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(54) **Title:** IMPLANTABLE DRIVER WITH CHARGE BALANCING

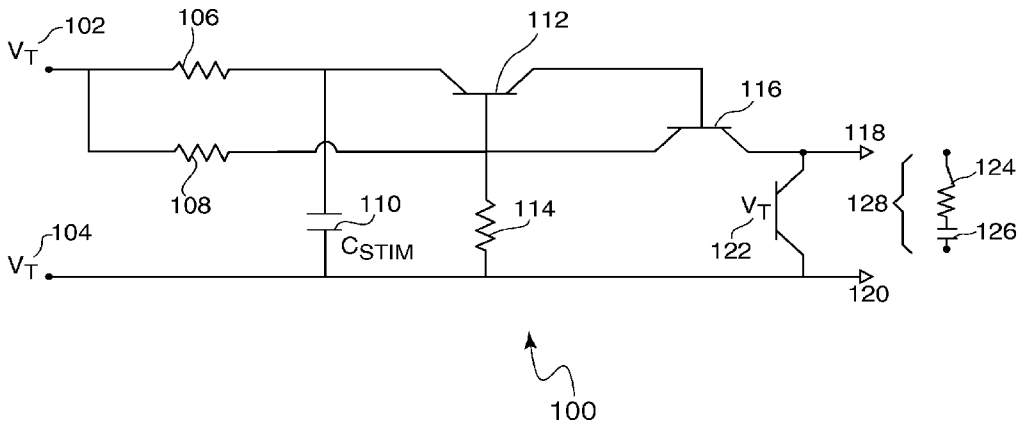

FIG. 1

(57) **Abstract:** A transponder includes a stimulus driver configured to discharge an electrical stimulus when a trigger signal is received. A first conducting electrode is coupled to the stimulus driver and conducts the electrical stimulus discharged by the stimulus driver. A second conducting electrode is coupled to the stimulus driver and conducts the electrical stimulus conducted by the first conducting electrode. A depolarization switch is gated by the trigger signal and connects the first conducting electrode to the second conducting electrode in response to the trigger signal.

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IMPLANTABLE DRIVER WITH CHARGE BALANCING

CROSS-REFERENCE TO ANOTHER APPLICATION

[001] US Provisional Patent Application (Serial No. 60/990,278 filed 11/26/2007, Attorney Ref MSTP-28P) is hereby incorporated by reference. This application may be related to the present application, or may merely have some drawings and/or disclosure in common.

BACKGROUND

[002] The present application relates to electrical tissue stimulation devices, and more particularly to a charge-balancing driver circuit.

[003] Note that the points discussed below may reflect the hindsight gained from the disclosed inventions, and are not necessarily admitted to be prior art.

[004] Human tissue may be stimulated by applying short pulses of electrical energy to the tissue. An electrode pair is positioned proximate to the intended tissue. The electrodes are generally implanted under the skin to provide stimulation to nerve tissue. Typically, a driver circuit connected to the electrodes generates pulses that energize the electrodes. As each pulse generates a voltage drop between the electrodes, current flows along a path through the tissue. The tissue is stimulated when a threshold current flows through the tissue.

SUMMARY

[005] Typically, a series of pulses are generated by the driver circuit, at a periodic frequency. When the frequency of these pulses is greater than two cycles per second, the tissue may become polarized. Polarized tissue holds a charge. Because the tissue becomes charged, a larger voltage drop is required to generate the desired stimulation threshold current.

[006] The present application discloses new approaches to a transponder including a stimulus driver configured to discharge an electrical stimulus when a trigger signal is received. A first conducting electrode is coupled to the stimulus driver and conducts the electrical stimulus discharged by the stimulus driver. A second conducting electrode is coupled to the stimulus driver and conducts the electrical stimulus conducted by the first conducting electrode.
A depolarization switch is gated by the trigger signal and connects the first conducting electrode to the second conducting electrode in response to the trigger signal. The connection provided through the depolarization switch removes polarization induced in the tissue.

[007] The disclosed innovations, in various embodiments, provide one or more of at least the following advantages. However, not all of these advantages result from every one of the innovations disclosed, and this list of advantages does not limit the various claimed inventions.

- charge balancing to accomplish depolarization of tissue
- charge balancing with a simple driver circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

[008] The disclosed inventions will be described with reference to the accompanying drawings, which show important sample embodiments of the invention and which are incorporated in the specification hereof by reference, wherein:

[009] **Figure 1** is a circuit diagram depicting a depolarizing microtransponder driver circuit, in accordance with an embodiment;

[0010] **Figure 2** is a graph depicting a stimulus voltage in accordance with an embodiment;

[0011] **Figure 3** is a block diagram depicting a microtransponder system, in accordance with an embodiment;

[0012] **Figure 4** is a circuit diagram depicting a driver circuit, in accordance with an embodiment;

[0013] **Figure 5** is a circuit diagram depicting a driver circuit, in accordance with an embodiment;

[0014] **Figure 6** is a circuit diagram depicting a driver circuit, in accordance with an embodiment;

[0015] **Figure 7** is a circuit diagram depicting a driver circuit, in accordance with an embodiment;

[0016] **Figure 8** is a circuit diagram depicting a tissue model.

DETAILED DESCRIPTION OF SAMPLE EMBODIMENTS

[0017] The numerous innovative teachings of the present application will be described with particular reference to presently preferred embodiments (by way of example, and not of limitation).

[0018] Various embodiments describe miniaturized, minimally invasive, wireless implants termed "microtransponders." The unprecedented miniaturization minimally invasive biomedical implants made possible with this wireless microtransponder technology would enable novel forms of distributed stimulation using micro-stimulators so small that implantation densities of 100 per square inch of skin are feasible. These groups or arrays of microtransponders may be used to sense a wide range of biological signals. The microtransponders may be used to stimulate a variety of tissues and may generate a variety of stimulation responses. The microtransponders may be designed to operate without implanted batteries. The microtransponders may be designed so that there is no need for wires to pass through the patient's skin. The microtransponders may be used to treat medical conditions such as chronic pain and similar afflictions.

[0019] Microtransponders typically receive energy from the flux of an electromagnetic field. Typically, the electromagnetic field may be generated by pliable coils placed on the surface of the overlying

skin. Wireless communication technologies may exploit near-field magnetic coupling between two simple coils tuned to resonate at the same or related frequencies. References to tuning a pair of coils to the "same frequency" may include tuning the pair of coils to harmonically related frequencies. Frequency harmonics make it possible for different, harmonically related, frequencies to transfer power effectively.

[0020] By energizing a coil at a related frequency, for example, a selected radio frequency, an oscillating electromagnetic field will be generated in the space around the coil. By placing another coil, tuned to resonate at the same selected radio frequency, in the generated oscillating electromagnetic field, a current will generated in the coil. This current may be detected, stored in a capacitor and used to energize circuits.

[0021] With reference to **Figure 1**, a schematic diagram depicts a depolarizing microtransponder driver circuit 100 in accordance with an embodiment. An oscillating trigger voltage (VT and -VT) may be applied between the input nodes 102 and 104 of the driver circuit 100. An auto-triggering microtransponder may employ a bi-stable switch 112 to oscillate between the charging phase that builds up a charge on the stimulus capacitor CSTIM 110 and the discharge phase that can be triggered when the charge reaches the desired voltage and closes the switch 112 to discharge the capacitor 110 through stimulus electrodes 118 and 120.

