Description

This invention relates to a transcutaneous electrical nerve stimulator to be used in pain control.

There is a long history of the employment of electrical shocks for various therapeutic needs. Centuries ago, electric eels were employed to provide the desired stimulation. Even to the present, it is believed by some to be beneficial to apply successive electrical shocks to the musculature, either to achieve muscular contractions, or for desired thermic action. See, for example, U.S. Patents 2,936,762 and 3,261,358 to P. D. Bernard.

Electrical stimulation of human tissue has received its greatest acceptance, in recent years, with respect to electrical stimulation of the heart to stimulate pumping action, and to maintain adequate blood flow through the system. Further, increasing sophistication in semiconductor components and miniaturization thereof has allowed for corresponding sophistication in terms not only of the types of application of electrical stimulation, but furthermore to the ultimate controllability of the stimulating signals themselves. Present applications include stimulation of the carotid sinus, the urinary bladder, the intestines, the diaphragm, and the like. Further, there is ever increasing interest in the utilization of electrical stimulation of the nervous system to alleviate pain.

It is well known that living cells, both nerve and muscle cells, consist of an outer membrane containing an inner fluid of more or less structured water, containing various chemical ions such as potassium, calcium, and sodium. These ions are charged particles, and their concentration inside and outside of the cell results in an electrical and chemical polarization between the inside and outside of the cell wall. Muscular contraction and nervous communication is carried on by a depolarization of these cells. It is also well known that depolarization of these cells can be initiated by artificial electrical stimulation.

Predictably, different types of cells generally require correspondingly different types of electrical stimulating signals. For example, even considering nerve cells, there are different strength and duration requirements for electrical pulses which will effectively stimulate sensor (Class A afferent), motor (efferent), and noxous (Class C nociceptor) cells. Generally this results from the rather wide differences involved in the ranges of natural pulse repetition frequencies found in the various nerves. For example, the repetition frequency of the nervous signal stimulating the heart is of the order of 1 Hz, while the repetition frequency of pain provoked signals in the Class C fibres is of the order to 100 Hz.

There also exist differences in the parameters required for stimulation when a stimulating electrode is placed adjacent the cells that are being stimulated (e.g. the heart), as opposed to less proximate electrode placement, (e.g. electrodes at skin surface for stimulating a nerve several millimeters beneath the skin). Included among the critical output stimulation parameters are pulse repetition frequency, pulse duration, and pulse amplitude.

Accordingly, selection of parameters of a given stimulator will be influenced by the particular type of stimulation sought. For example, it is generally held that very short pulses will be relatively more effective in stimulating small fibres, than are relatively long pulses. Hence, when an electrode is placed within the proximity of more than one nerve in the same general area, and it is desired to stimulate one of them, some selectivity may be achieved by optimizing the stimulating parameters for that particular nerve. The field of optimization and selectivity is at this time, however, rather nascent.

It is known that feedback-type effects exist in the nervous system (often clinically referred to as "reverberation", "re-entry", "reciprocal rhythms", and the like). Among the approaches to electrical stimulation is the injection of a properly timed signal of proper amplitude, which appropriately alters the natural feedback operation. Correspondingly, the physiological and perceptive aspects of the nervous operation are altered or effectively cancelled.

Further complicating the uniform administration of effective stimulation is the widespread diversity from person to person in physical nerve and muscle structure, and in associated electrical characteristics. These include not only the operational characteristics of the nerves, but also the locations of the nerves within the body and with respect to one another.

It is known in the art to provide stimulating apparatus for electrotherapy in, for example, muscle control. U.S. Patent Specification 2,350,797, for instance, describes such an apparatus where the output pulse signals are scanned through predetermined ranges of pulse frequency and amplitude. There is, however, a physiological difference between transcutaneous electrical nerve stimulation for the purposes of pain control, as employed in the present invention, and the application of electrical signals for therapeutic muscle stimulation. Apparatus suited for the latter is not necessarily identical nor suited to the former application. There is no disclosure in documents such as U.S. 2,350,797 that the apparatus is so suited or that it is intended for transcutaneous electrical nerve stimulation.

GB—A—1 488 957 discloses a transcutaneous electrical nerve stimulator to be used in pain control which generates electrical pulses having a pulse frequency between 10 and 300 Hz, a pulse width between 50 and 1000 µsec, and a pulse peak amplitude between 10 and 80 milliamperes. The exact parameters of the electrical pulses are manually adjustable.

