 to the common line G. In response to the signal coupled through the capacitor C5, the transistor Q7 is turned on which clamps the base of the transistor Q6, which is connected to the collector of the transistor Q7, to essentially the potential of the common line G thereby turning off the transistor Q6 of the bi-stable multivibrator. In response to the turning off of the transistor Q6, the transistor Q5 is turned on to its original bi-stable state.

Thus, at the beginning of the negative half-cycle of the input alternating wave form from the AC source 10, the transistor Q6 is turned off causing a signal to be coupled through a capacitor C6, which is connected between the collector of the transistor Q6 and the base electrode of a transistor Q9. The transistor Q9 and a transistor Q10 form the active elements of a monostable multivibrator. The transistor Q9 is normally turned off and the transistor Q10 is normally turned on in the stable state of the monostable multivibrator. In response to a signal being coupled through the capacitor C6 when the transistor Q6 is turned off, the transistor Q9 is turned on and the transistor Q10 is turned off. The emitters of the transistors Q9 and Q10 are commonly connected, with a resistor 27 connecting the emitters to the common line G. The base of the transistor Q9 is connected at a junction between a pair of resistors R21 and R22 which are connected respectively between the B+ line and the common line G. The collector of the transistor Q10 is connected through a resistor R25 to the B+ line, and the base thereof is connected through a resistor R26 to the B+ line. A capacitor C7 couples the base and collector electrodes of the transistors Q10 and Q9, respectively. A resistor R24 and a resistor R23 are connected in series between the collector of the transistor Q9 and the B+ line. The base of a transistor Q11 is connected between the junction of the resistors R23 and R24.

The transistor Q11 comprises a trigger transistor for the gating of the controlled rectifier SCR. The transistor Q11 is shown to be of the PNP type, while the transistors Q1 through Q10 are of the NPN type. The emitter of the transistor Q10 is connected to the B+ line, and the collector thereof is connected through a resistor R28 to the common line G. The series combination of a resistor R29 and a resistor R30 is connected between the collector of the transistor Q11 and the gate electrode of the controlled rectifier SCR. A capacitor C8 is connected between the junction of the resistors R29 and R30 and the common line G.

The transistor Q11 is normally nonconductive with the monostable multivibrator Q10 in its stable state with the transistor Q9 off and the transistor Q10 on. However, when the transistor Q9 is turned on in response to the turning off of the transistor Q6, the emitter of the transistor Q11 is rendered positive with respect to its base so as to turn on the transistor Q11. The turning on of the transistor Q11 causes a positive polarity gating pulse to be applied via the network including the resistors R28, R29, R30 and the capacitor C8 to the gate electrode of the controlled rectifier SCR. The transistor Q11 remains conductive until the monostable multivibrator Q9, Q10 reverts to its stable state, with the transistor Q9 turned off and the transistor Q10 turned on which will occur after a predetermined time interval.

As previously described the bi-stable multivibrator Q5-Q6 remains in its switched state, with the transistor Q6 on and the transistor Q5 off, in response to the closing of the switch S1, until the input waveform from the AC source 10 goes into its negative half-cycle. At this time the transistor Q8 is turned off and the transistor Q7 is turned on thereby to turn off the transistor Q6. The turning off of the transistor Q6 causes the transistor Q9 to be turned on which triggers the trigger transistor Q11 and supplies a positive going signal to the gate electrode of the controlled rectifier SCR. Hence, a gating signal is applied to the gate electrode sometime during the negative half-cycle of the input waveform from the AC source 10 which is continuously applied as long as the monostable multivibrator Q9, Q10 remains in its switched state. With a positive polarity gating signal being applied at the beginning of the positive half-cycle of the input waveform, the controlled rectifier SCR will begin to conduct current to provide a conductive path from the terminal T1 through the primary winding W1 of the output transformer TF, the anode-cathode circuit of the SCR to the common line G at the terminal T2. The energization of the primary winding W1 of the output transformer TF thus induces an output voltage at the secondary winding W2 and the terminals T3 and T4 to be applied to a patient as previously discussed with reference to FIGS. 1 and 2B. A diode string D5, D6 and D7 replaces the diode D3 of FIG. 1 between terminals T3-T4 and serve the same purpose of keeping the output pulse from going negative.

FIG. 3 includes the same biasing circuit as FIG. 1 comprising the diode D1, the potentiometer R_s, the resistor R_o, and the capacitor C_o. Through the use of the biasing circuit, the core 14 of the transformer TF is biased into negative saturation -B Sat. as shown in FIG. 2B until the controlled rectifier SCR begins to conduct at the beginning of the positive half-cycle of the input waveform from the AC source 10. At this time the magnetic core 14 will be driven through the entire range of magnetic flux from -B Sat. to +B Sat. and back to -B Sat. for the full utilization of flux change to provide the necessary change of flux for the desired output voltage. This permits a minimum use of magnetic material to minimize the weight of the core as previously discussed.