[0022] A resistor 106 regulates the stimulus frequency by limiting the charging rate. The stimulus peak and amplitude are largely determined by the effective tissue resistance 128, modeled with a resistance 124 and a capacitance 126. As such, the stimulus is generally independent of the applied RF power intensity. On the other hand, increasing the RF power may increase the stimulation frequency by reducing the time it takes to charge up to the stimulus voltage.

[0023] When a stimulation signal is applied to living tissue at frequencies higher than two hertz, the tissue typically becomes polarized, exhibiting an inherent capacitance 126 by storing a persistent electrical charge. In order to reduce the polarization effect, a depolarization switch 122 is connected between the electrodes 118 and 120. The gate terminal of the depolarization switch 122 is connected to the oscillating trigger voltage VT, so that once each cycle, the depolarization switch 122 shorts the electrodes 118 and 120 and reduces the charge stored in the inherent tissue capacitance 126. The timing of the depolarization switch 122 permits the stimulation pulse to be substantially discharged before the depolarization switch 122 closes and shorts the electrodes 118 and 120. Similarly, the depolarization switch 122 is timed to open before a subsequent stimulation pulse arrives. The timing of the depolarization switch 122 may be generated relative to the timing of the stimulation pulse, The timing may be accomplished using digital delays, analog delays, clocks, logic devices or any other suitable timing mechanism.

[0024] A simple zener diode component may be included in a stimulator circuit as presented in Figure 1. Asynchronous stimulations can be accomplished using the zener diode to accomplish voltage levels for auto-triggering.

[0025] With reference to **Figure 2**, a graph depicts an exemplary stimulus discharge in accordance with an embodiment. When a trigger signal is received, the stimulus capacitor discharges current between the electrodes. Depending on the tissue resistance, the voltage quickly returns to a rest voltage level at approximately the initial voltage level. When the frequency of the trigger signal is increased, a polarization effect causes the rest voltage to rise to a polarization voltage above the initial voltage. With a depolarization switch between the electrodes, each trigger signal causes the rest voltage to be re-established and lowered to about the initial voltage level.

[0026] With reference to **Figure 3**, a block diagram depicts a depolarizing microtransponder system 300 in accordance with an embodiment. A control component energizes an external resonator element 304 positioned externally relative to an organic layer boundary 318. Energized, the external resonator element 304 resonates energy at a resonant frequency, such as a selected RF. Internal resonator element 306, positioned internally relative to an organic layer boundary 318, is tuned to resonate at the same resonant frequency, or a harmonically related resonant frequency as the external resonator element 304. Energized by the resonating energy,

the internal resonator element 306 generates pulses of energy rectified by a rectifier 318. The energy may typically be stored and produced subject to timing controls or other forms of control. The energy is provided to the depolarizing driver 310. A first electrode 312 is polarized relative to a second electrode 316 so that current is drawn through the tissue 314 being stimulated, proximate to the electrode 312 and 316. The first electrode 312 is polarized relative to the second electrode 316 in the opposite polarization to draw an oppositely directed current through the tissue 314, depolarizing the tissue 314. The electrodes 312 and 316 may be typically made of gold or iridium, or any other suitable material.

[0027] With reference to **Figure 4**, a circuit diagram depicts a depolarization driver circuit 400, in accordance with an embodiment. A trigger signal is applied between electrodes 402 and 404. A stimulation charge is charged on the charge capacitance 414. Schottky diode 412 prevents the backflow of stimulus charge during the trigger phase. The charge rate is regulated by resistances 410, 406 and 408. Resistances 406 and 408 form a voltage divider so that a portion of the trigger signal operate the bipolar switches 420 and 422. The trigger signal closes CMOS 418 through resistance 416, connecting the pulse between electrodes 426 and 428. A depolarization resistance 424 is connected between the electrodes 426 and 428 to balance the charge stored in the tissue between the electrodes 426 and 428 between pulses. The specific breakdown voltage of the optional Zener diode 411 provides for auto-triggering setting the upper limit of the voltage divider, at which point the

bipolar switches are triggered by any further increase in the stimulus voltage. In addition to providing this auto-triggering feature for the purpose of asynchronous stimulation, the particular breakdown voltage of this Zener diode 411 sets the maximum stimulus voltage. Otherwise the stimulus voltage is a function of the RF power level reaching the transponder from the external reader coil when the stimulus is triggered.

[0028] With reference to **Figure 5**, a circuit diagram depicts a depolarization driver circuit 500, in accordance with an embodiment. A trigger signal is applied between electrodes 502 and 504. A charge capacitance 514 is charged on the charge capacitance 514. Schottky diode 512 prevents the backflow of stimulus charge during the trigger phase. The charge rate is regulated by resistances 510, 506, 534 and 508. Resistances 506 and 508 form a voltage divider so that a portion of the trigger signal operate the bipolar switches 520 and 522. The trigger signal closes CMOS 518 through resistance 516, connecting the pulse between electrodes 526 and 528. Depolarization resistances 524 and 538 are connected to a depolarization CMOS 540 between the electrodes 526 and 528 to balance the charge stored in the tissue between the electrodes 526 and 528 between pulses. The specific breakdown voltage of the optional Zener diode 511 provides for auto-triggering setting the upper limit of the voltage divider, at which point the bipolar switches are triggered by any further increase in the stimulus voltage. In addition to providing this auto-triggering feature for the purpose of asynchronous stimulation, the particular breakdown voltage of this Zener diode 511 sets the maximum stimulus voltage.

Otherwise the stimulus voltage is a function of the RF power level reaching the transponder from the external reader coil when the stimulus is triggered.

[0029] With reference to **Figure 6**, a circuit diagram depicts a depolarization driver circuit 600, in accordance with an embodiment. A trigger signal is applied between electrodes 602 and 604. A charge capacitance 614 is charged the charge capacitance 614. Schottky diode 612 prevents the backflow of stimulus charge during the trigger phase. The charge rate is regulated by resistances 610, 606 and 608. Resistances 606 and 608 form a voltage divider so that a portion of the trigger signal operate the bipolar switches 620 and 622. The trigger signal closes switch 618 through resistance 616, connecting the pulse between electrodes 626 and 628. A depolarization resistance 624 is connected to a bipolar switch 630 between the electrodes 626 and 628 to balance the charge stored in the tissue between the electrodes 626 and 628 between pulses. The specific breakdown voltage of the optional Zener diode 611 provides for auto-triggering setting the upper limit of the voltage divider, at which point the bipolar switches are triggered by any further increase in the stimulus voltage. In addition to providing this auto-triggering feature for the purpose of asynchronous stimulation, the particular breakdown voltage of this Zener diode 611 sets the maximum stimulus voltage. Otherwise the stimulus voltage is a function of the RF power level reaching the transponder from the external reader coil when the stimulus is triggered.

