United States Patent

[11] **3,618,615**

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[54] **SELF CHECKING CARDIAC PACEMAKER**
15 Claims, 1 Drawing Fig.

[52] **U.S. Cl.** .... **128/419 P,** 128/422
[51] **Int. Cl.** **A61n 1/36**
[50] **Field of Search** .... 128/419 P, 421, 422

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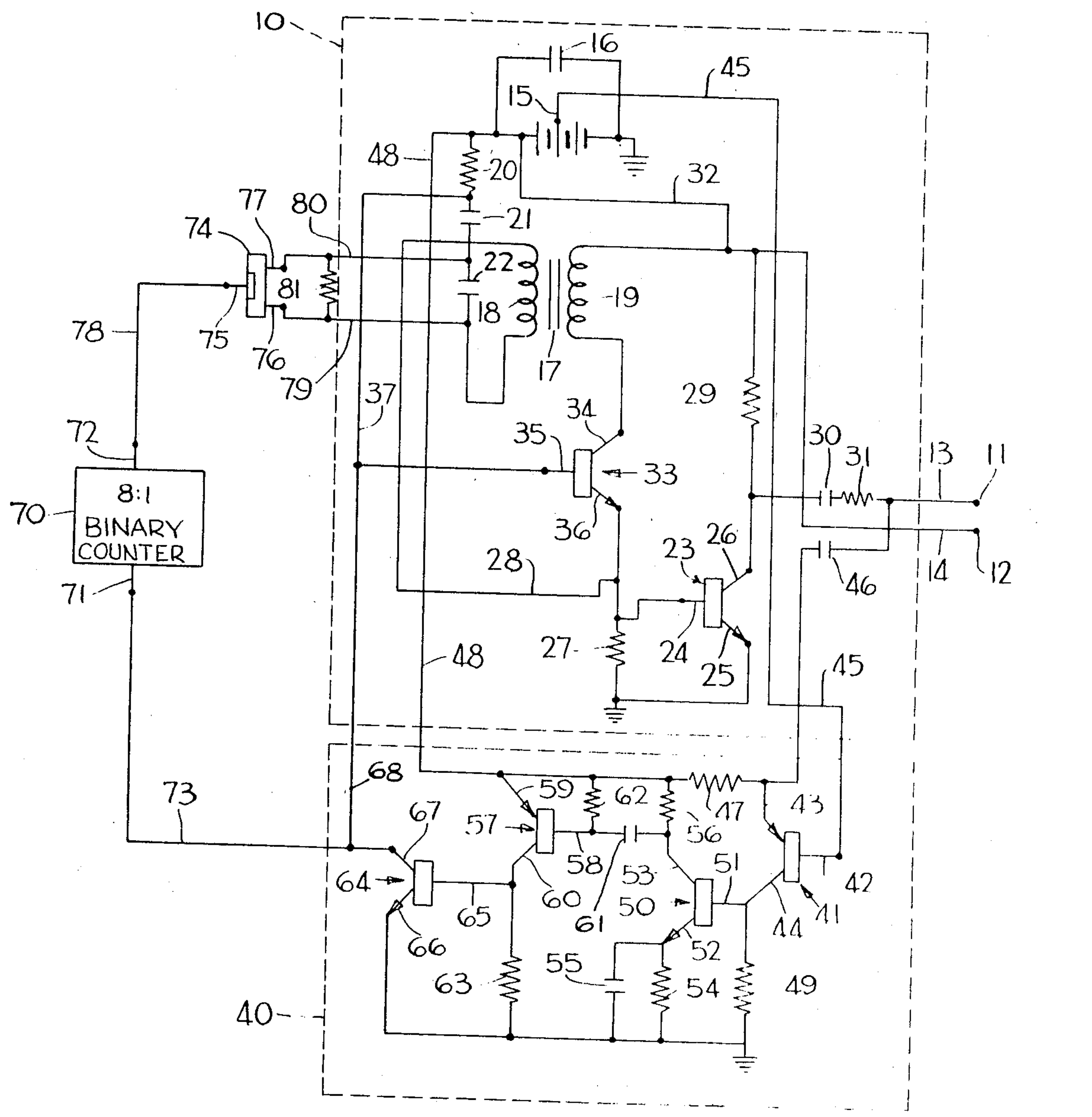
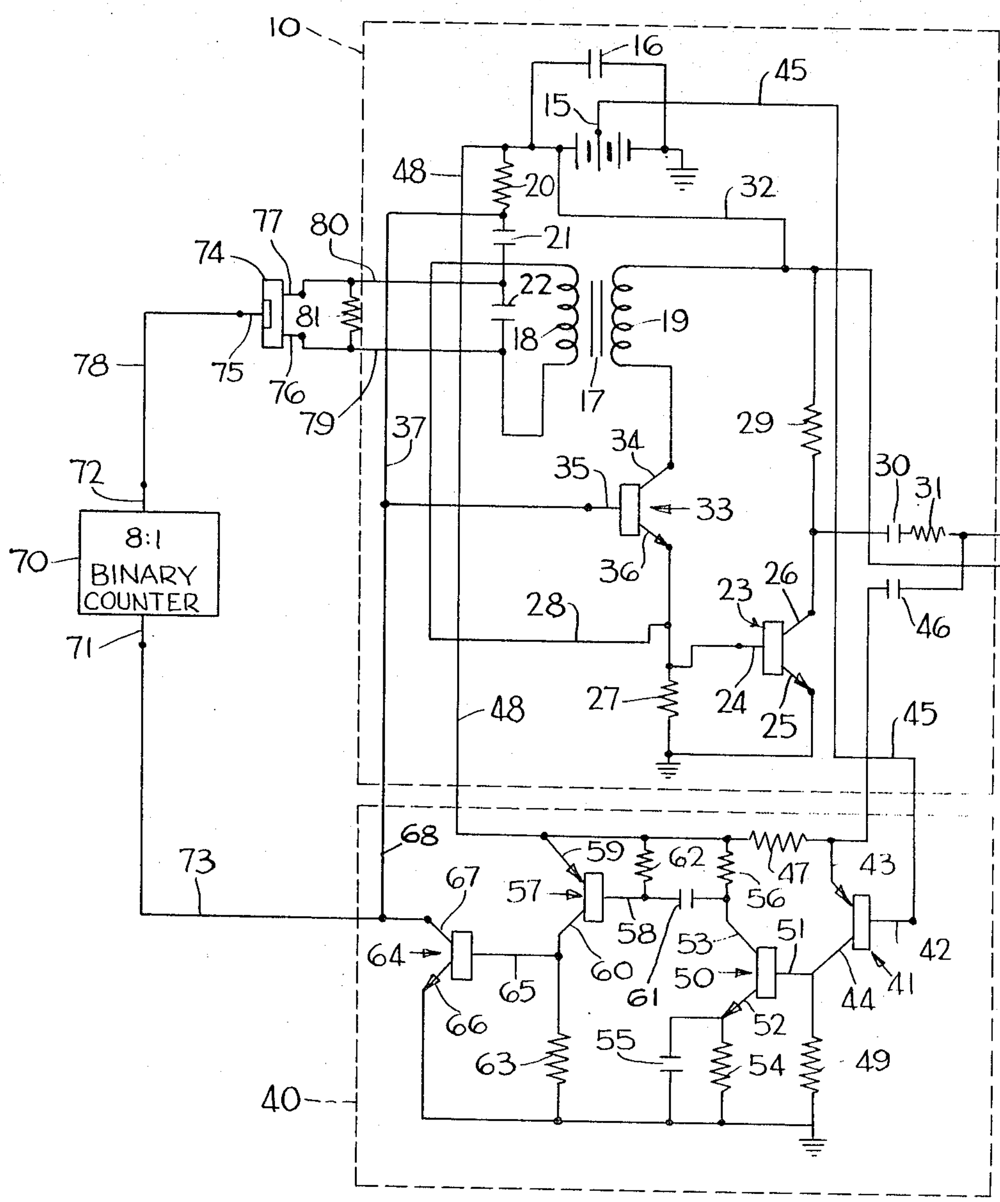
ABSTRACT: A cardiac pacer including a pair of output terminals, at least one of which is adapted to be placed in operative contact with a patient's heart, coupled to a pulse generator which includes an RC timing circuit connected to a power supply. A signal responsive circuit coupled to one of the output terminals provides a signal in response to each ventricular beat of the patient's heart. The capacitance of the timing circuit is periodically reduced by a capacitor connected in series with the timing circuit and in parallel with a field effect transistor controlled by a binary counter connected to the pacer signal responsive circuit. The resulting periodic test pulse of reduced width is utilized to indicate marginal pacer operation and possible impending failure if the patient's heart fails to respond to the test pulse.





