

[54] **PULSE GENERATOR**

[76] Inventor: **Thomas H. Charters**, 6855 S.W.
Raleighwood Way, Portland, Oreg.
97225

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307/252 R, 252 B; 328/59, 60, 65

[56] **References Cited**

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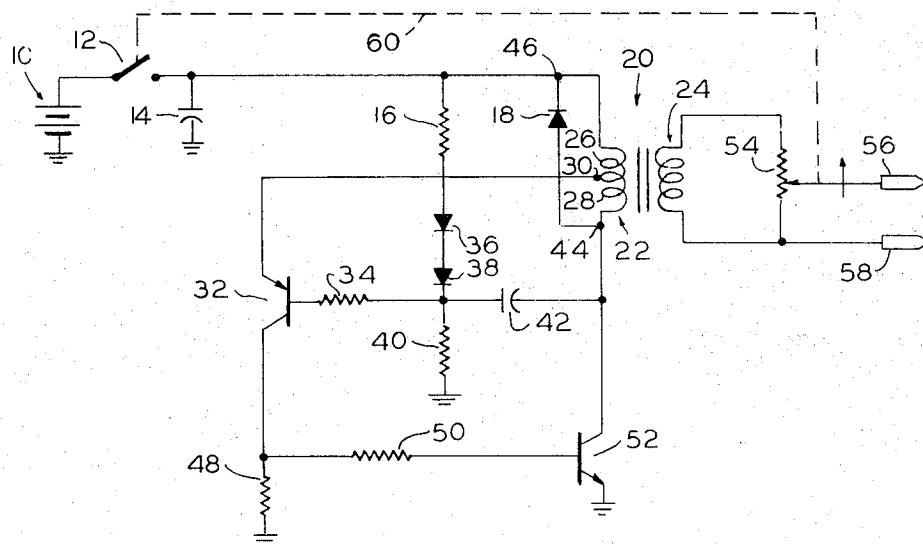
Primary Examiner—Herman J. Hohaus
Attorney—Stephen W. Blore et al.

[57]

ABSTRACT

A pulse generator for providing electrical impulses used for relieving muscle spasm comprises a low impedance source including a capacitor in parallel with a battery connected to one terminal of a step-up transformer's primary winding and a multivibrator switching circuit connected to the remaining terminals of the transformer's primary winding. The multivibrator is adapted for periodically completing the primary circuit and includes R-C time constant means causing the pulse generator to supply an output of definite pulse width and pulse period.