[0030] With reference to **Figure 7**, a circuit diagram depicts a depolarization driver circuit 700, in accordance with an embodiment. A trigger signal is applied between electrodes 702 and 704. A charge capacitance 714 is charged on the charge capacitance 714. Schottky diode 412 prevents the backflow of stimulus charge during the trigger phase. The charge rate is regulated by resistances 710, 706 and 708. Resistances 706 and 708 form a voltage divider so that a portion of the trigger signal operate the CMOS switches 730, 732, 734, 736, 738 and 740. The trigger signal closes CMOS 730, 734 and 736 connecting the pulse between electrodes 726 and 728. A depolarization CMOS 742 is connected between the electrodes 726 and 728 to balance the charge stored in the tissue between the electrodes 726 and 728 between pulses. The specific breakdown voltage of the optional Zener diode 711 provides for auto-triggering setting the upper limit of the voltage divider, at which point the bipolar switches are triggered by any further increase in the stimulus voltage. In addition to providing this auto-triggering feature for the purpose of asynchronous stimulation, the particular breakdown voltage of this Zener diode 711 sets the maximum stimulus voltage. Otherwise the stimulus voltage is a function of the RF power level reaching the transponder from the external reader coil when the stimulus is triggered.

[0031] With reference to **Figure 8**, a circuit diagram depicts a tissue model. Depolarization becomes important because the tissue behaves as a non-linear load that can be modeled as shown. A resistance 802 is in series with a resistance 804 in parallel with a capacitance 806. This arrangement is parallel to a second capacitance

808. The capacitances 806 and 808 result in charge being stored in the circuit when an intermittent signal is applied, as happens in the tissue being stimulated by intermittent stimulation signals.

Modifications and Variations

[0032] As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a tremendous range of applications, and accordingly the scope of patented subject matter is not limited by any of the specific exemplary teachings given. It is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims

[0033] According to various embodiments, there is provided a wireless transponder comprising a stimulus driver configured to output an electrical stimulus; first and second conducting electrodes operatively coupled to said stimulus driver and connected to receive the electrical stimulus discharged by said stimulus driver through tissue there between; and a depolarization switch connecting said first conducting electrode to said second conducting electrode after said stimulus.

[0034] According to various embodiments, there is provided the wireless transponder system comprising an external resonator; an internal resonator receiving resonant energy from said external resonator; a depolarizing driver connected to said internal resonator; and biocompatible electrodes connected to said depolarizing driver; wherein said depolarizing driver provides a voltage between said biocompatible electrodes and subsequently shorts said electrodes.

[0035] According to various embodiments, there is provided a depolarizing driver comprising a voltage source; a stimulation switch connecting said voltage source to a first biocompatible electrode and a second biocompatible electrode; and a depolarizing switch connecting said first biocompatible electrode to said second biocompatible electrode at a time relative to the connection of said stimulation switch.

[0036] According to various embodiments, there is provided an biocompatible electrical stimulation circuit comprising a voltage source; biocompatible electrodes coupled to said voltage source; a first switch coupled between said voltage source and said electrodes and connecting said voltage source to said electrodes in response to a intermittent trigger signal; a second switch coupled between said electrodes, wherein said second switch is in an open state when said first switch connects said voltage source to said electrodes and wherein said second switch is in a closed state at a determined time after said first switch connects.

[0037] According to various embodiments, there is provided a biocompatible electrical stimulation circuit comprising a voltage source; biocompatible electrodes coupled to said voltage source; a first switch coupled between said voltage source and said electrodes and connecting said voltage source to said electrodes in response to a intermittent trigger signal; a second switch coupled between said electrodes, wherein said second switch is in an open state when said first switch connects said voltage source to said electrodes and

wherein said second switch is in a closed state at a determined time after said first switch connects.

[0038] According to various embodiments, there is provided an electrical stimulation device comprising: biocompatible electrodes; a intermittent stimulation voltage source connected between said biocompatible electrodes and intermittently providing an exponentially decaying pulse to said biocompatible electrodes; wherein said biocompatible electrodes are shorted during a tail of said exponentially decaying intermittent pulse, wherein a voltage of said pulse has decayed to less than ten percent.

[0039] According to various embodiments, there is provided a method of providing electrical stimulation to cellular matter comprising: generating intermittent stimulation voltages between biocompatible electrodes in contact with cellular matter; shorting said biocompatible electrodes during said stimulation voltages and thereby reducing polarization in said cellular matter.

[0040] According to various embodiments, there is provided a bio-electrical stimulation system comprising: a transcutaneous transformer; a stimulation driver receiving power from said transcutaneous transformer; and biocompatible electrodes connected to said stimulation driver and receiving intermittent stimulation pulses from said stimulation driver; wherein said biocompatible electrodes are shorted during said intermittent stimulation pulses.

[0041] According to various embodiments, there is provided a transponder includes a stimulus driver configured to discharge an electrical stimulus when a trigger signal is received. A first conducting electrode is coupled to the stimulus driver and conducts the electrical stimulus discharged by the stimulus driver. A second conducting electrode is coupled to the stimulus driver and conducts the electrical stimulus conducted by the first conducting electrode.
A depolarization switch is gated by the trigger signal and connects the first conducting electrode to the second conducting electrode in response to the trigger signal.

[0042] The following applications may contain additional information and alternative modifications: Attorney Docket No. MTSP-29P, Serial No. 61/088,099 filed 8/12/2008 and entitled “In Vivo Tests of Switched-Capacitor Neural Stimulation for Use in Minimally- Invasive Wireless Implants; Attorney Docket No. MTSP-30P, Serial No. 61/088,774 filed 8/15/2008 and entitled “Micro-Coils to Remotely Power Minimally Invasive Microtransponders in Deep Subcutaneous Applications”; Attorney Docket No. MTSP-31P, Serial No. 61/079,905 filed 7/8/2008 and entitled “Microtransponders with Identified Reply for Subcutaneous Applications"; Attorney Docket No. MTSP-33P, Serial No. 61/089,179 filed 8/15/2008 and entitled "Addressable Micro-Transponders for Subcutaneous Applications"; Attorney Docket No. MTSP-36P Serial No. 61/079,004 filed 7/8/2008 and entitled “"Microtransponder Array with Biocompatible Scaffold"; Attorney Docket No. MTSP-38P Serial No. 61/083,290 filed 7/24/2008 and entitled “Minimally Invasive Microtransponders for

Subcutaneous Applications" Attorney Docket No. MTSP-39P Serial No. 61/086,116 filed 8/4/2008 and entitled "Tintinnitus Treatment Methods and Apparatus"; Attorney Docket No. MTSP-40P, Serial No. 61/086,309 filed 8/5/2008 and entitled "Wireless Neurostimulators for Refractory Chronic Pain"; Attorney Docket No. MTSP-41P, Serial No. 61/086,314 filed 8/5/2008 and entitled "Use of Wireless Microstimulators for Orofacial Pain"; Attorney Docket No. MTSP-42P, Serial No. 61/090,408 filed 8/20/2008 and entitled "Update: In Vivo Tests of Switched-Capacitor Neural Stimulation for Use in Minimally- Invasive Wireless Implants"; Attorney Docket No. MTSP-43P, Serial No. 61/091,908 filed 8/26/2008 and entitled "Update: Minimally Invasive Microtransponders for Subcutaneous Applications"; Attorney Docket No. MTSP-44P, Serial No. 61/094,086 filed 9/4/2008 and entitled "Microtransponder MicroStim System and Method"; Attorney Docket No. MTSP-28, Serial No. _____, filed _____ and entitled "Implantable Transponder Systems and Methods"; Attorney Docket No. MTSP-30, Serial No. _____, filed _____ and entitled "Transfer Coil Architecture"; Attorney Docket No. MTSP-32, Serial No. _____, filed _____ and entitled "A Biodelivery System for Microtransponder Array"; Attorney Docket No. MTSP-46, Serial No. _____, filed ____ and entitled "Implanted Driver with Resistive Charge Balancing"; Attorney Docket No. MTSP-47, Serial No. _____, filed _____ and entitled "Array of Joined Microtransponders for Implantation"; and Attorney Docket No. MTSP-48, Serial No. _____, filed _____ and entitled "Implantable

Transponder Pulse Stimulation Systems and Methods" and all of which are incorporated by reference herein.