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SELF CHECKING CARDIAC PACEMAKER

BACKGROUND OF THE INVENTION

This invention relates to electronic cardiac pacer and, more particularly, to a cardiac pacer which may or may not be implantable within the human body and which is inherently self-checking.

Artificial cardiac pacer of the implantable variety have come into widespread use in recent times for patients suffering from complete heartblock. The acceptance of these pacers by the medical profession has increased the life expectancy of these patients from a 50 percent probability of 1 year to nearly the life expectancy of physically comparable humans not suffering from the same heart disorder.

While artificial stimulation thus has been successful as a solution to this primary medical problem, its characteristics have given rise to a number of secondary problems. A significant secondary problem is determining when the implanted, battery-operated pacer should be replaced. A number of solutions to this problem have been proposed, one being replacement at 30month intervals and thus accepting a 10 percent risk or probability of premature pacer failure. Another proposed solution is to establish pacer "clinics" where photographic analysis techniques are used to detect imminent failure.

None of these proposed solutions is entirely satisfactory for detecting, simply and positively, a degradation of pacer system performance. The risk of undetected premature failure associated with periodic replacement at intervals of about 30 months is obviously undesirable. Photoanalysis techniques are complicated, not positive in detection, and obviously would not be readily available to physician and patient on short notice but rather, as mentioned previously, would be available only at special clinics.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide artificial electrical stimulation of a human organ, such as the heart, in a way permitting ready evaluation, without surgery, of the stimulator power supply and also of the condition and placement of the stimulating electrode.

It is a further object of the present invention to provide an implanted medical electronic pulse generator which is inherently self-checking and thus permits detection of impending generator failure without surgery and with simple measurement means.

It is a more particular object of the present invention to provide such a medical electronic pulse generator which can be employed in an implanted or externally worn artificial cardiac pacer of either the demand, synchronous or nonsynchronous types or combinations thereof.

The present invention provides an artificial cardiac pacemaker wherein the pulse generator thereof at regular intervals produces a stimulating impulse of significantly lower energy than the other impulses. In addition, the lowered energy pulse occurs at a time in the operating cycle earlier than that at which the regular stimulating impulses occur so as to avoid confusion when the pacer is operating in a demand mode. If the heart responds to the reduced energy stimulating pulse, an adequate safety factor remains, but if the heart does not respond, e.g., no beat is detected in response to the test pulse, marginal operation and possible imminent failure is ascertained.

The foregoing and additional advantages and characterizing features of the present invention will become clearly apparent upon a reading of the ensuing detailed description of an illustrative embodiment thereof together with the included drawing depicting the same.

BRIEF DESCRIPTION OF THE DRAWING FIGURE

The single drawing FIGURE is a schematic diagram of an artificial cardiac pacer constructed in accordance with the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

An artificial cardiac pacer is shown schematically in the drawing and comprises a pulse generator, designated generally at 10, and a pair of pacemaker output terminals or electrodes 11 and 12 at least one of which is surgically placed in contact with the heart of a patient. In particular, electrode 11 would be placed surgically in contact with the ventricle of the patient's heart, and electrode 12, which can function as an indifferent or reference electrode, could be subcutaneously implanted at another part of the patient's body. Alternatively, electrode 12 also can be placed in contact with the patient's heart. Electrodes 11 and 12 are connected to pulse generator 10 by leads or wires 13 and 14, respectively, which leads would be enveloped by a moistureproof and human body reaction-free material such as silicone rubber or suitable plastic. A power supply for the pacer is included in the form of battery 15, and a capacitor 16 is connected across battery 15 for the purpose of reducing the peak current drain on the battery and thus increasing the useful life thereof.