FR—A—2 147 792 discloses an electrotherapy apparatus for applying a heating effect to a muscle which generates electrotherapy pulses in which the pulse width and pulse frequency are varied inversely in order to prevent burning as the pulse frequency increases.

It is an object of the present invention to provide a transcutaneous electrical nerve stimulator suitable for pain control which achieves relatively optimum effectiveness for a broad class of nerve types, and also accommodates a relatively broad range of variability in physiological structure of the nerves.

According to the present invention, there is provided a transcutaneous electrical nerve stimulator to be used in pain control comprising:

an oscillator for generating electrical pulses; and

an amplifier for amplifying the electrical pulses to produce an output stimulating signal;

characterised in that it further comprises:

a frequency modulator for continuously and automatically varying through a range of 50 to 150 Hz the frequency of the electrical pulses;

a pulse duration modulator for continuously and automatically varying through a range of 20 to 150 µsec the pulse width of the electrical pulses; and

an intensity modulator for continuously and automatically varying through a predetermined range the pulse amplitude of the amplified electrical pulses.

The present invention is grounded on the proposition of a manifold approach to the application of electronic stimulation in pain control, utilizing a scanning of the various output parameters over respective predetermined ranges so that optimum parameter values are achieved at least a portion of the time that the stimuli are being provided. For example, if a given repetition frequency is optimum for a particular person for a particular type of nerve, although it is unlikely ever to effectively identify that optimum value, the stimulator of the present invention will periodically produce a signal having that value as the stimulation signal is scanned through a frequency range which on one hand is of minimal or negligible effect during portions of the scan, but which on the other hand does achieve the optimum for a clinically acceptable portion of the total time involved. Correspondingly, extensive and ultimately haphazard iterative fine tunings are obviated, and there also even results an accommodation to spontaneous variation of the optimum within the system over the clinical time period.

In an illustrative embodiment, a first oscillator means, having controllably variable pulse width, pulse amplitude, and pulse frequency parameters, provides the ultimate generation of the stimulating signals. A second, or scanning oscillator operates at least an order to magnitude slower than the first, and provides control for the variation of the output parameters.

Hence, the periodicity of the scanning oscillator effectively establishes the frequency range of 50 to 150 Hz at which the undetermined optimum stimulating characteristic is reached. Preferably, the output of the scanning oscillator is a successively increasing and decreasing linear ramp signal. Separate pulse duration, pulse amplitude, and pulse frequency controls operate in response to the amplitude of the ramp from the scanning generator, and responsively thereto bring about a variation of the associated parameter at the first oscillator, each within respective clinically acceptable ranges mentioned in claim 1 in which the respective optimums are most likely to occur. In turn, the respective control functions are programmably variable, thereby adding further flexibility in terms of pulse rate, pulse duration, and pulse amplitude features.

Figure 1 shows a block diagrammatic version of an illustrative embodiment of the present invention; and

Figures 2A and 2B, when appropriately joined as shown, show a circuit schematic of a preferred embodiment of the present invention.

Referring first to Figure 1, there is shown a block diagram of a transcutaneous nerve stimulation unit according to the present invention. A power supply 101 is understood suitably to deliver energizing voltages and current, as required, to the various other functional blocks of the unit. Generally, the power supply 101 is embodied as any of the numerous compact, long life dry cell batteries which are readily commercially available.

An output stage 109 furnishes a stimulation pulse signal at output terminal 110, which conventionally is coupled to one or more electrodes deposited on the patient, as is known in the art. From the standpoint of the present invention, the more important parameters with respect to the output signal at 110 are its pulse duration, pulse frequency, and pulse amplitude.

An oscillator 102 generates the basis of the stimulating signals, and couples them for suitable output amplification to the output stage 109. Functionally, the oscillator 102 is divided into two parts, a repetition rate generator 103 and a pulse width generator 104. In practice, the repetition rate generation and pulse width generation may not be completely discrete as shown in functional blocks 103 and 104 of Figure 1, but from the standpoint of respective variation of each, they may be deemed functionally discrete as shown. The output signal from the oscillator 102 to the output stage 109, and in turn from the output terminal 110 to the patient, involves a frequency range of 50 to 150 Hz, the width of each pulse varying between 20 and 150 µsec.

