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(71) Applicant *(for all designated States except US)*: **PAINBAN UK LIMITED** [GB/GB]; 2 Ryder Court, Saxon Way East, Oakley Hay Business Park, Northamptonshire, NN18 9NX (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **BONNER, James** [IE/GB]; 29 Violet Street, Waterside, Londonderry, BT47 2AR (GB). **ELDER, Iain** [GB/GB]; 54 Bredfield Road, Woodbridge, Suffolk, IP12 1JE (GB).

(74) Agents: **WALLACE, Alan** et al.; F.R. Kelly & Co., 4 Mount Charles, Belfast BT7 1NZ, Northern Ireland (GB).

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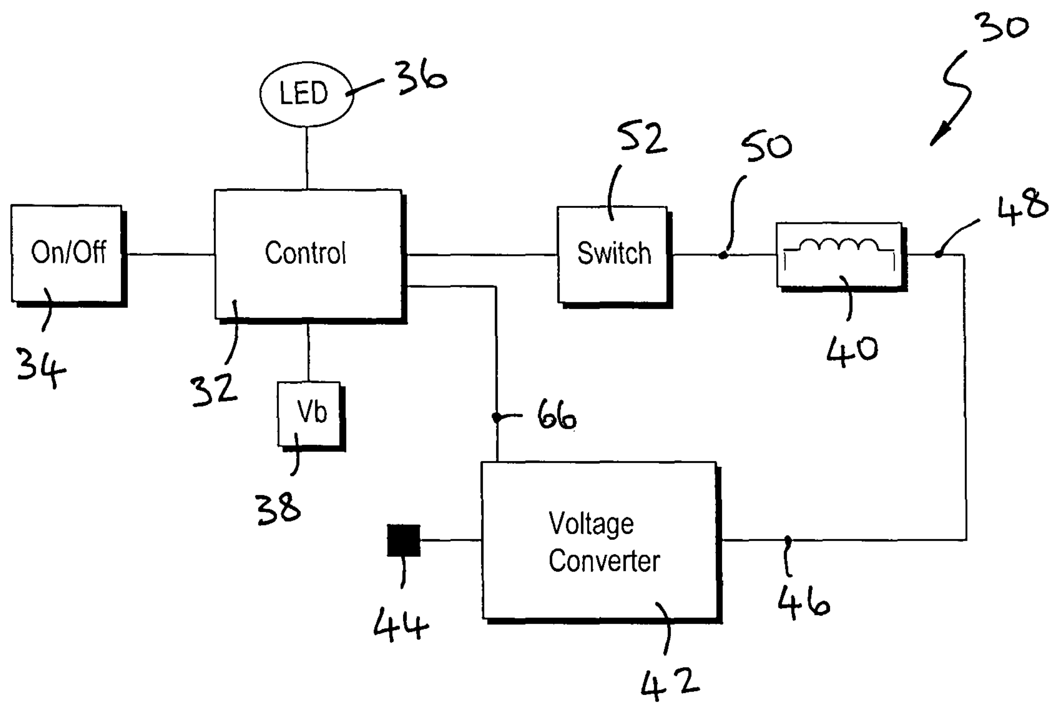
(54) Title: DEVICE AND METHOD FOR CREATING PULSED MAGNETIC FIELDS



(57) Abstract: A device for generating a pulsed magnetic field, especially in a hand held unit for medial applications. The device comprises an inductor located between first and second load terminals, means for applying a DC voltage to said first terminal, and means for causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed manner.

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DEVICE AND METHOD FOR CREATING PULSED MAGNETIC FIELDS

Field of the Invention

The present invention relates to a device and method for creating pulsed magnetic fields, especially in a hand held unit for medical or therapeutic applications.

Background to the Invention

Pulsed Magnetic Field Therapy (PMFT) is a known alternative to conventional methods of treating certain medial conditions. PMFT is particularly, but not exclusively, used to treat pain. Typically, all or part of a patient's body is exposed to a pulsating magnetic field, the filed being characterised by its pulse frequency and its magnetic flux density (usually measured in Tesla), or equivalent field strength measure. It is believed that the characteristics of the magnetic field have an effect on the effectiveness of the treatment.

Conventional devices for delivering Pulsed Magnetic Fields (PMFs) tend to be large and cumbersome and do not readily lend themselves to private personal use. Moreover, it is considered that the PMFs employed by conventional devices are less effective than they might be.

It would be desirable, therefore, to provide an apparatus and method for creating pulsed magnetic fields which is convenient to use and relatively effective in its treatment.

Summary of the Invention

A first aspect of the invention provides a device for generating a pulsed magnetic field, the device comprising an inductive load located between first and second load terminals; means for applying a DC voltage to said first terminal; and means for causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed manner.

In the preferred embodiment, the device is arranged to generate a pulsed magnetic field having a peak amplitude of approximately 10mT, advantageously at a frequency of between 18kHz and 23kHz, preferably approximately 21.3kHz. The pulsed magnetic field is typically characterised by successive peaks, said frequency preferably being the frequency of said peaks.

Advantageously, the device is arranged to generate a pulsed magnetic field having an associated pulsating electrical field with a peak amplitude of at least 30V peak to peak, preferably at least 50V peak to peak and most preferably between 80V and 100V peak to peak.

A second aspect of the invention provides a method of generating a pulsed magnetic field in a device comprising an inductive load located between first and second load terminals, the method comprising applying a DC voltage to said first terminal; and causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed

A third aspect of the invention provides a method of therapeutic treatment comprising applying a pulsed magnetic field having a peak amplitude of between 2mT and 20mT, preferably approximately 10mT, advantageously at a frequency of between 18kHz and 23kHz, preferably approximately 21.3kHz.

Further advantageous aspects of the invention will become apparent to those ordinarily skilled in the art upon review of the following description of a specific embodiment and with reference to the accompanying drawings.