Pulse generator 10 includes a transformer 17 having secondary and primary windings 18 and 19, respectively. The positive terminal of battery 15 is connected through a resistor 20 and series-connected capacitors 21 and 22 to one end or terminal of transformer secondary winding 18. Resistor 20 and capacitor 21 comprise capacitive timing means in the form of an RC timing circuit for pulse generator 10, capacitor 22 being normally shunted out of the circuit, the operation of which will be described in more detail presently. Pulse generator 10 also includes a semiconductor amplifier in the form of transistor 23 having base, emitter and collector terminals 24, 25 and 26, respectively. Base terminal 24 is connected to one terminal of a biasing resistor 27 which terminal also is connected by a lead 28 to the other end or terminal of transformer secondary winding 18. Emitter terminal 25 is connected directly to the other terminal of biasing resistor 27. Collector terminal 26 is connected to one terminal of a resistor 29 and is coupled through a capacitor 30 and resistor 31 to lead 13 and, hence, terminal or electrode 11. The other terminal of resistor 29 is connected to lead 14 and thus to electrode 12, and is connected to one end or terminal of transformer primary winding 19 and through a lead 32 to the positive terminal of battery 15. The negative terminal of battery 15 is connected to ground.

Pulse generator 10 finally includes a semiconductor oscillator in the form of transistor 33 having collector, base and emitter terminals 34, 35 and 36 respectively. Collector terminal 34 is connected to the other end or terminal of transformer primary winding 19, and base terminal 35 is connected through a lead 37 to the junction of resistor 20 and capacitor 21. Emitter terminal 36 is connected to base terminal 24 of amplifier transistor 23.

The artificial pacer provided by the present invention further comprises signal responsive means, designated generally at 40 in the drawing, for providing an output signal in response to ventricular beats of the heart. More specifically, signal responsive means 40 provides a bipolar output signal in response to a monopolar signal of either polarity appearing at electrode 11 and one line 13 indicative of each ventricular beat of the heart.

Signal responsive means 40 includes a first semiconductor amplifier in the form of transistor 41 having base, emitter and collector terminals 42, 43 and 44, respectively. Base terminal 42 is connected by a lead 45 to a positive bias voltage tap of battery 15 which preferably is taken at half the maximum battery voltage whereby transistor 41 is in common base configuration. Emitter terminal 43 is connected to one terminal of a coupling capacitor 46, the other terminal of which is connected to lead 13 and thus electrode 11. Emitter terminal 43 of transistor 41 also is connected through a resistor 47 and a lead 48 to the positive terminal of battery 15. Collector terminal 44 is connected through a resistor 49 to ground. Signal responsive means 40 further includes a second semiconductor amplifier in the form of transistor 50 having base, emitter and collector terminals 51, 52 and 53, respectively. Base terminal 51 is connected to collector terminal 44 of amplifier transistor 41, and emitter terminal 52 is connected to ground through the parallel combination of resistor 54 and capacitor 55. Collector terminal 53 of transistor 50 is connected through a resistor 56 to lead 48 and hence the positive terminal of battery 15.

Signal responsive means 40 also includes a first semiconductor switch in the form of transistor 57 having base, emitter and collector terminals 58, 59 and 60, respectively. Base terminal 58 is coupled through a capacitor 61 to collector terminal 53 of transistor 50 and is connected through a resistor 62 to lead 48 and hence the positive terminal of battery 15. Emitter terminal 59 is connected directly to lead 48, and collector terminal 60 is connected to ground through a resistor 63. Signal responsive means 40 finally comprises a second semiconductor switch in the form of transistor 64 having base, emitter and collector terminals 65, 66 and 67, respectively. Base terminal 65 is connected to collector terminal 60 of transistor 57, and emitter terminal 66 is connected directly to ground. Collector terminal 67 of transistor 64 is connected by a lead 68 to base terminal 35 of oscillator transistor 33.

The artificial pacer provided by the present invention finally comprises means coupled to signal responsive means 40 for reducing the capacitance of the capacitive timing means or RC timing circuit in pulse generator 10 by a predetermined amount and after a predetermined time interval in response to the occurrence of a given number of output signals provided by means 40. The means for reducing the capacitance includes a counting means in the form of an 8:1 binary counter 70 having input and output terminals 71 and 72, respectively. Counter 70 functions to provide an output pulse on terminal 72 in response to the occurrence of a predetermined number of input signals, in this particular example eight, appearing on input terminal 71. Inasmuch as binary counters such as counter 70 are well understood by those skilled in the electronics art and are readily available commercially, a detailed description of the construction and operation of counter 70 is believed unnecessary. Moreover, such counters are now available in integrated circuit form and thus occupy an extremely small volume so as to make feasible the inclusion of such a binary counter in an implantable cardiac pacer. The input terminal 71 of counter 70 is connected by a lead 73 to the output of signal responsive means 40, in particular to the collector terminal 67 of switching transistor 64. As a result, counter 70 will provide an output signal on terminal 72 after a predetermined number, here eight, of "R" waves produced in the heart and sensed by means 40.