A scan ramp generator 108 (second oscillator) produces a signal, based upon which the control of output pulse duration, pulse frequency, and pulse amplitude is maintained. Essentially, the scanning ramp generator 108 provides an output signal, advantageously defining successive increasing and decreasing ramps, the amplitude of which is the basis for respective frequency, pulse width, and pulse intensity modulation. Accordingly, the periodicity of the output signal from the scanning ramp generator 108 is substantially longer than the periodicity of the output from oscillator 102, preferably being at least an order of magnitude longer. In this fashion, the parameters

of the output signal at 110 will be scanned through their respective ranges once for each half cycle of the signal from scanning ramp generator 108.

As shown in Figure 1, the scanning ramp generator is coupled to the input terminals of a frequency modulator 105, a pulse duration modulator 106, and an intensity modulator 107. In turn, the frequency modulator 105 is coupled to repetition rate generator 103 of oscillator 102, the pulse duration modulator 106 is coupled to the pulse width generator 104 of oscillator 102, and the intensity modulator 107 is coupled to the output stage 109. Each of the modulators 105, 106, and 107 provides a control signal, which in accordance with the knowledge of those of ordinary skill in the art may be an analog control voltage or a suitable digital word, responsive to which the associated parameter of the output signal is varied within its range. Hence, as the scanning ramp traverses between its minimum and maximum values, and vice versa, the frequency modulator 105 correspondingly provides a varying output control signal to the repetition rate generator 103 of oscillator 102, in turn producing a continuous frequency variation between range extremities for the output of oscillator 102, and in turn for the output signal at terminal 110. The pulse duration modulator 106 operates similarly in response to the ramp from generator 108, causing pulse width generator 104 of oscillator 102 to provide continuous variation in pulse width, from one range extremity to the other, and similarly so for the output signal at 110. As shown in the drawing, the intensity modulator 107 controls the gain provided at the output stage 109, but it is understood that such modulation could also be accomplished directly at the output of oscillator 102. In any event, the pulse amplitude of the signal at 110 is thereby caused to be altered continuously between extremities of the selected pulse amplitude range.

It may be desirable to maintain a relatively constant stimulation effectiveness, or a relatively uniform subjective sensation by the patient; in such events, it is desirable to have output current decreased while output pulse duration increases. Likewise, for other applications, it may be similarly desirable to maintain a constant total or average energy per unit time delivered to the patient, or to maintain specific average ranges, or below specified maximum values. Of course, the problem of establishing total or average energy values, or specific relative rates of change of specific parameters with respect to the others, is akin in difficulty to a determination of optimum values for a given parameter.

Nevertheless, certain general tendencies may be followed, to be further altered by those of ordinary skill in the art. Thus, one might choose component values such that pulse duration changes in one direction during the cycle, while pulse amplitude is changing inversely as the square root of the change in pulse duration. In such an instance, a one hundred percent increase in pulse duration would be accompanied by approximately a thirty percent decrease in pulse amplitude. Similarly, utilizing the present invention as set forth herein, adaptations may be made with respect to the various parameters and parameter ranges, taken alone or together, to accommodate stimulation at different nerves or different areas of entry of the stimulation. Moreover, as different frequencies and different phases are involved, it is to be expected that there will be increased probability of entering those reverberating loops found in some types of chronic pain, or of disturbing the coded pattern of impulses to the brain.

Figures 2A and 2B, when joined at connections a—a' through s—s' respectively, show a detailed circuit schematic of a preferred embodiment of the present invention. It will be understood that the embodiment of Figures 2A and 2B defines a complete, operational transcutaneous electrical nerve stimulating unit, including not only the aspects set forth in block diagrammatic form in Figure 1, but also including other circuits and functional blocks suitable for incorporation in such a unit.

In Figure 2B, batteries B1, B2, and B3 are series connected, and when switches S1 and S2 are closed, power is provided to the various circuitry. The unit of Figures 2A and 2B is a dual output unit, having respective output stages at transformers T1 and T2, with the secondaries of each transformer being connectable to suitable leads, in turn conveying the output stimulating pulses to electrodes disposed at appropriate places on the patient's body.

