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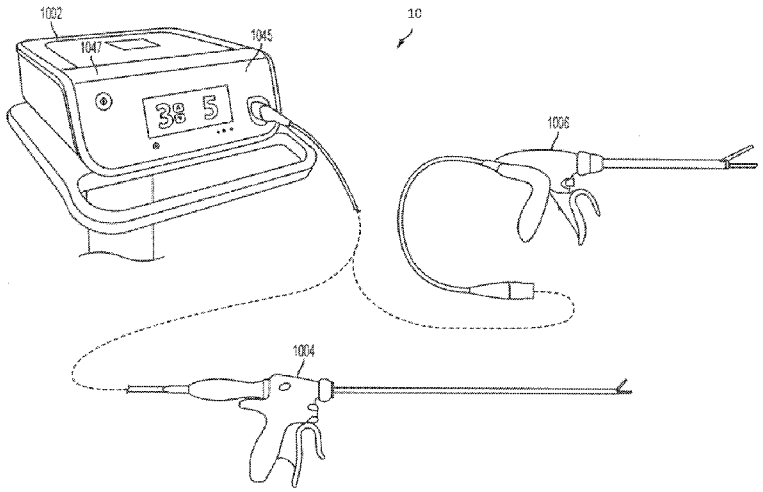
[Continued on next page]

(54) Title: SURGICAL INSTRUMENT WITH USER ADAPTABLE ALGORITHMS

FIG. 1



(57) Abstract: Various forms are directed to systems and methods for dissection and coagulation of tissue. A surgical instrument includes an end effector configured to dissect and seal tissue at a distal end thereof, and a selector switch having a plurality of surgical modes. A generator is electrically coupled to the surgical instrument and is configured to deliver energy to the end effector. Each surgical mode of the selector switch corresponds to an algorithm for controlling the power delivered from the generator to the end effector, and each algorithm corresponding to the plurality of surgical modes is configured to allow a user to control the power output level of the generator.

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SURGICAL INSTRUMENT WITH USER ADAPTABLE ALGORITHMS

TECHNICAL FIELD

[0001] The present disclosure generally relates to ultrasonic surgical systems and, more particularly, to ultrasonic and electrosurgical systems that allows surgeons to perform cutting and coagulation and adapt and customize algorithms for performing such procedures.

BACKGROUND

[0002] Ultrasonic surgical instruments are finding increasingly widespread applications in surgical procedures by virtue of the unique performance characteristics of such instruments. Depending upon specific instrument configurations and operational parameters, ultrasonic surgical instruments can provide substantially simultaneous cutting of tissue and hemostasis by coagulation, desirably minimizing patient trauma. The cutting action is typically realized by an-end effector, or blade tip, at the distal end of the instrument, which transmits ultrasonic energy to tissue brought into contact with the end effector. Ultrasonic instruments of this nature can be configured for open surgical use, laparoscopic, or endoscopic surgical procedures including robotic-assisted procedures.

[0003] Some surgical instruments utilize ultrasonic energy for both precise cutting and controlled coagulation. Ultrasonic energy cuts and coagulates by using lower temperatures than those used by electrosurgery. Vibrating at high frequencies (*e.g.*, 55,500 times per second), the ultrasonic blade denatures protein in the tissue to form a sticky coagulum. Pressure exerted on tissue with the blade surface collapses blood vessels and allows the coagulum to form a hemostatic seal. The precision of cutting and coagulation is controlled by the surgeon's technique and adjusting the power level, blade edge, tissue traction, and blade pressure.

[0004] Electrosurgical devices for applying electrical energy to tissue in order to treat and/or destroy the tissue are also finding increasingly widespread applications in surgical procedures. An electrosurgical device typically includes a hand piece, an instrument having a distally-mounted end effector (*e.g.*, one or more electrodes). The end effector can be positioned against the tissue such that electrical current is introduced into the tissue. Electrosurgical devices can be configured for bipolar or monopolar operation. During bipolar operation, current is introduced into and returned from the tissue by active and return electrodes, respectively, of the end effector.

During monopolar operation, current is introduced into the tissue by an active electrode of the end effector and returned through a return electrode (*e.g.*, a grounding pad) separately located on a patient's body. Heat generated by the current flowing through the tissue may form hemostatic seals within the tissue and/or between tissues and thus may be particularly useful for sealing blood vessels, for example. The end effector of an electrosurgical device may also include a cutting member that is movable relative to the tissue and the electrodes to transect the tissue.

[0005] Electrical energy applied by an electrosurgical device can be transmitted to the instrument by a generator in communication with the hand piece. The electrical energy may be in the form of radio frequency ("RF") energy. RF energy is a form of electrical energy that may be in the frequency range of 300 kilohertz (kHz) to 1 megahertz (MHz). In application, an electrosurgical device can transmit low frequency RF energy through tissue, which causes ionic agitation, or friction, in effect resistive heating, thereby increasing the temperature of the tissue. Because a sharp boundary is created between the affected tissue and the surrounding tissue, surgeons can operate with a high level of precision and control, without sacrificing un-targeted adjacent tissue. The low operating temperatures of RF energy is useful for removing, shrinking, or sculpting soft tissue while simultaneously sealing blood vessels. RF energy works particularly well on connective tissue, which is primarily comprised of collagen and shrinks when contacted by heat.

[0006] A challenge of using these medical devices is the inability to control and customize the power output depending on the type of procedures being performed. It would be desirable to provide a surgical instrument that overcomes some of the deficiencies of current instruments. The surgical system described herein overcomes those deficiencies.

FIGURES

[0007] The novel features of the described forms are set forth with particularity in the appended claims. The described forms, however, both as to organization and methods of operation, may be best understood by reference to the following description, taken in conjunction with the accompanying drawings in which:

[0008] FIG. 1 illustrates one form of a surgical system comprising a generator and various surgical instruments usable therewith;

[0009] FIG. 2 is a diagram of the ultrasonic surgical instrument of FIG. 16;

[0010] FIG. 3 is a diagram of the surgical system of FIG. 16;

[0011] FIG. 4 is a model illustrating motional branch current in one form;

[0012] FIG. 5 is a structural view of a generator architecture in one form;

[0013] FIG. 6 illustrates one form of a drive system of a generator, which creates the ultrasonic electrical signal for driving an ultrasonic transducer;

[0014] FIG. 7 illustrates one form of a drive system of a generator comprising a tissue impedance module;

[0015] FIG. 8 illustrates one form of a surgical instrument having a selector switch thereon for selecting a surgical mode;

[0016] FIG. 9 is a logic flow diagram for selecting a surgical mode corresponding to a tissue algorithm that may be implemented in one form of a generator;

[0017] FIG. 10 is a logic flow diagram for customizing a surgical mode corresponding to a tissue algorithm;

[0018] FIG. 11 is one form of a logic flow diagram for selecting a surgical mode corresponding to a tissue algorithm using the position of an end effector of a surgical instrument as an algorithm input;

[0019] FIG. 12 is another form of a logic flow diagram for selecting a surgical mode corresponding to a tissue algorithm using the position of an end effector of a surgical instrument as an algorithm input; and

[0020] FIG. 13 is a logic flow diagram for customizing a surgical mode corresponding to a tissue algorithm including a counter for counting the number of closures of an end effector of a surgical instrument.

DESCRIPTION

[0021] Before explaining various forms of ultrasonic surgical instruments in detail, it should be noted that the illustrative forms are not limited in application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The illustrative forms may be implemented or incorporated in other forms, variations and modifications, and may be practiced or carried out in various ways. Further, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of

describing the illustrative forms for the convenience of the reader and are not for the purpose of limitation thereof.

[0022] Further, it is understood that any one or more of the following-described forms, expressions of forms, examples, can be combined with any one or more of the other following-described forms, expressions of forms, and examples.

[0023] Various forms are directed to improved ultrasonic surgical instruments configured for effecting tissue dissecting, cutting, and/or coagulation during surgical procedures. In one form, an ultrasonic surgical instrument apparatus is configured for use in open surgical procedures, but has applications in other types of surgery, such as laparoscopic, endoscopic, and robotic-assisted procedures. Versatile use is facilitated by selective use of ultrasonic energy.

[0024] The various forms will be described in combination with an ultrasonic instrument as described herein. Such description is provided by way of example, and not limitation, and is not intended to limit the scope and applications thereof. For example, any one of the described forms is useful in combination with a multitude of ultrasonic instruments including those described in, for example, U.S. Patent Nos. 5,938,633; 5,935,144; 5,944,737; 5,322,055; 5,630,420; and 5,449,370.

[0025] As will become apparent from the following description, it is contemplated that forms of the surgical instrument described herein may be used in association with an oscillator unit of a surgical system, whereby ultrasonic energy from the oscillator unit provides the desired ultrasonic actuation for the present surgical instrument. It is also contemplated that forms of the surgical instrument described herein may be used in association with a signal generator unit of a surgical system, whereby electrical energy in the form of radio frequencies (RF), for example, is used to provide feedback to the user regarding the surgical instrument. The ultrasonic oscillator and/or the signal generator unit may be non-detachably integrated with the surgical instrument or may be provided as separate components, which can be electrically attachable to the surgical instrument.

[0026] One form of the present surgical apparatus is particularly configured for disposable use by virtue of its straightforward construction. However, it is also contemplated that other forms of the present surgical instrument can be configured for non-disposable or multiple uses. Detachable connection of the present surgical instrument with an associated oscillator and signal generator unit is presently disclosed for single-patient use for illustrative purposes only.

However, non-detachable integrated connection of the present surgical instrument with an associated oscillator and/or signal generator unit is also contemplated. Accordingly, various forms of the presently described surgical instruments may be configured for single use and/or multiple use with either detachable and/or non-detachable integral oscillator and/or signal generator unit, without limitation, and all combinations of such configurations are contemplated to be within the scope of the present disclosure.

[0027] With reference to FIGS. 1-5, one form of a surgical system 10 including an ultrasonic surgical instrument is illustrated. FIG. 1 illustrates one form of a surgical system 10 comprising a generator 1002 and various surgical instruments 1004, 1006 usable therewith. FIG. 2 is a diagram of the ultrasonic surgical instrument 1004 of FIG. 1. The generator 1002 is configurable for use with surgical devices. According to various forms, the generator 1002 may be configurable for use with different surgical devices of different types including, for example, the ultrasonic device 1004 and electrosurgical or RF surgical devices, such as, the RF device 1006. Although in the form of FIG. 1, the generator 1002 is shown separate from the surgical devices 1004, 1006, in one form, the generator 1002 may be formed integrally with either of the surgical devices 1004, 1006 to form a unitary surgical system. The generator 1002 comprises an input device 1045 located on a front panel of the generator 1002 console. The input device 1045 may comprise any suitable device that generates signals suitable for programming the operation of the generator 1002.

[0028] FIG. 3 is a diagram of the surgical system 10 of FIG. 1. In various forms, the generator 1002 may comprise several separate functional elements, such as modules and/or blocks. Different functional elements or modules may be configured for driving the different kinds of surgical devices 1004, 1006. For example, an ultrasonic generator module 1008 may drive ultrasonic devices such as the ultrasonic device 1004. An electrosurgery/RF generator module 1010 may drive the electrosurgical device 1006. For example, the respective modules 1008, 1010 may generate respective drive signals for driving the surgical devices 1004, 1006. In various forms, the ultrasonic generator module 1008 and/or the electrosurgery/RF generator module 1010 each may be formed integrally with the generator 1002. Alternatively, one or more of the modules 1008, 1010 may be provided as a separate circuit module electrically coupled to the generator 1002. (The modules 1008 and 1010 are shown in phantom to illustrate this option.) Also, in some forms, the electrosurgery/RF generator module 1010 may be formed integrally

with the ultrasonic generator module 1008, or vice versa. Also, in some forms, the generator 1002 may be omitted entirely and the modules 1008, 1010 may be executed by processors or other hardware within the respective instruments 1004, 1006.

[0029] In accordance with the described forms, the ultrasonic generator module 1008 may produce a drive signal or signals of particular voltages, currents, and frequencies, *e.g.*, 55,500 cycles per second (Hz). The drive signal or signals may be provided to the ultrasonic device 1004, and specifically to the transducer 1014, which may operate, for example, as described above. The transducer 1014 and a waveguide extending through the shaft 1015 (waveguide not shown in FIG. 2) may collectively form an ultrasonic drive system driving an ultrasonic blade 1017 of an end effector 1026. In one form, the generator 1002 may be configured to produce a drive signal of a particular voltage, current, and/or frequency output signal that can be stepped or otherwise modified with high resolution, accuracy, and repeatability.

[0030] The generator 1002 may be activated to provide the drive signal to the transducer 1014 in any suitable manner. For example, the generator 1002 may comprise a foot switch 1020 coupled to the generator 1002 via a footswitch cable 1022. A clinician may activate the transducer 1014 by depressing the foot switch 1020. In addition, or instead of the foot switch 1020 some forms of the ultrasonic device 1004 may utilize one or more switches positioned on the hand piece that, when activated, may cause the generator 1002 to activate the transducer 1014. In one form, for example, the one or more switches may comprise a pair of toggle buttons 1036a, 1036b (Figure 2), for example, to determine an operating mode of the device 1004. When the toggle button 1036a is depressed, for example, the ultrasonic generator 1002 may provide a maximum drive signal to the transducer 1014, causing it to produce maximum ultrasonic energy output. Depressing toggle button 1036b may cause the ultrasonic generator 1002 to provide a user-selectable drive signal to the transducer 1014, causing it to produce less than the maximum ultrasonic energy output. The device 1004 additionally or alternatively may comprise a second switch (not shown) to, for example, indicate a position of a jaw closure trigger for operating jaws of the end effector 1026. Also, in some forms, the ultrasonic generator 1002 may be activated based on the position of the jaw closure trigger, (*e.g.*, as the clinician depresses the jaw closure trigger to close the jaws, ultrasonic energy may be applied).

[0031] Additionally or alternatively, the one or more switches may comprises a toggle button 1036c that, when depressed, causes the generator 1002 to provide a pulsed output. The pulses

may be provided at any suitable frequency and grouping, for example. In certain forms, the power level of the pulses may be the power levels associated with toggle buttons 1036a, 1036b (maximum, less than maximum), for example.

[0032] It will be appreciated that a device 1004 may comprise any combination of the toggle buttons 1036a, 1036b, 1036c. For example, the device 1004 could be configured to have only two toggle buttons: a toggle button 1036a for producing maximum ultrasonic energy output and a toggle button 1036c for producing a pulsed output at either the maximum or less than maximum power level. In this way, the drive signal output configuration of the generator 1002 could be 5 continuous signals and 5 or 4 or 3 or 2 or 1 pulsed signals. In certain forms, the specific drive signal configuration may be controlled based upon, for example, EEPROM settings in the generator 1002 and/or user power level selection(s).

[0033] In certain forms, a two-position switch may be provided as an alternative to a toggle button 1036c. For example, a device 1004 may include a toggle button 1036a for producing a continuous output at a maximum power level and a two-position toggle button 1036b. In a first detented position, toggle button 1036b may produce a continuous output at a less than maximum power level, and in a second detented position the toggle button 1036b may produce a pulsed output (*e.g.*, at either a maximum or less than maximum power level, depending upon the EEPROM settings).

[0034] In accordance with the described forms, the electrosurgery/RF generator module 1010 may generate a drive signal or signals with output power sufficient to perform bipolar electrosurgery using radio frequency (RF) energy. In bipolar electrosurgery applications, the drive signal may be provided, for example, to electrodes of the electrosurgical device 1006, for example. Accordingly, the generator 1002 may be configured for therapeutic purposes by applying electrical energy to the tissue sufficient for treating the tissue (*e.g.*, coagulation, cauterization, tissue welding).

[0035] The generator 1002 may comprise an input device 1045 (FIG. 1) located, for example, on a front panel of the generator 1002 console. The input device 1045 may comprise any suitable device that generates signals suitable for programming the operation of the generator 1002. In operation, the user can program or otherwise control operation of the generator 1002 using the input device 1045. The input device 1045 may comprise any suitable device that generates signals that can be used by the generator (*e.g.*, by one or more processors contained in

the generator) to control the operation of the generator 1002 (*e.g.*, operation of the ultrasonic generator module 1008 and/or electrosurgery/RF generator module 1010). In various forms, the input device 1045 includes one or more of buttons, switches, thumbwheels, keyboard, keypad, touch screen monitor, pointing device, remote connection to a general purpose or dedicated computer. In other forms, the input device 1045 may comprise a suitable user interface, such as one or more user interface screens displayed on a touch screen monitor, for example. Accordingly, by way of the input device 1045, the user can set or program various operating parameters of the generator, such as, for example, current (I), voltage (V), frequency (f), and/or period (T) of a drive signal or signals generated by the ultrasonic generator module 1008 and/or electrosurgery/RF generator module 1010.

