

[54] HEARTBEAT ACTUATOR WITH CONTROLLED PULSE AMPLITUDE

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[57] ABSTRACT

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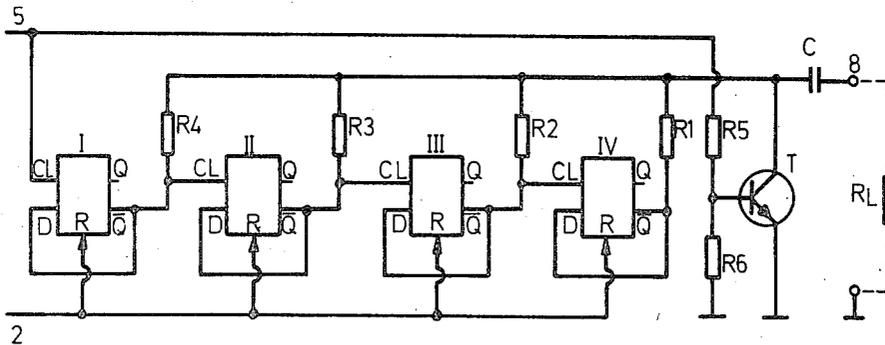
A heartbeat actuator, particularly an implantable heartbeat actuator has means for automatically lowering the amplitude of stimulating impulses produced by the beat actuator. The invention is particularly characterized by a stepwise switching device operated in rhythm with the stimulating impulses and used for connecting switching elements which influence the amplitude of the stimulating impulses. The elements are so dimensioned that the lowering of the amplitudes takes place in predetermined preferably equal steps.