The embodiment of Figures 2A and 2B includes a voltage regulator function, with regulator transistor 229 having its emitter connected to the switches S1 and S2, and its base controlled by a differential amplifier formed by the emitter base junctions of transistors 226 and 224. The differential amplifier 226 and 224 senses the voltage attained by the difference between emitter-base voltage drops of transistors 221 and 222, off the regulated voltage, V_{cc}, which is the voltage of the collector of regulating transistor 229 and the reference provided by the transistor 228. Essentially, the voltage regulator function provides an independence of system parameters from battery voltage, as the batteries age and the battery voltages decrease.

The aspects of the Figure 2A—2B embodiment relating to the functions of oscillator 102 of Figure 1 are located generally in the uppermost portion of Figure 2A. That oscillator, which provides the essence of the output waveform in terms of pulse frequency and duration, is a free running, multivibrator type of circuit, wherein transistors 207, 208, and 209 are "on" when an output pulse is being produced, and are "off" during the interval between output pulses. Pulse duration is established by the operation of capacitor 404 in conjunction with resistors 338 and 372. Output pulse repetition frequency is controlled by the capacitor 403 in conjunction with resistors 336 and 337.

The output pulse signal from the oscillator is coupled to the output stages, located at the rightmost portion of Figure 2B, via an alternating flip-flop including transistors 216 and 219, 217 and 218, and transistors 215 and 220. The flip-flop 216 and 219, in conjunction with steering transistors 217 and 218, provides an alternating pulse polarity.

The scanning oscillator which fulfills the functions set forth with respect to scanning generator 108 of the Figure 1 embodiment, is located at the lower leftmost portion of Figure 2A. As described previously, the scanning ramp generator is an oscillator which provides a substantially lower frequency than that of the output oscillator 102, the purpose of the scanning oscillator being to provide for parameter changes for scanning at a repetition frequency preferably measured in the range of seconds. The scanning oscillator includes transistors 235 and 236 connected in a monostable multivibrator configuration. Whenever transistor 235 is conducting, transistor 233 is also conducting to provide a current to transistors 232 and 237, with transistor 237 being a current source to capacitor 405. Conversely, if transistor 236 is conducting, transistor 238 acts as a current sink to the same capacitor, 405. Hence, whenever transistor 235 is conducting, the voltage on capacitor 405 is charging and changing positively, and when transistor 238 is conducting, the voltage on capacitor 405 is discharging and negative going. Transistor 241 determines the inflection point in the positive direction, and transistor 242 determines the inflection point in the negative direction. Accordingly, the voltage on capacitor 405 alternately rises and falls during the alternate two phases of each cycle of transistors 235 and 236, respectively. This upward and downward voltage on capacitor 405 is translated into corresponding upward and downward currents from transistors 247 and 250.

Transistor 247 modulates the charging current for capacitor 403, which in turn determines the repetition frequency of the basic oscillator. Thus, transistor 247 and its associated circuitry essentially fulfills the function attributed to the frequency modulator 105 of the Figure 1 embodiment. In Figure 2A, transistor 250 similarly modulates the pulse duration of the basic oscillator by modulating the charging current of capacitor 404. This corresponds to the operation of the pulse duration modulator 106 of Figure 1.

Since the current at the emitter of transistor 246 is nearly identical to the collector current of transistor 246, there occurs a similar alternating up and down current available from transistors 251 and 253, to that previously described. Transistors 251 and 253 provide currents to the output circuits in Figure 2B, so that the amplitude of pulses from transistors 260 and 267 is similarly modulated. The emitter resistances in transistors 247, 250, 251, and 253 are selected so that the amount of scan or warbling is determined. That is, resistors 365, 366, 349, 340, 346, 347, and 356 afford an opportunity for adjustability of the various modulation parameters.

Protection circuitry is provided at transistors 254, 255, 256, and 257 for sensing discontinuity at the output, such as might eventuate if the electrodes are detached from the patient. In order to avoid discomfort or danger to the patient, this aspect of the circuitry of Figures 2A and 2B provides an automatic disconnect function. Diode DS1 provides an indication to the user of the exercise of this feature.

The foregoing description of the embodiments of Figures 2A and 2B has focused largely on the aspects relating to the principles of the present invention, to wit, scanning the output parameters of pulse width, pulse frequency, and pulse amplitude. Operation of other detailed features of the circuitry will, in view of the schematic detail provided, be readily apparent to those of ordinary skill in the art.