[0036] The generator 1002 may also comprise an output device 1047 (FIG. 1), such as an output indicator, located, for example, on a front panel of the generator 1002 console. The output device 1047 includes one or more devices for providing a sensory feedback to a user. Such devices may comprise, for example, visual feedback devices (*e.g.*, a visual feedback device may comprise incandescent lamps, light emitting diodes (LEDs), graphical user interface, display, analog indicator, digital indicator, bar graph display, digital alphanumeric display, LCD display screen, LED indicators), audio feedback devices (*e.g.*, an audio feedback device may comprise speaker, buzzer, audible, computer generated tone, computerized speech, voice user interface (VUI) to interact with computers through a voice/speech platform), or tactile feedback devices (*e.g.*, a tactile feedback device comprises any type of vibratory feedback, haptic actuator).

[0037] Although certain modules and/or blocks of the generator 1002 may be described by way of example, it can be appreciated that a greater or lesser number of modules and/or blocks may be used and still fall within the scope of the forms. Further, although various forms may be described in terms of modules and/or blocks to facilitate description, such modules and/or blocks may be implemented by one or more hardware components, *e.g.*, processors, Digital Signal Processors (DSPs), Programmable Logic Devices (PLDs), Application Specific Integrated Circuits (ASICs), circuits, registers and/or software components, *e.g.*, programs, subroutines, logic and/or combinations of hardware and software components. Also, in some forms, the various modules described herein may be implemented utilizing similar hardware positioned within the instruments 1004, 1006 (*i.e.*, the generator 1002 may be omitted).

[0038] In one form, the ultrasonic generator drive module 1008 and electrosurgery/RF drive module 1010 may comprise one or more embedded applications implemented as firmware, software, hardware, or any combination thereof. The modules 1008, 1010 may comprise various executable modules such as software, programs, data, drivers, application program interfaces (APIs), and so forth. The firmware may be stored in nonvolatile memory (NVM), such as in bit-masked read-only memory (ROM) or flash memory. In various implementations, storing the firmware in ROM may preserve flash memory. The NVM may comprise other types of memory including, for example, programmable ROM (PROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), or battery backed random-access memory (RAM) such as dynamic RAM (DRAM), Double-Data-Rate DRAM (DDRAM), and/or synchronous DRAM (SDRAM).

[0039] In one form, the modules 1008, 1010 comprise a hardware component implemented as a processor for executing program instructions for monitoring various measurable characteristics of the devices 1004, 1006 and generating a corresponding output control signals for operating the devices 1004, 1006. In forms in which the generator 1002 is used in conjunction with the device 1004, the output control signal may drive the ultrasonic transducer 1014 in cutting and/or coagulation operating modes. Electrical characteristics of the device 1004 and/or tissue may be measured and used to control operational aspects of the generator 1002 and/or provided as feedback to the user. In forms in which the generator 1002 is used in conjunction with the device 1006, the output control signal may supply electrical energy (*e.g.*, RF energy) to the end effector 1032 in cutting, coagulation and/or desiccation modes. Electrical characteristics of the device 1006 and/or tissue may be measured and used to control operational aspects of the generator 1002 and/or provide feedback to the user. In various forms, as previously discussed, the hardware component may be implemented as a DSP, PLD, ASIC, circuits, and/or registers. In one form, the processor may be configured to store and execute computer software program instructions to generate the step function output signals for driving various components of the devices 1004, 1006, such as the ultrasonic transducer 1014 and the end effectors 1026, 1032.

[0040] FIG. 4 illustrates an equivalent circuit 1050 of an ultrasonic transducer, such as the ultrasonic transducer 1014, according to one form. The circuit 1050 comprises a first "motional" branch having a serially connected inductance L_s, resistance R_s and capacitance C_s that define the electromechanical properties of the resonator, and a second capacitive branch having a static

capacitance C_o. Drive current I_g may be received from a generator at a drive voltage V_g, with motional current I_m flowing through the first branch and current $I_g - I_m$ flowing through the capacitive branch. Control of the electromechanical properties of the ultrasonic transducer may be achieved by suitably controlling I_g and V_g. As explained above, conventional generator architectures may include a tuning inductor L_t (shown in phantom in FIG. 4) for tuning out in a parallel resonance circuit the static capacitance Co at a resonant frequency so that substantially all of generator's current output I_g flows through the motional branch. In this way, control of the motional branch current I_m is achieved by controlling the generator current output I_g. The tuning inductor L_t is specific to the static capacitance C_o of an ultrasonic transducer, however, and a different ultrasonic transducer having a different static capacitance requires a different tuning inductor L_t. Moreover, because the tuning inductor L_t is matched to the nominal value of the static capacitance Co at a single resonant frequency, accurate control of the motional branch current I_m is assured only at that frequency, and as frequency shifts down with transducer temperature, accurate control of the motional branch current is compromised.

[0041] Forms of the generator 1002 do not rely on a tuning inductor L_t to monitor the motional branch current I_m. Instead, the generator 1002 may use the measured value of the static capacitance C_o in between applications of power for a specific ultrasonic surgical device 1004 (along with drive signal voltage and current feedback data) to determine values of the motional branch current I_m on a dynamic and ongoing basis (*e.g.*, in real-time). Such forms of the generator 1002 are therefore able to provide virtual tuning to simulate a system that is tuned or resonant with any value of static capacitance C_o at any frequency, and not just at single resonant frequency dictated by a nominal value of the static capacitance C_o.

[0042] FIG. 5 is a simplified block diagram of one form of the generator 1002 for proving inductorless tuning as described above, among other benefits. Additional details of the generator 1002 are described in commonly assigned U.S. Patent Application Serial No. 12/896,360, entitled "Surgical Generator For Ultrasonic And Electrosurgical Devices," now U.S. Patent No. 9,060,775, the disclosure of which is incorporated herein by reference in its entirety. With reference to FIG. 5, the generator 1002 may comprise a patient isolated stage 1052 in communication with a non-isolated stage 1054 via a power transformer 1056. A secondary winding 1058 of the power transformer 1056 is contained in the isolated stage 1052 and may comprise a tapped configuration (*e.g.*, a center-tapped or a non-center-tapped configuration) to

define drive signal outputs 1060a, 1060b, 1060c for outputting drive signals to different surgical devices, such as, for example, an ultrasonic surgical device 1004 and an electrosurgical device 1006. In particular, drive signal outputs 1060a, 1060c may output an ultrasonic drive signal (*e.g.*, a 420V RMS drive signal) to an ultrasonic surgical device 1004, and drive signal outputs 1060b, 1060c may output an electrosurgical drive signal (*e.g.*, a 100V RMS drive signal) to an electrosurgical device 1006, with output 1060b corresponding to the center tap of the power transformer 1056.

[0043] In certain forms, the ultrasonic and electrosurgical drive signals may be provided simultaneously to distinct surgical instruments and/or to a single surgical instrument having the capability to deliver both ultrasonic and electrosurgical energy to tissue. It will be appreciated that the electrosurgical signal, provided either to a dedicated electrosurgical instrument and/or to a combined ultrasonic/electrosurgical instrument may be either a therapeutic or sub-therapeutic level signal.

[0044] The non-isolated stage 1054 may comprise a power amplifier 1062 having an output connected to a primary winding 1064 of the power transformer 1056. In certain forms the power amplifier 1062 may be comprise a push-pull amplifier. For example, the non-isolated stage 1054 may further comprise a logic device 1066 for supplying a digital output to a digital-to-analog converter (DAC) 1068, which in turn supplies a corresponding analog signal to an input of the power amplifier 1062. In certain forms the logic device 1066 may comprise a programmable gate array (PGA), a field-programmable gate array (FPGA), programmable logic device (PLD), among other logic circuits, for example. The logic device 1066, by virtue of controlling the input of the power amplifier 1062 via the DAC 1068, may therefore control any of a number of parameters (*e.g.*, frequency, waveform shape, waveform amplitude) of drive signals appearing at the drive signal outputs 1060a, 1060b, 1060c. In certain forms and as discussed below, the logic device 1066, in conjunction with a processor (*e.g.*, a digital signal processor discussed below), may implement a number of digital signal processing (DSP)-based and/or other control algorithms to control parameters of the drive signals output by the generator 1002.

[0045] Power may be supplied to a power rail of the power amplifier 1062 by a switch-mode regulator 1070. In certain forms the switch-mode regulator 1070 may comprise an adjustable buck regulator, for example. The non-isolated stage 1054 may further comprise a first processor 1074, which in one form may comprise a DSP processor such as an Analog Devices ADSP-

21469 SHARC DSP, available from Analog Devices, Norwood, MA, for example, although in various forms any suitable processor may be employed. In certain forms the processor 1074 may control operation of the switch-mode power converter 1070 responsive to voltage feedback data received from the power amplifier 1062 by the DSP processor 1074 via an analog-to-digital converter (ADC) 1076. In one form, for example, the DSP processor 1074 may receive as input, via the ADC 1076, the waveform envelope of a signal (*e.g.*, an RF signal) being amplified by the power amplifier 1062. The DSP processor 1074 may then control the switch-mode regulator 1070 (*e.g.*, via a pulse-width modulated (PWM) output) such that the rail voltage supplied to the power amplifier 1062 tracks the waveform envelope of the amplified signal. By dynamically modulating the rail voltage of the power amplifier 1062 based on the waveform envelope, the efficiency of the power amplifier 1062 may be significantly improved relative to a fixed rail voltage amplifier schemes.

[0046] In certain forms, the logic device 1066, in conjunction with the DSP processor 1074, may implement a direct digital synthesizer (DDS) control scheme to control the waveform shape, frequency and/or amplitude of drive signals output by the generator 1002. In one form, for example, the logic device 1066 may implement a DDS control algorithm by recalling waveform samples stored in a dynamically-updated look-up table (LUT), such as a RAM LUT, which may be embedded in an FPGA. This control algorithm is particularly useful for ultrasonic applications in which an ultrasonic transducer, such as the ultrasonic transducer 1014, may be driven by a clean sinusoidal current at its resonant frequency. Because other frequencies may excite parasitic resonances, minimizing or reducing the total distortion of the motional branch current may correspondingly minimize or reduce undesirable resonance effects. Because the waveform shape of a drive signal output by the generator 1002 is impacted by various sources of distortion present in the output drive circuit (*e.g.*, the power transformer 1056, the power amplifier 1062), voltage and current feedback data based on the drive signal may be input into an algorithm, such as an error control algorithm implemented by the DSP processor 1074, which compensates for distortion by suitably pre-distorting or modifying the waveform samples stored in the LUT on a dynamic, ongoing basis (*e.g.*, in real-time). In one form, the amount or degree of pre-distortion applied to the LUT samples may be based on the error between a computed motional branch current and a desired current waveform shape, with the error being determined on a sample-by-sample basis. In this way, the pre-distorted LUT samples, when processed

through the drive circuit, may result in a motional branch drive signal having the desired waveform shape (*e.g.*, sinusoidal) for optimally driving the ultrasonic transducer. In such forms, the LUT waveform samples will therefore not represent the desired waveform shape of the drive signal, but rather the waveform shape that is required to ultimately produce the desired waveform shape of the motional branch drive signal when distortion effects are taken into account.

[0047] The non-isolated stage 1054 may further comprise an ADC 1078 and an ADC 1080 coupled to the output of the power transformer 1056 via respective isolation transformers 1082, 1084 for respectively sampling the voltage and current of drive signals output by the generator 1002. In certain forms, the ADCs 1078, 1080 may be configured to sample at high speeds (*e.g.*, 80 MSPS) to enable oversampling of the drive signals. In one form, for example, the sampling speed of the ADCs 1078, 1080 may enable approximately 200x (depending on frequency) oversampling of the drive signals. In certain forms, the sampling operations of the ADC 1078, 1080 may be performed by a singe ADC receiving input voltage and current signals via a two-way multiplexer. The use of high-speed sampling in forms of the generator 1002 may enable, among other things, calculation of the complex current flowing through the motional branch (which may be used in certain forms to implement DDS-based waveform shape control described above), accurate digital filtering of the sampled signals, and calculation of real power consumption with a high degree of precision. Voltage and current feedback data output by the ADCs 1078, 1080 may be received and processed (*e.g.*, FIFO buffering, multiplexing) by the logic device 1066 and stored in data memory for subsequent retrieval by, for example, the DSP processor 1074. As noted above, voltage and current feedback data may be used as input to an algorithm for pre-distorting or modifying LUT waveform samples on a dynamic and ongoing basis. In certain forms, this may require each stored voltage and current feedback data pair to be indexed based on, or otherwise associated with, a corresponding LUT sample that was output by the logic device 1066 when the voltage and current feedback data pair was acquired. Synchronization of the LUT samples and the voltage and current feedback data in this manner contributes to the correct timing and stability of the pre-distortion algorithm.

[0048] In certain forms, the voltage and current feedback data may be used to control the frequency and/or amplitude (*e.g.*, current amplitude) of the drive signals. In one form, for example, voltage and current feedback data may be used to determine impedance phase. The

frequency of the drive signal may then be controlled to minimize or reduce the difference between the determined impedance phase and an impedance phase setpoint (*e.g.*, 0°), thereby minimizing or reducing the effects of harmonic distortion and correspondingly enhancing impedance phase measurement accuracy. The determination of phase impedance and a frequency control signal may be implemented in the DSP processor 1074, for example, with the frequency control signal being supplied as input to a DDS control algorithm implemented by the logic device 1066.

[0049] In another form, for example, the current feedback data may be monitored in order to maintain the current amplitude of the drive signal at a current amplitude setpoint. The current amplitude setpoint may be specified directly or determined indirectly based on specified voltage amplitude and power setpoints. In certain forms, control of the current amplitude may be implemented by control algorithm, such as, for example, a PID control algorithm, in the processor 1074. Variables controlled by the control algorithm to suitably control the current amplitude of the drive signal may include, for example, the scaling of the LUT waveform samples stored in the logic device 1066 and/or the full-scale output voltage of the DAC 1068 (which supplies the input to the power amplifier 1062) via a DAC 1086.

[0050] The non-isolated stage 1054 may further comprise a second processor 1090 for providing, among other things user interface (UI) functionality. In one form, the UI processor 1090 may comprise an Atmel AT91SAM9263 processor having an ARM 926EJ-S core, available from Atmel Corporation, San Jose, CA, for example. Examples of UI functionality supported by the UI processor 1090 may include audible and visual user feedback, communication with peripheral devices (*e.g.*, via a Universal Serial Bus (USB) interface), communication with the footswitch 1020, communication with an input device 1009 (*e.g.*, a touch screen display) and communication with an output device 1047 (*e.g.*, a speaker). The UI processor 1090 may communicate with the processor 1074 and the logic device 1066 (*e.g.*, via serial peripheral interface (SPI) buses). Although the UI processor 1090 may primarily support UI functionality, it may also coordinate with the DSP processor 1074 to implement hazard mitigation in certain forms. For example, the UI processor 1090 may be programmed to monitor various aspects of user input and/or other inputs (*e.g.*, touch screen inputs, footswitch 1020 inputs (FIG. 3), temperature sensor inputs) and may disable the drive output of the generator 1002 when an erroneous condition is detected.

[0051] In certain forms, both the DSP processor 1074 and the UI processor 1090, for example, may determine and monitor the operating state of the generator 1002. For the DSP processor 1074, the operating state of the generator 1002 may dictate, for example, which control and/or diagnostic processes are implemented by the DSP processor 1074. For the UI processor 1090, the operating state of the generator 1002 may dictate, for example, which elements of a user interface (*e.g.*, display screens, sounds) are presented to a user. The respective DSP and UI processors 1074, 1090 may independently maintain the current operating state of the generator 1002 and recognize and evaluate possible transitions out of the current operating state. The DSP processor 1074 may function as the master in this relationship and determine when transitions between operating states are to occur. The UI processor 1090 may be aware of valid transitions between operating states and may confirm if a particular transition is appropriate. For example, when the DSP processor 1074 instructs the UI processor 1090 to transition to a specific state, the UI processor 1090 may verify that requested transition is valid. In the event that a requested transition between states is determined to be invalid by the UI processor 1090, the UI processor 1090 may cause the generator 1002 to enter a failure mode.

[0052] The non-isolated stage 1054 may further comprise a controller 1096 for monitoring input devices 1045 (*e.g.*, a capacitive touch sensor used for turning the generator 1002 on and off, a capacitive touch screen). In certain forms, the controller 1096 may comprise at least one processor and/or other controller device in communication with the UI processor 1090. In one form, for example, the controller 1096 may comprise a processor (*e.g.*, a Mega168 8-bit controller available from Atmel) configured to monitor user input provided via one or more capacitive touch sensors. In one form, the controller 1096 may comprise a touch screen controller (*e.g.*, a QT5480 touch screen controller available from Atmel) to control and manage the acquisition of touch data from a capacitive touch screen.

[0053] In certain forms, when the generator 1002 is in a "power off" state, the controller 1096 may continue to receive operating power (*e.g.*, via a line from a power supply of the generator 1002, such as the power supply 2011 discussed below). In this way, the controller 196 may continue to monitor an input device 1045 (*e.g.*, a capacitive touch sensor located on a front panel of the generator 1002) for turning the generator 1002 on and off. When the generator 1002 is in the power off state, the controller 1096 may wake the power supply (*e.g.*, enable operation of one or more DC/DC voltage converters 2013 of the power supply 2011) if activation of the "on/off"

input device 1045 by a user is detected. The controller 1096 may therefore initiate a sequence for transitioning the generator 1002 to a "power on" state. Conversely, the controller 1096 may initiate a sequence for transitioning the generator 1002 to the power off state if activation of the "on/off" input device 1045 is detected when the generator 1002 is in the power on state. In certain forms, for example, the controller 1096 may report activation of the "on/off" input device 1045 to the processor 1090, which in turn implements the necessary process sequence for transitioning the generator 1002 to the power off state. In such forms, the controller 196 may have no independent ability for causing the removal of power from the generator 1002 after its power on state has been established.

