US 20200030904A1

(19) **United States**

(12) **Patent Application Publication**

Erdmann et al.

(10) **Pub. No.: US 2020/0030904 A1**

(43) **Pub. Date: Jan. 30, 2020**

(54) **SYSTEMS AND METHODS TO MITIGATE AUDIBLE NOISE IN WELDING-TYPE POWER SUPPLIES**

(71) Applicant: **ILLINOIS TOOL WORKS INC.**, GLENVIEW, IL (US)

(72) Inventors: **Jeremy John Erdmann**, Appleton, WI (US); **Maxwell Bode Brock**, Appleton, WI (US); **Craig Steven Knoener**, Appleton, WI (US); **Suneesh Thovarayi**, Appleton, WI (US); **Alan Adam Manthe**, New London, WI (US)

(21) Appl. No.: **16/044,807**

(22) Filed: **Jul. 25, 2018**

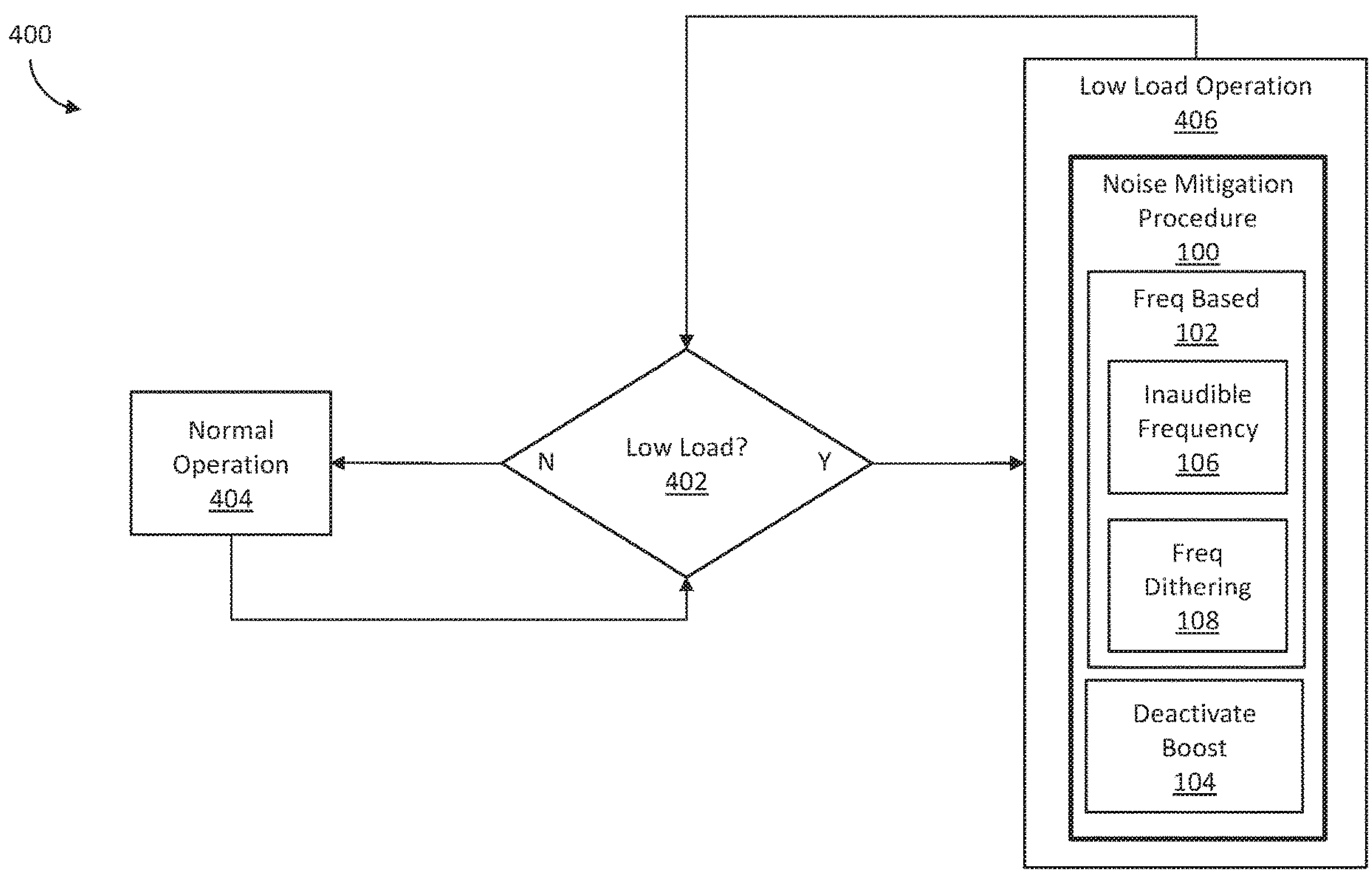
Publication Classification

(51) **Int. Cl.**
B23K 9/10 (2006.01)

(52) **U.S. Cl.**
CPC *B23K 9/1012* (2013.01)

(57) **ABSTRACT**

Apparatus, systems, and/or methods for mitigating audible noise generated by a welding-type power supply are disclosed. In some examples, the switching frequency of the welding-type power supply may be changed to a frequency that is outside the audible range for humans. This strategy takes advantage of the fact that the observed audible noise is generated by vibrating components within the welding-type power supply that vibrate at a frequency related to the switching frequency. Other noise mitigation strategies include dithering and deactivation of portions of the welding-type power supply that vibrate to generate the audible noise.