[0043] None of the description in the present application should be read as implying that any particular element, step, or function is an essential element which must be included in the claim scope: THE SCOPE OF PATENTED SUBJECT MATTER IS DEFINED ONLY BY THE ALLOWED CLAIMS. Moreover, none of these claims are intended to invoke paragraph six of 35 USC section 112 unless the exact words "means for" are followed by a participle.

[0044] A voltage booster may be inserted immediately after the rectifier element 318 to boost the supply voltage available for stimulation and operation of integrated electronics beyond the limits of what might be generated by a miniaturized LC resonant tank circuit. The voltage booster may enable electro-stimulation and other microtransponder operations using the smallest possible LC components, which may generate too little voltage, for example, less than .5 volts.

[0045] Examples of high efficiency voltage boosters include charge pumps and switching boosters using low-threshold Schottky diodes. However, it should be understood that any type of conventional high efficiency voltage booster may be utilized in this capacity as long as it can generate the voltage required by the particular application that the microtransponder is applied to.

[0046] The claims as filed are intended to be as comprehensive as possible, and NO subject matter is intentionally relinquished, dedicated, or abandoned.

CLAIMS

What is claimed is:

1. A wireless transponder comprising:

a stimulus driver configured to output an electrical stimulus;

first and second conducting electrodes operatively coupled to said stimulus driver and connected to receive the electrical stimulus discharged by said stimulus driver through tissue there between;

a depolarization switch connecting said first conducting electrode to said second conducting electrode after said stimulus.

2. The transponder of claim 1 further comprising an internal resonator providing electrical energy to said stimulus driver.

3. The transponder of claim 1, further comprising a delay. wherein said delay is connected to said depolarization switch.

4. The transponder of claim 1 wherein said electrical stimulus is monophasic.

5. The transponder of claim 1, wherein said depolarization switch is a bipolar junction transistor.

6. The wireless transponder system comprising:

an external resonator;

an internal resonator receiving resonant energy from said external resonator;

a depolarizing driver connected to said internal resonator; and

biocompatible electrodes connected to said depolarizing driver;

wherein said depolarizing driver provides a voltage between said biocompatible electrodes and subsequently shorts said electrodes.

7. The wireless transponder system of claim 6 wherein said depolarizing driver includes a depolarization switch connected between the electrodes.

8. The wireless transponder system of claim 6, wherein said biocompatible electrodes are placed proximate to living tissue such that the living tissue is stimulated when there is a voltage between the biocompatible electrodes.

9. The wireless transponder system of claim 8, wherein said living tissue is neural tissue.

10. The wireless transponder system of claim 9, wherein said wireless transponder system is used to treat chronic pain.

11. The wireless transponder system of claim 6, further comprising a control component connected to said external resonator and providing control signals to said external resonator.

12. The wireless transponder system of claim 11 wherein said control component receives data signals from said external resonator.

13. The wireless transponder system of claim 6 wherein said resonant energy resonates at a radio frequency.

14. A depolarizing driver comprising:

a voltage source;

a stimulation switch connecting said voltage source to a first biocompatible electrode and a second biocompatible electrode; and

a depolarizing switch connecting said first biocompatible electrode to said second biocompatible electrode at a time relative to the connection of said stimulation switch.

15. The depolarizing driver of claim 14, wherein said stimulation switch closes before said depolarizing switch closes.

16. The depolarizing driver of claim 14, wherein said depolarizing switch closes before said stimulation switch closes.

17. The depolarizing driver of claim 14, wherein said voltage source is oscillatory.

18. The depolarizing driver of claim 14 wherein said stimulation switch comprise a first switch having a base and emitter and a second switch having a base and an emitter and wherein said base of said first switch is connected to said emitter of said second switch and said base of said second switch is connected to said emitter of said first switch.

19. The depolarizing driver of claim 18, wherein said first electrode is connected to a source of said second switch.

20. The depolarizing driver of claim 14, wherein said voltage source is rectified.

21. An biocompatible electrical stimulation circuit comprising:

a voltage source;

biocompatible electrodes coupled to said voltage source;

a first switch coupled between said voltage source and said electrodes and connecting said voltage source to said electrodes in response to a intermittent trigger signal;

a second switch coupled between said electrodes, wherein said second switch is in an open state when said first switch connects said voltage source to said electrodes and wherein said second switch is in a closed state at a determined time after said first switch connects.

22. The electrical stimulation circuit of claim 21 wherein said second switch is a bipolar transistor.

23. The electrical stimulation circuit of claim 21 wherein said second switch is a CMOS.

24. The electrical stimulation circuit of claim 21 wherein said second switch is a bipolar transistor.

25. The electrical stimulation circuit of claim 21 wherein said second switch is a thyristor.

26. An electrical stimulation device comprising:

biocompatible electrodes;

a intermittent stimulation voltage source connected between said biocompatible electrodes and intermittently providing an exponentially decaying pulse to said biocompatible electrodes;

wherein said biocompatible electrodes are shorted during a tail of said exponentially decaying intermittent pulse, wherein a voltage of said pulse has decayed to less than ten percent.

27. A method of providing electrical stimulation to cellular matter comprising:

generating intermittent stimulation voltages between biocompatible electrodes in contact with cellular matter;

shorting said biocompatible electrodes during said stimulation voltages and thereby reducing polarization in said cellular matter.