[0054] In certain forms, the controller 1096 may cause the generator 1002 to provide audible or other sensory feedback for alerting the user that a power on or power off sequence has been initiated. Such an alert may be provided at the beginning of a power on or power off sequence and prior to the commencement of other processes associated with the sequence.

[0055] In certain forms, the isolated stage 1052 may comprise an instrument interface circuit 1098 to, for example, provide a communication interface between a control circuit of a surgical device (*e.g.*, a control circuit comprising hand piece switches) and components of the non-isolated stage 1054, such as, for example, the programmable logic device 1066, the DSP processor 1074 and/or the UI processor 190. The instrument interface circuit 1098 may exchange information with components of the non-isolated stage 1054 via a communication link that maintains a suitable degree of electrical isolation between the stages 1052, 1054, such as, for example, an infrared (IR)-based communication link. Power may be supplied to the instrument interface circuit 1098 using, for example, a low-dropout voltage regulator powered by an isolation transformer driven from the non-isolated stage 1054.

[0056] In one form, the instrument interface circuit 198 may comprise a logic device 2000 (*e.g.*, logic circuit, programmable logic circuit, PGA, FPGA, PLD) in communication with a signal conditioning circuit 2002. The signal conditioning circuit 2002 may be configured to receive a periodic signal from the logic circuit 2000 (*e.g.*, a 2 kHz square wave) to generate a bipolar interrogation signal having an identical frequency. The interrogation signal may be generated, for example, using a bipolar current source fed by a differential amplifier. The interrogation signal may be communicated to a surgical device control circuit (*e.g.*, by using a conductive pair in a cable that connects the generator 102 to the surgical device) and monitored

to determine a state or configuration of the control circuit. The control circuit may comprise a number of switches, resistors and/or diodes to modify one or more characteristics (*e.g.*, amplitude, rectification) of the interrogation signal such that a state or configuration of the control circuit is uniquely discernable based on the one or more characteristics. In one form, for example, the signal conditioning circuit 2002 may comprises an ADC for generating samples of a voltage signal appearing across inputs of the control circuit resulting from passage of interrogation signal therethrough. The logic device 2000 (or a component of the non-isolated stage 1054) may then determine the state or configuration of the control circuit based on the ADC samples.

[0057] In one form, the instrument interface circuit 1098 may comprise a first data circuit interface 2004 to enable information exchange between the logic circuit 2000 (or other element of the instrument interface circuit 1098) and a first data circuit disposed in or otherwise associated with a surgical device. In certain forms, for example, a first data circuit 2006 (FIG. 2) may be disposed in a cable integrally attached to a surgical device hand piece, or in an adaptor for interfacing a specific surgical device type or model with the generator 1002. The data circuit 2006 may be implemented in any suitable manner and may communicate with the generator according to any suitable protocol including, for example, as described herein with respect to the circuit 6006. In certain forms, the first data circuit may comprise a non-volatile storage device, such as an electrically erasable programmable read-only memory (EEPROM) device. In certain forms and referring again to FIG. 5, the first data circuit interface 2004 may be implemented separately from the logic device 2000 and comprise suitable circuitry (*e.g.*, discrete logic devices, a processor) to enable communication between the programmable logic device 2000 and the first data circuit. In other forms, the first data circuit interface 2004 may be integral with the logic device 2000.

[0058] In certain forms, the first data circuit 2006 may store information pertaining to the particular surgical device with which it is associated. Such information may include, for example, a model number, a serial number, a number of operations in which the surgical device has been used, and/or any other type of information. This information may be read by the instrument interface circuit 1098 (*e.g.*, by the logic device 2000), transferred to a component of the non-isolated stage 1054 (*e.g.*, to logic device 1066, DSP processor 1074 and/or UI processor 1090) for presentation to a user via an output device 1047 and/or for controlling a function or

operation of the generator 1002. Additionally, any type of information may be communicated to first data circuit 2006 for storage therein via the first data circuit interface 2004 (*e.g.*, using the logic device 2000). Such information may comprise, for example, an updated number of operations in which the surgical device has been used and/or dates and/or times of its usage.

[0059] As discussed previously, a surgical instrument may be detachable from a hand piece (*e.g.*, instrument 1024 may be detachable from hand piece) to promote instrument interchangeability and/or disposability. In such cases, conventional generators may be limited in their ability to recognize particular instrument configurations being used and to optimize control and diagnostic processes accordingly. The addition of readable data circuits to surgical device instruments to address this issue is problematic from a compatibility standpoint, however. For example, designing a surgical device to remain backwardly compatible with generators that lack the requisite data reading functionality may be impractical due to, for example, differing signal schemes, design complexity, and cost. Forms of instruments discussed herein address these concerns by using data circuits that may be implemented in existing surgical instruments economically and with minimal design changes to preserve compatibility of the surgical devices with current generator platforms.

[0060] Additionally, forms of the generator 1002 may enable communication with instrument-based data circuits. For example, the generator 1002 may be configured to communicate with a second data circuit 2007 contained in an instrument (*e.g.*, instrument 1024) of a surgical device (FIG. 2). In some forms, the second data circuit 2007 may be implemented in a many similar to that of the data circuit 6006 described herein. The instrument interface circuit 1098 may comprise a second data circuit interface 2010 to enable this communication. In one form, the second data circuit interface 2010 may comprise a tri-state digital interface, although other interfaces may also be used. In certain forms, the second data circuit may generally be any circuit for transmitting and/or receiving data. In one form, for example, the second data circuit may store information pertaining to the particular surgical instrument with which it is associated. Such information may include, for example, a model number, a serial number, a number of operations in which the surgical instrument has been used, and/or any other type of information. In some forms, the second data circuit 2007 may store information about the electrical and/or ultrasonic properties of an associated transducer 1014, end effector 1026, or ultrasonic drive system. For example, the first data circuit 2006 may indicate a burn-in frequency slope, as

described herein. Additionally or alternatively, any type of information may be communicated to second data circuit for storage therein via the second data circuit interface 2010 (*e.g.*, using the logic device 2000). Such information may comprise, for example, an updated number of operations in which the instrument has been used and/or dates and/or times of its usage. In certain forms, the second data circuit may transmit data acquired by one or more sensors (*e.g.*, an instrument-based temperature sensor). In certain forms, the second data circuit may receive data from the generator 1002 and provide an indication to a user (*e.g.*, an LED indication or other visible indication) based on the received data.

[0061] In certain forms, the second data circuit and the second data circuit interface 2010 may be configured such that communication between the logic device 2000 and the second data circuit can be effected without the need to provide additional conductors for this purpose (*e.g.*, dedicated conductors of a cable connecting a hand piece to the generator 1002). In one form, for example, information may be communicated to and from the second data circuit using a 1-wire bus communication scheme implemented on existing cabling, such as one of the conductors used transmit interrogation signals from the signal conditioning circuit 2002 to a control circuit in a hand piece. In this way, design changes or modifications to the surgical device that might otherwise be necessary are minimized or reduced. Moreover, because different types of communications implemented over a common physical channel can be frequency-band separated, the presence of a second data circuit may be "invisible" to generators that do not have the requisite data reading functionality, thus enabling backward compatibility of the surgical device instrument.

[0062] In certain forms, the isolated stage 1052 may comprise at least one blocking capacitor 2096-1 connected to the drive signal output 1060b to prevent passage of DC current to a patient. A single blocking capacitor may be required to comply with medical regulations or standards, for example. While failure in single-capacitor designs is relatively uncommon, such failure may nonetheless have negative consequences. In one form, a second blocking capacitor 2096-2 may be provided in series with the blocking capacitor 2096-1, with current leakage from a point between the blocking capacitors 2096-1, 2096-2 being monitored by, for example, an ADC 2098 for sampling a voltage induced by leakage current. The samples may be received by the logic circuit 2000, for example. Based changes in the leakage current (as indicated by the voltage samples in the form of FIG. 5), the generator 1002 may determine when at least one of the

blocking capacitors 2096-1, 2096-2 has failed. Accordingly, the form of FIG. 5 provides a benefit over single-capacitor designs having a single point of failure.

[0063] In certain forms, the non-isolated stage 1054 may comprise a power supply 2011 for outputting DC power at a suitable voltage and current. The power supply may comprise, for example, a 400 W power supply for outputting a 48 VDC system voltage. The power supply 2011 may further comprise one or more DC/DC voltage converters 2013 for receiving the output of the power supply to generate DC outputs at the voltages and currents required by the various components of the generator 1002. As discussed above in connection with the controller 1096, one or more of the DC/DC voltage converters 2013 may receive an input from the controller 1096 when activation of the "on/off" input device 1045 by a user is detected by the controller 1096 to enable operation of, or wake, the DC/DC voltage converters 2013.

[0064] Having described operational details of various forms of the surgical system 10 (FIG. 1) operations for the above surgical system 10 may be further described generally in terms of a process for cutting and coagulating tissue employing a surgical instrument comprising an input device 1045 and the generator 1002. Although a particular process is described in connection with the operational details, it can be appreciated that the process merely provides an example of how the general functionality described herein can be implemented by the surgical system 10. Further, the given process does not necessarily have to be executed in the order presented herein unless otherwise indicated. As previously discussed, the input devices 1045 may be employed to program the output (*e.g.*, impedance, current, voltage, frequency) of the surgical devices 1002, 1006 (FIG. 1).

[0065] FIG. 6 illustrates one form of a drive system 32 of the generator 1002, which creates an ultrasonic electrical signal for driving an ultrasonic transducer, also referred to as a drive signal. The drive system 32 is flexible and can create an ultrasonic electrical drive signal 416 at a desired frequency and power level setting for driving the ultrasonic transducer 50. In various forms, the generator 1002 may comprise several separate functional elements, such as modules and/or blocks. Although certain modules and/or blocks may be described by way of example, it can be appreciated that a greater or lesser number of modules and/or blocks may be used and still fall within the scope of the forms. Further, although various forms may be described in terms of modules and/or blocks to facilitate description, such modules and/or blocks may be implemented by one or more hardware components, *e.g.*, processors, Digital Signal Processors (DSPs),

Programmable Logic Devices (PLDs), Application Specific Integrated Circuits (ASICs), circuits, registers and/or software components, *e.g.*, programs, subroutines, logic and/or combinations of hardware and software components.

[0066] In one form, the generator 1002 drive system 32 may comprise one or more embedded applications implemented as firmware, software, hardware, or any combination thereof. The generator 1002 drive system 32 may comprise various executable modules such as software, programs, data, drivers, application program interfaces (APIs), and so forth. The firmware may be stored in nonvolatile memory (NVM), such as in bit-masked read-only memory (ROM) or flash memory. In various implementations, storing the firmware in ROM may preserve flash memory. The NVM may comprise other types of memory including, for example, programmable ROM (PROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), or battery backed random-access memory (RAM) such as dynamic RAM (DRAM), Double-Data-Rate DRAM (DDRAM), and/or synchronous DRAM (SDRAM).

[0067] In one form, the generator 1002 drive system 32 comprises a hardware component implemented as a processor 400 for executing program instructions for monitoring various measurable characteristics of the ultrasonic surgical instrument 1004 (FIG. 1) and generating a step function output signal for driving the ultrasonic transducer in cutting and/or coagulation operating modes. It will be appreciated by those skilled in the art that the generator 1002 and the drive system 32 may comprise additional or fewer components and only a simplified version of the generator 1002 and the drive system 32 are described herein for conciseness and clarity. In various forms, as previously discussed, the hardware component may be implemented as a DSP, PLD, ASIC, circuits, and/or registers. In one form, the processor 400 may be configured to store and execute computer software program instructions to generate the step function output signals for driving various components of the ultrasonic surgical instrument 1004, such as a transducer, an end effector, and/or a blade.

[0068] In one form, under control of one or more software program routines, the processor 400 executes the methods in accordance with the described forms to generate a step function formed by a stepwise waveform of drive signals comprising current (I), voltage (V), and/or frequency (f) for various time intervals or periods (T). The stepwise waveforms of the drive signals may be generated by forming a piecewise linear combination of constant functions over a plurality of

time intervals created by stepping the generator 30 drive signals, *e.g.*, output drive current (I), voltage (V), and/or frequency (f). The time intervals or periods (T) may be predetermined (*e.g.*, fixed and/or programmed by the user) or may be variable. Variable time intervals may be defined by setting the drive signal to a first value and maintaining the drive signal at that value until a change is detected in a monitored characteristic. Examples of monitored characteristics may comprise, for example, transducer impedance, tissue impedance, tissue heating, tissue transection, tissue coagulation, and the like. The ultrasonic drive signals generated by the generator 30 include, without limitation, ultrasonic drive signals capable of exciting the ultrasonic transducer 50 in various vibratory modes such as, for example, the primary longitudinal mode and harmonics thereof as well flexural and torsional vibratory modes.

[0069] In one form, the executable modules comprise one or more step function algorithm(s) 402 stored in memory that when executed causes the processor 400 to generate a step function formed by a stepwise waveform of drive signals comprising current (I), voltage (V), and/or frequency (f) for various time intervals or periods (T). The stepwise waveforms of the drive signals may be generated by forming a piecewise linear combination of constant functions over two or more time intervals created by stepping the generator's 1002 output drive current (I), voltage (V), and/or frequency (f). The drive signals may be generated either for predetermined fixed time intervals or periods (T) of time or variable time intervals or periods of time in accordance with the one or more stepped output algorithm(s) 402. Under control of the processor 400, the generator 1002 steps (*e.g.*, increment or decrement) the current (I), voltage (V), and/or frequency (f) up or down at a particular resolution for a predetermined period (T) or until a predetermined condition is detected, such as a change in a monitored characteristic (*e.g.*, transducer impedance, tissue impedance). The steps can change in programmed increments or decrements. If other steps are desired, the generator 1002 can increase or decrease the step adaptively based on measured system characteristics.

[0070] In operation, the user can program the operation of the generator 1002 using the input device 406 located on the front panel of the generator 1002 console. The input device 406 may comprise any suitable device that generates signals 408 that can be applied to the processor 400 to control the operation of the generator 1002. In various forms, the input device 406 includes buttons, switches, thumbwheels, keyboard, keypad, touch screen monitor, pointing device, remote connection to a general purpose or dedicated computer. In other forms, the input device

406 may comprise a suitable user interface. Accordingly, by way of the input device 406, the user can set or program the current (I), voltage (V), frequency (f), and/or period (T) for programming the step function output of the generator 30. The processor 400 then displays the selected power level by sending a signal on line 410 to an output indicator 412.

[0071] In various forms, the output indicator 412 may provide visual, audible, and/or tactile feedback to the surgeon to indicate the status of a surgical procedure, such as, for example, when tissue cutting and coagulating is complete based on a measured characteristic of the ultrasonic surgical instrument 1004, *e.g.*, transducer impedance, tissue impedance, or other measurements as subsequently described. By way of example, and not limitation, visual feedback comprises any type of visual indication device including incandescent lamps or light emitting diodes (LEDs), graphical user interface, display, analog indicator, digital indicator, bar graph display, digital alphanumeric display. By way of example, and not limitation, audible feedback comprises any type of buzzer, computer generated tone, computerized speech, voice user interface (VUI) to interact with computers through a voice/speech platform. By way of example, and not limitation, tactile feedback comprises any type of vibratory feedback provided through an instrument housing handle assembly.

[0072] In one form, the processor 400 may be configured or programmed to generate a digital current signal 414 and a digital frequency signal 418. These signals 414, 418 are applied to a direct digital synthesizer (DDS) circuit 420 to adjust the amplitude and the frequency (f) of the current output signal 416 to the transducer. The output of the DDS circuit 420 is applied to an amplifier 422 whose output is applied to a transformer 424. The output of the transformer 424 is the signal 416 applied to the ultrasonic transducer, which is coupled to a blade by way of a waveguide.

[0073] In one form, the generator 1002 comprises one or more measurement modules or components that may be configured to monitor measurable characteristics of the ultrasonic instrument 1004 (FIG. 1). In the illustrated form, the processor 400 may be employed to monitor and calculate system characteristics. As shown, the processor 400 measures the impedance Z of the transducer by monitoring the current supplied to the transducer 50 and the voltage applied to the transducer. In one form, a current sense circuit 426 is employed to sense the current flowing through the transducer and a voltage sense circuit 428 is employed to sense the output voltage applied to the transducer. These signals may be applied to the analog-to-digital converter 432

(ADC) via an analog multiplexer 430 circuit or switching circuit arrangement. The analog multiplexer 430 routes the appropriate analog signal to the ADC 432 for conversion. In other forms, multiple ADCs 432 may be employed for each measured characteristic instead of the multiplexer 430 circuit. The processor 400 receives the digital output 433 of the ADC 432 and calculates the transducer impedance Z based on the measured values of current and voltage. The processor 400 adjusts the output drive signal 416 such that it can generate a desired power versus load curve. In accordance with programmed step function algorithms 402, the processor 400 can step the drive signal 416, *e.g.*, the current or frequency, in any suitable increment or decrement in response to the transducer impedance Z.