Capacitor 22 in signal generating means 10 is connected in parallel with a normally closed, controlled switch in the form of field effect transistor 74 having control electrode 75 and source and drain electrodes 76 and 77, respectively. Control electrode 75 is connected to output terminal 72 of counter 70 by a lead 78, and source and drain electrodes 76 and 77 are connected by leads 79 and 80, respectively, to the terminals of capacitor 22. A high megohm resistance 81 can be connected across capacitor 22 to insure an equitable long term distribution of total charge between the two capacitors 21 and 22.

In operation, pulse generator 10 of the pacer provided by this invention, when no natural cardiac activity is present, produces regular periodic pulses at a rate of approximately one per second between electrodes 11 and 12 at least one of which is surgically placed in contact with the heart of a patient. During this free-running or nonsynchronous operation, a sawtooth waveform exists at base terminal 35 of oscillator transistor 33 which waveform falls quickly to nearly zero volts immediately upon cessation of the stimulating pulse, which as a duration of about 2 milliseconds. The waveform at base terminal 35 then rises exponentially in about 1 second to a voltage level, for example 0.6 volts, sufficient to drive transistor 33 into conduction and initiate another pacer stimulating pulse. In particular, current flows from battery 15 through resistor 20 and charges capacitor 21, capacitor 22 being shorted out of the circuit by the normally closed switch in the form of field effect transistor 74. The time interval required for the voltage at base terminal 35 of transistor 33 to rise to the critical value thus is determined by the values of resistor 20 and capacitor 21 which constitute an RC timing circuit for pulse generator 10.

When transistor 33 turns on, current flows from battery 15, through transformer primary winding 19, and through resistor 27. The flow of current through winding 19 induces a flow of current in secondary winding 18 which, in turn, elevates the voltage on base terminal 24 of transistor 23 to a level sufficient to turn on transistor 23. The voltage on collector terminal 26, as a result, drops to nearly ground potential, and since the voltage across capacitor 30 cannot change instantaneously, electrode 11 is driven negatively to a value nearly equal to the supply voltage.

The induced flow of current in transformer winding 18 causes capacitor 21 to discharge and recharge in the opposite direction. Transformer 17 saturates, the field in winding 19 begins to collapse, which immediately reverses the polarity and direction of current in winding 18. This, in turn, immediately drives transistors 23 and 33 into cutoff and ends the pacer stimulating pulse. The reverse charge on capacitor 21 holds transistor 33 cutoff until the charge is reversed again by current through resistor 20. It is apparent, therefore, that both the duration or width as well as the time interval between output pulses produced by pulse generator 10 are determined in part by the magnitudes of capacitor 21 and resistor 20 which constitute an RC timing circuit for pulse generator 10. It should be apparent also, that had capacitor 22 not been switched out of the circuit, the fact that it is connected in series between transformer winding 18 and capacitor 21 would change the duration of and time interval between pacer stimulating pulses. The role of capacitor 22 will be explained hereafter.

Capacitor 16 is charged slowly by battery 15 in the time interval between pulses generated by transistor 33, the pulsed saturation of transistor 23 rapidly discharging capacitor 16 over a very short interval to provide large amplitude peak pulse currents for electrodes 11, 12 through capacitor 30. Capacitor 30 acts as a coupling capacitor which charges in one polarity sense by the pacer pulses and discharges between pacer pulses to provide a reversed current. It is believed that such reversal of current through the patient's heart is beneficial in that it prevents any harmful effects which might result from the passage of a unidirectional current through the heart.

Signal responsive means 40 responds to the natural "R" voltage wave of a normal heartbeat, when present, to inhibit or disable pulse generator 10 so as to prevent the occurrence of generated pacer electronic pulses upon electrodes 11 and 12 when the heart is functioning normally. The means 40 is designed to respond to "R" waves of either polarity because some patients can generate successive "R" waves of opposite polarity.