Brief Description of the Drawings

An embodiment of the invention is now described by way of example and with reference to the accompanying drawings in which:

Figures 1A to 1D are perspective views of a device for generating a pulsed magnetic field, embodying the invention;

Figure 2 is a block diagram of an electrical/electronic system for generating a pulsed magnetic field, embodying the invention;

Figure 3 is a circuit diagram illustrating a preferred implementation of the system of Figure 2;

Figure 4 shows control waveforms suitable for use in the circuit of Figure 3;

Figure 5 shows a preferred electrical field generated by the system of Figure 2; and

Figure 6 shows a preferred magnetic field generated by the system of Figure 2.

Detailed description of the Drawings

Referring now to Figures 1A to 1D of the drawings there is shown, generally indicated as 10, a device for generating pulsed magnetic fields (PMFs). Figures 1B and 1D show the device 10 in an assembled state while Figures 1A and 1C show the device 10 in two parts so that its interior may be viewed. The device 10 is a hand held, portable, device having a body portion 12 and a head portion 14. The body portion 12 is conveniently shaped and dimensioned to be gripped by, and preferably gripped within, a user's hand (not shown). The device 10 comprises a casing which, in the illustrated embodiment, comprises two parts, and which contains various operating components of the device 10 as is described below. The device 10 contains an electrical/electronic system for generating PMFs (as is described in more detail hereinafter), including an electrical power source typically in the form of one or more batteries 16, which may be rechargeable or non-rechargeable. In the case where the batteries are rechargeable, the device 10 is provided with an electrical connector 18 for allowing a charging device (not shown) to be connected to the device 10.

Figure 2 shows a block diagram of an electrical/electronic system 30 for generating the PMF. The system 30 includes a control unit 32 typically comprising a programmable data processor, e.g. a microprocessor or microcontroller programmed with, or programmable with, suitable computer program code.

The system 30 may be switched on and off by means of a switch 34 , the output of the switch 34 being connected to the control unit 32. The switch 34 is conveniently incorporated into the device 10 for activation be a user.

Since the PMF is not directly detectable by the user, it is preferred that the device 10 includes means for indicating the state of the device 10 to the user. In the preferred embodiment, the indicating means indicates whether the device 10 is on or off. The indicating means may comprise an LED 36, or other lamp, conveniently controlled by the control unit 32. Advantageously, the indicating means includes a vibration unit 38 which, e.g. under the control of the control unit 32, imparts vibrations to the casing of the device 10 when the device 10 is in use, e.g. when a PMF is being generated. The vibrations are detectable by a user holding the device 10 and it is considered that the sensation provides a reassurance to the user that the device 10 is working. Any suitable conventional vibration device may be used as unit 38.

The system 30 includes a load element 40 which, during use, is supplied with electrical power in order to generate a PMF. The load element 40 preferably comprises a reactive load and more particularly an inductive load, i.e. a load exhibiting an inductive reactance. In the preferred embodiment, the load element comprises an inductor which, in the illustrated example, has an inductance of approximately 2.2mH and may, for example, comprise a 262LY-22K inductor supplied by Toko Electronics. Advantageously, the inductor 40 is driven by applying a pulsating voltage to it, e.g. a pulsed voltage or a voltage in the form of a square wave. The frequency of the applied voltage signal, the amplitude of the applied voltage and the reactance of the inductor 40 each affect the characteristics of the magnetic field produced by the inductor 40 and of the associated electrical field. In the illustrated embodiment, the voltage signal applied to the inductor 40 is approximately 50V peak-to-peak and is conveniently provided in the form of a square wave signal at a preferred frequency of approximately 18 to 23 kHz (more preferably approximately 18.6kHz or approximately 20kHz). This voltage signal, in conjunction with the preferred inductor 40 of 2.2mH generates a pulsed magnetic field and associated electrical field having characteristics that are considered to be advantageous for medial applications. More specifically, the generated PMF has a frequency of between 18 to 23 kHz (preferably approximately 21.3kHz) and a peak amplitude of between 2mT and 10mT, preferably approximately 10mT (milli-Tesla).

The PMF generated by the illustrated embodiment is illustrated in Figure 6. The amplitude of the magnetic field diminishes over time between adjacent peaks (of approximately 10mT). In one embodiment, the amplitude falls substantially linearly to approximately zero between adjacent peaks, e.g. over a period of approximately 40 microseconds. The corresponding pulsating electrical field is illustrated in Figure 5. The electrical field also has a frequency of approximately 21.3kHz, and has similar characteristics to the PMF of Figure 6, although Figure 5 is not shown with the same scale as Figure 6. In the preferred embodiment where the voltage signal applied to the inductor 40 is approximately 50V peak-to-peak, the generated electrical field has an amplitude of approximately 90-100V peak-to-peak. Typically, the amplitude of the electrical field varies between –30 or –40V (as a result of back EMF) to +50V. The amplitude of the generated electrical field is relatively high in comparison with electrical fields normally associated with PMFs for medical applications, and this is considered to be advantageous. More generally, it is the inductor 40 may be driven such that an electrical field with a peak amplitude of at least 5V to 10V peak-to-peak is generated. It is preferred, however, that the peak amplitude of the electrical field is at least 30V peak to peak, and more preferably at least 50V peak to peak. In contrast, the strength of the generated magnetic field is relatively low in comparison to conventional PMFs for similar applications. The combination of a relatively low strength magnetic field and relatively high strength electrical field is found to be effective in application as well as lending itself to being implemented by a device that is relatively small, e.g. a hand held device.