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1 Claim, 3 Drawing Figures



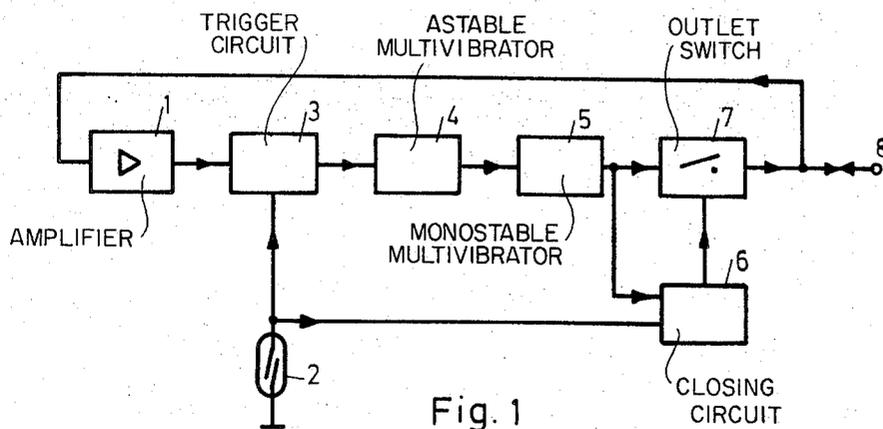


Fig. 1

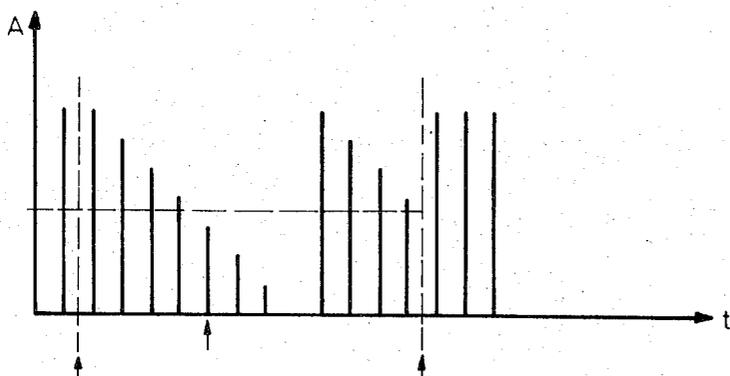


Fig. 2

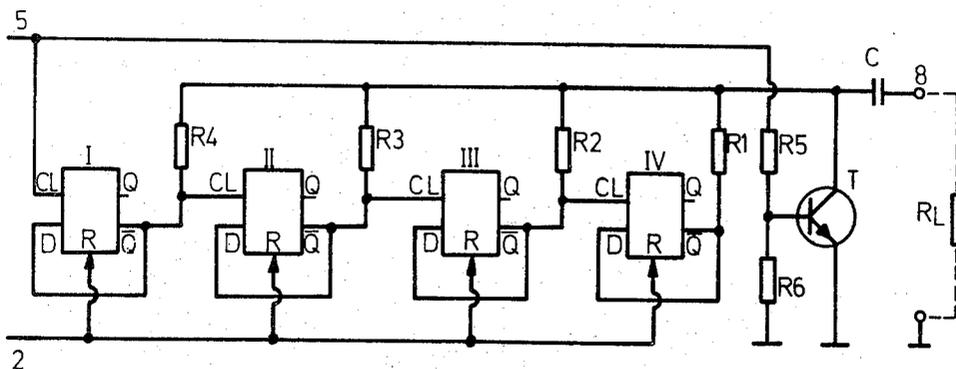


Fig. 3

## HEARTBEAT ACTUATOR WITH CONTROLLED PULSE AMPLITUDE

This invention relates to a heartbeat actuator, particularly an implantable heartbeat actuator having means for automatically lowering the amplitude of stimulating impulses produced by the beat actuator.

Beat actuators of this type have the purpose of determining the threshold value of the stimulus of the heart by means of the actuator. For that purpose, for example, in case of an implanted beat actuator, the actuator is influenced by action of a magnetic field upon a switch sensitive to the magnetic field and provided in the actuator, so that it operates with a fixed frequency and so that the amplitude of the produced stimulating impulses is continuously lowered. A measure for calculating the threshold value of the stimulus of the heart is provided from the number of produced effective impulses of the heartbeat maker calculated from the switching of the switch which depends upon the magnetic field up to an absence of an answer from the irritated heart. The lowering of the amplitude of the stimulating impulses can be produced by using the charging condition of a condenser which can be charged through a resistance, to operate the charging current of that condenser which is discharged through the heart for producing a stimulating impulse. However, this manner of producing the lowering of the amplitudes results in a poorly definable gradation of the amplitudes and the reproduction of the gradation cannot be carried out with sufficient precision and replaceability.

An object of the present invention is to produce a heartbeat maker of the described type wherein the lowering of the amplitudes of the stimulating impulses takes place in precisely definable steps. The reproduction of the gradation should be possible with simple and cheap means. All these objects should be carried out by the least possible number of structural elements requiring a small amount of space.

An object of the present invention can be accomplished by providing a stepwise switching device operated in rhythm with the stimulating impulses for connecting switching elements influencing the amplitude of the stimulating impulses. The elements are so dimensioned that the lowering of the impulses takes place in predetermined preferably equal steps.

According to a further development of the present invention a digital counter is used as the stepwise switching device and is preferably made as an integrated structure. In this manner a space saving and cheap switching device is produced. As switching elements influencing the amplitude of the threshold value of the stimulus, preferably fixed resistances are used which are small and cheap and the value of which can be fixed very precisely.

In known heartbeat actuator circuits the amount of the amplitude of a stimulating impulse is determined by the charge condition of a condenser discharging for impulse production. In accordance with the present invention in such connection the fixed resistances are switched on by the stepwise switching device into the charging circuit of the condenser.

The present invention further provides that the least possible number of resistances can be used if their size is arranged in steps according to a geometrical series and if they can be combined individually with each other. By the use of different possible combinations

and when using an  $n$ -step binary counter as the stepwise switching device it is possible to provide with  $n$  fixed resistances  $2^n - 1$  combinations of resistances the values of which may provide that the amplitudes can be lowered in equal steps to zero.

The invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawing showing by way of example only, a preferred embodiment of the inventive idea.

In the drawing:

FIG. 1 is a switch circuit illustrating the basis of the present invention.

FIG. 2 is a diagram showing the desired stepwise arrangement of the amplitudes as a function of time.

FIG. 3 is a switch circuit showing the various parts causing the lowering of the impulses.