The controlled rectifier SCR will continue to conduct current until the end of the positive half-cycle of the input waveform from the AC source 10. The time constant of the monostable multivibrator Q9-Q10 is so selected that the monostable reverts to its normal stable state, with the transistor Q9 off and the transistor Q10 on, during the positive half-cycle of the input waveform from the AC source 10, with the transistor Q11 returning to its turned off state in response to the switching of the monostable multivibrator. All of the transistors of the circuit are thus at this time in their normal conductive or non-conductive state for the next period when it is desired to generate a pulse from the output transformer TF. It should be noted, however, that due to the one second delay of the monostable multivibrator Q2-Q3 that the accidental closing of the switch S1 or any other line transient or spurious signals introduced into the circuitry will not permit another pulse to be generated at the output terminals T3 and T4 which may be hazardous to the patient or which may have not permitted sufficient time for the bias current to restore the core to -B Sat. Earlier triggering may force the core to saturation and cause excessive line current to flow. Also it should be noted that the removal of the gating pulse from the gate of the controlled rectifier SCR does not effect the conductivity of the SCR which will continue to conduct during a full positive half-cycle of the input waveform from the AC source 10. Thus, by starting the application of a gating pulse sometime during the negative half-cycle of the input waveform, the controlled rectifier SCR becomes immediately conductive upon the input waveform going positive so that a

complete positive half-cycle of the input waveform is supplied to the winding W1, with a full half cycle waveform of substantially sinusoidal shape being developed at the secondary winding W2 for application via the terminals T3 and T4 to a patient. It has been found that such a full half wave pulse is highly desirable for use in defibrillation.

After the one second delay the monostable multivibrator Q2-Q3 returns to its normal state with the transistor Q2 off and the transistor Q1 on. The defibrillator apparatus is then ready to generate a pulse again which may be accomplished by the closing of the switch S1 with the cycle repeating itself as described above.

Although the present invention has been described with a certain degree of particularity, it should be understood that the present disclosure has been made only by way of example and that numerous changes in the details of the circuitry and the combination and arrangement of parts, elements and components may be resorted to without departing from the spirit and the scope of the present invention.

I claim as my invention:

1. In defibrillator apparatus for applying an electrical pulse to a living subject and operative with a source of alternating current, the combination of:
 - a transformer including a magnetic core, a primary winding and a secondary winding;
 - a controlled switching device operatively connected between said primary winding and said source for providing a unidirectional current path through said primary winding when turned on;
 - turn-on means for generating a turn-on signal and applying said signal to said controlled device to turn on said device;
 - a biasing circuit for biasing said magnetic core in a direction opposite to the direction of magnetization caused by current through said unidirectional current path; and
 - means for extracting said electrical pulse developed at said secondary winding for application to a living subject.
2. The combination of claim 1 wherein:
 - said biasing circuit operative to bias said magnetic core into saturation in a direction opposite to the direction of magnetization caused by said current through said unidirectional path so that said magnetic core is driven between both directions of saturation to provide a large change of magnetic flux in response to said current.
3. The combination of claim 2 wherein:
 - said magnetic core comprises a magnetic material having a relatively square B-H loop.
4. The combination of claim 3 wherein:
 - said turn-on means including means for instigating the generation of said electrical pulse.
5. The combination of claim 4 wherein:
 - said turn-on means including means for preventing the generation of one of said electrical pulses until a predetermined time after the instigation of the next previous of said electrical pulses.
6. The combination of claim 5 wherein:
 - said turn-on means operative to supply said turn-on signals at a time in the half cycle of said alternating current waveform from said source preceding the half cycle during which said unidirectional current path is to be completed so that a full half cycle of the alternating current waveform is supplied through said primary winding.
7. The combination of claim 6 wherein:
 - said turn-on means including line responsive means responsive to the polarity of the alternating current waveform from said source to initiate the generation of said turn-on signal in response to a predetermined polarity of the alternating current waveform.

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8. The combination of claim 2 wherein:
said biasing circuit including a rectifying device operatively connected between said source and said transformer and being so poled to supply biasing current for biasing said magnetic core.

9. The combination of claim 6 wherein:
said biasing circuit including a rectifying device operatively connected between said source and said primary winding and being so poled to supply biasing current for biasing said magnetic core.

10. The combination of claim 9 wherein:
said biasing circuit including an adjustable resistor operatively connected between said rectifying device and said primary winding and being adjustable to control the biasing current supplied to said transformer so that said magnetic core is biased into saturation.

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WILLIAM E. KAMM, Primary Examiner

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