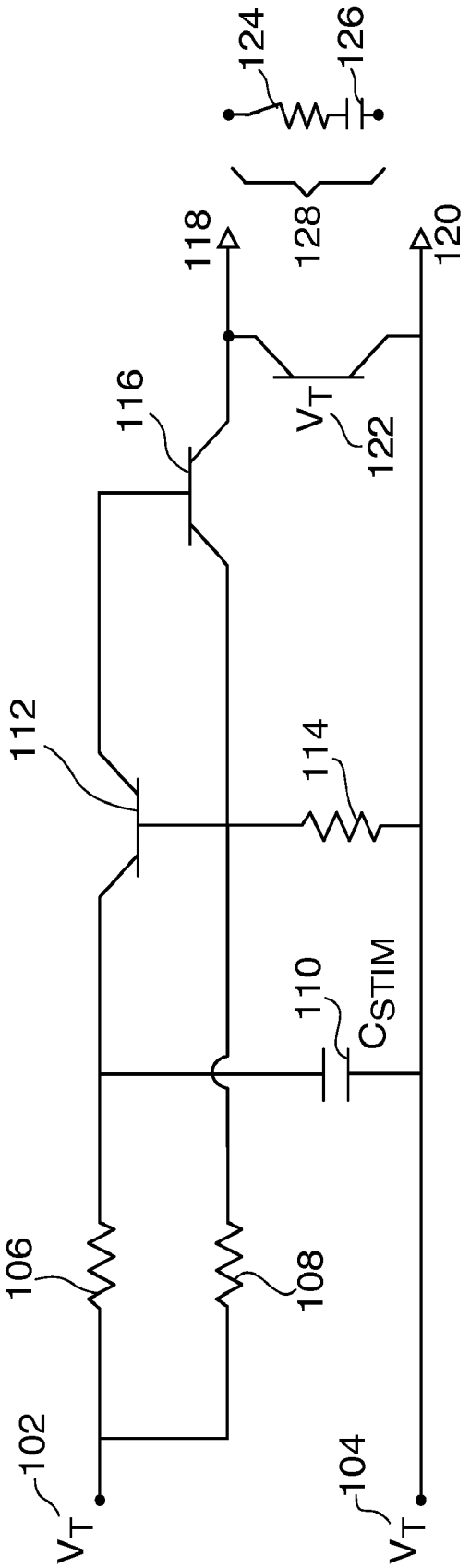
28. A bio-electrical stimulation system comprising:

a transcutaneous transformer;

a stimulation driver receiving power from said transcutaneous transformer; and

biocompatible electrodes connected to said stimulation driver and receiving intermittent stimulation pulses from said stimulation driver;

wherein said biocompatible electrodes are shorted during said intermittent stimulation pulses.


124
126
118
128
120
116
V_T
122
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114
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110
C_{STIM}
106
108
102
104
V_T
V_T