In this connection, it is preferred that the power source is self-contained, e.g. a battery, so that the device 10 does not need to be plugged into a wall socket during use. Given this, and given that the device 10 is relatively small (small enough to be hand held), the system 30 includes a voltage converter 42. The voltage converter 42 is connected to the battery 16, or other power source (preferably a DC power source), either directly or indirectly via terminal 44 and produces stepped up voltage output signal at output 46. The operation of the converter 42 is controlled by the control unit 32 as is described in more detail below. The output 46 of the voltage converter 42 is connected to one end or terminal 48 of the inductor 40. The other end or terminal 50 of the inductor 40 is connected, directly or indirectly, to an output of the control unit 32. During use, the control unit 32 supplies (directly or indirectly) a voltage control signal, or voltage signal, to the end 50 of the inductor which controls how voltage is applied across the inductor 40. In the preferred embodiment, the voltage control signal supplied by the control unit 32 takes the form of a pulsed signal (i.e. a signal toggling between an on and off state), e.g. a square wave. Typically, a switching and, preferably, amplifying circuit 52, is provided between the control unit 32 and inductor end 50. The circuit 52, which conveniently comprises a transistor 53, e.g. a power FET, acting as a switch and an amplifier, acts as a switch which is turned on and off by the control signal from the control unit 32 as well as amplifying the signal provided by the control unit 32 to a level suitable for driving the inductor (typically at least 3V). When the transistor 53 is off, it behaves as open circuit and substantially no voltage is applied across the inductor 40. When the transistor is on, at least some of the DC voltage at terminal 64 is applied across the inductor 40. Hence the output of the circuit 52 which is applied to the inductor 40 comprises a pulsed signal which causes a pulsed voltage to be applied across the inductor 40 thereby creating a PMF. When the transistor 53 is fully on, substantially all of the DC voltage at terminal 64 is applied across the inductor 40. When the transistor 53 is partially on, some of the DC voltage at terminal 64 is applied across the inductor 40 and some is applied across the transistor 53. This results in a PMF of lower peak amplitude. Hence, by controlling the level of the voltage control signal provided by the control unit, the peak amplitude of the PMF can be adjusted.

Figure 3 is a circuit diagram of one implementation of the system 30. Figure 3 uses the same numerals as Figure 2 in order to illustrate which circuit parts of Figure 3 provide an implementation of which blocks of Figure 2. The power supply V_{DD} is provided by the battery16 in conventional manner. In the illustrated embodiment, the battery 16 is assumed to provide a supply of approximately 4.5V. The switch 34, LED 36 and inductor 40 are not shown in Figure 3. A connector 60 is provided with a respective terminal 3,2 for connection to the LED 36 and the switch 34, and a third terminal 1 connected to electrical ground. The terminal 3 for the LED is connected to an output (pin 5) of the control unit 32. The terminal 2 for the switch 34 is connected to an input (pin 4) of the control unit. A second connector 62 is provided for connection to the inductor 40. The connector 60 has a terminal 64 (shown in Figure 3 as two terminals connected together) for connection to the end 48 of the inductor 40, and a terminal 67 for connection to the end 50 of the inductor 40. The vibration unit 38 may be connected to an output of the control unit 32, conveniently pin 5, or may be connected between the output 46 of the charge pump 42 and the terminal 67, as shown in Figure 3. This preferred arrangement causes the vibration unit 38 to be vibrated when the PMF is being generated and at the same frequency.

The voltage converter 42 takes the form of a DC to DC step up converter, preferably comprising a charge pump circuit. The circuit portion indicated as 42 in Figure 3 is an example of a suitable charge pump circuit, although it will be understood that other suitable conventional charge pump circuits may be used. The voltage converter 42 has an input 66 for receiving control signals from an output (pin 7) of the control unit 32. In the present example, the charge pump circuit 42 converts the battery voltage of 4.5V DC (supplied at terminal 44) to approximately 50V DC (provided at output 46).

Figure 4 shows, by way of example, waveforms which may be generated by the control unit 32 in order to control the system 30. Figure 4A depicts a signal which may be used to control the LED 36 and, optionally, also the vibration unit 38. The signal of Figure 4A conveniently takes the form of a square wave which toggles periodically between an on state and an off state, the on state substantially corresponding to when the PMF is being generated and the off state substantially corresponding to when the PMF is not being generated. In the illustrated example, the signal has a cycle of approximately 1 second, the on period being approximately 0.3 seconds in length. The control unit 32 may be programmed in any convenient manner to produce the signal of Figure 4A at pin 5. In alternative embodiments, the LED and vibration unit may be controlled by separate respective signals which may be independently generated by the control unit 32. Another alternative is to derive the signal(s) for controlling the LED and/or vibration unit from one or more other control signals, e.g. the signals of Figures 4B or 4C.

Figure 4B depicts a signal for controlling the application of voltage to the inductor 40. The signal of Figure 4B is applied to terminal 50 of the inductor 40 (in this case via the amplifier 52). The control unit 32 may be programmed in any convenient manner to produce the signal of Figure 4B at one of its outputs, e.g. pin 6 in the present example. The signal of Figure 4B is conveniently a periodic or cyclical signal and, in each cycle, comprises waveform, e.g. a square wave or other on/off waveform, of a desired frequency for a desired duration (the "on period"), typically followed by a quiescent period. In the illustrated example, the control signal has a period of approximately 1 second and, during each cycle a 18 - 23kHz square wave is provided for a duration of approximately 0.1 seconds. It will be understood that the frequency and duration of the pulse signal may be varied to suit the application.

Figure 4C depicts a control signal for controlling the operation of the voltage converter or charge pump 42 via input 66. The control unit 32 may be programmed in any convenient manner to produce the signal of Figure 4C at, in this example, pin 7. The signal of Figure 4C conveniently takes the form of a square wave which toggles periodically between an on state and an off state, the on state substantially corresponding to when it is desired to generate a PMF. When the signal is in the on state, the charge pump 42 is effectively switched on and so provides a DC voltage, or charge, at output 46. When the control signal is in its off state, the charge pump 42 is switched off. In the illustrated example, the signal has a cycle of approximately 1 second, the on period being approximately 0.2 seconds in length. It is preferred that the on period of the control signal for the charge pump 42 is longer than the on period of the signal of Figure 4B, i.e. that the charge pump 42 is switched on and providing its voltage for longer than the pulse signal is applied to the end 50 of inductor 40. The signals of Figures 4A to 4C are synchronised with one another in any convenient manner.