[0074] Having described operational details of various forms of the surgical system 10, operations for the above surgical system 10 may be further described in terms of a process for cutting and coagulating a blood vessel employing a surgical instrument comprising the input device 1045 and the transducer impedance measurement capabilities described with reference to FIG. 6. Although a particular process is described in connection with the operational details, it can be appreciated that the process merely provides an example of how the general functionality described herein can be implemented by the surgical system 10. Further, the given process does not necessarily have to be executed in the order presented herein unless otherwise indicated.

[0075] In various forms, feedback is provided by the output indicator 412 shown in FIGS. 6 and 7. The output indicator 412 is particularly useful in applications where the tissue being manipulated by the end effector is out of the user's field of view and the user cannot see when a change of state occurs in the tissue. The output indicator 412 communicates to the user that a change in tissue state has occurred. As previously discussed, the output indicator 412 may be configured to provide various types of feedback to the user including, without limitation, visual, audible, and/or tactile feedback to indicate to the user (*e.g.*, surgeon, clinician) that the tissue has undergone a change of state or condition of the tissue. By way of example, and not limitation, as previously discussed, visual feedback comprises any type of visual indication device including incandescent lamps or LEDs, graphical user interface, display, analog indicator, digital indicator, bar graph display, digital alphanumeric display. By way of example, and not limitation, audible feedback comprises any type of buzzer, computer generated tone, computerized speech, VUI to interact with computers through a voice/speech platform. By way of example, and not limitation, tactile feedback comprises any type of vibratory feedback provided through the

instrument housing handle assembly. The change of state of the tissue may be determined based on transducer and tissue impedance measurements as previously described, or based on voltage, current, and frequency measurements.

[0076] In one form, the various executable modules (*e.g.*, algorithms) comprising computer readable instructions can be executed by the processor 400 (FIGS. 6, 7) portion of the generator 1002. In various forms, the operations described with respect to the algorithms may be implemented as one or more software components, *e.g.*, programs, subroutines, logic; one or more hardware components, *e.g.*, processors, DSPs, PLDs, ASICs, circuits, registers; and/or combinations of software and hardware. In one form, the executable instructions to perform the algorithms may be stored in memory. When executed, the instructions cause the processor 400 to determine a change in tissue state provide feedback to the user by way of the output indicator 412. In accordance with such executable instructions, the processor 400 monitors and evaluates the voltage, current, and/or frequency signal samples available from the generator 1002 and according to the evaluation of such signal samples determines whether a change in tissue state has occurred. As further described below, a change in tissue state may be determined based on the type of ultrasonic instrument and the power level that the instrument is energized at. In response to the feedback, the operational mode of the ultrasonic surgical instrument 1004 may be controlled by the user or may be automatically or semi-automatically controlled.

[0077] The surgical instruments described herein can also include features to allow a user, such as a clinician, to select from a plurality of surgical modes based on the type of surgical procedure being performed and the type of tissue being treated by an end effector of a surgical instrument. Each surgical mode corresponds to an algorithm for controlling the power output from a generator, such as generator 1002, that is delivered to the end effector of the surgical instrument. As illustrated in FIG. 8, a surgical instrument 20 can include a selector switch 22 that allows a clinician to select between various surgical modes.

[0078] Various algorithms can be used to allow for the selection of a plurality of surgical modes. In one form, a surgical mode can be based on the tissue being treated by the end effector. The surgical mode can also vary by the type of energy being delivered by the generator. It is possible for the generator to deliver energy that is adaptive based on changes to the tissue as the tissue is being treated by the end effector. In one form, the generator can monitor the temperature of the tissue and adjust the frequency of the output to regulate the temperature

change in the tissue. In one form, the surgical instrument can include a switch for disabling the adaptive energy such that the user can control the delivery of adaptive energy from the generator regardless of the selected surgical mode. For example, one surgical mode can be selected for cutting avascular tissue and can include a high power output from the generator that is optimized for transection speed. Another surgical mode can be selected for coagulating tissue or vessels and can include low power output from the generator that is optimized for hemostasis of vessels. Another surgical mode can be selected for the treatment of solid organs and can include a lower power level output without adaptive energy from the generator that is optimized for the hemostasis of solid organs.

[0079] Although FIG. 8 illustrates a selector switch to control the selection of a surgical mode, various other techniques can be employed to allow a user to select a surgical mode. In one form, software on the surgical instrument can be used. For example, the surgical instruments can include a display such that the plurality of available surgical modes can be selected using the display. Similarly, in another form, the generator, such as generator 1002, can include software and a display such that the plurality of available surgical modes can be selected using the display on the generator. In another form, software can be included, either in the generator or the surgical instrument, to allow voice activation of a surgical mode. In another form, an external communication device can be used to communicate with either the generator or the surgical instrument to allow for the selection of a surgical mode. For example, any type of personal communication device can communicate with either the generator or the surgical instrument using a variety of techniques, including but not limited to short range radio, WiFi, or bluetooth technologies. The personal communication device can include software having the plurality of surgical modes such that a user can select one or more desired surgical modes using the personal communication device.

[0080] FIG. 9 illustrates a logic flow diagram 30 of one form of selecting a surgical mode corresponding to a tissue algorithm that may be implemented in one form of a generator. With reference now to the logic flow diagram 30 shown in FIG. 9 and the surgical system 10 of FIG. 1, a user selects 32 a surgical mode that corresponding to an algorithm for controlling the generator 1002 using a selector switch, such as the selector switch 22 of FIG. 8. The selected algorithm is used to control 34 the power output from the generator 1002. The power output from the generator 1002 is delivered 36 to the end effector of the surgical instrument such that

the end effector can be used to treat tissue positioned within the end effector. A user determines 38 if an additional surgical mode is required to continue the surgical procedure being performed. If an additional surgical mode is not needed, the generator 1002 can be deactivated 40. If an additional surgical mode is required to continue the procedure, the user can select 42 another of the plurality of surgical modes to continue and complete the procedure. Any number of surgical modes can be selected in succession until the surgical procedure is completed.

[0081] Different clinicians often have different techniques for using ultrasonic surgical instruments and systems as described herein. In some forms, algorithms that can be customized and modified by a clinician can be employed. There are various aspects of the surgical mode algorithms that can be customized by a user. In one form, the power output from the generator and/or the timing of any drop in power can be selected. In one form, feedback from any component of the surgical system 10 can be selected, including the functionality of any monitors of audio feedback, such that the user can customize the feedback received during a surgical procedure.

[0082] The user also can communicate with the surgical system in a variety of ways to allow the use of the customized surgical modes. In one form, the generator can include a receptacle for receiving an input device having customized surgical modes thereon. For example, the input device can be in the form of an RFID swipe key, a USB device, or some form of digital passcode. The input device can also be in the form of a personal communication device that allows the user to create and modify customized surgical modes thereon and communicate, either wired and wirelessly with the generator. The input device can communicate the customized surgical modes to the generator such that, when a surgical mode is selected for use in a surgical procedure, the generator will deliver an output that corresponds to the setting customized for that particular user.

[0083] FIG. 10 illustrates a logic flow diagram 50 of one form of customizing a surgical mode corresponding to a tissue algorithm that may be implemented in one form of a generator. With reference now to the logic flow diagram 50 shown in FIG. 10 and the surgical system 10 of FIG. 1, a user selects 52 a surgical mode for customization that corresponding to an algorithm for controlling the generator 1002. The selected algorithm is customized by selecting 54 a desired power output from the generator 1002. For example, a user can select 54 a minimum and/or maximum power output to be delivered by the generator during the use of that surgical mode.

The selected algorithm is customized by selecting 56 a power drop and timing of the power drop for the power output from the generator during the use of that surgical mode. The customized algorithm is communicated 58 to the generator 1002 using any of the techniques described herein. It will be appreciate that any aspect of the power output from the generator 1002 can be customized and modified by a user to create a custom algorithm for use during a surgical procedure.

[0084] It can also be advantageous to employ techniques to lengthen the life of the energy pads on the end effectors. For example, the pad life can be improved by waiting for closure of the end effector around the tissue as both energy delivered to the pads without tissue compressed therebetween and friction can decreased the life and number of uses of the end effector pads. In various forms, this and other problems may be addressed by configuring a surgical instrument with a closure switch indicating when the end effector is fully closed with tissue therebetween. The generator may be configured to refrain from activating the surgical instrument until or unless the closure switch indicates that the clamp arm is fully closed. The closure switch can have various forms, including being positioned in a handle of a surgical device. The closure switch may be in electrical communication with the generator, such as generator 1002, for example. In one form, the generator is programmed not to activate the surgical instrument unless the switch indicates that the end effector is closed. For example, if the generator receives an activation request from one or more of the switches described herein, it may respond to the activation request only if the closure switch is activated to indicate that the end effector is closed. This allows the position of the end effector and the state of the closure switch to be used as an input to an algorithm for controlling the power output of the generator.

[0085] In another form, the generator is programmed not to activate any type of adaptive energy unless the switch indicates that the end effector is closed. For example, if the generator receives an activation request from one or more of the switches described herein, it may respond to the activation request with adaptive energy only if the closure switch is activated to indicate that the end effector is closed. If the closure switch is not activated, indicating that the end effector is open, the generator can respond by delivering non-adaptive energy that can be used in certain surgical situations, such as back cutting or transecting a solid organ. If the closure switch is activated, indicating that the end effector is closed, the generator can respond by delivering adaptive energy that will be activated for the full activation cycle of the selected surgical mode,

and can be used to most surgical situations such as any normal use of the end effector on tissue or vessels.

[0086] As illustrated in FIG. 2, the surgical instrument can include a trigger that is used to move the end effector 1026. In one form, the trigger moves the end effector between a first position in which the end effector is opened and a second position in which the end effector is closed on a tissue for treatment. When the end effector is closed, the generator can deliver adaptive energy to the end effector to treat the tissue.

[0087] FIG. 11 illustrates a logic flow diagram 60 for selecting a surgical mode corresponding to a tissue algorithm using the position of an end effector of a surgical instrument as an algorithm input. With reference now to the logic flow diagram 60 shown in FIG. 11 and the surgical system 10 of FIG. 1, a user selects 62 a surgical mode corresponding to an algorithm for controlling the generator 1002. The selected algorithm is used to control 64 the power output from the generator. Before the power is delivered to the end effector, the positon of the closure switch on the surgical instrument is checked 66. For example, the positon of the trigger used to control the end effector is used an input to the algorithm. When the closure switch, or trigger, is in a first position such that switch and the end effector are open, the adaptive energy mode of the generator is disabled such that the adaptive energy cannot be delivered 68 to the end effector. When the closure switch, or trigger, is in a second position such that switch and the end effector are closed on the tissue to be treated, the adaptive energy mode of the generator is enabled such that the adaptive energy can be delivered 70 to the end effector.

[0088] In one form, it is possible to measure the position of the end effector to more precisely control the power output from the generator based on the position of the end effector relative to the tissue. In addition to the end effector being opened or closed around tissue, the end effector can also be partially closed around tissue. The angle of the partial closure of the end effector can be used to modify the power output from the generator rather that just activate or deactivate the adaptive energy delivered therefrom. FIG. 12 illustrates another form of a logic flow diagram 80 for selecting a surgical mode corresponding to a tissue algorithm using the position of an end effector of a surgical instrument as an algorithm input. With reference now to the logic flow diagram 80 shown in FIG. 12 and the surgical system 10 of FIG. 1, a user selects 82 a surgical mode corresponding to an algorithm for controlling the generator 1002. The selected algorithm is used to control 84 the power output from the generator. Before the power is delivered to the

end effector, the positon of the closure switch on the surgical instrument is checked 86. For example, the positon of the trigger used to control the end effector is used an input to the algorithm. When the closure switch, or trigger, is in a first position such that switch and the end effector are open, the adaptive energy mode of the generator is disabled such that the adaptive energy cannot be delivered 88 to the end effector. When the closure switch, or trigger, is in a second position such that switch and the end effector are closed on the tissue to be treated, the adaptive energy mode of the generator is enabled such that the adaptive energy can be delivered 92 to the end effector. Measurement of the angle of closure of the end effector is used to adjust 90 the energy delivered from the generator 1002. In one form, the frequency slope of the energy can be varied depending on the angle of closure of the end effector. As the pressure on the tissue by the end effector increases and the angle of closure decreases, the power can be altered depending on the desired effect on tissue for the selected surgical mode. For example, the energy can be decreased to maintain constant cutting of the tissue as the angle of closure decreases.

[0089] The pad life of the end effectors can also be improved by taking in account the number of activation of the end effectors when the end effectors are closed on tissue. Thus, the adaptive energy delivered from the generator can be varied as a function of the number of closed activations of the end effectors. In one form, the adaptive energy can be delivered closer to the start of an activation cycle for a selected surgical mode as the number of closed activations of the end effectors increases. For example, a counter can be employed that tracks the number of closed activations of the end effectors and can be used as an input to the algorithm for controlling the energy delivered to the end effectors from the generator. Thus, the delivered adaptive energy can be varied based on the number of activations of the energy pads on the end effectors.

[0090] FIG. 13 illustrates another form of a logic flow diagram 100 for selecting a surgical mode corresponding to a tissue algorithm using the position of an end effector of a surgical instrument as an algorithm input. With reference now to the logic flow diagram 100 shown in FIG. 13 and the surgical system 10 of FIG. 1, a user selects 102 a surgical mode corresponding to an algorithm for controlling the generator 1002. The selected algorithm is used to control 104 the power output from the generator. Before the power is delivered to the end effector, the positon of the closure switch on the surgical instrument is checked 106. For example, the

positon of the trigger used to control the end effector is used an input to the algorithm. When the closure switch, or trigger, is in a first position such that switch and the end effector are open, the adaptive energy mode of the generator is disabled such that the adaptive energy cannot be delivered 108 to the end effector. When the closure switch, or trigger, is in a second position such that switch and the end effector are closed on the tissue to be treated, a counter that measures the number of closed activations of the end effectors is increased 110. It is possible to compare 112 the counter to a threshold, for example, that could inform a user that the energy pads on the end effectors should be replaced as there have been a large number of closed activations. The adaptive energy mode of the generator is enabled such that the adaptive energy can be delivered 114 to the end effector. The adaptive energy delivered will be affected by the counter as the counter will be used as an input for the algorithm that controls the energy delivered by the generator.

[0091] As explained above, there are a plurality of surgical modes that can be utilized for controlling the output from the generator. The following table, Table 1, illustrates exemplary surgical modes and algorithms for controlling the power output from the generator.

Surgical Mode	Generator output	Effect on tissue
Solid organ mode	Adaptive energy is disabled and closure switch detection is disabled	The end effector is hot enough to seal bloody tissue and can be used when the end effector is partially open
Wet field mode	The overall current setpoint increases for higher heat and faster cutting	Tissue sealing in a wet field is increased as the system overdrives to account for the heat sinking fluid
Marching mode	Adaptive energy delivery is delayed and drops current less during the activation cycle, and if it is active for a threshold amount of time then the adaptive energy is re-engaged to a normal level to increase the pad life. The maximum button set point for current increases.	The end effector heats up, the transection time decreases, and the pad life is preserved
Low-heat mode	High and low current is pulsed after an impedance threshold is met	Cutting speed is increased and the heat at the end effector is lowered
Adaptive energy	The time before adaptive energy is	Slow transections are prevented

Surgical Mode	Generator output	Effect on tissue
delay	triggered in an activation cycle is increased	

Table 1

[0092] While various details have been set forth in the foregoing description, it will be appreciated that the various aspects of the serial communication protocol for medical device may be practiced without these specific details. For example, for conciseness and clarity selected aspects have been shown in block diagram form rather than in detail. Some portions of the detailed descriptions provided herein may be presented in terms of instructions that operate on data that is stored in a computer memory. Such descriptions and representations are used by those skilled in the art to describe and convey the substance of their work to others skilled in the art. In general, an algorithm refers to a self-consistent sequence of steps leading to a desired result, where a "step" refers to a manipulation of physical quantities which may, though need not necessarily, take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It is common usage to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like. These and similar terms may be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities.

[0093] Unless specifically stated otherwise as apparent from the foregoing discussion, it is appreciated that, throughout the foregoing description, discussions using terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0094] It is worthy to note that any reference to "one aspect," "an aspect," "one form," or "an form" means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one aspect. Thus, appearances of the phrases "in one aspect," "in an aspect," "in one form," or "in an form" in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner in one or more aspects.

[0095] Some aspects may be described using the expression "coupled" and "connected" along with their derivatives. It should be understood that these terms are not intended as synonyms for each other. For example, some aspects may be described using the term "connected" to indicate that two or more elements are in direct physical or electrical contact with each other. In another example, some aspects may be described using the term "coupled" to indicate that two or more elements are in direct physical or electrical contact. The term "coupled," however, also may mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other.