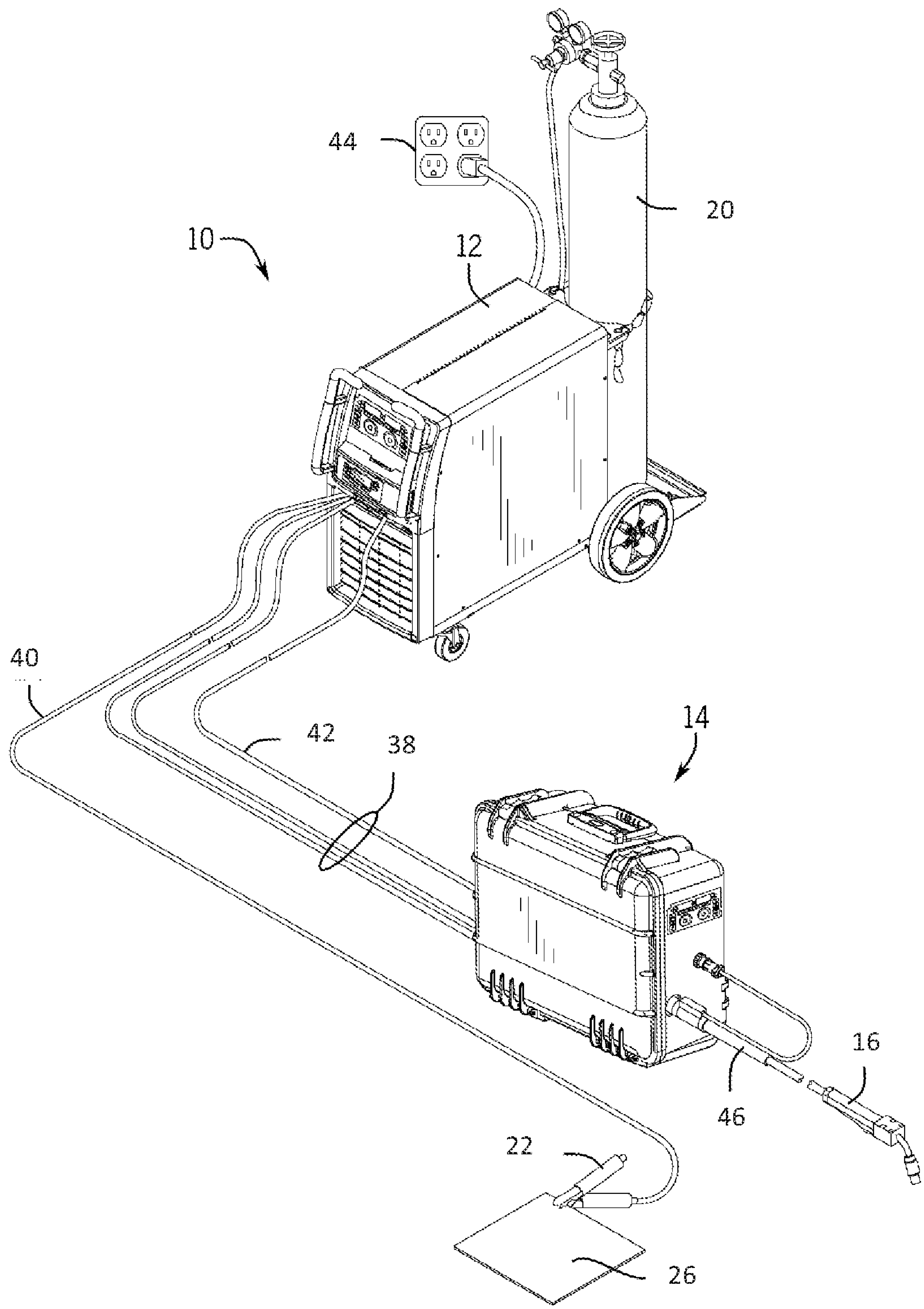


FIG. 1

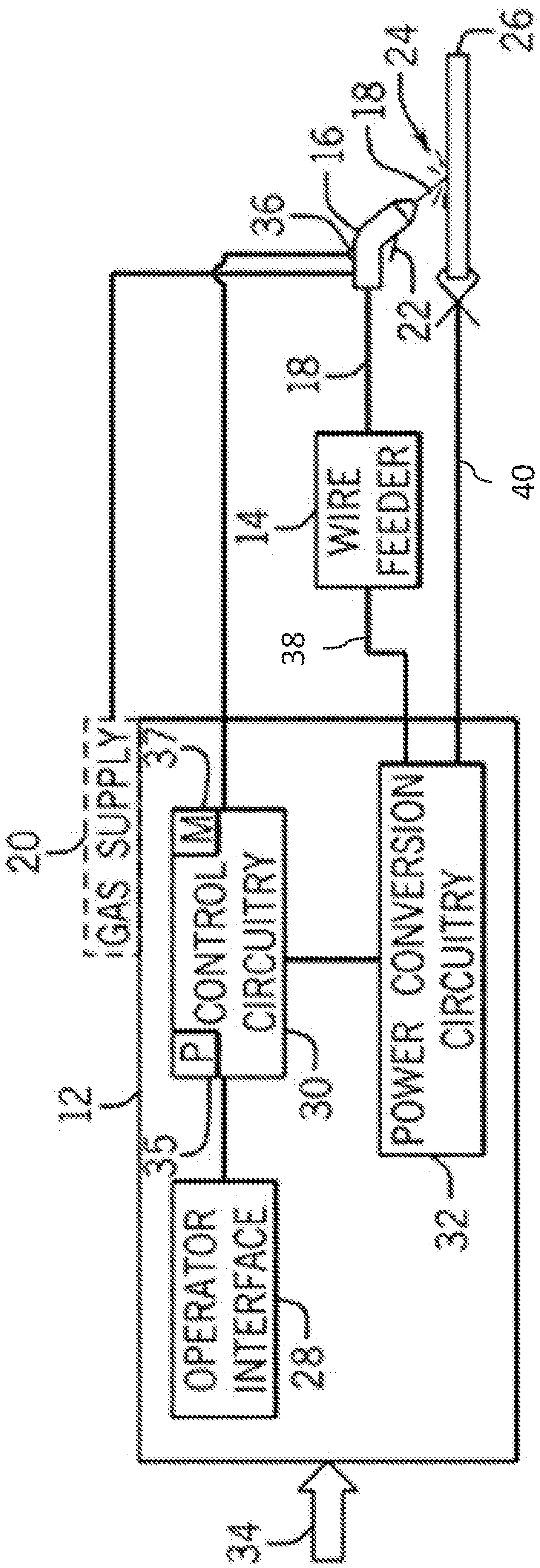

10
20
GAS SUPPLY
12
37
P
M
CONTROL
CIRCUITRY
35
30
OPERATOR
INTERFACE
28
POWER CONVERSION
CIRCUITRY
32
34
14
WIRE
FEEDER
38
40
18
36
16
18
22
24
26

FIG. 2

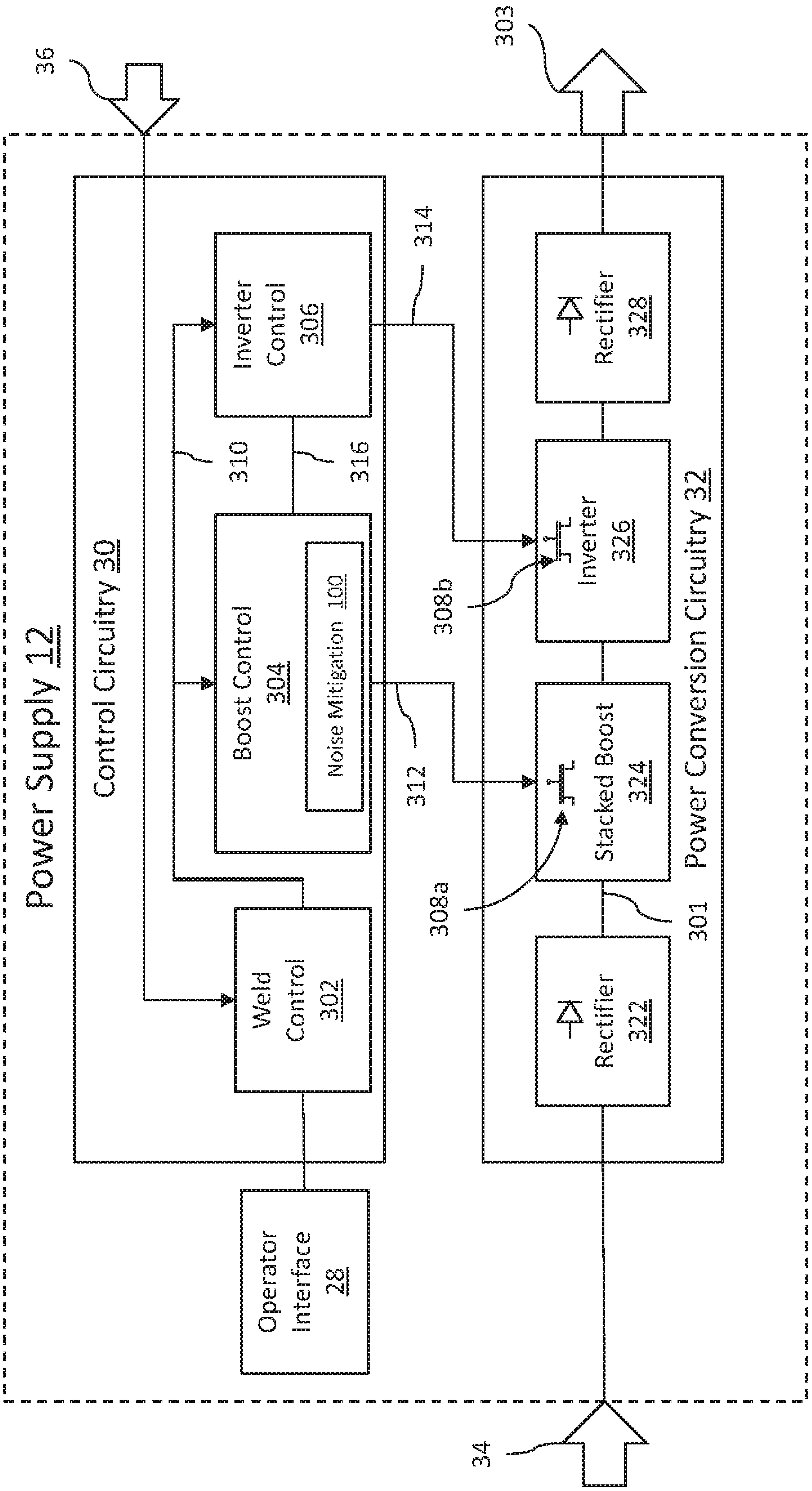

36
303
Power Supply 12
Control Circuitry 30
Inverter Control 306
Boost Control 304
Noise Mitigation 100
Weld Control 302
Operator Interface 28
314
310
316
308b
312
308a
301
Rectifier 328
Inverter 326
Stacked Boost 324
Rectifier 322
Power Conversion Circuitry 32
34