14 Claims, 2 Drawing Figures



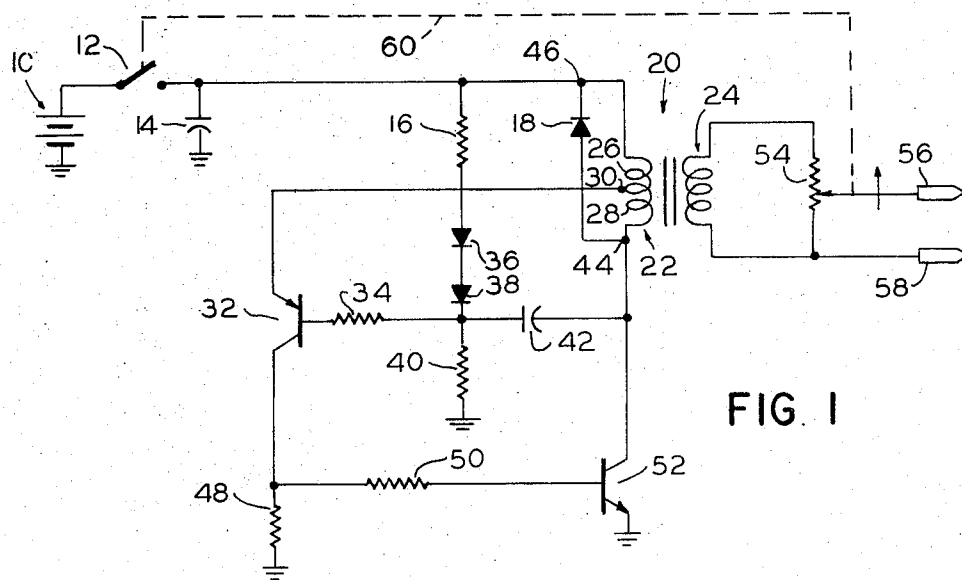


FIG. 1

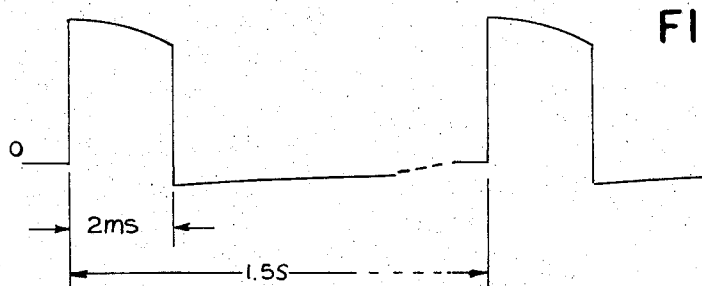


FIG. 2

PULSE GENERATOR

BACKGROUND OF THE INVENTION

Reduction of muscle fatigue spasm or myostatic contracture can be accomplished by the use of compounds which increase the high energy phosphates, and by mild, rhythmic, muscle movement. Experimental work with a myograph and chemical analysis indicates that fatigued muscle restores its energy in light, free motion at a rate below 60 contractions per minute. Fatigue spasm can be reduced by electrical stimulation wherein a low milliampere output on the order of 100 volts, in a diphasic wave, is provided to the patient at a rate of 40 to 60 impulses per minute. Treatment of this type has been found useful and is reported in medical literature for the relief of tension headaches and "whiplash" injuries. This kind of treatment has also been found useful in treating disorders of the temporomandibular joint, i.e., where a patient's jaw is immobile.

Various electrical pulse stimulators are known and are said to provide muscle exercise and the like wherein pulse bursts having a relatively high frequency and repetition rate are provided. However, apparatus of this kind is relatively complex and expensive, and moreover pulsation having somewhat different characteristics and adapted for relieving muscle spasm is preferred according to the present invention. In addition, some circuits adapted to provide pulse outputs are either subject to operating or aging characteristics of components, so far as the pulse width and their repetition rate are concerned, or are rendered unduly complex if these factors are maintained at values found most advantageous for relaxing muscle spasm.

SUMMARY OF THE INVENTION

In accordance with the present invention, a pulse generator comprises a step-up transformer having a secondary winding for delivering an output pulse for muscle stimulation, and a primary winding adapted to be coupled to a low impedance DC source. A multivibrator switching circuit is coupled to complete the circuit of the said primary winding and the DC source, so that current from the source flows through the primary winding and generates the output pulse at the secondary winding. The multivibrator circuit includes an R-C time constant means adapting the multivibrator to switch current through the primary winding for relatively short and predictable pulse duration intervals separated by relatively longer and predictable intervals therebetween. The multivibrator circuit preferably comprises a pair of active elements coupled respectively to a terminal of said primary winding and a tap on such primary winding, wherein the remaining primary winding terminal is coupled to said low impedance DC source.

It is accordingly an object of the present invention to provide an improved pulse generator adapted to supply muscle relaxing impulses.

It is a further object of the present invention to provide an improved pulse generator adapted to provide muscle relaxing impulses, wherein said impulses are of predictable duration and spacing.

It is a further object of the present invention to provide an improved pulse generator for providing muscle relaxing impulses, wherein the construction of such generator is compact and economical.

The subject matter which I regard as my invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. The invention, however, both as to organization and method of operation, together with further advantages and objects thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings wherein like reference characters refer to like elements.

DRAWINGS

FIG. 1 is a schematic diagram of a pulse generator according to the present invention; and

FIG. 2 depicts an output pulse waveform delivered by the FIG. 1 circuit.