[0096] It is worthy to note that any reference to "one aspect," "an aspect," "one form," or "an form" means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one aspect. Thus, appearances of the phrases "in one aspect," "in an aspect," "in one form," or "in an form" in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner in one or more aspects.

[0097] Although various forms have been described herein, many modifications, variations, substitutions, changes, and equivalents to those forms may be implemented and will occur to those skilled in the art. Also, where materials are disclosed for certain components, other materials may be used. It is therefore to be understood that the foregoing description and the appended claims are intended to cover all such modifications and variations as falling within the scope of the disclosed forms. The following claims are intended to cover all such modification and variations.

[0098] In a general sense, those skilled in the art will recognize that the various aspects described herein which can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or any combination thereof can be viewed as being composed of various types of "electrical circuitry." Consequently, as used herein "electrical circuitry" includes, but is not limited to, electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out

processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment). Those having skill in the art will recognize that the subject matter described herein may be implemented in an analog or digital fashion or some combination thereof.

[0099] The foregoing detailed description has set forth various forms of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one form, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the forms disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative form of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Video Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link (e.g., transmitter, receiver, transmission logic, reception logic, etc.), etc.).

[0100] All of the above-mentioned U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications, non-patent publications referred to in this specification and/or listed in any Application Data Sheet, or any other disclosure material are incorporated herein by reference, to the extent not inconsistent herewith. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

[0101] One skilled in the art will recognize that the herein described components (e.g., operations), devices, objects, and the discussion accompanying them are used as examples for the sake of conceptual clarity and that various configuration modifications are contemplated. Consequently, as used herein, the specific exemplars set forth and the accompanying discussion are intended to be representative of their more general classes. In general, use of any specific exemplar is intended to be representative of its class, and the non-inclusion of specific components (e.g., operations), devices, and objects should not be taken limiting.

[0102] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations are not expressly set forth herein for sake of clarity.

[0103] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected," or "operably coupled," to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable," to each other to achieve

the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components, and/or wirelessly interactable, and/or wirelessly interacting components, and/or logically interacting, and/or logically interactable components.

[0104] In some instances, one or more components may be referred to herein as "configured to," "configurable to," "operable/operative to," "adapted/adaptable," "able to," "conformable/conformed to," etc. Those skilled in the art will recognize that "configured to" can generally encompass active-state components and/or inactive-state components and/or standby-state components, unless context requires otherwise.

[0105] While particular aspects of the present subject matter described herein have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of the subject matter described herein. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to claims containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations.

[0106] In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that typically a disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms unless context dictates otherwise. For example, the phrase "A or B" will be typically understood to include the possibilities of "A" or "B" or "A and B."

[0028] With respect to the appended claims, those skilled in the art will appreciate that recited operations therein may generally be performed in any order. Also, although various operational flows are presented in a sequence(s), it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently. Examples of such alternate orderings may include overlapping, interleaved, interrupted, reordered, incremental, preparatory, supplemental, simultaneous, reverse, or other variant orderings, unless context dictates otherwise. Furthermore, terms like "responsive to," "related to," or other past-tense adjectives are generally not intended to exclude such variants, unless context dictates otherwise.

[0107] In certain cases, use of a system or method may occur in a territory even if components are located outside the territory. For example, in a distributed computing context, use of a distributed computing system may occur in a territory even though parts of the system may be

located outside of the territory (e.g., relay, server, processor, signal-bearing medium, transmitting computer, receiving computer, etc. located outside the territory).

[0108] A sale of a system or method may likewise occur in a territory even if components of the system or method are located and/or used outside the territory. Further, implementation of at least part of a system for performing a method in one territory does not preclude use of the system in another territory.

[0109] Although various forms have been described herein, many modifications, variations, substitutions, changes, and equivalents to those forms may be implemented and will occur to those skilled in the art. Also, where materials are disclosed for certain components, other materials may be used. It is therefore to be understood that the foregoing description and the appended claims are intended to cover all such modifications and variations as falling within the scope of the disclosed forms. The following claims are intended to cover all such modification and variations.

[0110] In summary, numerous benefits have been described which result from employing the concepts described herein. The foregoing description of the one or more forms has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the precise form disclosed. Modifications or variations are possible in light of the above teachings. The one or more forms were chosen and described in order to illustrate principles and practical application to thereby enable one of ordinary skill in the art to utilize the various forms and with various modifications as are suited to the particular use contemplated. It is intended that the claims submitted herewith define the overall scope.

[0111] Examples

[0112] In one general aspect, a surgical instrument assembly embodying the principles of the described forms is configured to permit selective dissection, cutting, coagulation, and clamping of tissue during surgical procedures. A generator may generate at least one electrical signal, which may be monitored against a first set of logic conditions. When the first set of logic conditions is met, a first response of the generator may be triggered.

[0113] In certain forms, ultrasonic impedance of the surgical instrument is monitored. When the ultrasonic impedance of the surgical instrument exceeds a threshold impedance, a resonant frequency of the at least one electrical signal may be stored as a baseline frequency. Also, the first response of the generator may be triggered when either the first set of logic conditions is

met or the resonant frequency of the at least one electrical signal differs from the baseline frequency by a baseline deviation threshold.

[0114] In certain forms, load events at an end effector of the surgical instrument may be monitored. The first response of the generator may be triggered when the first set of logic conditions is met and a load event is detected.

[0115] In accordance with one general form, there is provided a switch assembly for an ultrasonic surgical instrument that includes a handle housing that is configured to be supported in one hand. In at least one form, the switch assembly comprises a first switch arrangement that is operably supported on a forward portion of the handle housing and is selectively movable relative to at least one first switch contact. The switch assembly further comprises a second switch arrangement that may comprise at least one of a right switch button and a left switch button. The right switch button may be movably supported on a right side of the handle housing and be selectively movable relative to at least one right switch contact supported by the handle housing. The left switch button may be movably supported on a left side of the handle housing and be selectively movable relative to at least one left switch contact supported by the handle housing. The first and second switch arrangements may be configured to be selectively operated by a single hand supporting the handle housing.

[0116] In accordance with at least one other general form, there is provided an ultrasonic surgical instrument. In at least one form, the ultrasonic surgical instrument comprises a generator for generating ultrasonic signals and a handle assembly that includes a handle housing that is configured to be operably supported in one hand. The instrument may further comprise a switch assembly that includes a first switch arrangement that is operably supported on a forward portion of the handle housing and is selectively movable relative to at least one first switch contact that communicates with the generator. The switch assembly may further include a second switch arrangement that comprises at least one of a right switch button and a left switch button. The right switch button may be movably supported on a right side of the handle housing and be selectively movable relative to at least one right switch contact that is supported by the handle housing. The at least one right switch contact may communicate with the generator. The left switch button may be movably supported on a left side of the handle housing and be selectively movable relative to at least one left switch contact that is supported by the handle housing and may operably communicate with the generator. The first and second switch

arrangements may be configured to be selectively operated by a single hand supporting the handle housing.

[0117] In accordance with still another general form, there is provided a switch assembly for an ultrasonic surgical instrument that includes a handle housing that is configured to be supported in one hand. In at least one form, the switch assembly comprises a button assembly that is movably supported by the handle housing for selective axial and pivotal travel relative to a right switch contact, a central switch contact and a left switch contact such that axial movement of the button assembly in a first direction causes the button assembly to actuate the central switch contact and pivotal movement of the button assembly in a first pivotal direction causes the button assembly to actuate the left switch contact and pivotal movement of the button assembly in a second pivotal direction causes the button assembly to actuate the right switch contact.

[0118] According to various forms, the connector module may be a modular component that may be provided as an accessory with the ultrasonic surgical instrument or components thereof but not attached thereto or may be used to repair, replace, or retrofit ultrasonic surgical instruments. In certain forms, however, the connector module may be associated with the handle assembly or the ultrasonic transducer. In one form, the connector module may comprise an assembly that may be easily removed and/or replaced by a user. The connector module may also comprise removable features allowing the user to, for example, remove and/or replace rotation couplings, switch conductors, or links. Accordingly, in certain forms, one or more connector modules may be included in a kit. The kit may comprise various rotation couplings configured for adaptable use with one or more ultrasonic transducers or hand pieces. The kit may include connector modules, rotation couplings, or housings comprising various configurations of user interfaces that may require one, two, or more conductive paths.

[0119] In one aspect, the present disclosure is directed to an ultrasonic surgical instrument. The ultrasonic instrument may comprise an end effector, a waveguide extending proximally from the end effector along a longitudinal axis, and a connector module for receiving an ultrasonic hand piece. The connector module may comprise a housing defining a spindle extending along the longitudinal axis, a coupling positioned on the spindle and rotatable relative to the housing, a first conductor mechanically coupled to the housing and extending at least partially around the longitudinal axis, and a first link rotatable about the longitudinal axis relative to the first conductor between a first position and a second position. The first link may comprise a first

contact positioned to electrically contact the first conductor when the first link is in the first position and the second position and a second contact electrically coupled to the first contact and positioned to electrically contact the ultrasonic hand piece when the first link is in the first position and the second position.

[0120] In one aspect, the first and second conductors each comprise a conductive lead configured to electrically couple to a user interface configured for receiving power control signals from a user. The ultrasonic hand piece may be adapted to electrically couple to a generator and rotationally couple to the first and second links when received by the connector module. The connector module may be configured to electrically couple the user interface circuit and the generator via the ultrasonic hand piece when the first and second links are in respective first and second positions. In one aspect, the user interface comprises a toggle switch operatively coupled to a handle assembly and the connector module is secured to the handle assembly. The ultrasonic hand piece may be rotatable relative to the handle assembly when received by the connector module. In one aspect, the housing electrically isolates the first and second conductors with respect to each other.

[0121] Various aspects of the subject matter described herein are directed to an apparatus, comprising a circuit configured to transmit a signal as a serial protocol over a pair of electrical conductors. The serial protocol may be defined as a series of pulses distributed over at least one transmission frame. At least one pulse in the transmission frame is simultaneously encoded by modulating an amplitude of the pulse to represent one of two first logic states and modulating a width of the pulse to represent one of two second logic states.

[0122] Various aspects of the subject matter described herein are directed to an instrument, comprising a circuit configured to transmit a signal as a serial protocol over a pair of electrical conductors. The serial protocol may be defined as a series of pulses distributed over at least one transmission frame. At least one pulse in the transmission frame may be simultaneously encoded by modulating an amplitude of the pulse to represent one of two first logic states and modulating a width of the pulse to represent one of two second logic states. The instrument may also comprise an output device coupled to an output of the circuit; and an input device coupled to an input of the circuit.

[0123] Various aspects of the subject matter described herein are directed to a generator, comprising a conditioning circuit configured to communicate to an instrument over a two wire

interface. The generator may comprises a control circuit configured to transmit a signal as a serial protocol over a pair of electrical conductors. The serial protocol may be defined as a series of pulses distributed over at least one transmission frame. At least one pulse in the transmission frame is simultaneously encoded by modulating an amplitude of the pulse to represent one of two first logic states and modulating a width of the pulse to represent one of two second logic states. The generator may also comprise an energy circuit configured to drive the instrument.

[0124] Various aspects are directed to methods of driving an end effector coupled to an ultrasonic drive system of an ultrasonic surgical instrument. A trigger signal may be received. In response to the trigger signal, a first drive signal may be provided to the ultrasonic drive system to drive the end effector at a first power level. The first drive signal may be maintained for a first period. At the end of the first period a second drive signal may be provided to the ultrasonic drive system to drive the end effector at a second power level less than the first power level.

[0125] In another aspect, after receiving a trigger signal, a surgical system generates feedback indicating that the ultrasonic surgical instrument is activated while maintaining the ultrasonic instrument in a deactivated state. At an end of the threshold time period, the ultrasonic surgical instrument is activated by providing a drive signal to the ultrasonic drive system to drive the end effector.

[0126] In another aspect, the ultrasonic surgical instrument is activated by generating a drive signal provided to the ultrasonic drive system to drive the end effector. A plurality of input variables may be applied to a multi-variable model to generate a multi-variable model output, where the multi-variable model output corresponds to an effect of the ultrasonic instrument on tissue. The plurality of input variables may comprise at least one variable describing the drive signal and at least one variable describing a property of the ultrasonic surgical instrument. When the multi-variable model output reaches a threshold value, feedback may be generated indicating a corresponding state of at least one of the ultrasonic surgical instrument and tissue acted upon by the ultrasonic surgical instrument.

[0127] In another aspect, in response to a trigger signal, a first drive signal at a first power level is provided to the ultrasonic drive system to drive the end effector. The first drive signal is maintained at the first level for a first period. A second drive signal is provided to the ultrasonic drive system to drive the end effector at a second power level less than the first power level. A

plurality of input variables may be applied to a multi-variable model to generate a multi-variable model output. The multi-variable model output may correspond to an effect of the ultrasonic instrument on tissue, and the plurality of variables may comprise at least one variable describing the drive signal and at least one variable describing a property of the ultrasonic surgical instrument. After the multi-variable model output exceeds a threshold value for a threshold time period, a first response may be triggered.

[0128] While several forms have been illustrated and described, it is not the intention of the applicant to restrict or limit the scope of the appended claims to such detail. Numerous variations, changes, and substitutions will occur to those skilled in the art without departing from the scope of the invention. Moreover, the structure of each element associated with the described forms can be alternatively described as a means for providing the function performed by the element. Accordingly, it is intended that the described forms be limited only by the scope of the appended claims.

[0129] Reference throughout the specification to "various forms," "some forms," "one form," or "an form" means that a particular feature, structure, or characteristic described in connection with the form is included in at least one form. Thus, appearances of the phrases "in various forms," "in some forms," "in one form," or "in an form" in places throughout the specification are not necessarily all referring to the same form. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more forms. Thus, the particular features, structures, or characteristics illustrated or described in connection with one form may be combined, in whole or in part, with the features structures, or characteristics of one or more other forms without limitation.

CLAIMS

We claim:

1. An apparatus for dissection and coagulation of tissue, comprising:

a surgical instrument having an end effector configured to dissect and seal tissue at a distal end thereof, the surgical instrument including a selector switch thereon having a plurality of surgical modes;

a generator electrically coupled to the surgical instrument and configured to deliver energy to the end effector;

wherein each surgical mode of the selector switch corresponds to an algorithm for controlling the power delivered from the generator to the end effector.

2. The apparatus of claim 1, wherein each algorithm corresponding to the plurality of surgical modes is configured to allow a user to control a power output level of the generator.

3. The apparatus of claim 2, wherein a maximum and minimum power output of the generator is controlled by the user.

4. The apparatus of claim 2, wherein each algorithm is configured to allow the user to modify timing of a drop in the power output during each surgical mode.

5. The apparatus of claim 1, wherein the algorithm corresponding to each of the plurality of surgical modes is configured to be modified by a user to allow customization of each of the plurality of surgical modes.

6. The apparatus of claim 1, wherein the surgical instrument includes a closure switch configured to move between a first position in which the end effector is opened to allow tissue to be positioned within the end effector and a second position in which the end effector is closed such that tissue to held by the end effector.

7. The apparatus of claim 6, wherein the generator is configured to deliver power to the end effector when the closure switch is in the second position and the end effector is closed.

8. The apparatus of claim 6, wherein one or more of the algorithms corresponding to the plurality of surgical modes includes a threshold counter for counting the number of activations of the end effector when the closure switch is in the second position such that the power output from the generator activates more quickly.

9. The apparatus of claim 6, wherein an adaptive energy mode of the generator is enabled such that adaptive energy can be delivered from the generator to the end effector when the closure switch is in the second position and the end effector is closed on the tissue.

10. The apparatus of claim 6, wherein an angle of closure of the end effector can be detected when the closure switch is positioned between the first and second positions, the angle of closure of the end effector being used to adjust the energy delivered from the generator to the end effector.

11. The apparatus of claim 10, wherein a frequency slope of the energy delivered from the generator can be varied depending on the angle of closure of the end effector.

12. An apparatus for dissection and coagulation of tissue, comprising:

a surgical instrument having an end effector configured to dissect and seal tissue at a distal end thereof;

a generator electrically coupled to the surgical instrument and configured to deliver energy to the end effector; and

a surgical mode selector input having a plurality of surgical modes for selection by a user such that each surgical mode corresponds to an algorithm for controlling the power output from the generator.

13. The apparatus of claim 12, wherein the surgical mode selector input is in the form of a selector switch on the surgical instrument such that the selector switch can be toggled between

the plurality of surgical modes to control the power output to the end effector.

14. The apparatus of claim 12, wherein the surgical mode selector input is in the form of a receptacle for an input device located on the generator.

15. The apparatus of claim 14, wherein the input device is an radio frequency identification (RFID) swipe key.

16. The apparatus of claim 14, wherein the input device is a universal serial bus (USB).

17. The apparatus of claim 14, wherein the input device includes customized surgical modes for controlling the power output of the generator to the end effector.

18. The apparatus of claim 17, wherein the surgical mode selector input is in the form of an external communication device in communication with the generator.

19. The apparatus of claim 18, wherein the external communication device is configured to wirelessly communicate with the generator.