FIG. 1

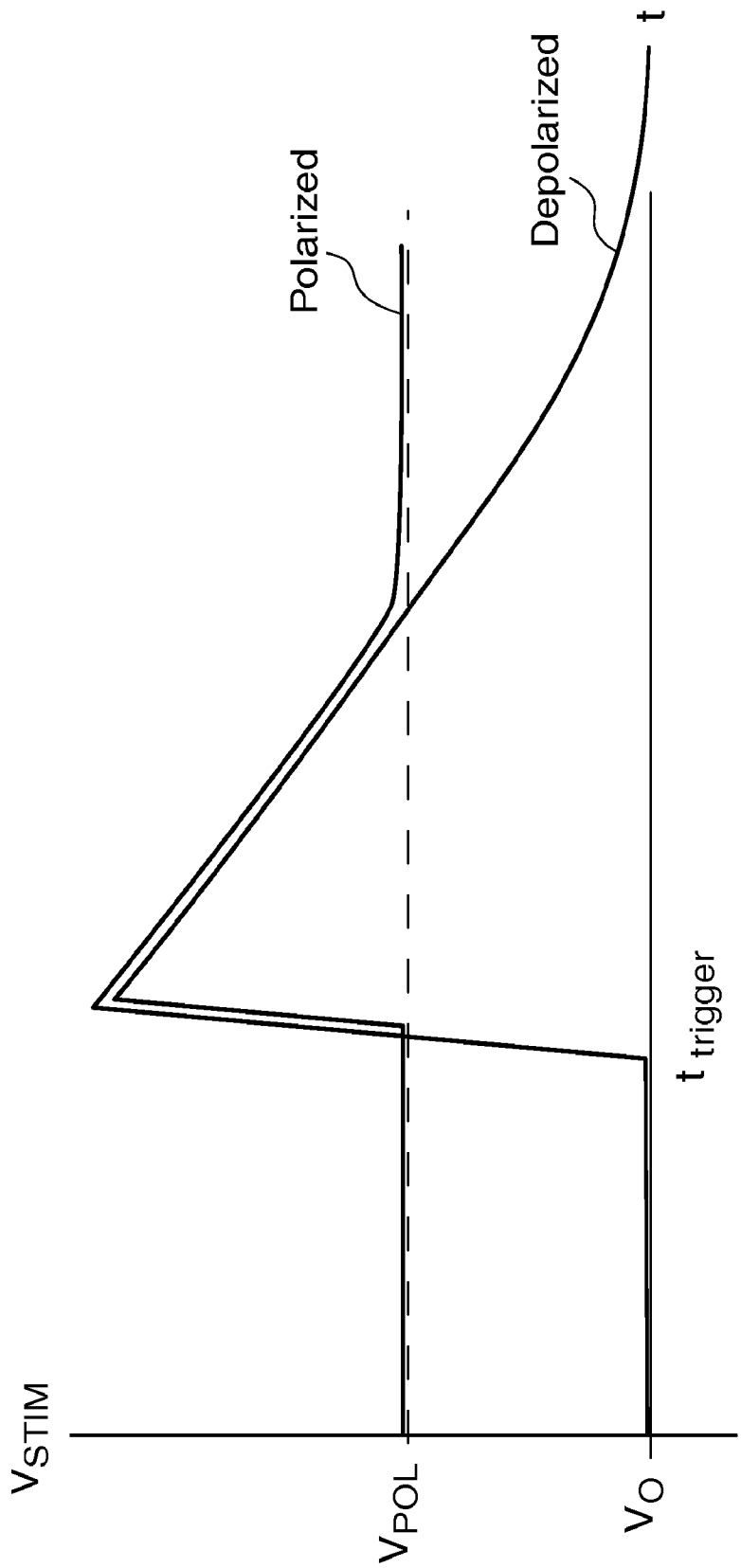

Fig. 2

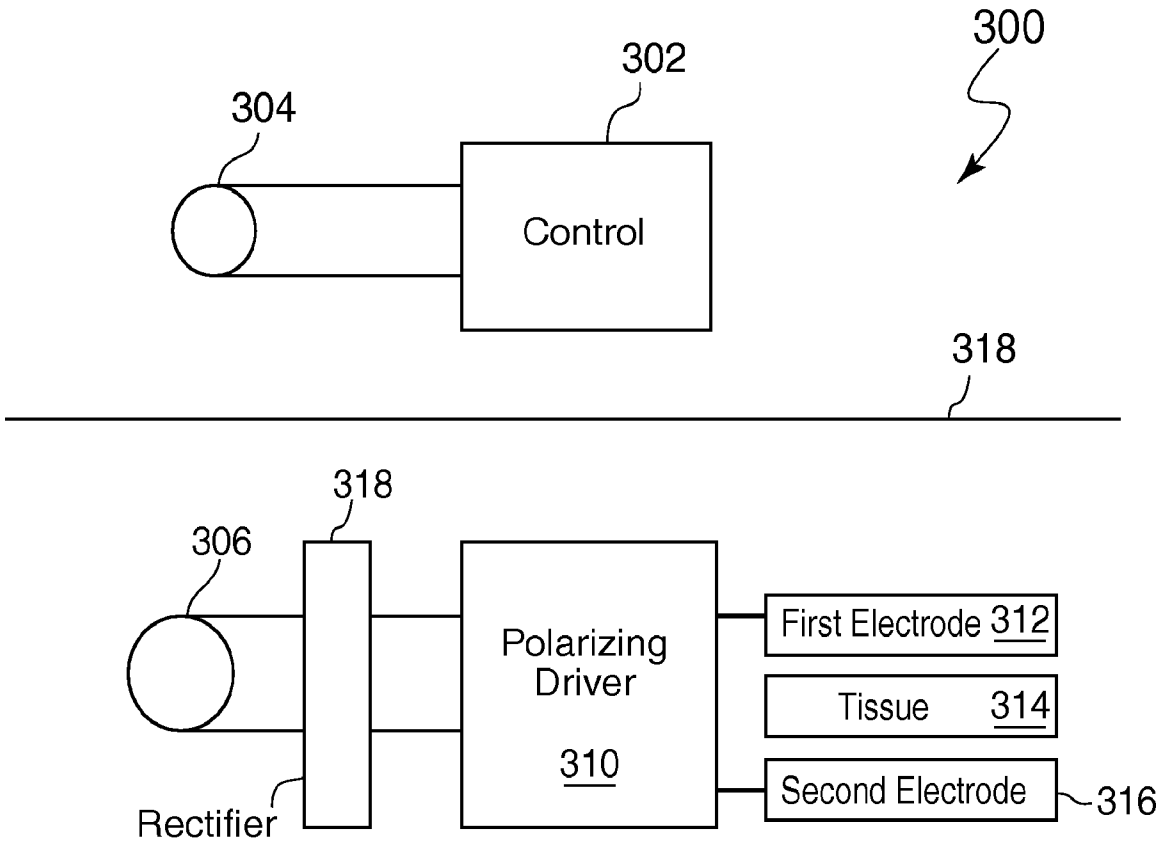
300
302
304
Control
318
318
306
Polarizing Driver
310
First Electrode 312
Tissue 314
Second Electrode
316
Rectifier