FIG. 3

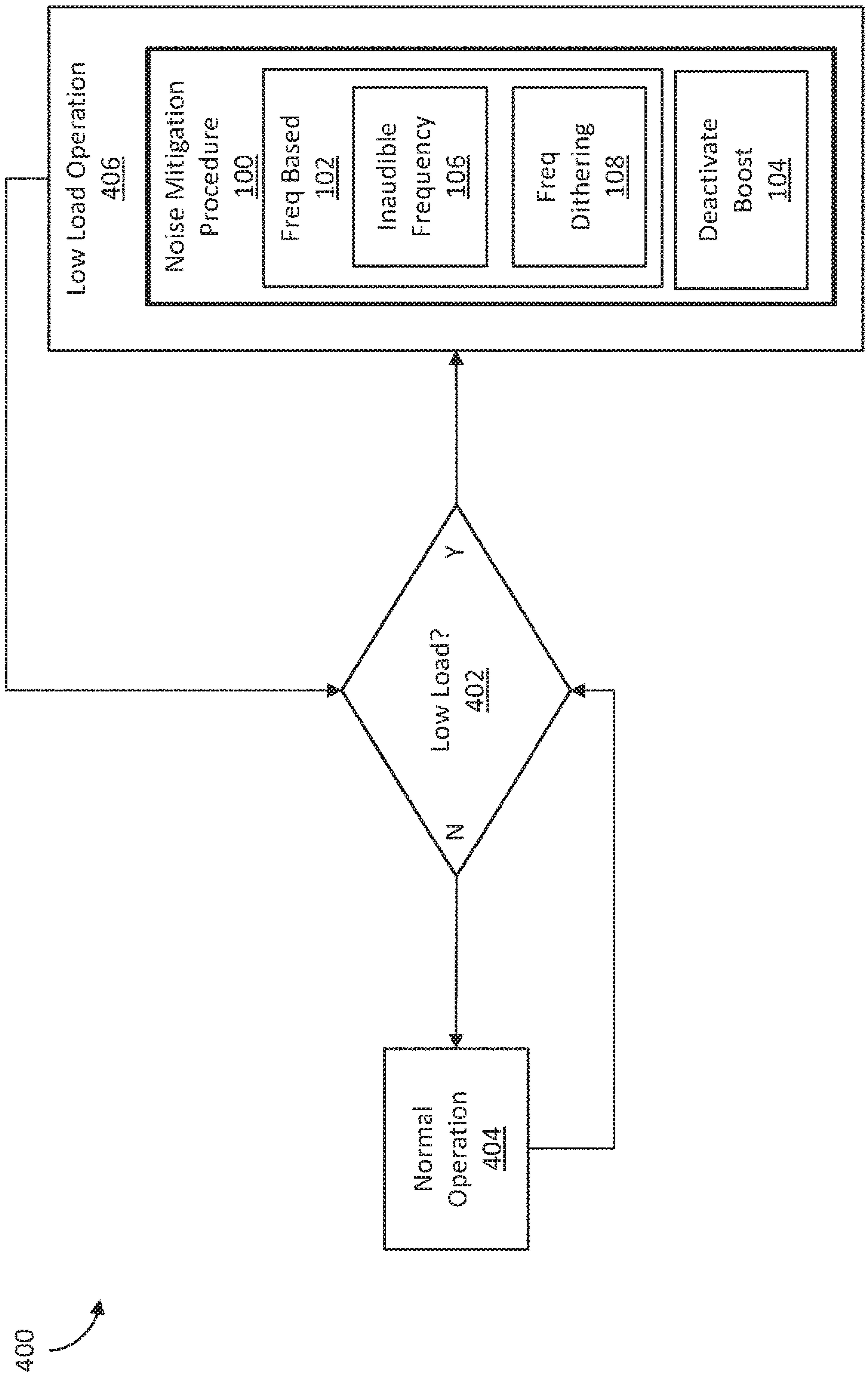

Low Load Operation
406
Noise Mitigation
Procedure
100
Freq Based
102
Inaudible
Frequency
106
Freq
Dithering
108
Deactivate
Boost
104
Y
Low Load?
402
N
Normal
Operation
404
400

FIG. 4

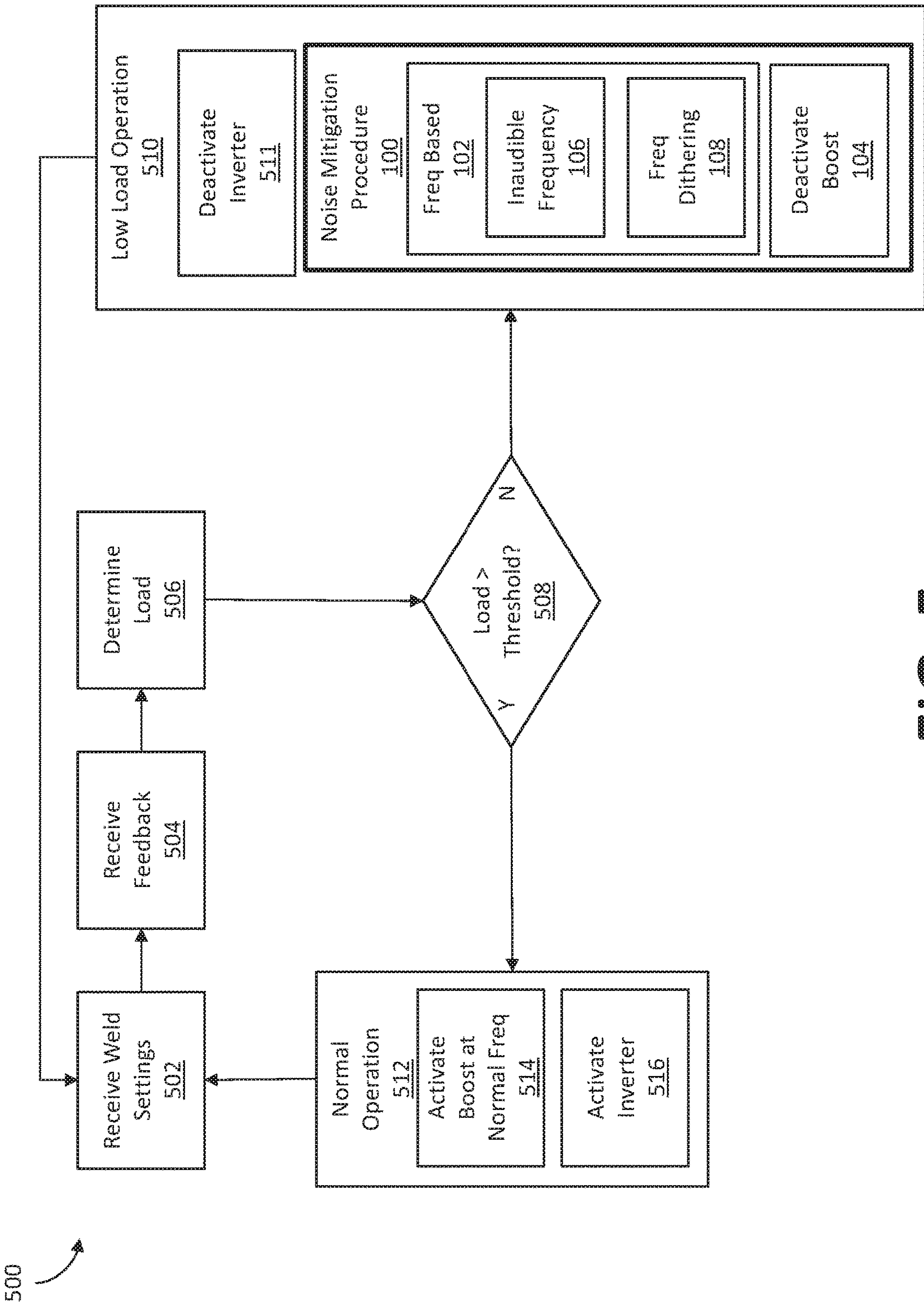

500
Receive Weld Settings 502
Receive Feedback 504
Determine Load 506
Load > Threshold? 508
Y
N
Low Load Operation 510
Deactivate Inverter 511
Noise Mitigation Procedure 100
Freq Based 102
Inaudible Frequency 106
Freq Dithering 108
Deactivate Boost 104
Normal Operation 512
Activate Boost at Normal Freq 514
Activate Inverter 516

FIG. 5

SYSTEMS AND METHODS TO MITIGATE AUDIBLE NOISE IN WELDING-TYPE POWER SUPPLIES

TECHNICAL FIELD

[0001] The present disclosure generally relates to welding-type power supplies and, more particularly, to systems and methods to mitigate audible noise in welding-type power supplies.