20. The apparatus for dissection and coagulation of tissue, comprising:

an end effector positioned on a distal end of a surgical instrument that is configured to dissect and seal tissue;

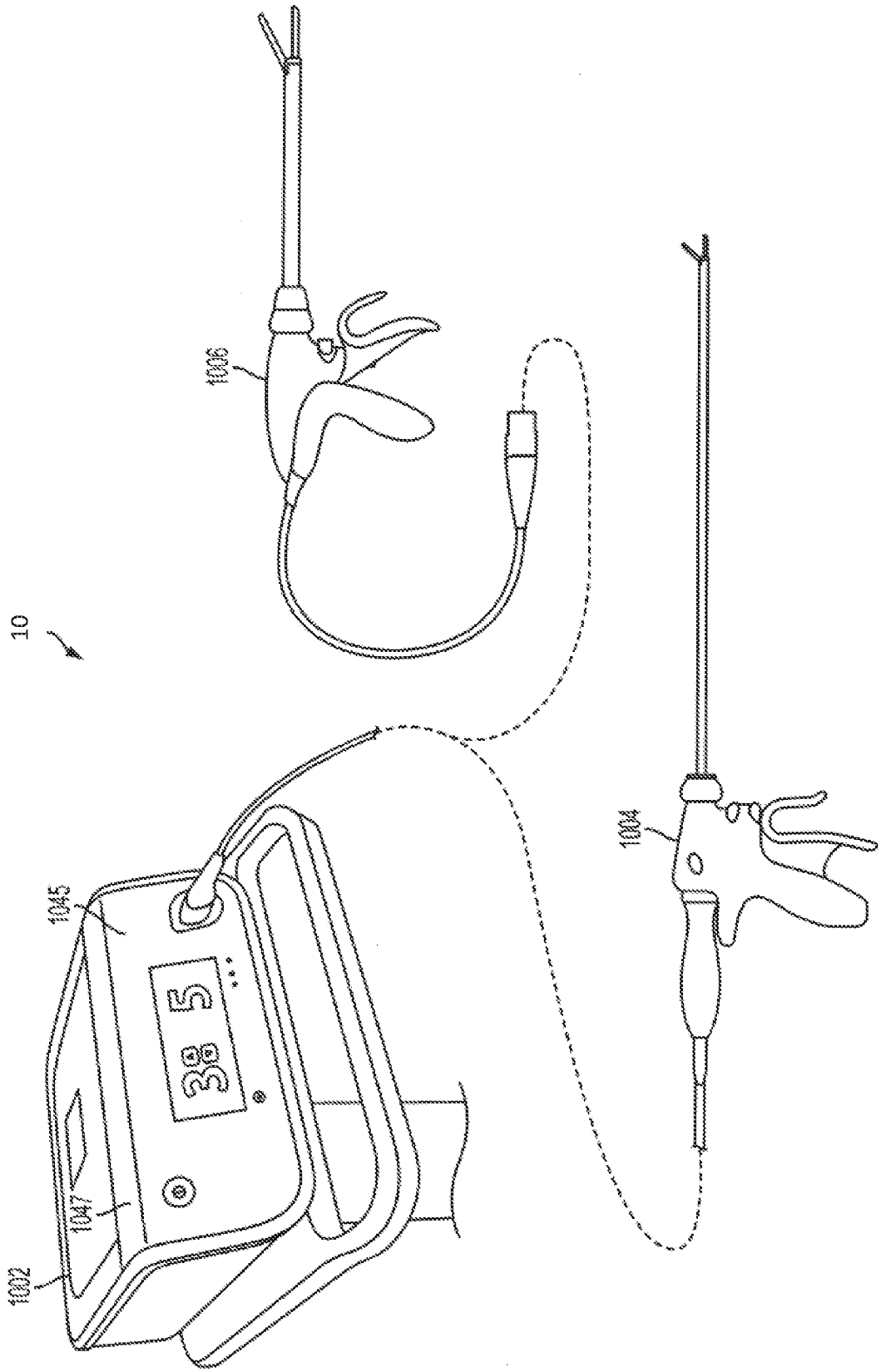
a closure switch on the surgical instrument that is configured to control the end effector such that the end effector is opened when the closure switch is in a first positon and the end effector is closed when the closure switch is in a second position;

a generator electrically coupled to the surgical instrument and configured to deliver energy to the end effector; qnd

a surgical mode selector input having a plurality of surgical modes for selection by a user such that each surgical mode corresponds to an algorithm for controlling the power output from the generator;

wherein the generator is configured to deliver power to the end effector when the end effector is closed around a tissue when the closure switch is in the second position.

FIG. 1



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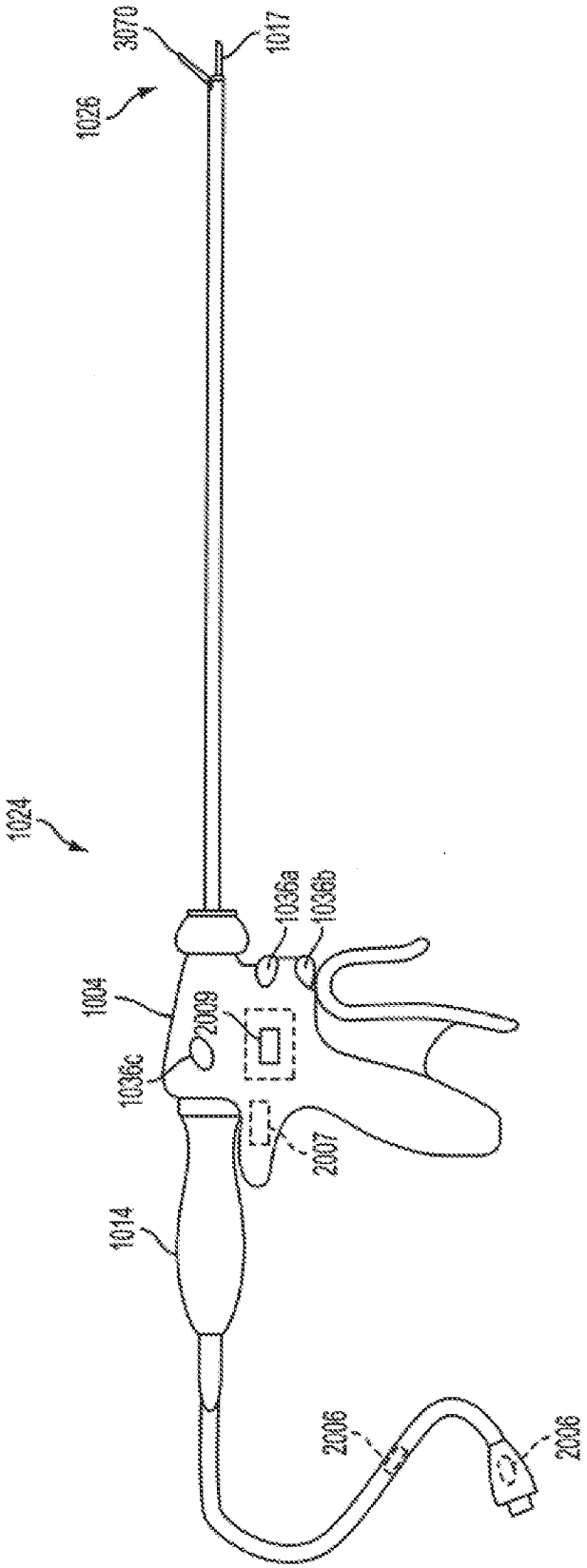
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FIG. 3

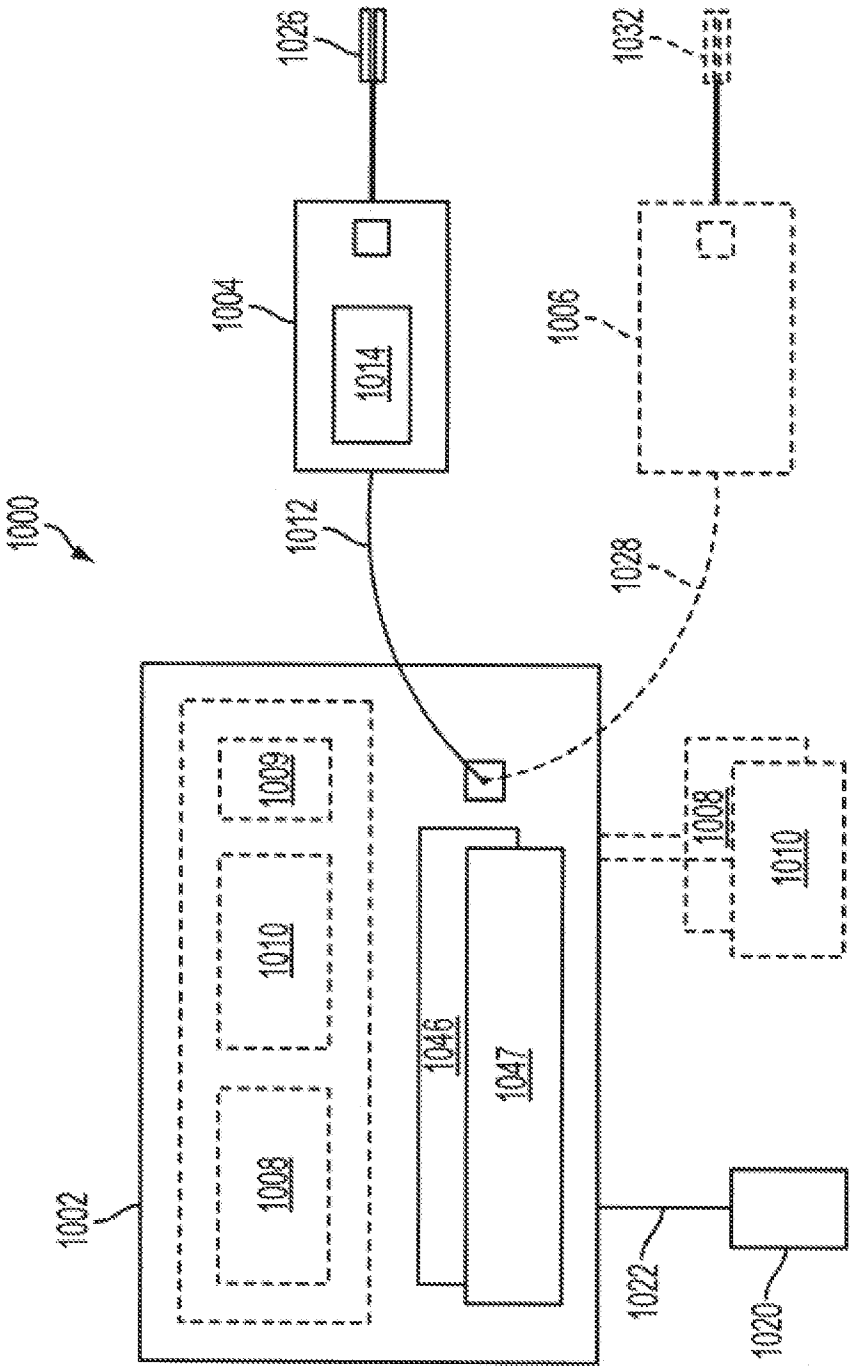
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FIG. 4

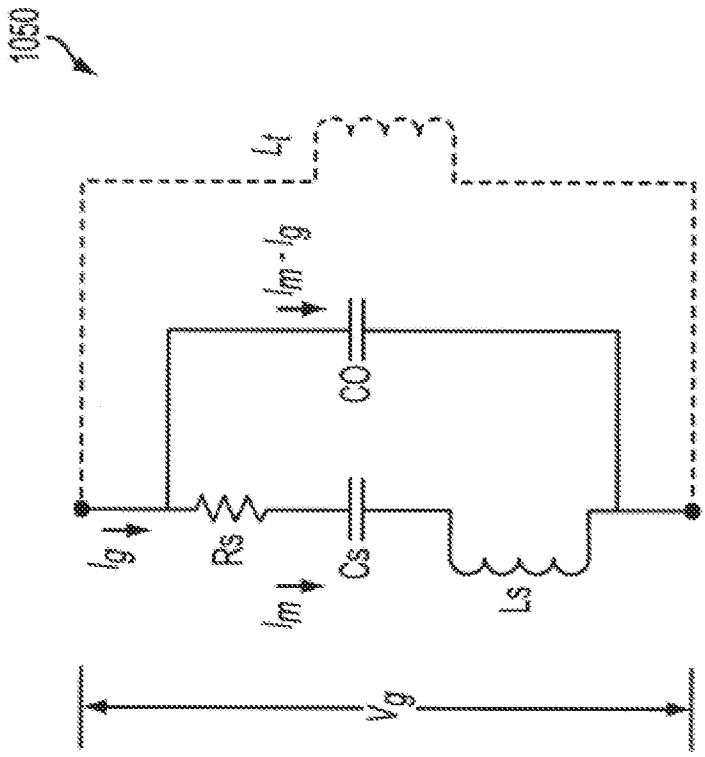

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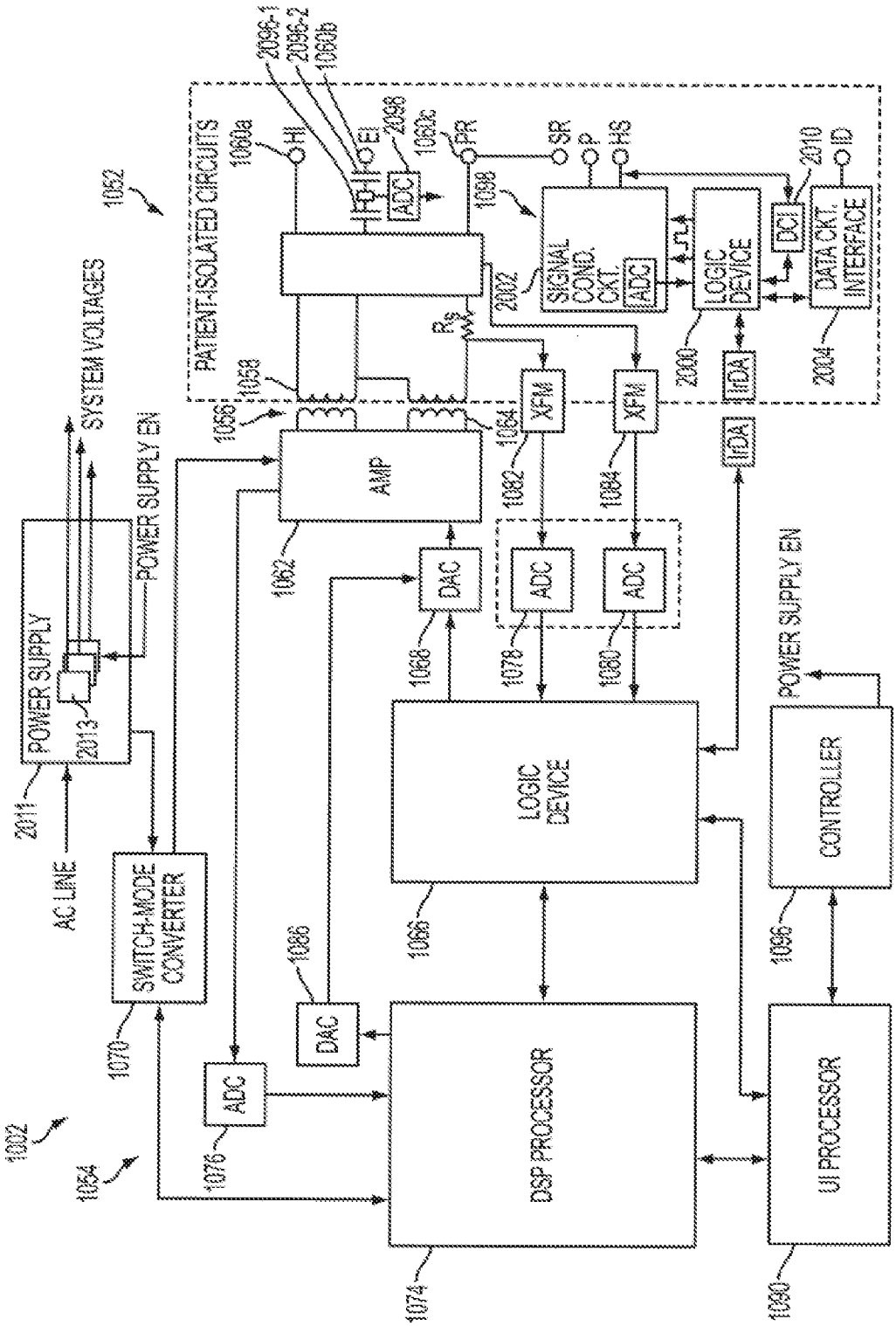
FIG. 5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1052
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POWER SUPPLY EN