Between generated pacer output pulses, a natural heartbeat, if it occurred, would generate an "R" wave of from about 2 to 20 millivolts which would be conducted back over the electrodes 11, 12 and leads 13, 14 to signal responsive means 40. Transistors 41 and 50, together with associated circuitry, amplify the "R" wave voltage signal of either polarity appearing on electrodes 11, 12, as produced by a normal heartbeat, and transform the "R" wave signal into a bipolar signal by mathematical differentiation. The differentiation is performed by capacitor 46 and resistor 47, by capacitor 55 and resistor 54, as well as by capacitor 61 and resistor 62. The particular pair or pairs of resistor and capacitor which perform the differentiation will depend upon the values selected for the components, as is readily apparent to those skilled in the art.

Transistors 57 and 64 are switching transistors for selectively disabling or inhibiting oscillator transistor 33 whenever a natural "R" wave appears in the normal heart. In other words, the natural and normal "R" wave will be amplified by transistor 41, again by transistor 50 to a bipolar signal with adequate amplitude in each polarity portion so that transistor switch 57, which is normally cutoff, is driven into conduction for 20 milliseconds or more, by that portion of the signal having the proper polarity for delivering a saturation pulse to switch on transistor 64. Transistor 64, functioning as an on-off switch, provides a low-impedance path between collector 67 and emitter 66, the latter being grounded. This, in turn, grounds base terminal 35 of oscillator transistor 33 long enough to discharge capacitor 21 and thereby reinitiate the pacer pulse generating cycle. In other words, switching transistor 64, by discharging capacitor 21, prevents the voltage on base terminal 35 from reaching the level sufficient to forward bias the base-emitter junction of transistor 33 which level in this particular example was previously mentioned to be about 0.6 volts. As a result, pulse generator 10 cannot provide an output or stimulating pulse until about 1 second following the last previous natural heartbeat. One second is approximately the normal frequency rate of oscillator transistor 33 under control of the RC timing network of resistor 20 and capacitor 21.

Signal responsive means 40 will, of course, provide an output signal in response to a stimulated "R" wave occurring as a result of the operation of pulse generator 10. This, however, does not have the effect of inhibiting pulse generator 10 because amplifier 40 saturates for about 100–300 milliseconds following a pacer pulse, providing a refractory period during which amplifier 40 is ineffective. In other words, actual inhibiting of pulse generator 10 by a signal from means 40 occurs only when a natural heartbeat follows a stimulated heartbeat at a time less than the interval determined by the RC timing network but greater than the refractory period.

In accordance with the present invention, each output signal provided by signal responsive means 40, in addition to being applied to base terminal 35 of oscillator transistor 33, is applied to the input terminal 71 of binary counter 70. After a predetermined number of signals each indicative of either a natural or a stimulated heartbeat counter 70 provides an output signal which is impressed upon base terminal 75 of field effect transistor 74 which, in turn, responds by behaving like an open semiconductor switch.

Capacitor 22 then is no longer shorted out of the RC timing circuit of should generator 10. Instead, capacitor 22 now is connected in series with resistor 20, capacitor 21 and transformer winding 18. As a result, the net capacitance of the RC timing circuit is reduced. This reduction in capacitance has a two-fold effect on the next stimulating pulse provided by pulse generator 10. One is a reduction in pulse width which should be apparent as a result of the earlier discussion wherein it was explained how the stimulating pulse width is dependent upon the magnitude of the capacitance connected between resistor 20 and transformer winding 18. The second effect is this reduced-energy pulse occurs at an earlier time relative to the occurrence of the regular pulses provided by generator 10.

This pacer impulse of significantly shorter duration occurring periodically, such as after every eight regular stimulating impulses, can be utilized to evaluate the operation of the artificial pacer and its power supply. If the heart can respond to the test pulse, then an adequate safety factor remains and the implanted pacer is left in place. If the heart does not respond to the lower energy test pulse, this indicates that the artificial pacer is operating in the marginal range and that failure may be imminent. The surgeon then will consider either replacement of the system or correction of the defect. Satisfactory operation of this testing procedure can be obtained if an energy reduction in the range of about 30 to 50 percent is made in the test pulse relative to a regular stimulating pulse.