Claims

1. A transcutaneous electrical nerve stimulator to be used in pain control comprising:
an oscillator (102) for generating electrical pulses; and
an amplifier (109) for amplifying the electrical pulses to produce an output stimulating signal, characterised in that it further comprises:
a frequency modulator (105) for continuously and automatically varying through a range of 50 to 150 Hz the frequency of the electrical pulses;
a pulse duration modulator (106) for continuously and automatically varying through a range of 20 to 150 µsec the pulse width of the electrical pulses; and
an intensity modulator (107) for continuously and automatically varying through a predetermined range the pulse amplitude of the amplified electrical pulses.

2. The stimulator of claim 1, wherein the pulse width and pulse amplitude are variable in opposite senses, whereby the average energy delivered by the stimulator is maintainable within an acceptable predetermined range of total energy.

3. The stimulator of claim 1 or claim 2, further including a second oscillator (108), having a pulse rate at least an order of magnitude slower than the pulse rate of the first oscillator (102), the modulators (105, 106, 107) being responsive to said second oscillator (108) for independently varying the parameters of the amplified electrical pulses at said second rate.

4. The stimulator of claim 3, wherein the second oscillator (108) is adapted to generate respectively successive substantially linear increasing and decreasing half cycles at the second output rate.

5. The stimulator of claim 3 or claim 4, wherein the frequency modulator (105) is responsive to the amplitude of the output signal from the second oscillator (108).

6. The stimulator of any one of claims 3 to 5, wherein the pulse duration modulator (106) is responsive to the amplitude of the output signal from the second oscillator (108).

The output pulse signal from the oscillator is coupled to the output stages, located at the rightmost portion of Figure 2B, via an alternating flip-flop including transistors 216 and 219, 217 and 218, and transistors 215 and 220. The flip-flop 216 and 219, in conjunction with steering transistors 217 and 218, provides an alternating pulse polarity.

The scanning oscillator which fulfills the functions set forth with respect to scanning generator 108 of the Figure 1 embodiment, is located at the lower leftmost portion of Figure 2A. As described previously, the scanning ramp generator is an oscillator which provides a substantially lower frequency than that of the output oscillator 102, the purpose of the scanning oscillator being to provide for parameter changes for scanning at a repetition frequency preferably measured in the range of seconds. The scanning oscillator includes transistors 235 and 236 connected in a monostable multivibrator configuration. Whenever transistor 235 is conducting, transistor 233 is also conducting to provide a current to transistors 232 and 237, with transistor 237 being a current source to capacitor 405. Conversely, if transistor 236 is conducting, transistor 238 acts as a current sink to the same capacitor, 405. Hence, whenever transistor 235 is conducting, the voltage on capacitor 405 is charging and changing positively, and when transistor 238 is conducting, the voltage on capacitor 405 is discharging and negative going. Transistor 241 determines the inflection point in the positive direction, and transistor 242 determines the inflection point in the negative direction. Accordingly, the voltage on capacitor 405 alternately rises and falls during the alternate two phases of each cycle of transistors 235 and 236, respectively. This upward and downward voltage on capacitor 405 is translated into corresponding upward and downward currents from transistors 247 and 250.

Transistor 247 modulates the charging current for capacitor 403, which in turn determines the repetition frequency of the basic oscillator. Thus, transistor 247 and its associated circuitry essentially fulfills the function attributed to the frequency modulator 105 of the Figure 1 embodiment. In Figure 2A, transistor 250 similarly modulates the pulse duration of the basic oscillator by modulating the charging current of capacitor 404. This corresponds to the operation of the pulse duration modulator 106 of Figure 1.

Since the current at the emitter of transistor 246 is nearly identical to the collector current of transistor 246, there occurs a similar alternating up and down current available from transistors 251 and 253, to that previously described. Transistors 251 and 253 provide currents to the output circuits in Figure 2B, so that the amplitude of pulses from transistors 260 and 267 is similarly modulated. The emitter resistances in transistors 247, 250, 251, and 253 are selected so that the amount of scan or warbling is determined. That is, resistors 365, 366, 349, 340, 346, 347, and 356 afford an opportunity for adjustability of the various modulation parameters.

Protection circuitry is provided at transistors 254, 255, 256, and 257 for sensing discontinuity at the output, such as might eventuate if the electrodes are detached from the patient. In order to avoid discomfort or danger to the patient, this aspect of the circuitry of Figures 2A and 2B provides an automatic disconnect function. Diode DS1 provides an indication to the user of the exercise of this feature.