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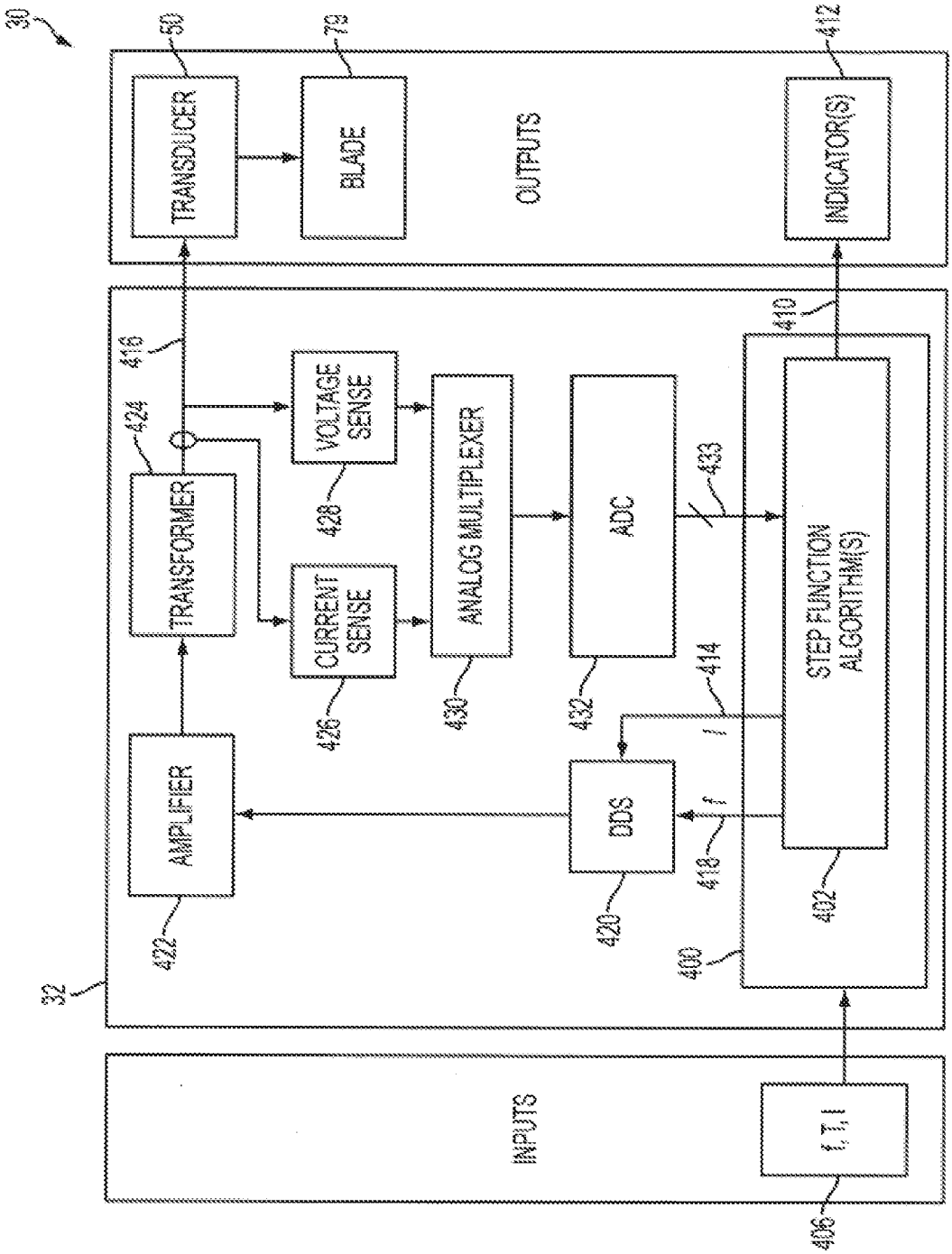
FIG. 6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CURRENT SENSE
426
ANALOG MULTIPLEXER
430
ADC
432
433
STEP FUNCTION ALGORITHM(S)
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INPUTS
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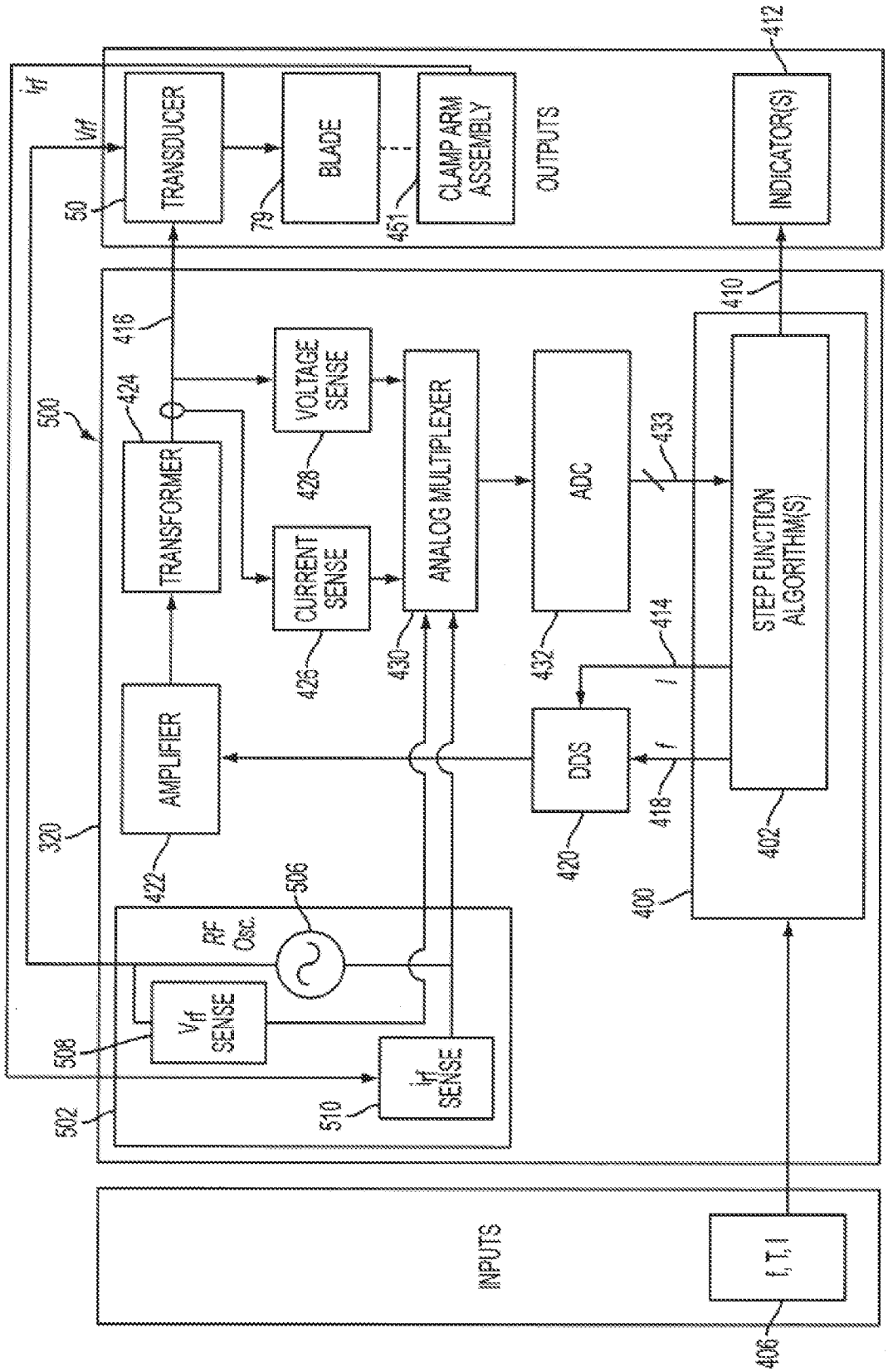
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CURRENT SENSE
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ANALOG MULTIPLEXER
ADC
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414
STEP FUNCTION ALGORITHM(S)
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INPUTS
406

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FIG. 7

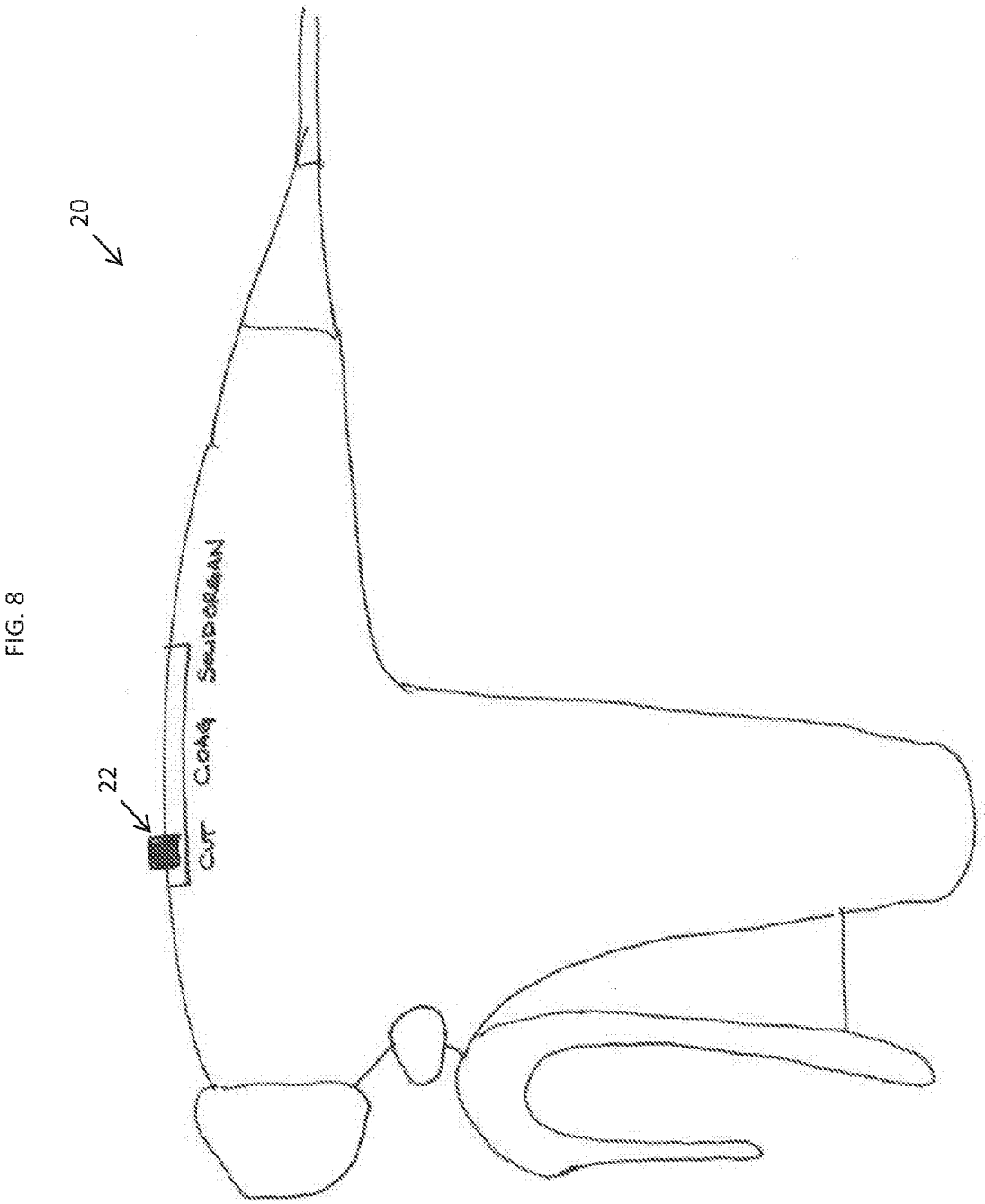

FIG. 8

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FIG. 9

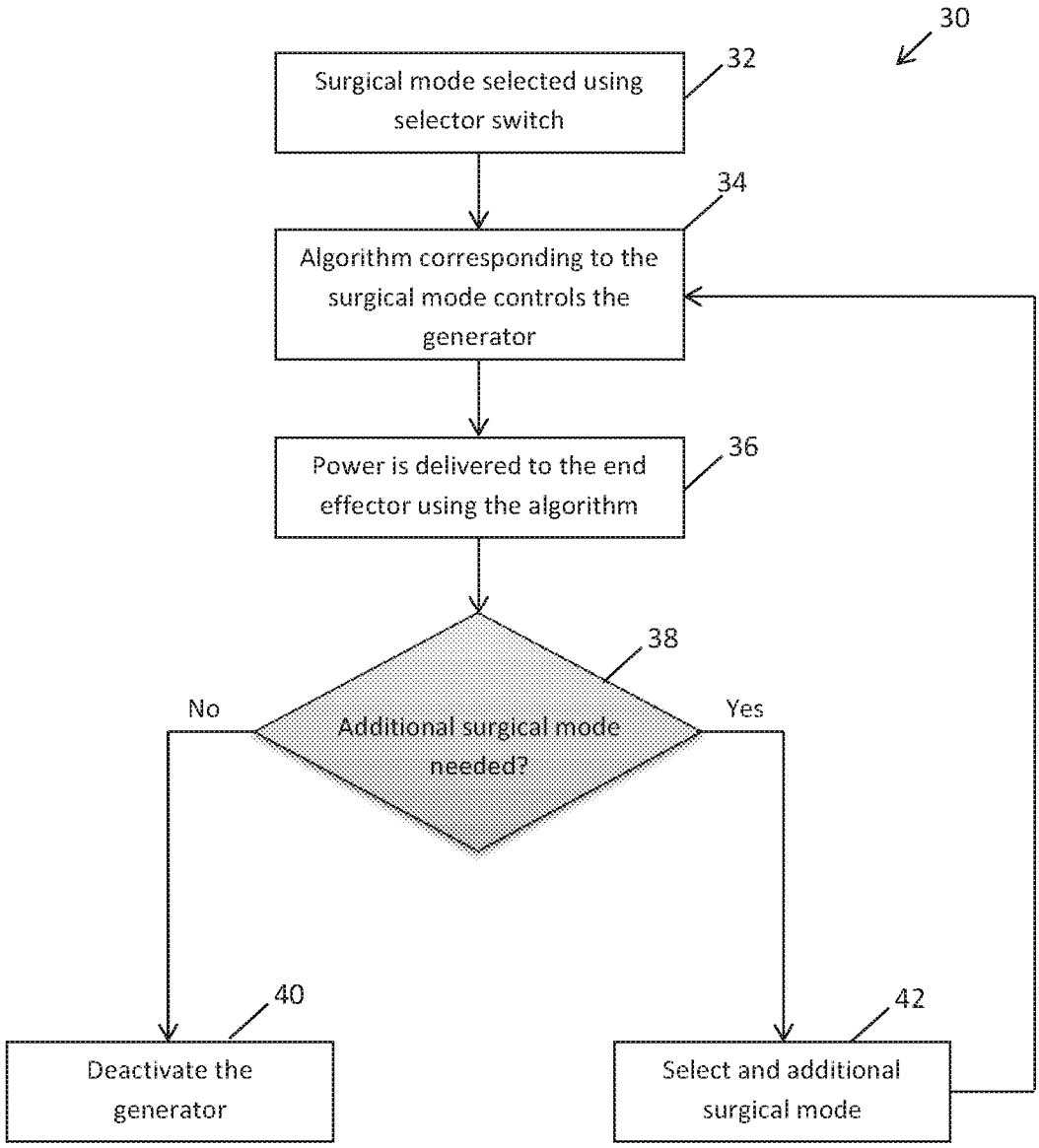

30
Surgical mode selected using selector switch
32
Algorithm corresponding to the surgical mode controls the generator
34
Power is delivered to the end effector using the algorithm
36
Additional surgical mode needed?
38
No
Yes
Deactivate the generator
40
Select and additional surgical mode
42

FIG. 10

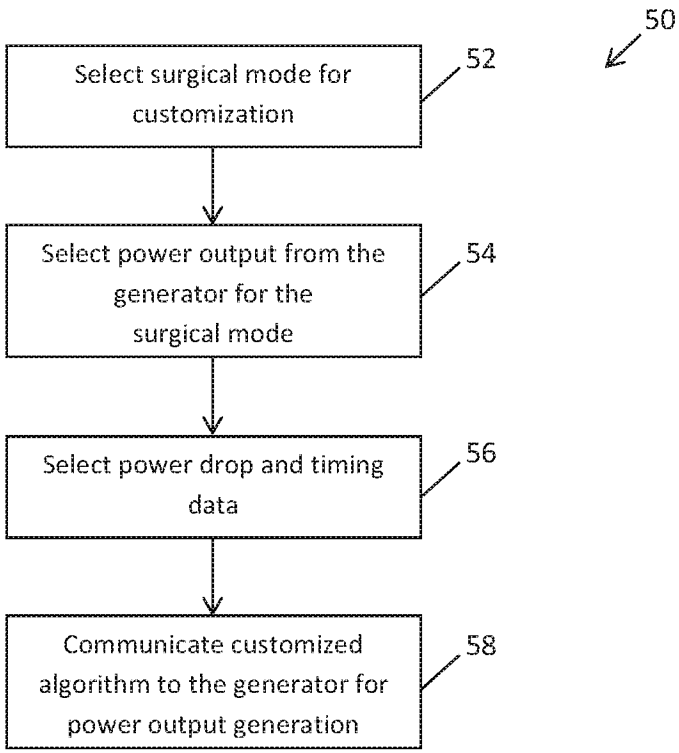

50
Select surgical mode for customization
52
Select power output from the generator for the surgical mode
54
Select power drop and timing data
56
Communicate customized algorithm to the generator for power output generation
58