BACKGROUND

[0002] Welding-type components (e.g., welding torches) are sometimes powered by welding-type power supplies. Conventional power supplies use a range of electrical components and/or electrical circuitry to produce appropriate welding-type power for various welding-type operations and/or welding-type components. Some conventional welding-type power supplies have been observed to generate audible noise. The audible noise was of sufficient intensity and pitch can be inconvenient and/or distracting to users of the equipment.

[0003] Limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with the present disclosure as set forth in the remainder of the present application with reference to the drawings.

SUMMARY

[0004] The present disclosure is directed to systems and methods to mitigate audible noise in welding-type power supplies, for example, substantially as illustrated by and/or described in connection with at least one of the figures, and as set forth more completely in the claims.

[0005] These and other advantages, aspects and novel features of the present disclosure, as well as details of an illustrated example thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** illustrates an example of a welding-type system, in accordance with aspects of this disclosure.

[0007] FIG. **2** is a block diagram of the example welding-type system of FIG. **1**, in accordance with aspects of this disclosure.

[0008] FIG. **3** is a block diagram of an example welding-type power supply, in accordance with aspects of this disclosure.

[0009] FIG. **4** is a flow chart illustrating an example method of operation of a boost controller of the example welding-type power supply of FIG. **3**, in accordance with aspects of this disclosure.

[0010] FIG. **5** is a flow chart illustrating an example method of operation of control circuitry of the example welding-type power supply of FIG. **3**, in accordance with aspects of this disclosure.

[0011] The figures are not necessarily to scale. Where appropriate, the same or similar reference numerals are used in the figures to refer to similar or identical elements. For example, reference numerals utilizing lettering (e.g., controllable circuit element **308***a*, controllable circuit element **308***b*) refer to instances of the same reference numeral that does not have the lettering (e.g., controllable circuit elements **308**).

DETAILED DESCRIPTION

[0012] Preferred examples of the present disclosure may be described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail because they may obscure the disclosure in unnecessary detail. For this disclosure, the following terms and definitions shall apply.

[0013] As used herein, the terms “about” and/or “approximately,” when used to modify or describe a value (or range of values), position, orientation, and/or action, mean reasonably close to that value, range of values, position, orientation, and/or action. Thus, the examples described herein are not limited to only the recited values, ranges of values, positions, orientations, and/or actions but rather should include reasonably workable deviations.

[0014] As used herein, “and/or” means any one or more of the items in the list joined by “and/or”. As an example, “x and/or y” means any element of the three-element set {(x), (y), (x, y)}. In other words, “x and/or y” means “one or both of x and y”. As another example, “x, y, and/or z” means any element of the seven-element set {(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)}. In other words, “x, y and/or z” means “one or more of x, y and z”.

[0015] As utilized herein, the terms “e.g.,” and “for example” set off lists of one or more non-limiting examples, instances, or illustrations.

[0016] As used herein the terms “circuits” and “circuitry” refer to physical electronic components (i.e., hardware) and any software and/or firmware (“code”) which may configure the hardware, be executed by the hardware, and or otherwise be associated with the hardware. As used herein, for example, a particular processor and memory may comprise a first “circuit” when executing a first one or more lines of code and may comprise a second “circuit” when executing a second one or more lines of code. As utilized herein, circuitry is “operable” and/or “configured” to perform a function whenever the circuitry comprises the necessary hardware and/or code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or enabled (e.g., by a user-configurable setting, factory trim, etc.).

[0017] As used herein, a control circuit may include digital and/or analog circuitry, discrete and/or integrated circuitry, microprocessors, DSPs, etc., software, hardware and/or firmware, located on one or more boards, that form part or all of a controller, and/or are used to control a welding process, and/or a device such as a power source or wire feeder.

[0018] As used herein, the term “processor” means processing devices, apparatus, programs, circuits, components, systems, and subsystems, whether implemented in hardware, tangibly embodied software, or both, and whether or not it is programmable. The term “processor” as used herein includes, but is not limited to, one or more computing devices, hardwired circuits, signal-modifying devices and systems, devices and machines for controlling systems, central processing units, programmable devices and systems, field-programmable gate arrays, application-specific integrated circuits, systems on a chip, systems comprising discrete elements and/or circuits, state machines, virtual machines, data processors, processing facilities, and combinations of any of the foregoing. The processor may be, for example, any type of general purpose microprocessor or microcontroller, a digital signal processing (DSP) processor, an application-specific integrated circuit (ASIC). The processor may be coupled to, and/or integrated with a memory device.

[0019] As used, herein, the term "memory" and/or "memory device" means computer hardware or circuitry to store information for use by a processor and/or other digital device. The memory and/or memory device can be any suitable type of computer memory or any other type of electronic storage medium, such as, for example, read-only memory (ROM), random access memory (RAM), cache memory, compact disc read-only memory (CDROM), electro-optical memory, magneto-optical memory, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically-erasable programmable read-only memory (EEPROM), a computer-readable medium, or the like.

[0020] The term "power" is used throughout this specification for convenience, but also includes related measures such as energy, current, voltage, and enthalpy. For example, controlling "power" may involve controlling voltage, current, energy, and/or enthalpy, and/or controlling based on "power" may involve controlling based on voltage, current, energy, and/or enthalpy.

[0021] As used herein, welding-type power refers to power suitable for welding, cladding, brazing, plasma cutting, induction heating, CAC-A and/or hot wire welding/preheating (including laser welding and laser cladding), carbon arc cutting or gouging, and/or resistive preheating.

[0022] As used herein, a welding-type power supply and/or power source refers to any device capable of, when power is applied thereto, supplying welding, cladding, brazing, plasma cutting, induction heating, laser (including laser welding, laser hybrid, and laser cladding), carbon arc cutting or gouging and/or resistive preheating, including but not limited to transformer-rectifiers, inverters, converters, resonant power supplies, quasi-resonant power supplies, switch-mode power supplies, etc., as well as control circuitry and other ancillary circuitry associated therewith.

[0023] Some examples of the present disclosure relate to a welding-type power supply, comprising power conversion circuitry configured to convert input power to welding-type output power, and control circuitry configured to control the power conversion circuitry using a control signal, the control signal having a signal frequency, and the control circuitry configured to set the signal frequency based on a load state, wherein the control circuitry is configured to set the signal frequency to a second frequency outside of an audible frequency range in response to the load state comprising a low load.

[0024] In some examples, the load state comprises a high load or a low load. In some examples, the load state comprises a high load when the welding-type output power is used during a welding-type operation and the low load when the welding-type output power is not used during a welding-type operation. In some examples, the control circuitry is configured to set the signal frequency to a first frequency in response to the load state comprising the high load, and to the second frequency in response to the load state comprising the low load. In some examples, the first frequency is within the audible frequency range. In some examples, the second frequency is higher than the first frequency. In some examples, the first frequency is between approximately 7 kHz and 15 kHz, and the second frequency is not between approximately 7 kHz and 15 kHz. In some examples, the power conversion circuitry comprises a stacked boost converter having a controllable circuit element, the controllable circuit element configured to switch between a first state and a second state based on the control signal.

[0025] Some examples of the present disclosure relate to a welding-type system, comprising a welding-type instrument configured to use welding-type output power during a welding-type operation, and a welding-type power supply, comprising power conversion circuitry configured to convert input power to the welding-type output power, and control circuitry configured to control the power conversion circuitry using a control signal, the control signal having a signal frequency, and the control circuitry configured to set the signal frequency based on a load state, wherein the control circuitry is configured to set the signal frequency to a second frequency outside of an audible frequency range in response to the load state comprising a low load.

[0026] In some examples, the load state comprises a high load when the welding-type instrument is conducting the welding-type operation and the low load when the welding-type instrument is not conducting the welding-type operation. In some examples, the control circuitry is configured to set the signal frequency to a first frequency in response to the load state comprising the high load, and to the second frequency in response to the load state comprising the low load. In some examples, the second frequency is zero. In some examples, the control circuitry is further configured to set the signal frequency to a third frequency in response to the load state comprising the low load. In some examples, the first frequency is within the audible frequency range. In some examples, the first frequency is between approximately 7 kHz and 15 kHz, and the second frequency is not between approximately 7 kHz and 15 kHz.