The foregoing description of the embodiments of Figures 2A and 2B has focused largely on the aspects relating to the principles of the present invention, to wit, scanning the output parameters of pulse width, pulse frequency, and pulse amplitude. Operation of other detailed features of the circuitry will, in view of the schematic detail provided, be readily apparent to those of ordinary skill in the art.

Claims

1. A transcutaneous electrical nerve stimulator to be used in pain control comprising:
an oscillator (102) for generating electrical pulses; and
an amplifier (109) for amplifying the electrical pulses to produce an output stimulating signal, characterised in that it further comprises:
a frequency modulator (105) for continuously and automatically varying through a range of 50 to 150 Hz the frequency of the electrical pulses;
a pulse duration modulator (106) for continuously and automatically varying through a range of 20 to 150 µsec the pulse width of the electrical pulses; and
an intensity modulator (107) for continuously and automatically varying through a predetermined range the pulse amplitude of the amplified electrical pulses.

2. The stimulator of claim 1, wherein the pulse width and pulse amplitude are variable in opposite senses, whereby the average energy delivered by the stimulator is maintainable within an acceptable predetermined range of total energy.

3. The stimulator of claim 1 or claim 2, further including a second oscillator (108), having a pulse rate at least an order of magnitude slower than the pulse rate of the first oscillator (102), the modulators (105, 106, 107) being responsive to said second oscillator (108) for independently varying the parameters of the amplified electrical pulses at said second rate.

4. The stimulator of claim 3, wherein the second oscillator (108) is adapted to generate respectively successive substantially linear increasing and decreasing half cycles at the second output rate.

5. The stimulator of claim 3 or claim 4, wherein the frequency modulator (105) is responsive to the amplitude of the output signal from the second oscillator (108).

6. The stimulator of any one of claims 3 to 5, wherein the pulse duration modulator (106) is responsive to the amplitude of the output signal from the second oscillator (108).

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7. The stimulator of any one of claims 3 to 6, wherein the intensity modulator (107) is responsive to the amplitude of the output signal from the second oscillator (108).

8. The stimulator of any one of claims 3 to 7, wherein the first oscillator (102) comprises two R—C section (403, 336, 337; 404, 338, 372) for establishing the pulse frequency and pulse width respectively, and wherein the frequency modulator (105) and pulse width modulator (106) are adapted to alter the charging-discharging cycle of its respective R—C section, thereby correspondingly altering the frequency or pulse width respectively.

Revendications

1. Neurostimulateur électrique transcutané pour le contrôle de la douleur, comprenant:

— un oscillateur (102) servant à produire des impulsions électriques, et

— un amplificateur (109) servant à amplifier les impulsions électriques de manière à produire un signal de stimulation de sortie, caractérisé en ce qu'il comprend en outre:

— un modulateur de fréquence (105) servant à modifier de façon continue et automatique la fréquence des impulsions électriques dans une gamme comprise entre 50 et 150 Hz,

— un modulateur d'impulsions en durée (106) servant à modifier de façon continue et automatique la durée des impulsions électriques dans une gamme comprise entre 20 et 150 µs, et

— un modulateur d'intensité (107) servant à modifier de façon continue et automatique l'amplitude des impulsions électriques amplifiées dans une gamme prédéterminée.

2. Stimulateur selon la revendication 1, dans lequel la durée et l'amplitude des impulsions sont variables en des sens opposés, ce qui a pour effet que l'énergie moyenne délivrée par le stimulateur peut être maintenue dans une gamme prédéterminée admissible de valeurs de l'énergie totale.

3. Stimulateur selon la revendication 1 ou 2, comprenant en outre un second oscillateur (108) possédant une fréquence d'impulsions qui est inférieure d'au moins un ordre de grandeur, à la fréquence des impulsions du premier oscillateur (102), les modulateurs (105, 106, 107) étant sensibles audit second oscillateur (108) pour modifier de façon indépendante les paramètres des impulsions électriques amplifiées, qui possèdent ladite seconde fréquence.

4. Stimulateur selon la revendication 3, dans lequel le second oscillateur (108) est apte à produire des alternances successives, qui augmentent et diminuent d'une façon essentiellement rectiligne, avec la seconde fréquence de sortie.