DETAILED DESCRIPTION

Referring to the drawings and particularly to FIG. 1, a pulse generator according to the present invention comprises a battery 10 coupled by a switch 12 to a first terminal of a storage capacitor 14. The remaining terminals of the capacitor and the battery are returned to ground or a point of reference potential. The ungrounded terminal of the capacitor is connected to a first end terminal 46 of primary winding 22 of a step-up transformer 20. The transformer typically has a step-up ratio from primary winding 22 to secondary winding 24 of about 1 to 20 whereby a relatively high voltage pulse may be generated across the secondary winding 24. A potentiometer 54 is connected across the secondary winding and output terminals 56 and 58 are respectively connected to the tap on the potentiometer and one end of winding 24. These output terminals are suitably connected to sponge pads or the like for application to the body of the patient in the region of muscle fatigue, and preferably on opposite sides of the body.

The circuit further comprises a multivibrator switching circuit including a first NPN transistor 52 having its collector connected to the remaining end terminal 44 of primary winding 22, and its emitter terminal returned to ground or a point of reference potential. The multivibrator switching circuit further comprises a second PNP transistor 32 having its emitter connected to a center tap 30 on primary winding 22 and having its collector coupled via resistor 50 to the base of the aforementioned transistor 52. The collector of transistor 52 is further returned to ground or a source of reference potential through load resistor 48. A time constant circuit including capacitor 42 and resistor 40 is serially disposed between terminal 44 of primary winding 22 and ground or point of reference potential, with the junction between elements 42 and 40 being coupled to the base of transistor 32 through resistor 34. The aforementioned junction is additionally coupled to terminal 46 via a charging circuit comprising resistor 16 in series with diodes 36 and 38 poled to provide current flow to capacitor 42 from battery 10 and capacitor 14 with the battery polarity shown, i.e., with the ungrounded terminal of the battery positive. Thus, the cathodes of the series connected diodes 36 and 38 are oriented toward capacitor 42. Resistor 16 and diodes 36, 38 also form part of the time constant circuit.

Battery 10 together with capacitor 14 connected thereacross, when switch 12 is closed, comprises a low

impedance DC source for providing relatively high current for a short period of time through primary winding 22 of the transformer when transistor 52 conducts. The multivibrator, wherein transistors 52 and 32 form the active elements, periodically provides the return for primary winding 22 whereby current is passed through the primary winding for short periods on the order of milliseconds, separated by much longer periods on the order of a second or somewhat greater. The resulting output pulse is illustrated in FIG. 2 where, in this instance, the output pulses across secondary winding 24 are approximately 2 milliseconds in duration, and are separated by a period of 1.5 seconds, resulting in a frequency of 40 pulses per minute. The amplitude of the pulse is suitably between 40 and 80 volts as applied between output terminals 56 and 58, and under load conditions, wherein this particular voltage, pulse duration, and pulse period, have been found to provide advantageous results in the case of muscular spasm. Naturally, the pulse duration, voltage, and pulse period may vary somewhat from these values, but in general a voltage above 40 volts is found necessary to provide significant stimulation to the patient, while a pulse much above 80 volts (under load conditions) is found to be excessive or to cause discomfort. The pulse width should be on the order of milliseconds, with the pulse period being on the order of seconds. This pulse width is found to be physiologically related to muscle stimulating pulses generated by the body itself for bringing about muscle contraction, while the pulse period of 40 pulses per minute is also related to muscle stimulating pulses in the body. The steep rise and fall time of the pulse outputs provided according to the present invention are also important in providing the proper stimulation.

Further considering operation of the circuit, let us assume both transistors 32 and 52 are conducting, i.e., primary 22 is carrying a current for producing an output pulse. At the start of the pulse, current through the primary 22 will be comparatively low and will increase to the point where approximately an amp is coupled through primary 22 and transistor 52. At the same time, capacitor 42 is charged through diodes 36 and 38 and the transistor 52, with the left-hand terminal of capacitor 42 becoming more positive until the voltage at the junction between diode 38 and capacitor 42 rises to the point where transistor 32 is cut off. It will be noted that capacitor 42 charges toward a higher voltage than the transformer tap voltage to which the emitter of transistor 32 is connected so as to make the timing of the circuit predictable. When transistor 32 cuts off, its collector voltage drops and transistor 52 is also cut off. Transistor 52 collector and transformer primary center-tap 30 both rise toward battery voltage. However, the rate of change of voltage at the transistor 52 collector is greater than the rate of change at transformer primary center-tap 30, keeping transistor 32 cut off. Diode 18, connected across the primary winding, attenuates a positive spike which would have a deleterious effect upon transistor 52. Assuming battery 10 has a terminal voltage of 9 volts, both terminals 46 and 44 will be at 9 volts when the transformer stops conducting at the end of a pulse.