[0027] Some examples of the present disclosure relate to a method for controlling a welding-type power supply, comprising determining a load state of a welding-type power supply, setting a non-zero signal frequency of a control signal based on the load state, wherein the signal frequency is set to a second frequency outside of an audible frequency range in response to the load state comprising a low load, and controlling power conversion circuitry of the welding-type power supply using the control signal.

[0028] In some examples, determining the load state comprises determining whether an inverter of the power conversion circuitry is active. In some examples, determining whether the inverter is active comprises determining whether a welding-type operation is active. In some examples, the load state comprises a high load when the welding-type operation or the inverter is active and the low load when the welding-type operation or the inverter is inactive. In some examples, determining the load state comprises predicting a future load state based on sensor input. In some examples, setting the signal frequency comprises setting the signal frequency to a first frequency when the load state is a high load and setting the signal frequency to the second frequency when the load state is the low load, the second frequency being higher than the first frequency.

[0029] Some examples of the present disclosure relate to welding-type power supplies with audible noise mitigation. In some circumstances, audible noise (e.g., a beeping and/or tone) is generated by some welding-type power supplies. Sources of noise may include combination(s) of vibrating components in power conversion circuitry of the welding-type power supplies. For example, a combination of vibrating components of a boost converter in the power conversion circuitry, such as the input inductor, precharge relays, and boost capacitor, may cause audible noise. The vibration has been observed to occur at frequencies related to a switching frequency of the boost converter (i.e., the frequency at which certain controllable circuit elements used in the boost converter are "switched" from one state to another).

[0030] The present disclosure contemplates certain systems, methods, operations, and/or strategies that may mitigate the occurrence and/or unpleasantness of the audible noise. For example, the present disclosure contemplates dynamically changing the switching frequency to combat the noise. In some examples, control circuitry that controls the boost converter controls the switching frequency to be outside the typical audible range for humans. This strategy takes advantage of the fact that the vibrating components that generate the audible noise were observed to vibrate at a frequency related to the switching frequency (which was in the audible range for humans when the audible noise was observed). By dynamically changing the switching frequency to a frequency outside the audible range, the control circuitry controls the noise to be inaudible to human ears.

[0031] Operating at a substantially different frequency while under a heavy load may result in undesirable thermal loading of the power supply. However, the thermal implications of the inaudible switching frequency may be significantly less under a low load (e.g., when no welding-type operation is taking place) than under a heavy load. At least in systems in which audible noise is limited to periods of relatively low load (and/or power consumption), some of the disclosed systems and methods involve dynamically switching to an inaudible switching frequency (and/or to more than one inaudible switching frequencies) during periods of low load.

[0032] Other disclosed systems and methods provide mitigation of audible noise by dithering (and/or randomizing), the switching frequency to spread out the magnitude of the observed frequency over a wider range of frequencies with smaller magnitude.

[0033] Still other disclosed systems and methods involve deactivating the boost converter completely during low loads to mitigate the audible noise. Disclosed example systems and methods reactivate the boost converter after deactivation while avoiding potential system stability challenges (e.g., transformer saturation) which can occur during periods of higher loads.

[0034] Thus, the present disclosure contemplates welding-type power supplies that undertake certain noise mitigation strategies when under a low load (and/or low power consumption, burst/idle mode, etc.), so as to reduce and/or prevent the power supply from producing unwanted audible noise.

[0035] FIGS. **1** and **2** show a perspective view and block diagram view, respectively, of an example of a welding-type system **10**. It should be appreciated that, while the example welding-type system **10** shown in FIGS. **1** and **2** may be described as a gas metal arc welding (GMAW) system, the presently disclosed system may also be used with other arc welding processes (e.g., flux-cored arc welding (FCAW), gas shielded flux-cored arc welding (FCAW-G), gas tungsten arc welding (GTAW), submerged arc welding (SAW), shielded metal arc welding (SMAW), or similar arc welding processes) or other metal fabrication systems, such as plasma cutting systems, induction heating systems, and so forth.

[0036] In the example of FIG. **1**, the welding-type system **10** includes a welding-type power supply **12** (i.e., a welding-type power source), a welding wire feeder **14**, a gas supply **20**, and a welding torch **16**. The welding-type power supply **12** generally supplies power for the welding-type system **10** and/or other various accessories, and may be coupled to the welding wire feeder **14** via one or more weld cables **38**, as well as coupled to a work piece **26** using a lead cable **40** having a clamp **22**. In the illustrated example, the welding wire feeder **14** is coupled to the welding torch **16** via coupler **46** in order to supply welding wire and/or welding-type power to the welding torch **16** during operation of the welding-type system **10**. In some examples, the welding-type power supply **12** may couple and/or directly supply welding-type power to the welding torch **16**. In the illustrated example, the power supply **12** is separate from the wire feeder **14**, such that the wire feeder **14** may be positioned at some distance from the power supply **12** near a welding location. However, it should be understood that the wire feeder **14**, in some examples, may be integral with the power supply **12**. In some examples, the wire feeder **14** may be omitted from the system **10** entirely.

[0037] In the examples of FIGS. **1** and **2**, the welding-type system **10** includes a gas supply **20** that may supply a shielding gas and/or shielding gas mixtures to the welding torch **16**. A shielding gas, as used herein, may refer to any gas or mixture of gases that may be provided to the arc and/or weld pool in order to provide a particular local atmosphere (e.g., shield the arc, improve arc stability, limit the formation of metal oxides, improve wetting of the metal surfaces, alter the chemistry of the weld deposit, and so forth). In the example of FIG. **1**, the gas supply **20** is coupled to the welding torch **16** through the wire feeder **14** via a gas conduit **42** that is part of the weld cables **38** from the welding-type power supply **12**. In such an example, the welding wire feeder **14** may regulate the flow of gas from the gas supply **20** to the welding torch **16**. In the example of FIG. **2**, the gas supply **20** is depicted as coupled directly to the welding torch **16** rather than being coupled to the welding torch **16** through the wire feeder **14**.

[0038] In the example of FIG. **2**, the wire feeder **14** supplies a wire electrode **18** (e.g., solid wire, cored wire, coated wire) to the torch **16**. The gas supply **20**, which may be integral with or separate from the power supply **12**, supplies a gas (e.g., CO2, argon) to the torch **16**. In some examples, no gas supply **20** may be used. The welding-type power supply **12** may power the welding wire feeder **14** that, in turn, powers the welding torch **16**, in accordance with demands of the welding-type system **10**. The lead cable **40** terminating in the clamp **22** couples the welding-type power supply **12** to the work piece **26** to close the circuit between the welding-type power supply **12**, the work piece **26**, and the welding torch **16**. An operator may engage a trigger **22** of the torch **16** to initiate an arc **24** between the electrode **18** and a work piece **26**. In some examples, engaging the trigger **22** of the torch **16** may initiate a different welding-type function, instead of an arc **24**.

[0039] In the example of FIG. **2**, the welding-type power supply **12** includes an operator interface **28**, control circuitry **30**, and power conversion circuitry **32**. In some examples, the welding-type system **10** may receive weld settings from the operator via the operator interface **28** provided on the power supply **12** (and/or power source housing, such as on a front panel of the power source housing, for example). The weld settings may relate to the type of welding-type power desired. In the example of FIG. **2**, the operator interface **28** is coupled to the control circuitry **30**, and may communicate the weld settings to the control circuitry **30** via this coupling.

[0040] In the example of FIG. **2**, the welding-type power supply **12** includes power conversion circuitry **32** that receives input power from a power source (e.g., the AC power grid, an engine/generator set, or a combination thereof), conditions the input power, and provides DC and/or AC welding-type output power via the weld cable(s) **38** and/or lead cable **40**. In the example of FIG. **2**, the source of electrical power is indicated by arrow **34**. The source may be a power grid, an engine-driven generator, batteries, fuel cells or other alternative sources. In the example of FIG. **1**, the source is an electrical outlet **44**. The power conversion circuitry **32** may include circuit elements (e.g., transformers, rectifiers, capacitors, inductors, diodes, transistors, switches, and so forth) capable of converting the AC input power to a direct current electrode positive (DCEP) output, direct current electrode negative (DCEN) output, DC variable polarity, and/or a variable balance (e.g., balanced or unbalanced) AC output, as dictated by the demands of the welding-type system **10** (e.g., based on the type of welding process performed by the welding-type system **10**, and so forth).