Referring again to Figure 1, the inductor 40 (or other inductive load) is preferably positioned in the head portion 14 of the device 10, more preferably at the tip 15 of the head 14. The inductor 40, which typically comprises a coil of conductive material and an iron-filled core, is preferably selected such that it generates a directed PMF (as opposed to an omni-directional field), e.g. in the form of a beam (not illustrated). The beam may be generally conical in shape. The preferred arrangement is such that the PMF emanates from the tip 15 in a direction substantially along (or at least substantially centred on) the longitudinal axis of the device 10.

In the preferred embodiment, the control unit 32 is arranged to switch the device 10 off after a pre-set period after the on/off switch 34 is activated to turn the device on. The preferred period is approximately 7 minutes.

In use, in order to create the PMF, the charge pump 42 provides a DC voltage at one end 48 of the inductor 40 while a pulsed control signal (e.g. square waveform or other on/off waveform) is supplied to the other end 50 of the inductor 40 (via the amplifier circuit 52). As a result, a pulsed voltage is applied across the inductor 40 thereby causing the PMF to be created.

In alternative embodiments, the device 10 may be adapted to generated PMFs and associated electrical fields of different characteristics than those described herein. Conveniently, this may be achieved by one or more of the following: changing the inductance of the inductive load; changing the peak amplitude of the voltage signal applied to the inductive load; and/or changing the frequency of the voltage signal applied to the inductive load. Preferably, the control unit 32 is programmable to allow adjustment of at least the frequency of said voltage signal. To this end (and for other programming and testing purposes) the system 30 preferably comprises a connector 63 for providing links between the control unit 32 and an external processor or computer (not shown).

The preferred device 10 allows the creation of pulsed magnetic fields, for the treatment of medical conditions, which may be specific in wave shape and magnetic field density for the intended application. The wave shape and/or magnetic field density may be created and/or adjusted using a suitable programmed processor (e.g. control unit 32).

Optionally, the device 10 may be provided with means for applying an electrical current or voltage directly to a user's body. For example, this may take the form of an electrical terminal 70 (Figure 1) exposed on the external surface of the device 10, preferably on the head portion 14. The voltage provided by the terminal 70 may be derived from the battery 16 or the charge pump 42 and is at a level that causes sensation when applied to a user (e.g. approximately 25V at approximately 3kHz). Conveniently, the voltage may be controlled (i.e. turned on and off) by the same signal used to control the LED 34 and/or the vibration unit 38. Hence, the presence of a voltage at the terminal 70 is arranged to substantially coincide with the generation of a PMF. To assist in the application of the voltage, the external surface of the head portion 14 is preferably provided with a region 72 of electrically conductive material in electrical contact with the terminal 70.

In the preferred embodiment, the control unit 32 is programmable to create a desired PMF in which the frequency and/or the peak amplitude is selectable. To this end, the switch 34, or other user operable switch (not shown) connected to the control unit 32, may be operable to set an amplitude level for the control signal (from pin 6 in the present example) provided by the control unit 32 and so to adjust the peak amplitude of the generated PMF. Optionally, the control unit 32 may be arranged to modulate additional frequencies onto a carrier frequency when creating the PMF. This may be achieved by internally referencing in the control unit a pre-programmed frequency which may then be changed through the control unit's registers to provide the desired PMFs.

The characteristics (including frequency and amplitude) of the voltage waveform applied to the inductor 40 under the control of the control unit 32 typically are not identical to the desired characteristics of the resulting PMF and electrical field.

This is a result of non-ideal behaviour of components in the system 30 (including the inductor 40 and the transistor 53). Hence, the control unit is programmed to take into account the tolerances and effects of the circuitry of the system 30.

Preferably, the system 30 is programmed to adopt a fail-safe mode (e.g. to turn itself off) when a fault condition is detected. Details of the detected fault may be stored in the control unit 32 for analysis.

The invention is not limited to the embodiment described herein which may be modified or varied without departing from the scope of the invention.

CLAIMS:

1. A device for generating a pulsed magnetic field, the device comprising an inductive load located between first and second load terminals; means for applying a DC voltage to said first terminal; and means for causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed manner.

2. A device as claimed in Claim 1, wherein said means for causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed manner is operable by a pulsed control signal toggling between an on state and an off state, wherein, when said control signal is in the on state, at least part of said DC voltage is applied across said inductive load and, when said control signal is in the off state, substantially none of said DC voltage is applied across the inductive load.

3. A device as claimed in Claim 2, wherein said means for causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed manner includes a switch device connected to said second terminal, the switch device being operable between at least one on state in which at least part of said DC voltage is applied across said inductive load, and an off state in which substantially none of said DC voltage is applied across the inductive load, the switch device being operated by said pulsed control signal.

4. A device as claimed in Claim 3, wherein said switch device is operable between a plurality of on states, each state causing a respective different voltage level to be applied to said second terminal, thereby determining the voltage applied across said inductive load.

5. A device as claimed in Claim 3 or 4, wherein said switch device comprises a transistor, preferably a FET (field effect transistor).

6. A device as claimed in any preceding claim, wherein said device includes a DC electrical power source, said DC voltage applying means including a DC to DC step up voltage converter arranged to step up the DC voltage provided by said DC power source.

7. A device as claimed in any preceding claim, wherein said DC voltage applying means comprises a charge pump.

8. A device as claimed in any preceding claim, wherein said DC voltage applying means is arranged to provide to said first terminal a DC voltage of at least 15V, preferably between 20V and 100V, and most preferably approximately 50V.

9. A device as claimed in any preceding claim, further including a programmable control unit, for example a microprocessor or microcontroller, programmed to provide said pulsed control signal.

10. A device as claimed in Claim 9, wherein said control unit produces a second control signal for turning said DC voltage applying means on and off, said second control signal being synchronised with said pulsed control signal in order to turn said DC voltage applying means on only when said pulsed control signal causes a pulsed magnetic field to be generated.

11. A device as claimed in any preceding claim, wherein said inductive load comprises an inductor.

12. A device as claimed in Claim 11, wherein said inductor is arranged to generate a directional or focused magnetic field centred about a first axis.

13. A device as claimed in any preceding claim, wherein said device is a portable unit capable of being hand held.

14. A device as claimed in Claim 13, wherein said device includes a casing defining a body portion and a head portion, said body portion being capable of being hand held, and wherein said inductive load is located in said head portion an arranged to project, in use, the pulsed magnetic field outwardly of the device.

15. A device as claimed in Claim 14, wherein said inductive load is arranged to generate a directional or focused magnetic field centred about a first axis, the load being positioned in the device such that said first axis is substantially parallel with, or substantially co-incident with, the longitudinal axis of the device.

16. A device as claimed in any preceding claim, arranged to generate a pulsed magnetic field having a peak amplitude of between 2mT and 20mT, preferably approximately 10mT.

17. A device as claimed in any preceding claim, arranged to generate a pulsed magnetic field at a frequency of between 18kHz and 23kHz, preferably approximately 21.3kHz.

18. A device as claimed in any preceding claim, arranged to generate a pulsed magnetic field having an associated pulsating electrical field with a peak amplitude of at least 30V peak to peak, preferably at least 50V peak to peak and most preferably between 80V and 100V peak to peak.

19. A device as claimed in any preceding claim, further including a vibration device arranged to vibrate when said pulsed magnetic field is generated.

20. A method of generating a pulsed magnetic field in a device comprising an inductive load located between first and second load terminals, the method comprising applying a DC voltage to said first terminal; and causing at least part of said DC voltage to be applied across said first and second terminals in a pulsed manner.

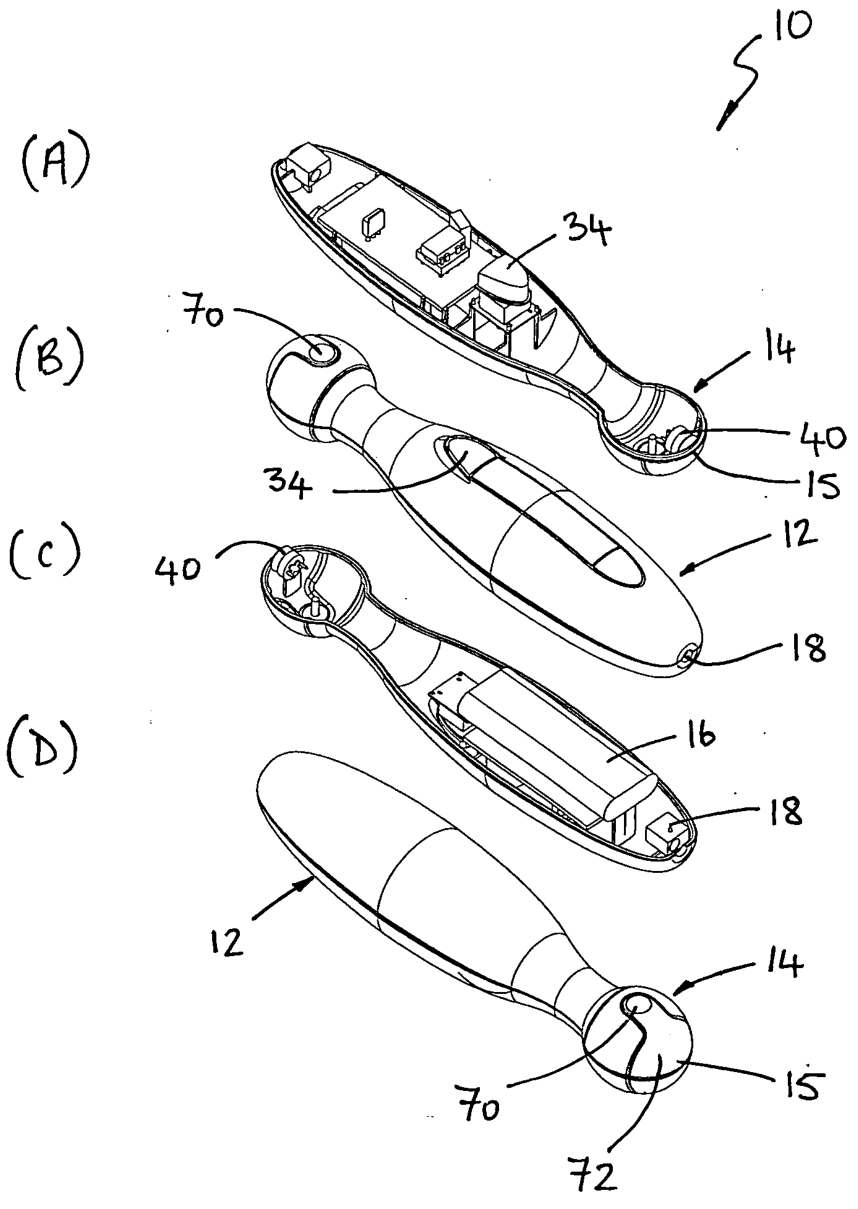


FIG. 1

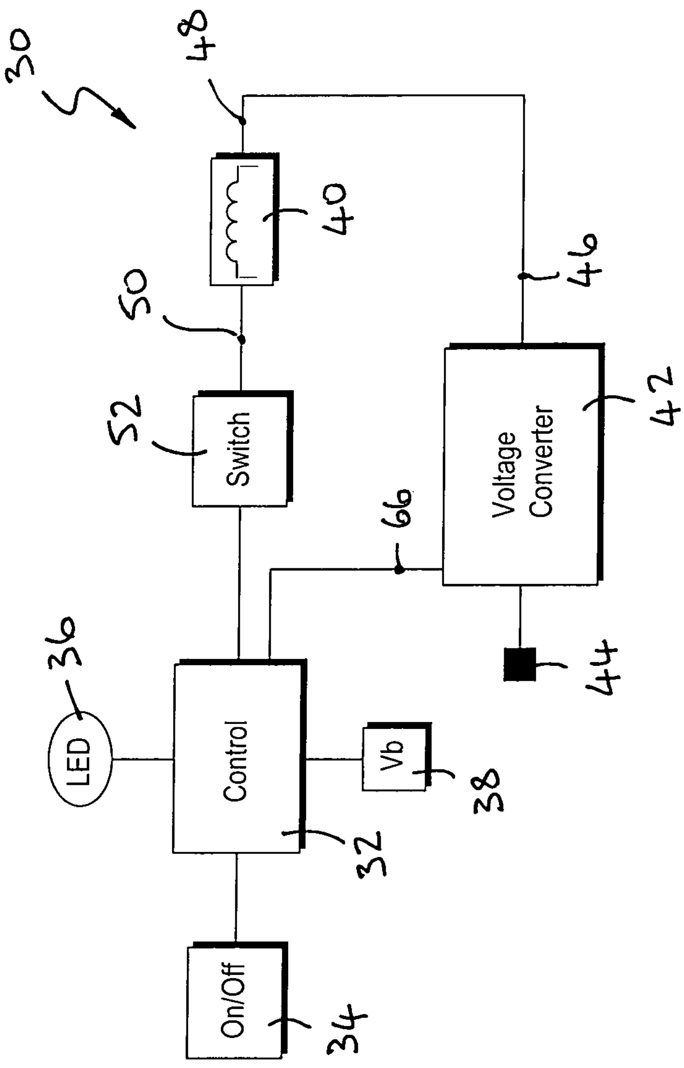
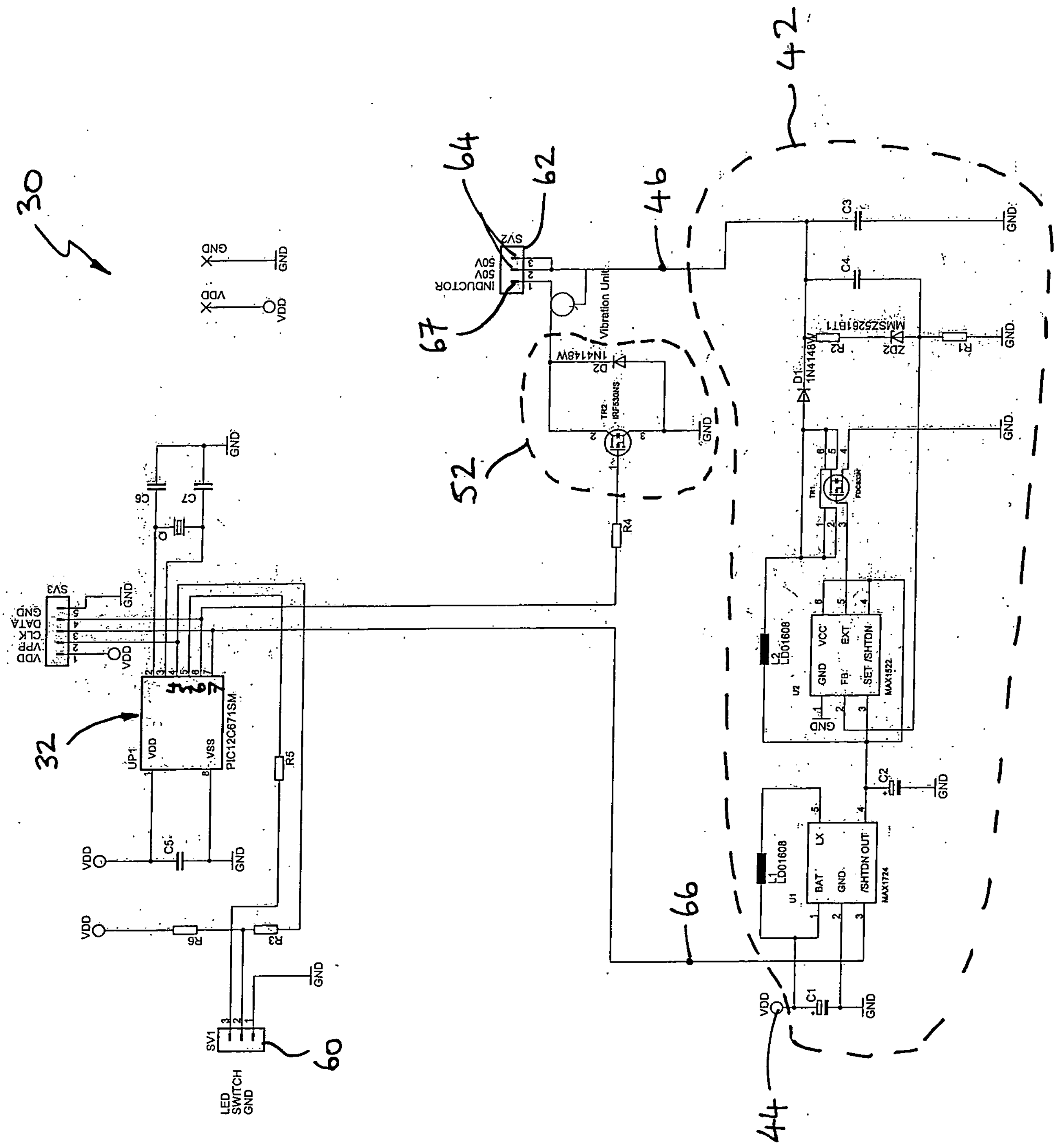

30
48
40
46
50
52
Switch
42
Voltage Converter
66
36
LED
Control
Vb
38
44
32
On/Off
34

FIG. 2


30
32
42
44
46
52
60
62
64
66
67
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MAX1522
MAX1724
Vibration Unit
INDUCTOR
LED
SWITCH
GND
VDD

FIG.3

Timing diagram (Not to scale)

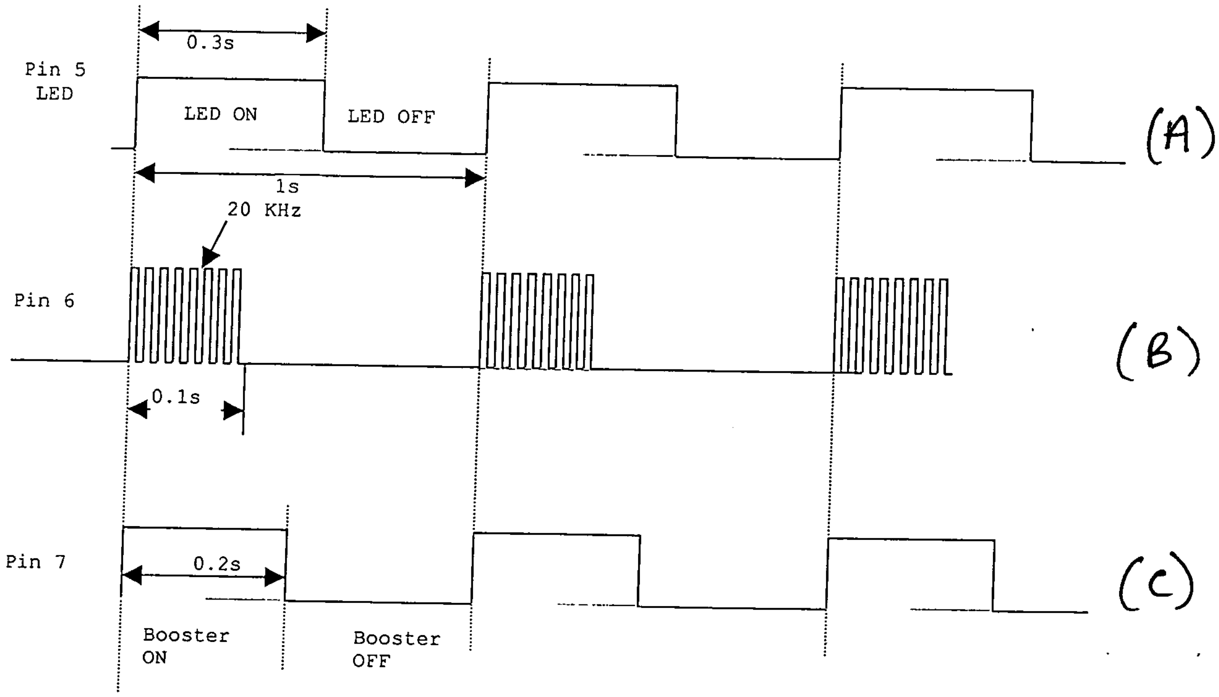


FIG. 4

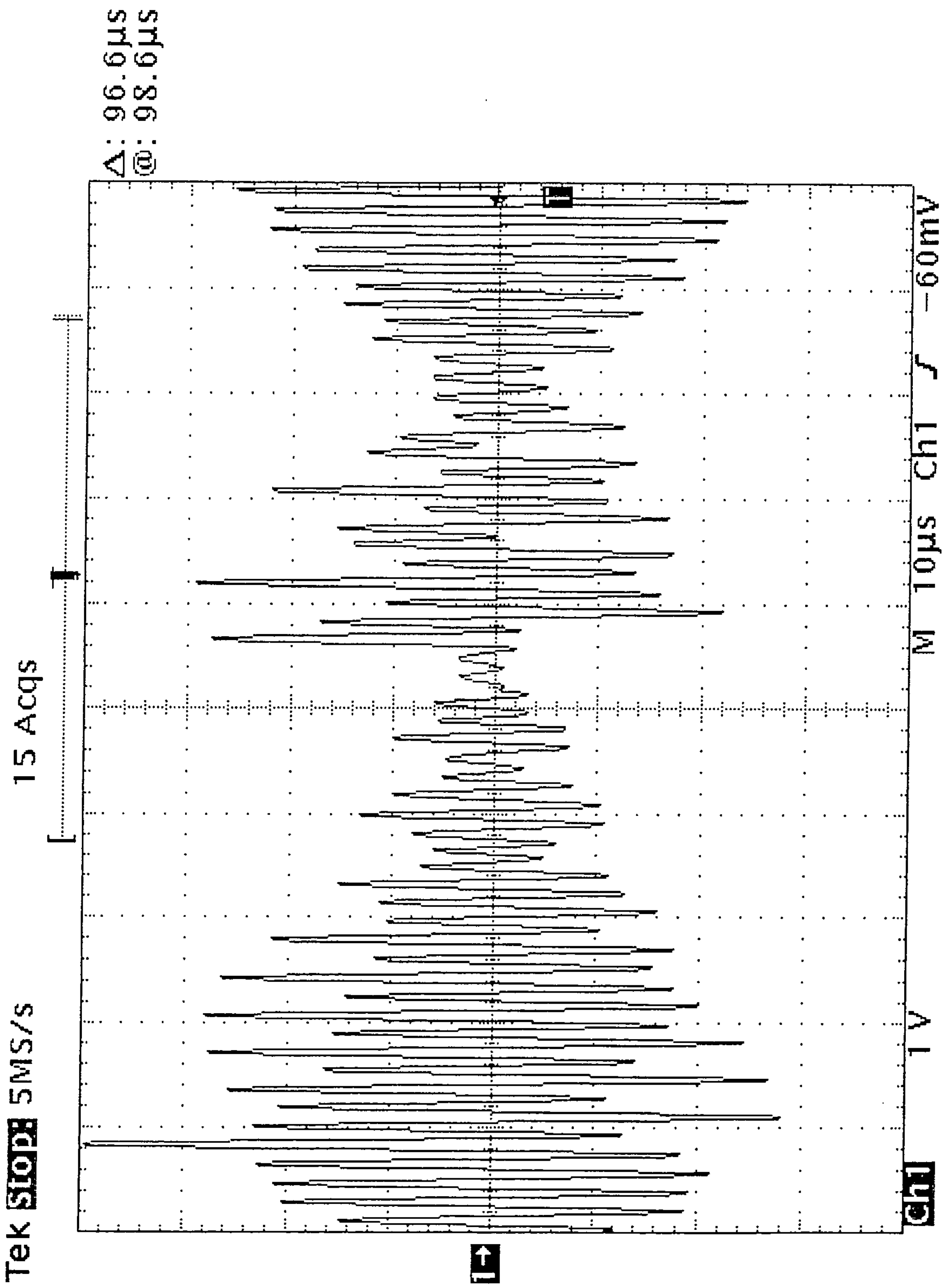
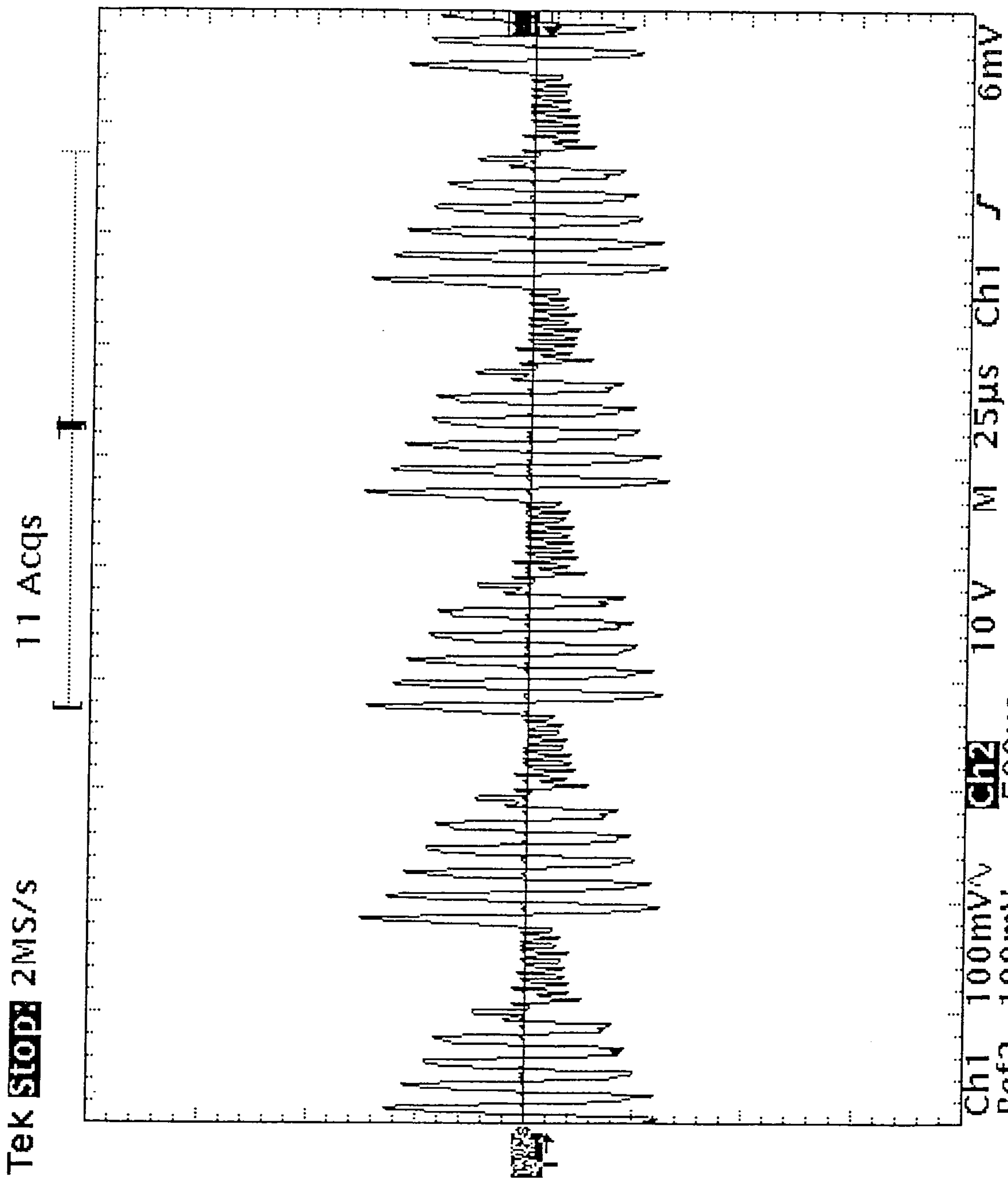


FIG.5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11 Acqs
Ch1 100mV∿ Ch2 500µs 10 V M 25µs Ch1 ∫ 6mV
Ref2 100mV

FIG. 6