During the period between pulses, capacitor 42 discharges through resistor 40, as well as primary wind-

ing 22 and the battery, and the resistance of resistor 40 is arranged to be rather high in comparison to the resistance of resistor 16 through which the capacitor charged. Therefore, the period of discharge or the period between pulses is much longer. Eventually, in a matter of seconds, capacitor 42 discharges to the point where the voltage at the junction between capacitor 42 and resistor 40 allows transistor 32 to conduct. Conduction in transistor 32 rapidly brings about conduction in transistor 52 and another pulse is generated.

Assuming battery 10 has a terminal voltage of approximately 9 volts, capacitor 42 charges to approximately a voltage of 4 volts on its left-hand plate for cutting off transistor 32. When the pulse thus concludes, both terminals 46 and 44 of the transformer will be at approximately 9 volts, and the left-hand plate of capacitor 42 will then be at a correspondingly higher voltage and will discharge through resistor 40. The pair of diodes 36 and 38 are employed in series so that as capacitor 42 discharges, sufficient drop will be provided across elements 16, 36, and 38 to insure turn-on of transistor 32 for generation of the next pulse.

Among the advantages of the circuit are the economy of components and the small number of variable components. Only one potentiometer, i.e., potentiometer 54, is employed to adjust the output, and is ganged with switch 12 as indicated at 60. However, resistors 16 and 40 can be made adjustable if so desired in which case resistor 16 is utilized for adjusting pulse width and resistor 40 is employed for adjusting the period between pulses.

The R-C time constant circuit employed in the multivibrator renders the pulse width and repetition rate quite predictable and in any case not dependent upon the vagaries of the transistors, nor the characteristics of the transformer employed. As has been mentioned, the pulse width and repetition rate are important factors for providing proper muscle stimulation and it is therefore desired that these pulses and the periods therebetween be predictable. The present circuit is also not to be confused with instruments providing packets of high frequency pulses sometimes used for other purposes than relaxing muscle spasm. Furthermore, the multivibrator suitably causes the steep rise and fall times desirably associated with the pulses.

It is in accordance with a feature of the invention that the emitter of transistor 32 is tapped at an intermediate voltage, i.e., along the transformer primary winding, suitably at a center-tap thereof, dividing the transformer primary winding into separate portions 26 and 28, whereby the capacitor 42 can charge to a higher value which will definitely cut off transistor 32 at a specific time. Moreover, the current flows through the entire primary winding, the transformer utilization is maximized, and additional power supplies or tapped input batteries are avoided. Alternatively, a center-tapped, resistive voltage divider may be employed across or instead of winding 22, with the emitter of transistor 32 connected to the center-tap thereof. A transformer winding is preferred since the reverse transformer voltage at the pulse conclusion then aids in turning transistor 32 off.

The circuit according to the present invention may be provided with additional outputs if desired. Thus, an additional transformer may be connected essentially in

parallel with transformer 20, with the primary winding of such transformer connected to terminals 44 and 46. In such case, the capacitance of element 14 would desirably be increased. Furthermore, an additional emitter-follower stage can be advantageously interposed between the collector of transistor 32 and the resistor 50. A mechanical timer or the like can suitably be employed to operate switch 12, if desired, for limiting the total duration of pulse generation to approximately 5 to 15 minutes. The source 10, 12, 14 may alternatively be coupled to center-tap 30, if desired, in which case a lower voltage battery can be used.