[0041] In the example of FIG. **2**, the control circuitry **30** is coupled to the power conversion circuitry **32**. In some examples, the control circuitry **30** operates to control the conversion circuitry **32**, so as to ensure the conversion circuitry **32** generates the appropriate welding-type power for carrying out the desired welding-type operation. In some examples, the control circuitry **30** may control the power conversion circuitry **32** to produce an appropriate and/or desired current and/or voltage of the welding-type power supplied to the torch **16**, as selected, for example, by an operator through the operator interface **28**.

[0042] In the example of FIG. **2**, the control circuitry comprises one or more processors **35** and/or memory **37**. The processor(s) **35** may include one or more microprocessors, such as one or more "general-purpose" microprocessors, one or more special-purpose microprocessors and/or application specific integrated circuits (ASICS), or some combination thereof. For example, the processor(s) may include one or more reduced instruction set (RISC) processors (e.g., Advanced RISC Machine (ARM) processors), one or more digital signal processors (DSPs), and/or other appropriate processors. The one or more processors **35** may use data stored in the memory **37** to execute control algorithms. The data stored in the memory **37** may be received via the operator interface **28**, one or more input/output ports, a network connection, and/or be preloaded prior to assembly of the control circuitry **30**.

[0043] The control circuitry **30** may monitor the current and/or voltage of the arc **24** using on one or more sensors **36** positioned on, within, along, and/or proximate to the wire feeder **14**, weld cable **38**, and/or torch **16**. The one or more sensors **36** may comprise, for example, current sensors, voltage sensors, impedance sensors, temperature sensors, acoustic sensors, and/or other appropriate sensors. In some examples, the control circuitry **30** may determine and/or control the power conversion circuitry **32** to produce an appropriate power output, arc length, and/or electrode extension based at least in part on feedback from the sensors **36**.

[0044] FIG. **3** shows a more detailed view of the control circuitry **30** and power conversion circuitry **32** of the welding-type power supply **12**. In some examples, the power supply **12** may comprise a switched mode power supply. As shown, the power conversion circuitry **32** includes an input rectifier **322**, a stacked boost converter **324**, an inverter **326**, and an output rectifier **328**, connected along a common bus **301**. In some examples, the input rectifier **322** and/or output rectifier **328** may be half wave rectifiers or full wave rectifiers. In some examples, the inverter **326** has a half bridge topology or a full bridge topology, though other topologies may be used. In some examples, the stacked boost converter **324** may be a more traditional boost converter. In some examples, the stacked boost converter **324** may be a more general pre-regulator, such as, for example, a boost converter, a buck converter, and/or be a boost/buck converter.

[0045] In operation, the input rectifier **322** rectifies the AC input power **34** to DC power. The stacked boost converter **324** may then step up (and/or "boost") the DC power as desired. In examples where the stacked boost converter **324** includes a buck converter, the DC power may also be stepped down (or "bucked"). The inverter **326** may then invert the DC power to AC power to achieve additional power performance. Finally, the output rectifier **328** converts the AC power back to DC power for output (as shown, via arrow **303**) to the previously discussed welding components (e.g., wire feeder **14** and/or welding torch **16**). In some examples, welding components may use AC rather than DC power, and the output rectifier **328** may be omitted or bypassed.

[0046] In the example of FIG. **3**, the control circuitry **30** includes a weld controller **302**, a boost controller **304**, and an inverter controller **306**. As shown, the boost controller **304** controls the stacked boost converter **324**, and the inverter controller **306** controls the inverter **326**. More particularly, the boost controller **304** outputs one or more boost control signals to the stacked boost converter **324** via line **312**, and the inverter controller **306** outputs one or more inverter control signals to the inverter **326** via line **314**. In some examples, the weld controller **302**, boost controller **304**, and/or inverter controller **306** may be implemented through one or more single integrated circuit package and/or through one or more discrete circuits. In some examples, the weld controller **302**, boost controller **304**, and/or inverter controller **306** may be implemented through one or more processors **35** executing machine readable instructions stored in one or more memories **37**.

[0047] In the example of FIG. **3**, the stacked boost converter **324** includes controllable circuit elements **308***a*, and the inverter **326** includes one or more controllable circuit elements **308***b*. The controllable circuit elements **308** (e.g., transistors, switches, relays etc.) are configured to change states (e.g., open/close, turn off/on, etc.) in response to (and/or according to) the boost control signal(s) and/or inverter control signal(s), respectively. In examples where the controllable circuit elements comprise transistors, the transistors may comprise any suitable transistors, such as, for example MOSFETs, JFETs, IGBTs, BJTs, etc.

[0048] In some examples, the operation of the stacked boost converter **324** and/or inverter **326** may be dependent upon the boost control signal(s) and inverter control signal (s), respectively, and/or the controllable circuit elements **308** they control. For example, the power output of the stacked boost converter **324** may be dependent on (amongst other things) a duty cycle of the boost control signal(s). Likewise, the power output of the inverter **326** may be dependent on (amongst other things) a duty cycle of the inverter control signal(s).

[0049] In the example of FIG. **3**, the weld controller **302** outputs one or more weld control signals to the boost controller **304** and inverter controller **306** via line **310**. In some examples, the boost controller **304** and inverter controller **306** are configured to control the stacked boost converter **324** and inverter **326** using, at least in part, the weld control signal(s) (and/or data and/or information encoded in and/or represented by the weld control signal(s)). For example, the weld controller **302** may determine that more or less power (and/or voltage/current) needs to be output by the power conversion circuitry **32**, and output weld control signals to the boost controller **304** and/or inverter **326** representative of this determination. The boost controller **304** and/or inverter controller **306** may adjust the boost and/or inverter control signals accordingly, such as by increasing or decreasing the duty cycle of their respective control signals, for example. Though not shown, in some examples the weld control signal(s) may be processed through a filter (such as, for example, a Proportional-Integral-Derivative (PID) controller and/or an Infinite Impulse Response (IIR) filter) before being received by the boost controller **304** and/or inverter controller **306**.

[0050] In the example of FIG. **3**, the weld controller **302** receives operator input from the operator interface **28** and feedback input from the various sensors **36** of the welding-type system **10**. While not shown, in some examples the boost controller **304** and/or inverter controller **306** may also receive feedback input from the sensors **36** and use this input when outputting the boost control signal(s) and/or inverter control signal(s) to control the stacked boost converter **324** and/or inverter **326**, respectively. In some examples, some or all of the feedback input from the various sensors **36** may be processed through a filter (such as, for example, a Proportional-Integral-Derivative (PID) controller and/or an Infinite Impulse Response (IIR) filter), before being received and/or used by the weld controller **302**, boost controller **304**, and/or inverter controller **306**. In some examples, some or all of the feedback input from the various sensors **36** may be processed through a filter (such as, for example, a Proportional-Integral-Derivative (PID) controller and/or an Infinite Impulse Response (IIR) filter) with the weld control signal (s).

[0051] In some examples, the weld controller **302** may use the operator input and/or feedback input when generating the weld control signal(s) sent to the boost controller **304** and/or inverter **326**. For example, the operator may input weld settings through the operator interface **28**, which are then communicated to the weld controller **302**. The weld settings may indicate a particular type of target welding operation and/or welding-type power. The feedback input may indicate the type (and/or characteristics, parameters, properties, etc.) of welding-type power being presently output by the welding-type power supply **12**, via the power conversion circuitry **32**. The weld controller **302** may thus determine what, if any, adjustments need to be made to welding-type power output to achieve the target welding-type power and/or operation, and output its weld control signal(s) to the boost controller **304** and/or inverter controller **306** to effect these adjustments.

[0052] In some examples, the weld controller **302** may determine, predict, and/or derive a load (and/or draw) on the welding-type power supply **12** based on operator input via the operator interface **28** and/or feedback from the feedback sensors **22**, **36**. For example, the weld controller **302** may receive operator input relating to the load on the welding-type power supply **12**, and/or the welding-type power being used (and/or consumed, conducted, drawn, etc.), such as an indication that a certain welding-type operation is about to occur and/or command to produce a welding-type output for a certain welding-type operation. As another example, one of the sensors **22**, **36** may be a torch sensor that sends one or more signals to the weld controller **302** representative of a torch activation and/or deactivation (e.g., via trigger pull/release). In such an example, the weld controller **302** may determine, derive, and/or predict there is (or soon will be) a significant load (e.g., a load greater than a threshold load, and/or above a target power and/or current output) on the welding-type power supply **12** while the torch is activated, and/or a low load (e.g., a load less than a threshold load, and/or below a target power and/or current output) when the torch is deactivated (and/or following a timeout period after deactivation).