5. Stimulateur selon la revendication 3 ou 4, dans lequel le modulateur de fréquence (105) est sensible à l'amplitude du signal de sortie délivré par le second oscillateur (108).

6. Stimulateur selon l'une quelconque des revendications 3 à 5, dans lequel le modulateur d'impulsions en durée (106) est sensible à l'amplitude du signal de sortie délivré par le second oscillateur (108).

7. Stimulateur selon l'une quelconque des revendications 3 à 6, dans lequel le modulateur d'intensité (107) est sensible à l'amplitude du signal de sortie délivré par le second oscillateur (108).

8. Stimulateur selon l'une quelconque des revendications 3 à 7, dans lequel le premier oscillateur (102) comporte deux sections R—C (403, 336, 337; 404, 338, 372) servant à établir respectivement la fréquence et la durée des impulsions, et dans lequel le modulateur de fréquence (150) et le modulateur d'impulsions en durée (106) peuvent modifier le cycle de charge-décharge de leur section R—C respective, ce qui permet de modifier de façon correspondante respectivement la fréquence ou la durée des impulsions.

Patentansprüche

1. Transkutaner elektrischer Nervenstimulator zur Verwendung bei der Schmerzkontrolle mit:

einem Oscillator (102) zum Erzeugen elektrischer Impulse und

einem Verstärker (109) zum Verstärken der elektrischen Impulse, um ein Stimulations-Ausgangssignal zu erzeugen, dadurch gekennzeichnet, daß er weiter aufweist:

einen Frequenzmodulator (105), um kontinuierlich und automatisch über einen Bereich von 50 bis 150 Hz die Frequenz der elektrischen Impulse zu variieren,

einen Impulsdauermodulator (106), um kontinuierlich und automatisch über einen Bereich von 20 bis 150 µsec die Pulsbreite der elektrischen Impulse zu variieren, und

einen Intensitätsmodulator (107), um kontinuierlich und automatisch über einen vorgegebenen Bereich die Impulsamplitude der verstärkten elektrischen Impulse zu variieren.

2. Stimulator nach Anspruch 1, bei dem die Pulsbreite und die Pulsamplitude in entgegengesetzten Richtungen änderbar sind, wodurch die von dem Stimulator gelieferte mittlere Energie innerhalb eines akzeptablen, vorgegebenen Bereiches der Gesamtenergie haltbar ist.

3. Stimulator nach Anspruch 1 oder Anspruch 2, der weiter einen zweiten Oszillator (108) aufweist, dessen Impulsfolge wenigstens eine Größenordnung langsamer ist als die Impulsfolge des ersten Oszillators (102), wobei die Modulatoren (105, 106, 107) auf den zweiten Oszillator (108) ansprechen, um unabhängig die Parameter der verstärkten elektrischen Impulse mit der zweiten Impulsfolgefrequenz zu variieren.

4. Stimulator nach Anspruch 3, bei dem der zweite Oszillator (108) geeignet ist, um gewells aufeinanderfolgende, im wesentlichen linear ansteigende und abfallende Halbzyklen mit der zweiten Ausgangsfolgefrequenz zu erzeugen.

5. Stimulator nach Anspruch 3 oder Anspruch 4, bei dem der Frequenzmodulator (105) auf die

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Amplitude des Ausgangssignals des zweiten Oszillators (108) anspricht.

6. Stimulator nach einem der Ansprüche 3 bis 5, bei dem der Impulsdauermodulator (106) auf die Amplitude des Ausgangssignals des zweiten Oszillators (108) anspricht.

7. Stimulator nach einem der Ansprüche 3 bis 6, bei dem der Intensitätsmodulator (107) auf die Amplitude des Ausgangssignals des zweiten Oszillators (108) anspricht.

8. Stimulator nach einem der Ansprüche 3 bis 7, bei dem der erste Oszillator (102) zwei R-C-Glieder (403, 336, 337; 404, 338, 372) aufweist, um jeweils die Impulsfrequenz und die Impulsbreite einzustellen, und wobei der Frequenzmodulator (105) und der Impulsbreitenmodulator (106) geeignet sind, den Lade-Entlade-Zyklus des jeweiligen R-C-Gliedes zu ändern und dementsprechend die Frequenz bzw. die Impulsbreite zu verändern.

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