The components of the FIG. 1 circuit had the following values and component part designations in a particular embodiment, these to be taken in an exemplary sense and not in a limiting sense:

Capacitor 14	1000 microfarads
Resistor 16	390 ohms
Resistor 40	470 K ohms
Resistor 34	1 K ohm
Capacitor 42	10 microfarads
Resistor 48	10 K ohms
Resistor 50	39 ohms
Potentiometer 54	5 K ohms
Transistor 32	2N3702
Transistor 52	2N5189
Transformer 20	Stancor P6465
Battery 10	9 volts

While I have shown and described the preferred embodiment of my invention, it will be apparent to those skilled in the art that many changes and modifications may be made without departing from my invention in its broader aspects. I therefore intend the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

I claim:

1. A pulse generator comprising a step-up transformer having a secondary winding for delivering an output pulse for muscle stimulation, said transformer also having primary winding,

a low impedance DC source means for coupling to said primary winding,

and a multivibrator switching circuit coupled to complete the circuit of said primary winding so that current from said source flows through said primary winding,

said multivibrator switching circuit including a pair of active elements and an R-C time constant means therebetween causing said multivibrator to switch current through said primary winding in impulses of relatively short duration, separated by relatively longer intervals between pulses, to provide separate output pulses across said secondary winding.

2. The apparatus according to claim 1 wherein a terminal of the primary winding of said transformer is connected in series relation with a first of said active elements, a principal electrode of the remaining active element being returned to a tap on said primary winding.

3. The apparatus according to claim 1 wherein a terminal of the primary winding of said transformer is connected in series relation with a first of said active elements, a principal electrode of the remaining active element being returned to a tap on a voltage divider connected across said primary winding.

4. The apparatus according to claim 2 wherein said active elements comprise complementary transistors and said R-C time constant circuit comprises a capacitor coupled between said terminal of the primary of said transformer and the control terminal of the remaining transistor, and a resistor coupling the capacitor to a point of reference potential establishing a relatively long period between pulsations.

5. The apparatus according to claim 4 further including a charging circuit for said capacitor including diode means coupling the junction of said capacitor and said resistor to a terminal of said primary winding of said transformer other than the first mentioned terminal, wherein said diode means is adapted to conduct current in a direction for charging said capacitor through the first of said active elements and adapting said capacitor to interrupt conduction in the remaining active element to conclude a pulse.

6. The apparatus according to claim 1 wherein said low impedance DC source means comprises a DC voltage source and a capacitor coupled thereacross.

7. A pulse generator comprising:

a DC source,

a transformer having a primary winding connected to said DC source, said winding having a first terminal and a second terminal as well as a tap between said first and second terminals, said transformer having a secondary output winding,

a multivibrator switching circuit comprising a first transistor connected to the second terminal of said transformer primary for returning said second terminal to said source, said multivibrator switching circuit further including a second transistor having a first principal terminal connected to said transformer tap and a second principal terminal coupled to the control terminal of the first transistor, and an R-C time constant circuit comprising a capacitor coupled between the second terminal of said transformer primary winding and the control terminal of said second transistor, said time constant circuit further including a resistor returning the control terminal end of said capacitor to a point of reference potential.

8. The apparatus according to claim 7 further including charging means for said capacitor including diode means coupled between said first terminal and the junction between said capacitor and said resistor.

9. The apparatus according to claim 7 further including diode means coupled across the primary of said transformer to reduce an output spike at the end of conduction through said transformer primary winding.

10. The apparatus according to claim 7 wherein said first transistor comprises an NPN transistor and said second transistor comprises a PNP transistor, wherein the collector of said first transistor is connected to the second terminal of said transformer primary winding, and the emitter terminal of said second transistor is connected to said tap, said R-C time constant circuit coupling the collector of the first transistor to the base of the second transistor, while circuit means couple the collector of the second transistor to the base of the first transistor.

11. The apparatus according to claim 7 wherein said resistor is variable to provide an adjustable pulse period.

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12. The apparatus according to claim 8 including a variable resistor in series with said diode means to provide an adjustable pulse width.

13. The apparatus according to claim 7 wherein said R-C time constant circuit is adapted to provide pulses on the order of milliseconds in duration separated by periods on the order of 1 second.

14. A pulse generator comprising a multivibrator switching circuit including a pair of active elements, and tapped load means connected in series relation with a first of said active elements, a principal terminal of the remaining active element being

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returned to the tap of said load means, an R-C time constant circuit coupling said two elements for causing said multivibrator switching circuit to switch,

said time constant circuit including a capacitor coupled from the junction of the first active element and the load means to the control terminal of the remaining active element, and a charging circuit for said capacitor coupling said capacitor to the remaining terminal of said load means.

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