[0053] As yet another example, one of the sensors **36** may be a foot switch sensor that sends one or more signals to the weld controller **302** representative of a foot switch activation and/or deactivation. In such an example, the weld controller **302** may determine, derive, and/or predict there is (or soon will be) a significant load on the welding-type power supply **12** while the foot switch is activated, and/or a low load when the foot switch is deactivated (and/or following a timeout period after deactivation). As an additional example, one of the feedback sensors **22**, **36** may be a current sensor, and the weld controller **302** may use the current through the system to determine a load on the system (e.g., no or low current=no or low load). In some examples, one or more of the sensors **36** may be a motion sensor (e.g., an accelerometer, light sensor, video sensor, ultrasonic sensor, microwave sensor, etc.), and the weld controller **302** may determine, derive, and/or predict a significant load when the motion sensor detects motion of an associated welding component (e.g., the welding torch **16** and/or workpiece **26**). In some examples, the weld controller **302** may receive one or more signals from one or more sensors **36** that indicate an immediate and/or impending short circuit and/or a break in the arc **24**, and the weld controller **302** may determine, derive, and/or predict the load on the system from this information. In some examples, the weld controller **302** may determine, derive, and/or predict that a short circuit and/or break in the arc **24** has occurred (or will occur) based on one or more signals from the one or more sensors **36**, and determine, derive, and/or predict the load on the system from this information.

[0054] The example weld controller **302** implements certain low load (and/or burst/idle mode) procedures when the weld controller **302** detects and/or determines there is a sufficiently low load. In some examples, the weld controller **302** may compare the load on the welding-type power supply **12** to a threshold load level to determine whether there is a sufficiently low load. In some examples, the threshold load level may be programmatically determined (e.g., based on sensor input and/or operator input), stored in memory **37**, entered by an operator through the operator interface, or otherwise established. Once a low load is determined, the weld controller **302** may take certain actions to increase (e.g., maximize) efficiency.

[0055] In particular, the weld controller **302** may adjust control of the boost controller **304** and/or inverter controller **306** during low loads. For example, the weld controller **302** may output one or more weld control signals to the inverter controller **306** that are representative of a command to deactivate and/or cease sending inverter control signals to the inverter **326**. In some examples, the inverter controller **306** may be implemented through one or more processors **35** and/or integrated circuit packages, which function only when receiving an enable signal from the weld controller **302**. In such an example, the weld controller **302** may decline to provide an enable signal (e.g., as one or more of the weld control signals sent to the inverter controller **306**) during periods of low load, such that the no inverter control signals are sent to the inverter **326**. Without the inverter control signals, the controllable circuit elements **308*b*** of the inverter **326** may remain in a single state (e.g., off, open, deactivated, etc.) and the inverter **326** may effectively stop functioning and/or be turned off (and/or deactivated).

[0056] In some examples, the weld controller **302** may instead, or additionally, output one or more weld control signals to the inverter controller **306** representative of a command to change the frequency and/or duty cycle of its inverter control signals, so as to more effectively function in a low load state where less output power is needed. In some examples, the weld controller **302** may instead, or additionally, output one or more weld control signals to the boost controller **304** that are representative of a command to cease sending boost control signals, and/or change the frequency and/or duty cycle of the boost control signals, so as to more effectively function in a low load state where less output power is needed. In some examples, the boost controller **304** may be implemented through one or more processors **35** and/or integrated circuit packages, which function only when receiving an enable signal from the weld controller **302**. In such an example, the weld controller **302** may decline to provide an enable signal (e.g., as one or more of the weld control signals sent to the boost controller **304**) during periods of low load, such that the no boost control signal(s) are sent to the stacked boost converter **324**.

[0057] In the example of FIG. **3**, the inverter controller **306** shares a connection **316** with the boost controller **304**. The inverter controller **306** and the boost controller **304** may share information and/or data through this connection **316**. For example, the boost controller **304** may receive data from the inverter controller **306** indicating whether the inverter controller **306** (and/or inverter **326**) is enabled or disabled (and/or activated/deactivated). In some examples, the boost controller **304** may receive data from the inverter controller **306** indicating a frequency and/or duty cycle of the inverter control signals. The boost controller **304** may determine that the power supply **12** is operating in a low load (and/or idle, burst, etc.) mode when the inverter controller **306** (and/or inverter **326**) is disabled/deactivated and/or operating at a low duty cycle and/or low frequency (e.g., a frequency and/or duty cycle below an input, stored, and/or derived threshold level). In some examples, the boost controller **304** may conclude that the power supply **12** is operating at a low load based on weld control signals the boost controller **304** receives directly from the weld controller **302** (e.g., a command to reduce the duty cycle and/or frequency of the boost control signals below an input, stored, and/or derived threshold level).

[0058] In the example of FIG. **3**, the boost controller **304** implements a noise mitigation procedure **100**. In some examples, the noise mitigation procedure **100** may be implemented through one or more analog and/or discrete circuits. In some examples, the noise mitigation procedure **100** may be implemented through programmatic instructions saved in memory **37** and/or executed by one or more processors **35**, such as in examples where some or all of the functions of the boost controller **304** are implemented by one or more processors **35** executing programmatic instructions saved in memory **37**. The noise mitigation procedure **100** may be executed when the power supply **12** is under a low load (e.g., in response to a determination and/or signal indication of low load) in order to ensure that audible noise is prevented, suppressed, and/or minimized.

[0059] FIG. **4** shows a flowchart illustrating a method **400** of operating the boost controller **304**. Block **402** of the method **400** is representative of a recurring decision (and/or loop) of the method **400**, where the boost controller **304** determines whether the power supply **12** is operating at a low load (and/or in a burst/idle mode). If there is not a low load (e.g., normal load, high load, etc.) then the method **400** proceeds to block **404**, where normal operation of the boost controller **304** is executed. If there is a low load, then the method **400** proceeds to block **406**, where the noise mitigation procedure **100** is executed.

[0060] As shown in the example of FIG. **4**, the noise mitigation procedure **100** may include any one or more of several component procedures. As shown, the noise mitigation procedure **100** includes frequency based components **102**, and a deactivation component **104**. The frequency based components **102** includes a frequency dithering component **108** and an inaudible frequency component **106**. In some examples, only one of the component procedures may actually be executed during low load. In some examples, several or all of the component procedures may be executed during low load. In some examples, the selection of component procedures to be executed and/or order of execution may be predetermined, determined via operator input, determined based on input from the sensors **36**, and/or otherwise determined.

[0061] The inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) when the power supply **12** is operating under a low load. During normal operation, the boost controller **304** (and/or stacked boost converter **324**) may operate at a switching frequency of approximately 10 kHz. In some examples, the boost controller **304** (and/or stacked boost converter **324**) may operate at a switching frequency between approximately 7 kHz and 15 kHz during normal operation. The inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency to be outside of this normal operating range. More particularly, the inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency to a frequency outside of the audible frequency range for humans.

[0062] The audible frequency range for humans is generally between 15 Hertz (Hz) and 18,000 Hz (or 18 kiloHertz (kHz)). Thus, in some examples, the inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) to be approximately 19 kHz or 20 kHz. In some examples, inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) to be above 20 kHz, such as 20.5 kHz, 21 kHz, 21.5 kHz, or 22 kHz. In some examples, the inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) to be between approximately 18 kHz and 22 kHz. In some examples, the inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) to be less than 18 kHz. For example, the inaudible frequency component **106** of the noise mitigation procedure **100** may change the switching frequency to be just outside of, or on the edge of, the approximately 7-15 kHz normal operating range (e.g., 14.8 kHz, 14.9 kHz, 15 kHz, 15.1 kHz, 15.2 kHz, etc.).

[0063] By changing the switching frequency to an inaudible frequency, the boost controller **304** controls the potentially vibrating components in the stacked boost converter **324** to avoid audible frequencies. By dynamically changing the switching frequency to a frequency outside the audible range during periods of low load, the boost controller **304** controls the noise generated by the vibrating components to be inaudible to human ears.

[0064] The frequency dithering component **108** of the noise mitigation procedure **100** may dither the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) to spread out the noise generated by the vibrating components of the stacked boost converter **324** over a wider range of frequencies with smaller magnitude. Dithering refers to an intentional application of noise to a signal in order to randomize and/or de-correlate the resulting signal. Thus, the frequency dithering component **108** may change the switching frequency of the boost controller **304** (and/or stacked boost converter **324**) according to some dithering (and/or randomizing) algorithm.