FIG. 1 shows an amplifier 1, a switch 2 dependent upon a magnetic field, a trigger circuit 3, an astable multivibrator 4, a monostable multivibrator 5, a so-called dosing circuit 6 and an outlet switch 7 of a heartbeat actuator. The outgoing impulses of the heartbeat actuator reach through the outlet clamp 8 the heart of the patient. The same conduit receives the EKG signals of the heart and transmits them to the amplifier. When natural heart actions are absent a sequence of impulses is produced in the multivibrator 4 corresponding to the switching time of this multivibrator; this sequence of impulses closes through the monostable tipping stage the switch 7 for a short time when there is an impulse and provides that a stimulating impulse is transmitted to the heart. When there are natural heart actions they are transmitted through the amplifier 1 and the trigger circuit 3 to the astable multivibrator 4 in such manner that it is set back to its initial position. In this manner when there is no natural heart action a stimulating impulse is transmitted to the heart. By applying a magnet upon the skin of the patient's body over the implanted heartbeat actuator it is possible to provide that the switch 2 dependent upon the magnetic field will be closed and will switch off the trigger circuit. Due to this arrangement natural heart actions will have no effect any more upon the production of stimulating impulses. Consequently the beat actuator will operate with the beat actuating frequency produced by the astable multivibrator. At the same time as the switch dependent upon the magnet field is switched on the dosing circuit is actuated in a manner which will be described later on. It serves after the switching on of the switch dependent upon the magnetic field to diminish stepwise in equal steps the amplitude of the outgoing impulses of the heartbeat actuator. FIG. 2 shows the desired run of the amplitudes, whereby the amplitude  $A$  of impulses produced by the beat actuator is shown as a function of the time  $t$ . The horizontal broken line indicates the threshold value of the stimulus of the heart and the two vertical broken lines show the limits of the time period during which the switch dependent upon the magnetic field was actuated by the application of a magnet. An arrow shows the first impulse of the series of impulses the amplitude of which is smaller than the threshold value of the stimulus of the heart and thus is not sufficient any more for stimulating the heart. The term "geometric row" is used to indicate the dimensioning and interconnection of resistances whereby the amplitude of exciting impulses is lowered in equal steps. A similar arrangement is described by A. Watson as "A

Staircase Function Generator" in Electronic Engineering, May 1965, pg, 329.

FIG. 3 shows the switch connections of the dosing circuit as well as the construction of the switch 7. The switch 7 consists of a transistor T through which a condenser C can be discharged. Normally the transistor is locked so that the condenser C can be charged through the resistance R<sub>1</sub>. However, as soon as an impulse from the monostable multivibrator 5 reaches the base of the transistor through the voltage dividers R<sub>5</sub>, R<sub>6</sub>, the transistor becomes conducting and permits the discharge of the condenser to the heart of the patient. The reserve resistance of the heart is indicated as R<sub>L</sub> in FIG. 3. By actuating the element 2 the binary counter consisting of switch members I to IV is switched on. This results in that resistance combinations of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> will be switched on in the rhythm of the beat actuator impulses; they determine by voltage division the voltage with which the condenser can be charged between two following impulses of the monostable multivibrator 5. The values of the resistances are geometrically stepped and thus when they are switched jointly they permit the formation of a linear resistance row. The switch elements I to IV are made in digital structure. They switch the resistances on and off one after the other depending upon impulses supplied from the monostable multivibrator 5, so that all possibilities of the joint connection of the resistances R<sub>1</sub> to R<sub>4</sub> are exhausted. The switching elements I to IV are provided with the usual connection indications, so that further description is unnecessary.

The quantitative determination of the maximum amplitude takes place by the use of a frequency measurer,

which determines precisely the frequency of the impulse sequence of the monostable multivibrator. Since there is a firm connection between this frequency and the voltage of the batteries, the maximum amplitude can be easily determined from the measured frequency, since it corresponds to the stimulation frequency

The present invention makes it possible to determine the threshold value of the stimulus heart with simple and cheap parts requiring little space in a continuously reproducible way and with precision and safety. Thus it is possible to determine expected life duration of the heartbeat actuator relatively to the required amplitude height provided by the heart threshold value of the stimulus.

What is claimed is:

1. A heartbeat actuator, particularly an implantable heartbeat actuator, comprising a condenser, a charging circuit connected with said condenser for controlling pulse amplitude, means producing stimulating impulses, said charging circuit including a digital counter actuated by the pulses and a plurality of resistances connected thereto, whereby the counter combines the resistances to control pulse amplitude, said resistances having values arranged according to a geometrical row, means combining said resistances with each other, and means connected with said condenser and said impulse-producing means for applying the generated impulses to the heart, the combined resistances being switched into said charging circuit by said counter so that the lowering of the amplitudes takes place in predetermined equal steps.

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