FIG. 3

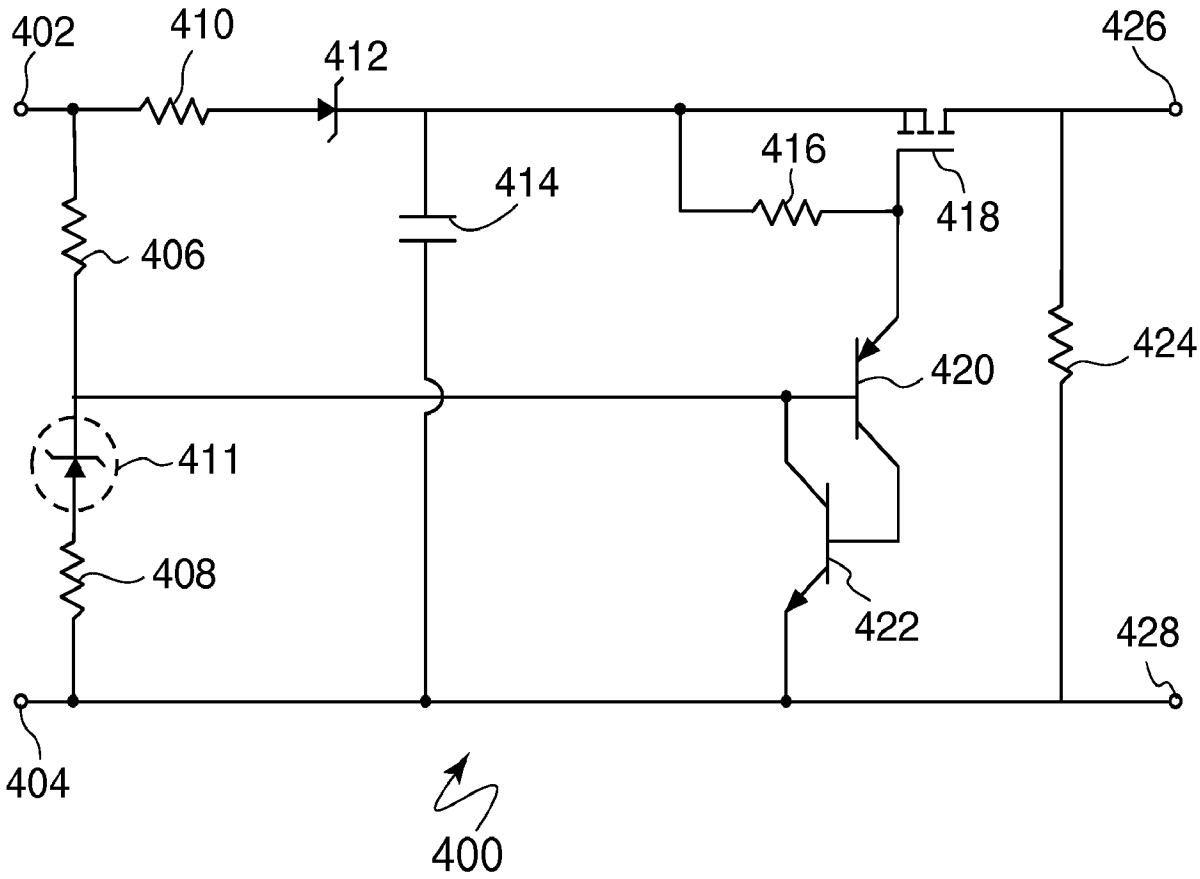

FIG. 4

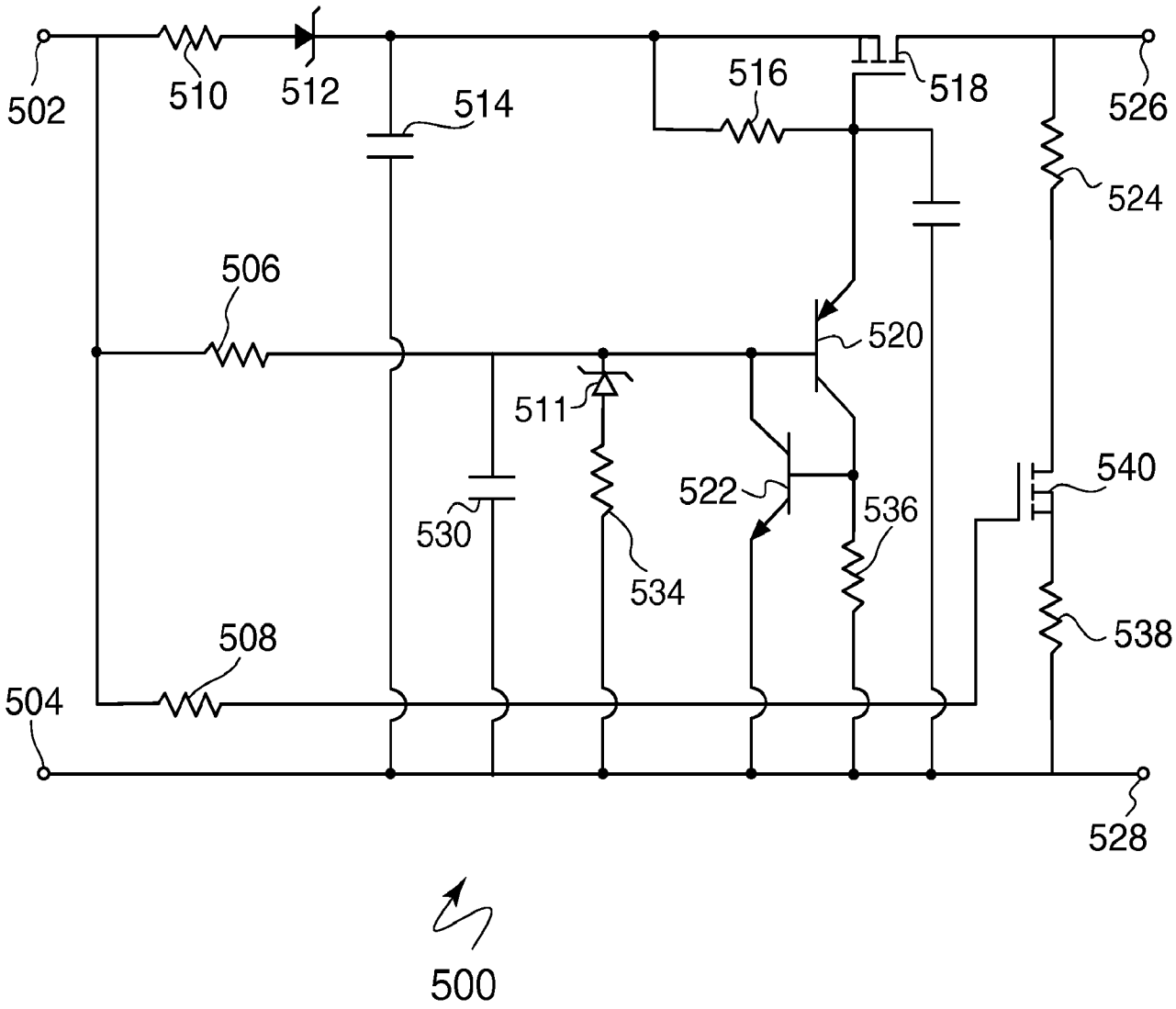
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FIG. 5