[0065] In some examples, the dithering algorithm may shift the switching frequency among and/or between frequencies outside of the audible range. In some examples, the dithering algorithm may shift the switching frequency among and/or between frequencies within the audible range. In some examples, the dithering algorithm may shift the switching frequency among and/or between frequencies both within and outside of the audible range. When the switching frequency changes, the frequency of the noise produced by the vibrating components will change as well. In some examples, the dithering may be conducted continually, without regard to (high or low) load. If the dithering is done correctly, any noise generated by the vibrating components of the stacked boost converter **324** will be less audible and less distracting, and/or more subtle, subdued, and/or muted.

[0066] The deactivation component **104** of the noise mitigation procedure **100** deactivates the boost controller **304** and/or the stacked boost converter **324**. More particularly, execution of the deactivation component **104** causes the boost controller **304** to cease sending boost control signals to the stacked boost converter. As the controllable circuit elements **308***a* of the stacked boost converter **324** are dependent upon the boost control signals to change state, and the stacked boost converter **324** dependent upon controllable circuit elements **308** to operate, the cessation of boost control signals may effectively deactivate and/or disable the stacked boost converter **324**. Deactivated, the vibrating components of the stacked boost converter **324** will produce no audible noise.

[0067] FIG. **5** shows method **500** of operating the control circuitry **30** of the welding power supply **12**. The method **500** may be implemented by, for example, executing machine readable instructions (e.g., stored in memory **37**) using the control circuitry **30** (e.g., one or more processor **37**). At block **502**, the weld controller **302** receives operator input via the operator interface **28**. In some examples, the block **502** may be skipped if there is no operator input and/or if the operator input is not relevant. At block **504**, the weld controller **302** receives feedback from the various feedback sensors **36** of the welding-type system **10**. At block **506**, the weld controller **302** determines the load on the welding-type power supply **12**. In some examples, this determination may be based, at least in part, on feedback input and/or operator input, as outlined above. At block **508**, the weld controller **302** compares the load with a threshold load level, to determine whether the control circuitry **30** should perform a low load operation **510** or a normal operation **512**.

[0068] In normal operation **512**, the boost controller **304** and/or inverter controller **306** operate at a normal (e.g., default) switching frequency. As discussed above, in some examples, the normal switching frequency for the boost controller **304** (and/or stacked boost converter **324**) and/or the inverter controller **306** (and/or inverter **326**) may be between 7 kHz and 15 kHz (e.g., 10 kHz). At block **514**, during normal operation **512**, the weld controller **302** may send one or more weld control signals to activate and/or enable the boost controller **304** and/or stacked boost converter **324** at normal switching frequency. At block **516**, during normal operation **512**, the weld controller **302** may send one or more weld control signals to activate and/or enable the inverter controller **306** and/or inverter **326** to run at a normal switching frequency.

[0069] In some examples, where the boost controller **304** and/or stacked boost converter **324** were previously deactivated, the weld controller **302** may delay activating the inverter controller **306** and/or inverter **326** at block **516** for some time after activating the boost controller **304** and/or stacked boost converter **324** at block **514**. This delay may reduce some stability challenges (e.g., transformer saturation) that may present themselves during reactivation in periods of higher loads. For example, the weld controller **302** may delay for a period of time determined by the control circuitry **30** based on operator input via the operator interface **28**, and/or sensor input via the feedback sensors **36**. In some examples, the weld controller **302** may delay for approximately 200 milliseconds (ms). In some examples, the weld controller **302** may delay for a period of between 100 ms and 500 ms. Following this delay, the inverter controller **306** and/or inverter **326** may be reactivated at block **516**, and the method **500** may repeat beginning at block **502**.

[0070] During low load operation **510**, the weld controller **302** may deactivate the inverter **326** at block **511**, as previously discussed. The boost controller **304** may then determine the power supply **12** is operating at a low load, based on the deactivation of the inverter controller **306**, and/or on some other data, as previously described. The boost controller **304** may then execute the noise mitigation procedure **100** in response to a low load determination, as previously described.

[0071] One advantage of the present disclosure is that it is possible to implement the noise mitigation procedure **100** primarily (and/or entirely) as programmatic instructions (e.g., software), without requiring additional hardware changes and/or accommodations. This may allow the design to perform more flexibly, without adding bill of material cost. Another advantage relating to the software implementation is the design cycle time savings compared to changing hardware and repeating already completed testing.

[0072] While the present apparatus, systems, and/or methods have been described with reference to certain implementations, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present apparatus, systems, and/or methods. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. Therefore, it is intended that the present apparatus, systems, and/or methods not be limited to the particular implementations disclosed, but that the present apparatus, systems, and/or methods will include all implementations falling within the scope of the appended claims.

What is claimed is:

1. A welding-type power supply, comprising:

power conversion circuitry configured to convert input power to welding-type output power; and

control circuitry configured to control the power conversion circuitry using a control signal, the control signal having a signal frequency, and the control circuitry configured to set the signal frequency based on a load state, wherein the control circuitry is configured to set the signal frequency to a second frequency outside of an audible frequency range in response to the load state comprising a low load.

2. The power supply of claim **1**, wherein the load state comprises a high load or a low load.

3. The power supply of claim **1**, wherein the load state comprises a high load when the welding-type output power is used during a welding-type operation and the low load when the welding-type output power is not used during a welding-type operation.

4. The power supply of claim **3**, wherein the control circuitry is configured to set the signal frequency to a first frequency in response to the load state comprising the high load, and to the second frequency in response to the load state comprising the low load.

5. The power supply of claim **4**, wherein the first frequency is within the audible frequency range.

6. The power supply of claim **4**, wherein the second frequency is higher than the first frequency.

7. The power supply of claim **4**, wherein the first frequency is between approximately 7 kHz and 15 kHz, and the second frequency is not between approximately 7 kHz and 15 kHz.

8. The power supply of claim **1**, wherein the power conversion circuitry comprises a stacked boost converter having a controllable circuit element, the controllable circuit element configured to switch between a first state and a second state based on the control signal.

9. A welding-type system, comprising:

a welding-type instrument configured to use welding-type output power during a welding-type operation; and

a welding-type power supply, comprising:

power conversion circuitry configured to convert input power to the welding-type output power; and

control circuitry configured to control the power conversion circuitry using a control signal, the control signal having a signal frequency, and the control circuitry configured to set the signal frequency based on a load state, wherein the control circuitry is configured to set the signal frequency to a second frequency outside of an audible frequency range in response to the load state comprising a low load.

10. The welding system of claim **9**, wherein the load state comprises a high load when the welding-type instrument is conducting the welding-type operation and the low load when the welding-type instrument is not conducting the welding-type operation.

11. The welding system of claim **10**, wherein the control circuitry is configured to set the signal frequency to a first frequency in response to the load state comprising the high load, and to the second frequency in response to the load state comprising the low load.

12. The welding system of claim **11**, wherein the second frequency is zero.

13. The welding system of claim **11**, wherein the control circuitry is further configured to set the signal frequency to a third frequency in response to the load state comprising the low load.

14. The welding system of claim **11**, wherein the first frequency is between approximately 7 kHz and 15 kHz, and the second frequency is not between approximately 7 kHz and 15 kHz.

15. A method for controlling a welding-type power supply, comprising:

determining a load state of a welding-type power supply;

setting a non-zero signal frequency of a control signal based on the load state, wherein the signal frequency is set to a second frequency outside of an audible frequency range in response to the load state comprising a low load; and

controlling power conversion circuitry of the welding-type power supply using the control signal.

16. The method of claim **15**, wherein determining the load state comprises determining whether an inverter of the power conversion circuitry is active.

17. The method of claim **16**, wherein determining whether the inverter is active comprises determining whether a welding-type operation is active.

18. The method of claim **17**, wherein the load state comprises a high load when the welding-type operation or the inverter is active and the low load when the welding-type operation or the inverter is inactive.

19. The method of claim **15**, wherein determining the load state comprises predicting a future load state based on sensor input.

20. The method of claim **15**, wherein setting the signal frequency comprises setting the signal frequency to a first frequency when the load state is a high load and setting the signal frequency to the second frequency when the load state is the low load, the second frequency being higher than the first frequency.

* * * * *