One significant advantage is that the testing procedure in the case of a patient in complete block is quite simple and can be done anytime, anywhere and even by the patient himself. The patient's pulse is felt by hand, either by the doctor or by the patient himself. The manually sensed heartbeats are counted and if a beat is missing at a constant rate, as in this example every eighth beat, marginal operation of the pacer is indicated. Heart beats could, of course, be sensed by an electrocardiograph and a count taken therefrom.

Another advantage of the arrangement of the present invention is that it is readily adaptable to pacers of the demand type which type has achieved widespread use. A problem in determining whether or not a pacemaking system of the demand type is in good operating condition exists because an inserted test pulse can be confused with a normal heartbeat and thus be inhibited. The arrangement of the present invention, however, advantageously solves this problem by causing the lowered energy pulse to override the demand system and to be applied to the heart at a safe time regardless of whether the heart is in block or is beating normally in sinus rhythm. In other words, the reduced-energy test pulse occurs at an earlier time relative to the occurrence of the regular pulse provided by generator 10. To accomplish this, "R" waves both natural and stimulated are counted and the lowered energy test pulse is applied to the heart at a short but safe time delay after the last "R" wave in the counted train. The delay time must be short enough so that the test pulse occurs before the next possible natural "R" wave but long enough to occur well after the "T" wave which typically follows the "R" wave by about 0.3 seconds. A safe delay time would be 500 milliseconds.

While the arrangement of the present invention advantageously prevents confusion of a test pulse with a normal heartbeat in a demand-type pacer, it can of course be employed in a pacer of the nondemand or free-running type. In the latter case, the signal responsive means 40 would be replaced by a simpler means connecting one of the pacer terminals to the input of counter 70 for providing a signal thereto in response to each ventricular beat of the heart.

Since a synchronous pacer is always in operation at its nonsynchronous rate or faster, the arrangement of the present invention is applicable to a synchronous pacer in the same manner as it is applicable to a nonsynchronous pacer.

Another advantage of the present invention is the simplicity of the means for accomplishing the stated objectives. A periodic reduction in the capacity of the timing capacitor is a simple and effective means of accomplishing at the same time both a reduction in duration and, hence, energy of the test pulse and a reduction in delay time after the last preceding "R" wave. The fact that such reduction is applied periodically to one of the normal stimulating pulses in the train rather than inserting an extra pulse renders unnecessary the provision of any extra or additional pulse-generating means.

Power for operating counter 70 and for biasing transistor 74 can be obtained from a separate battery or from battery 15 as by a connection to lead 48. If the latter alternative is selected, battery 15 may have to be of a slightly larger rating. Minor additional biasing arrangements may be necessary to insure that the output from counter 70 is at a level sufficient to activate transistor 74. In addition, the output of counter 70 should be applied to the input of transistor 74 only for a time sufficient to reduce the capacity of the RC timing circuit and thereby to insert a reduced energy pulse between two normally occurring pulses from generator 10. The value of capacitor 22 relative to the value of capacitor 21 is selected so as to provide the previously mentioned energy reduction of 30 to 50 percent in the test pulse as compared to the regular stimulating impulses. To be implanted, the entire pacer, including its battery which can be rechargeable, is encased in an envelope of a moistureproof and human body reaction-free material such as silicone rubber or suitable plastic so as to permit long term implantation within the human body.

It is thus apparent that the present invention accomplishes its intended objects. While the present invention has been described in detail, this has been done by way of illustration without thought of limitation.

I claim:

1. A cardiac pacer comprising:

a. a pulse generator;

b. a pair of output terminals coupled to said pulse generator, at least one of which is adapted to be operatively coupled to a patient's heart;

c. a power supply;

d. said pulse generator including capacitive timing means connected to said power supply whereby said pulse generator provides output pulses at a rate and for a duration depending upon the magnitude of the capacitance in said timing means; and

e. means coupled to one of said terminals for sensing each ventricular beat of the heart and for reducing the capacitance of said timing means by a predetermined amount and for a predetermined time in response to the occurrence of a predetermined number of ventricular beats.