FIG. 11

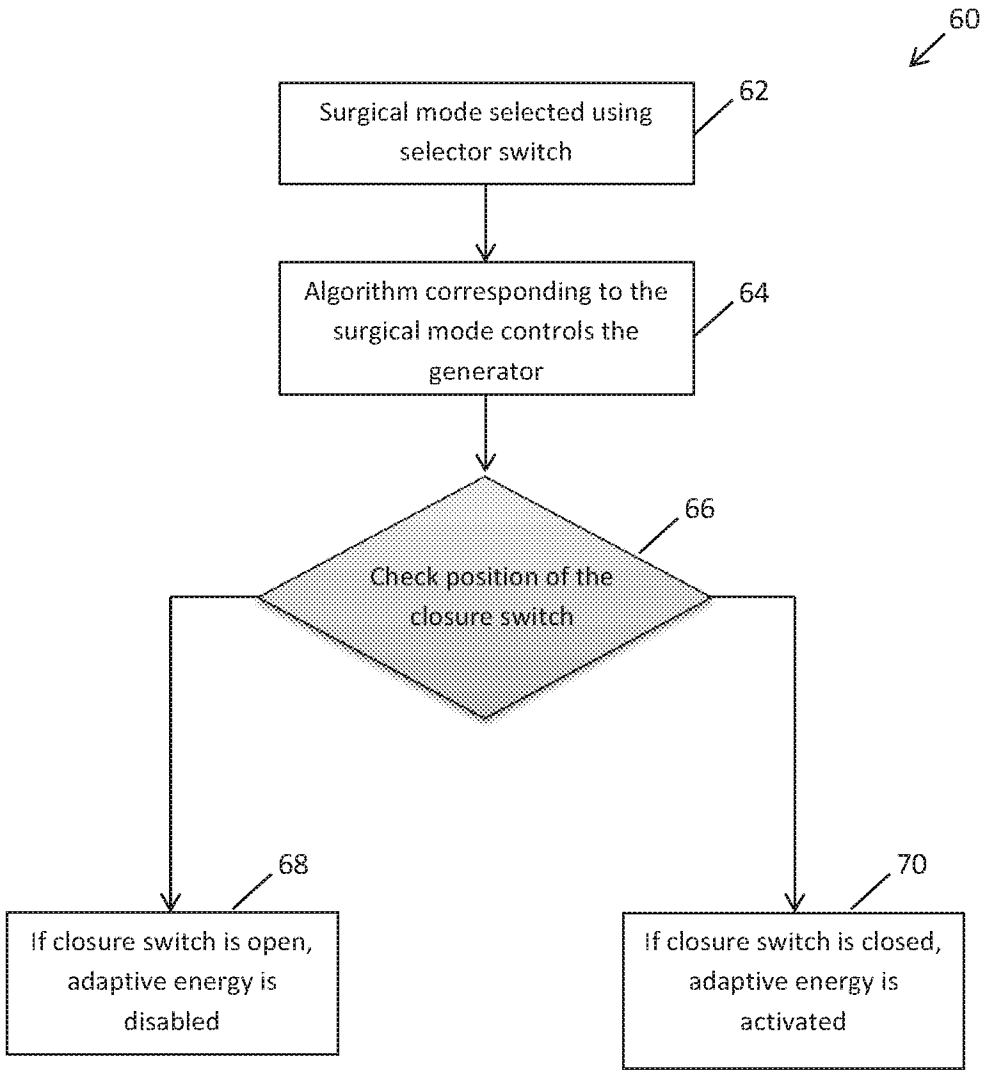

60
Surgical mode selected using selector switch
62
Algorithm corresponding to the surgical mode controls the generator
64
Check position of the closure switch
66
If closure switch is open, adaptive energy is disabled
68
If closure switch is closed, adaptive energy is activated
70

FIG. 12

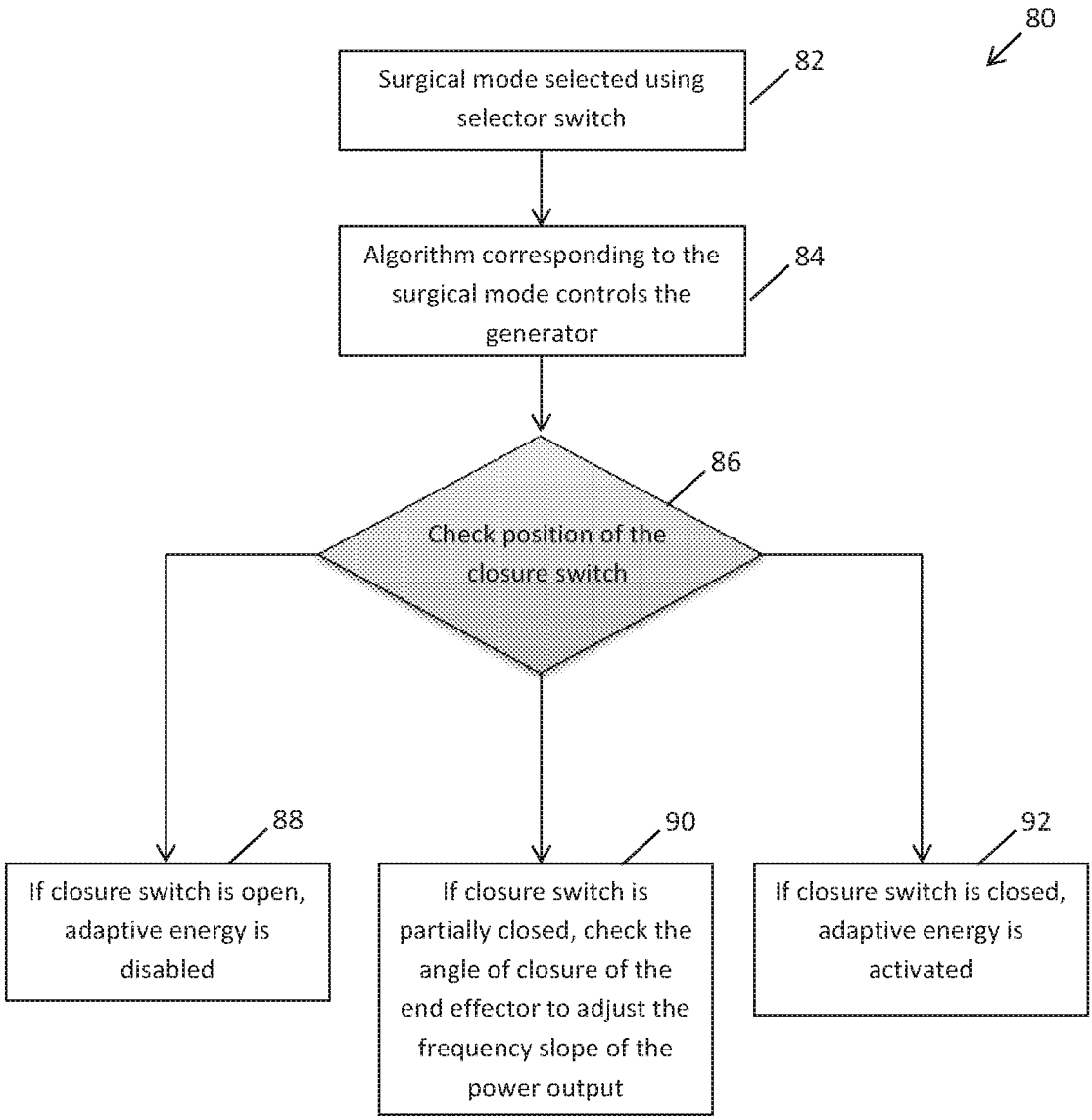
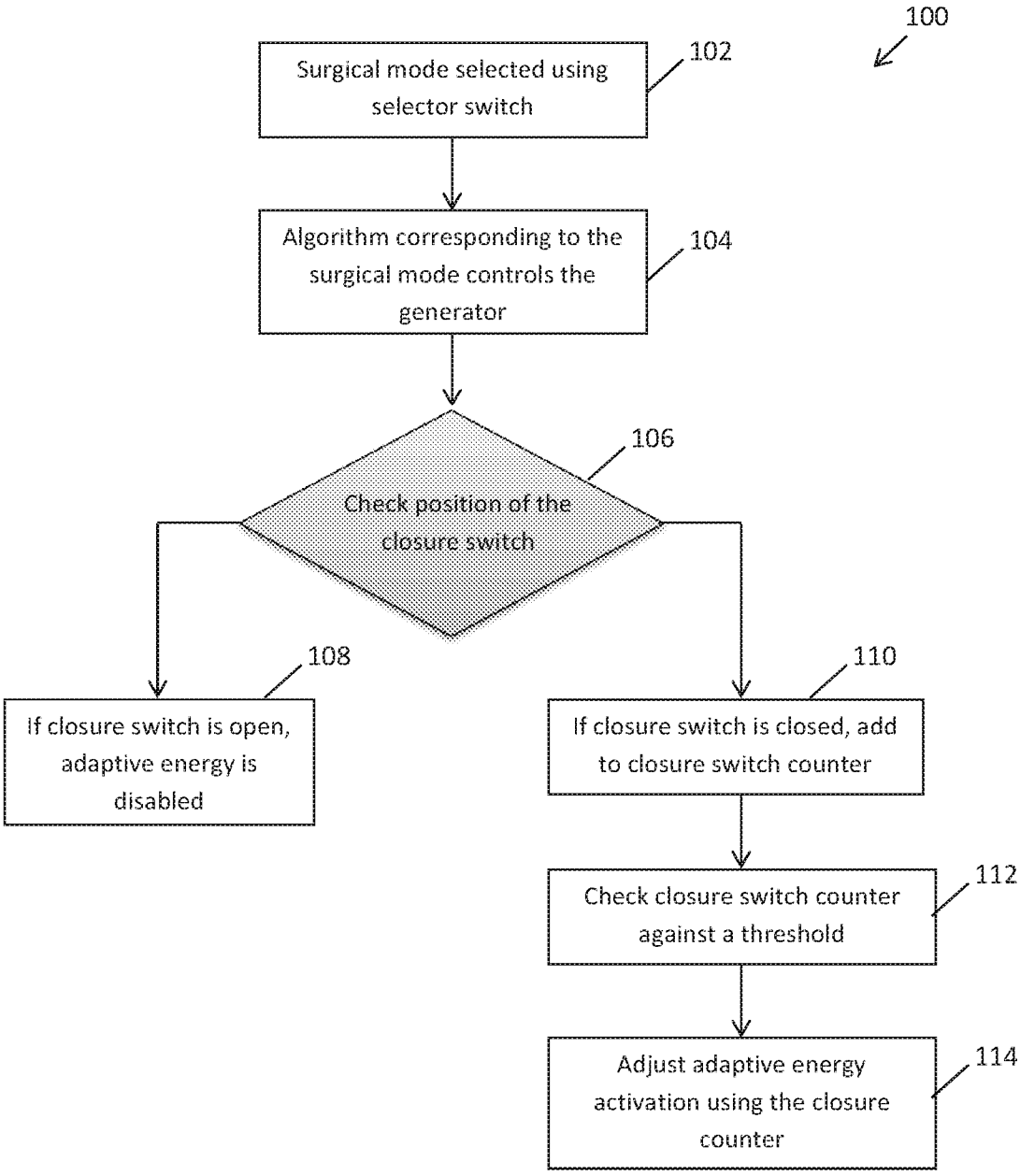

80
Surgical mode selected using selector switch
82
Algorithm corresponding to the surgical mode controls the generator
84
Check position of the closure switch
86
If closure switch is open, adaptive energy is disabled
88
If closure switch is partially closed, check the angle of closure of the end effector to adjust the frequency slope of the power output
90
If closure switch is closed, adaptive energy is activated
92

FIG. 13


100
Surgical mode selected using selector switch
102
Algorithm corresponding to the surgical mode controls the generator
104
Check position of the closure switch
106
If closure switch is open, adaptive energy is disabled
108
If closure switch is closed, add to closure switch counter
110
Check closure switch counter against a threshold
112
Adjust adaptive energy activation using the closure counter
114

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/039215

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B17/32 A61B18/14 A61B90/00
ADD.

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)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/087212 A1 (ALDRIDGE JEFFREY L [US] ET AL) 14 April 2011 (2011-04-14) the whole document	1-20
X	US 2013/267975 A1 (TIMM RICHARD W [US] ET AL) 10 October 2013 (2013-10-10) the whole document	1-20
X	EP 2 772 206 A2 (ETHICON ENDO SURGERY INC [US]) 3 September 2014 (2014-09-03) paragraph [0104] - paragraph [0113]	1-9, 12-20
A	WO 2014/178436 A1 (OLYMPUS CORP) 6 November 2014 (2014-11-06) paragraph [0006]	1-20

☐ 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

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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
3 August 2016	11/08/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Emirdag, Eda

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/039215

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011087212 A1	14-04-2011	AU 2010303385 A1	03-05-2012
		AU 2015238883 A1	29-10-2015
		BR 112012009383 A2	07-06-2016
		CA 2777103 A1	14-04-2011
		CN 102665585 A	12-09-2012
		EP 2485670 A2	15-08-2012
		EP 2901940 A2	05-08-2015
		ES 2531014 T3	10-03-2015
		JP 5766705 B2	19-08-2015
		JP 2013507190 A	04-03-2013
		KR 20120093273 A	22-08-2012
		US D695407 S1	10-12-2013
		US 2011087212 A1	14-04-2011
		US 2011087213 A1	14-04-2011
		US 2011087214 A1	14-04-2011
		US 2011087215 A1	14-04-2011
		US 2011087216 A1	14-04-2011
		US 2011087217 A1	14-04-2011
		US 2011087256 A1	14-04-2011
		US 2015182276 A1	02-07-2015
		US 2015182277 A1	02-07-2015
		US 2015340586 A1	26-11-2015
		WO 2011044338 A2	14-04-2011
US 2013267975 A1	10-10-2013	AU 2013246233 A1	09-10-2014
		CA 2869897 A1	17-10-2013
		CN 104349733 A	11-02-2015
		EP 2836143 A2	18-02-2015
		JP 2015515330 A	28-05-2015
		KR 20150003290 A	08-01-2015
		RU 2014145016 A	10-06-2016
		US 2013267975 A1	10-10-2013
		WO 2013154921 A2	17-10-2013
EP 2772206 A2	03-09-2014	AU 2014223703 A1	06-08-2015
		AU 2014223708 A1	06-08-2015
		AU 2014223709 A1	06-08-2015
		AU 2014223712 A1	20-08-2015
		AU 2014223714 A1	06-08-2015
		AU 2014223719 A1	13-08-2015
		AU 2014223723 A1	13-08-2015
		AU 2014223727 A1	13-08-2015
		AU 2014223730 A1	06-08-2015
		AU 2014226427 A1	20-08-2015
		CA 2902897 A1	04-09-2014
		CA 2902899 A1	04-09-2014
		CA 2903202 A1	04-09-2014
		CA 2903207 A1	04-09-2014
		CA 2903211 A1	04-09-2014
		CA 2903214 A1	12-09-2014
		CA 2903219 A1	04-09-2014
		CA 2903223 A1	04-09-2014
		CA 2903228 A1	04-09-2014
		CA 2903233 A1	04-09-2014
		CN 105007835 A	28-10-2015
		CN 105007836 A	28-10-2015
		CN 105007837 A	28-10-2015
		CN 105025813 A	04-11-2015

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/039215

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		CN 105025818 A	04-11-2015
		CN 105025819 A	04-11-2015
		CN 105025820 A	04-11-2015
		CN 105025821 A	04-11-2015
		CN 105025826 A	04-11-2015
		CN 105101887 A	25-11-2015
		EP 2772196 A2	03-09-2014
		EP 2772204 A2	03-09-2014
		EP 2772205 A1	03-09-2014
		EP 2772206 A2	03-09-2014
		EP 2772207 A2	03-09-2014
		EP 2772208 A1	03-09-2014
		EP 2772209 A1	03-09-2014
		EP 2772210 A2	03-09-2014
		EP 2772211 A2	03-09-2014
		EP 2772214 A2	03-09-2014
		US 2014246471 A1	04-09-2014
		US 2014246472 A1	04-09-2014
		US 2014246473 A1	04-09-2014
		US 2014246474 A1	04-09-2014
		US 2014246475 A1	04-09-2014
		US 2014246476 A1	04-09-2014
		US 2014246477 A1	04-09-2014
		US 2014246478 A1	04-09-2014
		US 2014246479 A1	04-09-2014
		US 2014249557 A1	04-09-2014
		WO 2014134007 A2	04-09-2014
		WO 2014134012 A1	04-09-2014
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		WO 2014134034 A2	04-09-2014
		WO 2014137662 A1	12-09-2014
WO 2014178436 A1	06-11-2014	CN 104883992 A	02-09-2015
		EP 2992847 A1	09-03-2016
		JP 5678242 B1	25-02-2015
		US 2015201960 A1	23-07-2015
		WO 2014178436 A1	06-11-2014