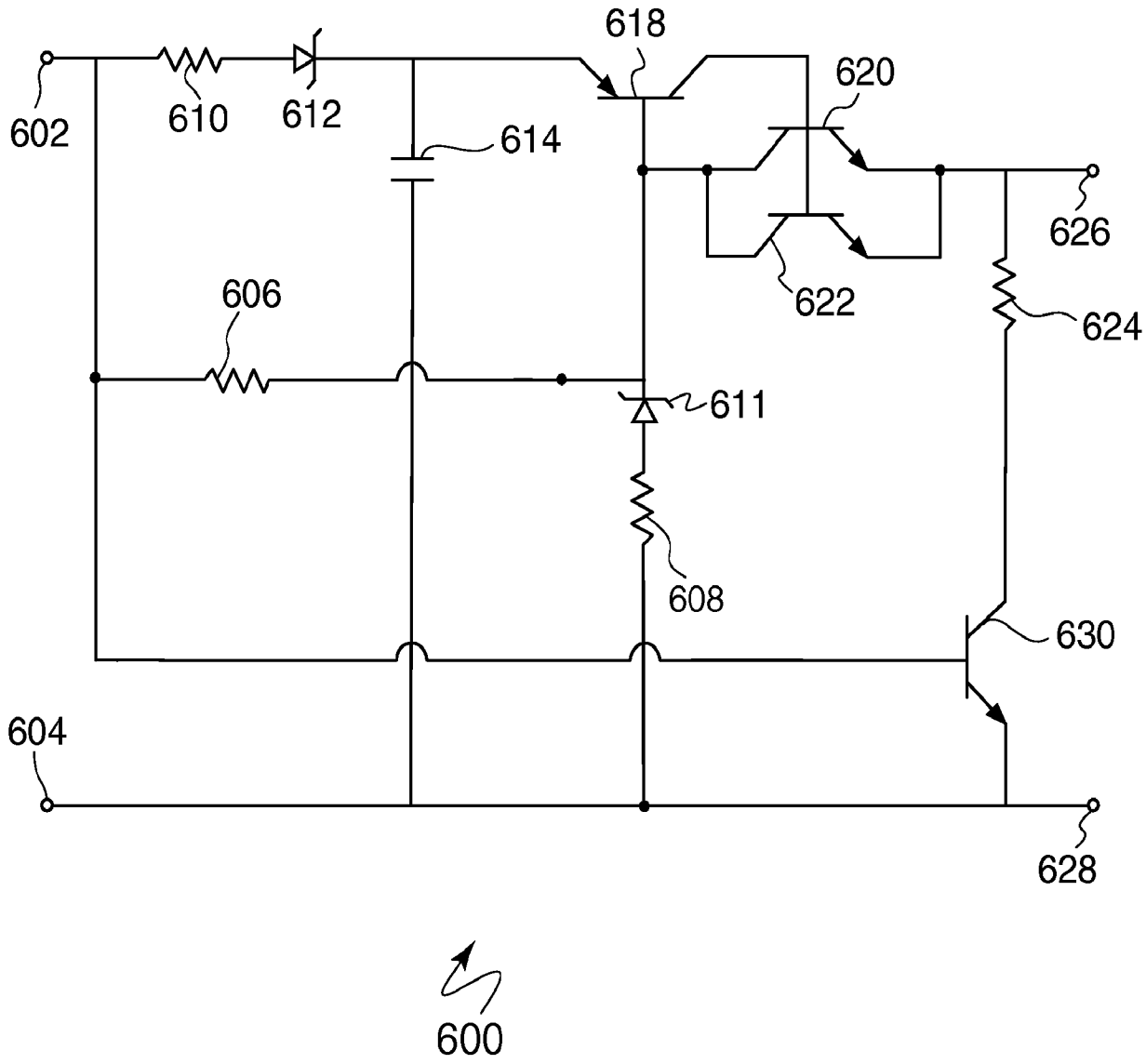

FIG. 6

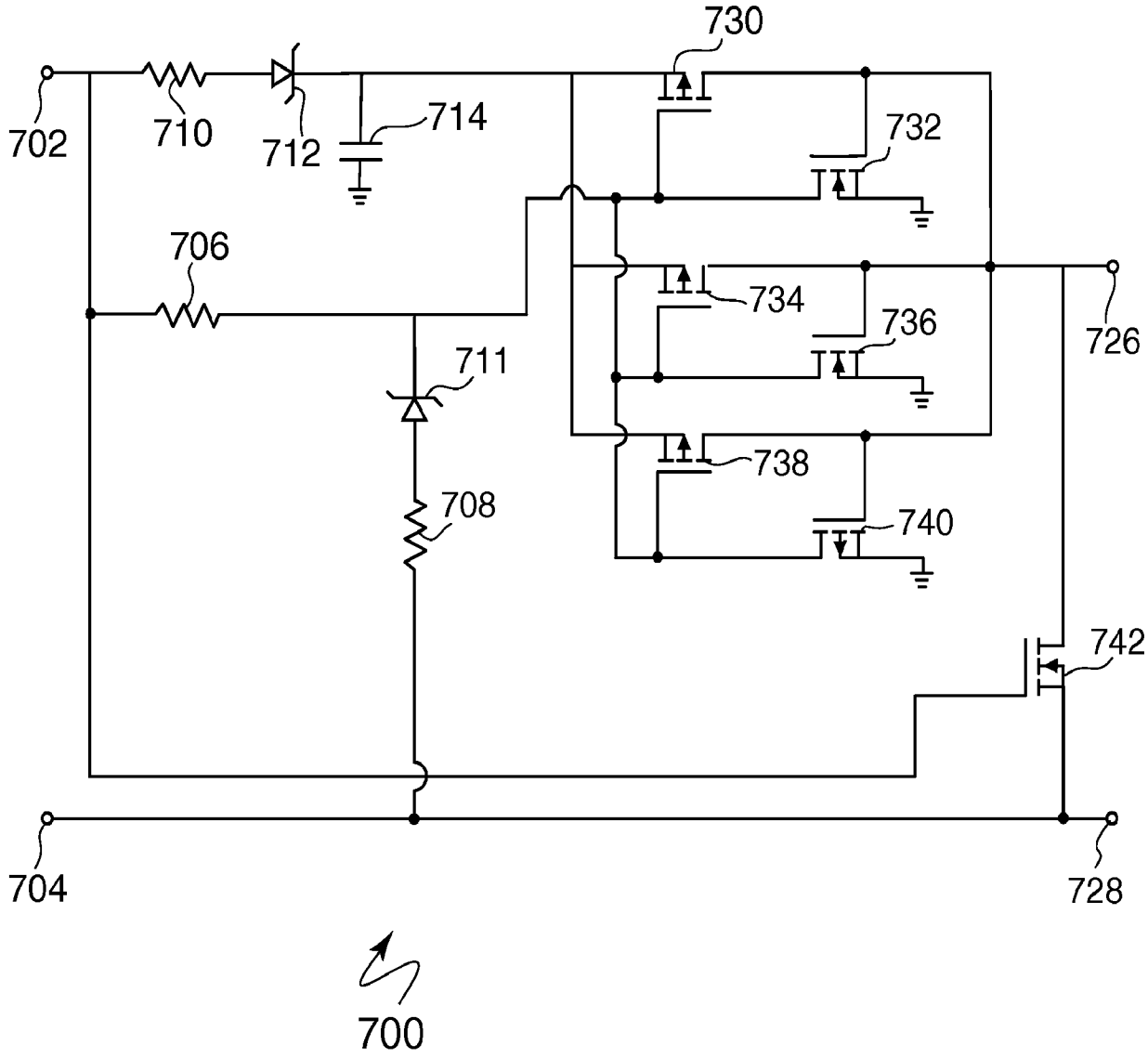
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FIG. 7

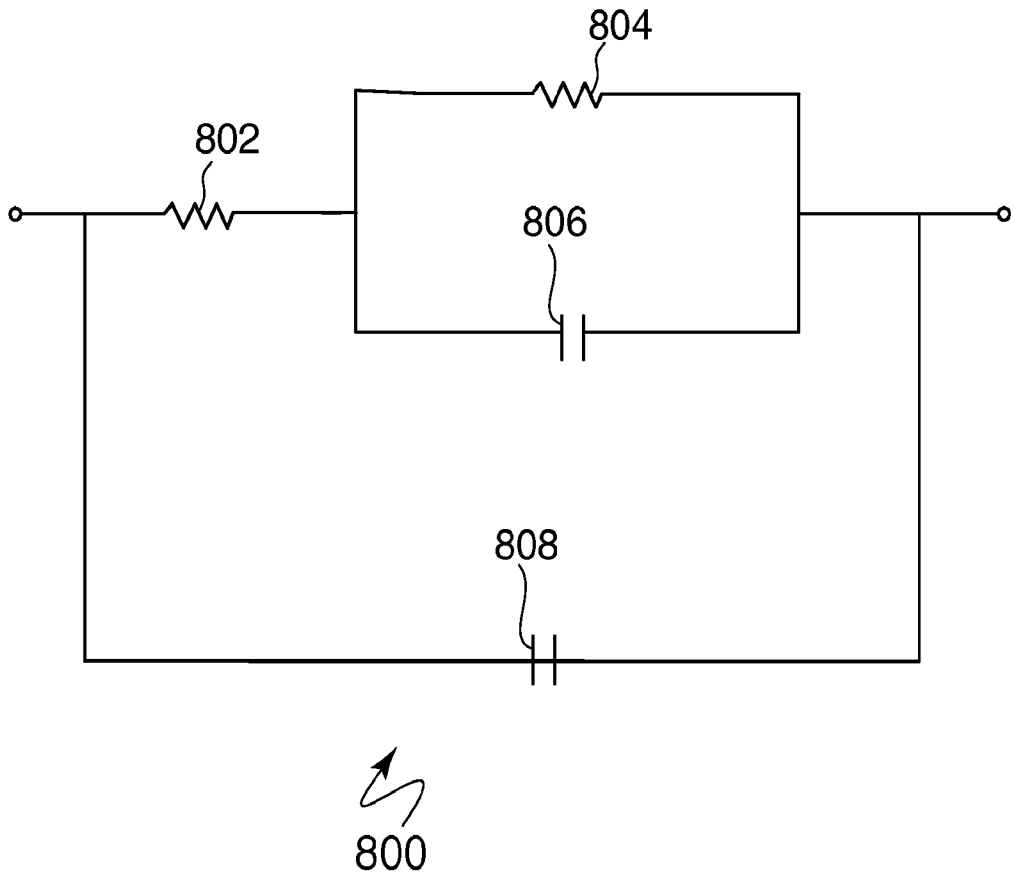

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/084926

A. CLASSIFICATION OF SUBJECT MATTER

H04B 1/04(2006.01)i, A61F 2/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC A61N, A61B, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS (KIPO internal) & keywords : "transponder", "biocompatible", "discharge, depolariz*", "circuit"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6185452 B1 (JOSEPH H. SCHULMAN et al.) 06 February 2001 See column 3, lines 21-29; column 6, line 50- column 7, line 10; figures 1, 2.	1-17, 20-28
X	US 5782880 A (STUART P.LAHTINEN et al.) 21 July 1998 See figures 2, 3 and corresponding detailed description.	1, 3-5, 14-16, 21-28
A	US 6447448 B1 (AKIRA ISHIKAWA et al.) 10 September 2002 See figure 20 and corresponding detailed description.	1-28
A	US 2007-0067004 A1 (BIRINDER R. BOVEJA et al.) 22 March 2007 See figure 41 and corresponding detailed description.	1-28
A	US 2005-0107833 A1 (GARY A. FREEMAN et al.) 19 May 2005 See figure 1 and corresponding detailed description.	1-28

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 APRIL 2009 (22.04.2009)	**23 APRIL 2009 (23.04.2009)**

Name and mailing address of the ISA/KR
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Facsimile No. 82-42-472-7140

Authorized officer
KIM, Jung Hun
Telephone No. 82-42-481-5949

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2008/084926

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