2. A cardiac pacer as defined in claim 1 wherein said capacitive timing means comprises an RC circuit.

3. A cardiac pacer as defined in claim 1 wherein said means for reducing the capacitance of said timing means comprises:

a. counting means having an input and an output, said counting means being operative to provide an output signal in response to the occurrence of a predetermined number of signals applied to the input thereof;

b. means connected to the input of said counting means for providing a signal thereto in response to each ventricular beat of the heart;

c. a controlled, normally closed switch connected in controlled relation to the output of said counting means; and

d. a capacitor connected in series with said capacitive timing means and in parallel with said controlled switch.

4. A cardiac pacer as defined in claim 3 wherein said controlled switch comprises a field effect transistor, the gate terminal of which is connected to the output of said counting means and the source and drain terminals of which are connected across said capacitor.

5. A cardiac pacer as defined in claim 3 wherein said means connected to the input of said counting means includes means for converting a monopolar signal of either polarity into a bipolar signal regardless of the polarity of the monopolar signal.

6. A cardiac pacer comprising:

a. a pulse generator;

b. a pair of output terminals coupled to said pulse generator, at least one of which is adapted to be operatively coupled to a patient's heart;

c. a power supply;

d. said pulse generator including capacitive timing means connected to said power supply whereby said pulse generator provides output pulses at a rate and for a duration depending upon the magnitude of the capacitance in said timing means;

e. signal-responsive means coupled to one of said terminals for providing an output signal in response to each ventricular beat of the heart; and

f. means coupled to said signal-responsive means for reducing the capacitance of said timing means by a predetermined amount and for a predetermined time in response to the occurrence of a predetermined number of output signals.

7. A cardiac pacer as defined in claim 6 wherein said capacitive timing means comprises an RC circuit.

8. A cardiac pacer as defined in claim 6 wherein said means for reducing the capacitance of said timing means comprises;

a. counting means having an input connected to the output of said signal responsive means and an output, said counting means being operative to provide an output signal in response to the occurrence of a predetermined number of signals applied to the input thereof;

b. a controlled, normally closed switch connected in controlled relation to the output of said counting means; and

a. a capacitor connected in series with said capacitive timing means and in parallel with said controlled switch.

9. A cardiac pacer as defined in claim 8 wherein said controlled switch comprises a field effect transistor, the gate terminal of which is connected to the output of said counting means and the source and drain terminals of which are connected across said capacitor.

10. A cardiac pacer as defined in claim 6 wherein said signal responsive means includes means for converting a monopolar signal of either polarity into a bipolar signal regardless of the polarity of the monopolar signal.

11. A cardiac pacer as defined in claim 10 wherein said converting means comprises differentiating means.

12. A cardiac pacer as defined in claim 6 further including means connecting the output of said signal responsive means to said pulse generator for inhibiting said pulse generator for a predetermined time in response to a ventricular beat of the heart.

13. A cardiac pacer comprising:

a. a pulse generator adapted to be connected to a power supply and to be coupled to a pair of electrodes, at least one of which is adapted to be placed in operative contact with a patient's heart;

b. said pulse generator including capacitive timing means whereby output pulses are provided at a rate and for a duration depending upon the magnitude of the capacitance in said timing means;

c. signal-responsive means adapted to be coupled to one of the electrodes for providing an output signal in response to ventricular signals of either polarity in the patient's heart;

d. counting means having an input connected to said signal-responsive means and operative to provide an output signal in response to the occurrence of a predetermined number of signals applied to the input thereof;

e. a normally closed semiconductor switch connected in controlled relation to the output of said counting means; and

f. a capacitor connected in series with said capacitive timing means and in parallel with said semiconductor switch.

14. A cardiac pacer as defined in claim 13 wherein said capacitive timing means comprises an RC circuit.

15. A cardiac pacer as defined in claim 13 wherein said semiconductor switch comprises a field effect transistor, the gate terminal of which is connected to the output of said counting means and the source and drain terminals of which are connected across said capacitor.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,618,615 Dated November 9, 19(71)

Inventor(s) Wilson Greatbatch

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, line 5, "Patented Nov. 9, 1917" should be --Patented Nov. 9, 1971--

Column 1, line 8, "pacer" should be --pacers--.

Column 1, line 21, "30month" should be --30 month--.

Column 5, line 44, "should" should be --pulse--.

Column 8, line 4, after comprises, ";" should be --:--.

Column 8, line 12, "a" (first occurrence), should be --c--.

Signed and sealed this 2nd day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents