US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12390873
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Pfaller; Andrew

Systems and methods to control welding-type power supplies using AC waveforms and/or DC pulse waveforms

Abstract

An example welding-type power supply includes: power conversion circuitry configured to convert input power to welding-type power having at least one of an alternating current (AC) waveform or a pulse waveform; an interface configured to receive an input representative of a selected frequency of the AC waveform or the pulse waveform; and control circuitry configured to: determine an amperage parameter of the welding-type power; based on the amperage parameter, determine a range of frequencies of the AC waveform or the pulse waveform; control the interface to output an indication of the selected frequency with respect to the determined range of frequencies; and control the power conversion circuitry to output the welding-type power at the selected frequency and based on the amperage parameter.

Inventors: **Pfaller; Andrew (Hilbert, WI)**

Applicant: **Illinois Tool Works Inc.** (Glenview, IL)

Family ID: **1000008767322**

Assignee: **Illinois Tool Works Inc. (Glenview, IL)**

Appl. No.: **17/066806**

Filed: **October 09, 2020**

Prior Publication Data

Document Identifier	Publication Date
US 20210129251 A1	May. 06, 2021

Related U.S. Application Data

us-provisional-application US 62929252 20191101

Publication Classification

Int. Cl.: **B23K9/09** (20060101); **B23K9/095** (20060101)

U.S. Cl.:

CPC **B23K9/093** (20130101); **B23K9/0953** (20130101);

Field of Classification Search

CPC: B23K (9/09); B23K (9/095); B23K (9/0953); B23K (9/0956); B23K (9/10); B23K (9/1056)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
5473139	12/1994	Matsui	219/130.51	B23K 9/092
6335511	12/2001	Rothermel	N/A	N/A
8993925	12/2014	Fujiwara	219/130.33	B23K 9/125
9776273	12/2016	Fujiwara	N/A	N/A
2004/0251910	12/2003	Smith	N/A	N/A
2005/0189334	12/2004	Stava	N/A	N/A
2007/0170164	12/2006	Nadzam	N/A	N/A
2008/0245775	12/2007	Opderbecke	219/121.45	B23K 9/167
2009/0071949	12/2008	Harris	219/130.1	B23K 9/1062
2010/0133250	12/2009	Sardy	219/130.31	B23K 9/125
2010/0237052	12/2009	Daniel	219/136	B23K 9/0953
2011/0114611	12/2010	Cole	N/A	N/A
2011/0204033	12/2010	Schartner	N/A	N/A
2012/0006800	12/2011	Ryan	219/130.21	B23K 9/0953
2012/0241429	12/2011	Knoener	N/A	N/A
2013/0226479	12/2012	Grosjean	702/58	G01R 31/52
2014/0110385	12/2013	Hearn	219/130.1	B23K 9/091
2014/0251969	12/2013	Stoner et al.	N/A	N/A
2014/0251971	12/2013	Hearn	N/A	N/A
2015/0041449	12/2014	Fujiwara	N/A	N/A
2015/0076129	12/2014	Spear	N/A	N/A
2016/0167152	12/2015	Ulrich	219/130.32	B23K 9/1006
2017/0036288	12/2016	Albrecht	N/A	N/A
2017/0165775	12/2016	Knoener	N/A	N/A
2017/0225254	12/2016	Ulrich	N/A	B23K 9/0953
2018/0050412	12/2017	Kadlec	N/A	N/A
2019/0015922	12/2018	Inoue	N/A	N/A
2019/0070689	12/2018	Bunker	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
1453927	12/2002	CN	N/A

105531063	12/2015	CN	N/A

OTHER PUBLICATIONS

Canadian Office Action Appln No. 3,096,648 dated Oct. 28, 2021. cited by applicant
Canadian Office Action Appln No. 3,096,651 dated Oct. 28, 2021. cited by applicant
European Office Communication Appln No. 20203385.8 dated Apr. 8, 2021. cited by applicant

---

Primary Examiner: Abraham; Ibrahime A

Assistant Examiner: Mills, Jr.; Joe E

Attorney, Agent or Firm: McAndrews, Held & Malloy, Ltd.

Background/Summary

BACKGROUND
(1) This disclosure relates generally to welding-type systems using repeated waveforms and, more particularly, to systems and methods to control welding-type power supplies using AC waveforms and/or DC pulse waveforms.
SUMMARY
(2) Systems and methods to control welding-type power supplies using AC waveforms and/or DC pulse waveforms are disclosed, substantially as illustrated by and described in connection with at least one of the figures, as set forth more completely in the claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a schematic diagram of an example welding system including a welding-type power supply configured to output welding-type power, in accordance with aspects of this disclosure.
(2) FIG. **2**A is an example user interface that may implement the user interface of FIG. **1** to enable an operator to adjust one or more parameters of a welding-type output waveform, and/or to output an indication of a selected parameter with respect to a determined range of parameters.
(3) FIG. **2**B illustrates the example user interface in response to a change in the frequency for a selected amperage
(4) FIG. **2**C is another example user interface that may implement the user interface of FIG. **1** to enable an operator to adjust one or more parameters of a welding-type output waveform, and/or to output another type of indication of a selected parameter with respect to a determined range of parameters.
(5) FIG. **2**D is another example user interface that may implement the user interface of FIG. **1** to output an indication of a selected frequency with respect to a determined range of frequencies.
(6) FIG. **3**A is a chart representative of an example table or function that may be used by the welding-type power supply of FIG. **1** to determine a frequency parameter, a frequency range, an amperage parameter, and/or an amperage range.
(7) FIG. **3**B is a chart representative of another example table or function that may be used by the welding-type power supply of FIG. **1** to determine a frequency parameter, a frequency range, an amperage parameter, and/or an amperage range.
(8) FIG. **3**C is a chart representative of another, multi-dimensional table or function that may be used by the welding-type power supply of FIG. **1** to determine a frequency parameter, a frequency

range, an amperage parameter, and/or an amperage range, based on one or more additional parameters.
(9) FIG. **4** is a flowchart illustrating example machine readable instructions which may be executed by the welding-type power supply of FIG. **1** to select and control a frequency of an output waveform.
(10) FIG. **5** is a flowchart illustrating example machine readable instructions which may be executed by the welding-type power supply of FIG. **1** to determine whether a frequency modification is acceptable based on one or more predetermined relationships.
(11) FIG. **6** is a flowchart illustrating example machine readable instructions which may be executed by the welding-type power supply of FIG. **1** to control an interface to output an indication of a selected frequency with respect to a determined range, based on one or more predetermined relationships.
(12) FIG. **7** is a flowchart illustrating example machine readable instructions which may be executed by the welding-type power supply of FIG. **1** to select and control an amperage parameter of an output waveform.
(13) FIG. **8** is a flowchart illustrating example machine readable instructions which may be executed by the welding-type power supply of FIG. **1** to determine whether an amperage modification is acceptable based on one or more predetermined relationships.
(14) FIG. **9** is a flowchart illustrating example machine readable instructions which may be executed by the welding-type power supply of FIG. **1** to control an interface to output an indication of a selected amperage with respect to a determined range, based on one or more predetermined relationships.
(15) The figures are not to scale. Where appropriate, the same or similar reference numerals are used in the figures to refer to similar or identical elements.

DETAILED DESCRIPTION

(16) Gas tungsten arc welding (GTAW), also referred to as TIG welding, enable weld operators to use cyclic waveforms that repeat based on a selected frequency and/or non-cyclic waveforms that occur based on the selected frequency. For example, an operator may select a frequency of an AC waveform and/or a number of pulses per second for an AC or DC pulse waveform (referred to herein as the “frequency” of the DC pulse waveform. Conventional welding-type power supplies enable operators to select the frequency within the capabilities of the welding-type power supply. However, the resistance and/or inductance of the welding circuit can result in poor welding performance in certain ranges of parameters and/or combinations of parameters.
(17) As used herein, “amperage” refers to an amount of welding-type current, and may include an instantaneous current, an average current, an RMS current, a peak current, an electrode negative (EN) current, and/or an electrode positive (EP) current.
(18) Disclosed methods and apparatus reduce the likelihood of poor welding conditions when using AC and/or DC pulse waveforms by 1) automatically selecting one or more AC and/or DC pulse parameters in response to changes in other parameter(s), and/or 2) providing an indication to an operator of a selected or modified parameter value with respect to an empirically determined acceptable range of values for the selected or modified parameter. In some examples, the welding power supply stores one or more tables, algorithms, and/or other data representative of predetermined relationships between the waveform frequency and amperage parameter(s). The predetermined relationships may include 1) 1:1 corresponding relationships between amperage and frequency to automatically select frequency based on amperage, 2) preferred or optimal combinations of frequencies and amperages (e.g., ranges of frequencies for a given amperage, ranges of amperages for a given frequency, etc.) 3) acceptable (e.g., less effective, less preferred) combinations of frequencies and amperages, and/or 4) unacceptable or disallowed combinations of frequencies and amperages. The relationships, combinations, and/or ranges may be selected based on other parameters or conditions (e.g., measured inductance, waveform type, etc.).

(19) In some example systems and methods, a frequency of the AC and/or pulse waveform is automatically controlled or selected based on a commanded amperage parameter, such as a target current. The dependency of the frequency on the commanded amperage parameter may be based on an average current, an RMS current, a peak current, an electrode negative (EN) current, and/an electrode positive (EP) current. Additionally or alternatively, the amperage may be controlled or selected based on the commanded frequency.

(20) In some examples, the frequency is automatically and synchronously adjusted in response to changes to preset amperages (e.g., via an operator interface, via remote control, etc.). Additionally or alternatively, the welding system may enable the operator to select one of multiple dependency levels (e.g., low, medium, high), in which different dependency levels have a different relationship (e.g., slope) between the amperage and the frequency.

(21) While lower frequencies and/or lower currents are less likely to be adversely affected by inductance of the welding circuit than higher frequencies and/or higher currents, lower frequencies can result in poor welding performance. Some example systems and methods apply a lower limit to the frequency. Additionally or alternatively, the welding power supply may apply an upper limit to the frequency to avoid operating in amperage and frequency ranges that exceed the ability of the power supply to drive current as required by the waveform.

(22) In some examples, the frequency and/or the amperage may be controlled based on additional parameters, such as a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance. The additional parameters may be reflected in the predetermined relationships stored in the welding power supply for control and/or notifications.

(23) In addition or as an alternative to automatically controlling the frequency based on the amperage parameter (and/or vice versa), example systems and methods may output an indication of a selected frequency (or amperage) with respect to range of frequencies determined based on the amperage (or frequency).

(24) As used herein, “power conversion circuitry” and/or “power conversion circuits” refer to circuitry and/or electrical components that convert electrical power from one or more first forms (e.g., power output by a generator) to one or more second forms having any combination of voltage, current, frequency, and/or response characteristics. The power conversion circuitry may include power limiting circuitry, output selection circuitry, measurement and/or control circuitry, and/or any other circuits to provide appropriate features.

(25) As used herein, the terms “first” and “second” may be used to enumerate different components or elements of the same type, and do not necessarily imply any particular order. For example, while in some examples a first time occurs prior to a second time within a time period, the terms “first time” and “second time” do not imply any specific order in which the first or second times occur relative to the other within the time period.

(26) The term “welding-type system,” as used herein, includes any device capable of supplying power suitable for welding, plasma cutting, induction heating, Carbon Arc Cutting-Air (e.g., CAC-A) and/or hot wire welding/preheating (including laser welding and laser cladding), including inverters, converters, choppers, resonant power supplies, quasi-resonant power supplies, etc., as well as control circuitry and other ancillary circuitry associated therewith.

(27) As used herein, the term “welding-type power” refers to power suitable for welding, plasma cutting, induction heating, CAC-A and/or hot wire welding/preheating (including laser welding and laser cladding). As used herein, the term “welding-type power supply” and/or “power supply” refers to any device capable of, when power is applied thereto, supplying welding, plasma cutting, induction heating, CAC-A and/or hot wire welding/preheating (including laser welding and laser cladding) power, including but not limited to inverters, converters, resonant power supplies, quasi-resonant power supplies, and the like, as well as control circuitry and other ancillary circuitry associated therewith.

(28) As used herein, a “circuit,” or “circuitry,” includes any analog and/or digital components, power and/or control elements, such as a microprocessor, digital signal processor (DSP), software, and the like, discrete and/or integrated components, or portions and/or combinations thereof.

(29) The terms “control circuit,” “control circuitry,” and/or “controller,” as used herein, may include digital and/or analog circuitry, discrete and/or integrated circuitry, microprocessors, digital signal processors (DSPs), and/or other logic circuitry, and/or associated software, hardware, and/or firmware. Control circuits or control circuitry may be located on one or more circuit boards that form part or all of a controller, and are used to control a welding process, a device such as a power source or wire feeder, and/or any other type of welding-related system.

(30) As used herein, the term “memory” includes volatile and non-volatile memory devices and/or other storage device.

(31) As used herein, the term “torch,” “welding torch,” “welding tool” or “welding-type tool” refers to a device configured to be manipulated to perform a welding-related task, and can include a hand-held welding torch, robotic welding torch, gun, gouging tool, cutting tool, or other device used to create the welding arc.

(32) As used herein, the term “welding mode,” “welding process,” “welding-type process” or “welding operation” refers to the type of process or output used, such as current-controlled (CC), voltage-controlled (CV), pulsed, gas metal arc welding (GMAW), flux-cored arc welding (FCAW), gas tungsten arc welding (GTAW, e.g., TIG), shielded metal arc welding (SMAW), spray, short circuit, CAC-A, gouging process, cutting process, and/or any other type of welding process.

(33) Disclosed example welding-type power supplies include: power conversion circuitry configured to convert input power to welding-type power having at least one of an alternating current (AC) waveform or a pulse waveform, an interface configured to receive an input representative of a selected frequency of the AC waveform or the pulse waveform, and control circuitry configured to: determine an amperage parameter of the welding-type power; based on the amperage parameter, determine a range of frequencies of the AC waveform or the pulse waveform; control the interface to output an indication of the selected frequency with respect to the determined range of frequencies; and control the power conversion circuitry to output the welding-type power at the selected frequency and based on the amperage parameter.

(34) In some examples, each cycle of the AC waveform comprises an electrode negative portion and an electrode positive portion. In some example welding-type power supplies, the amperage parameter includes at least one of an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive peak current, or an electrode positive commutation current.

(35) In some example welding-type power supplies, the interface is configured to receive the amperage parameter. In some example welding-type power supplies, the control circuitry is configured to limit the selection of the frequency via the operator interface, based on at least one of an upper frequency limit or a lower frequency limit. Some example welding-type power supplies further include an output device configured to output a notification in response to determining that a difference between the selected frequency and a frequency limit is less than a threshold difference.

(36) In some example welding-type power supplies, the control circuitry is configured to determine an inductance of a welding-type circuit to which the power conversion circuitry is coupled to output the welding-type power, and the control circuitry is configured to determine the frequency based on the amperage parameter and the determined inductance. In some example welding-type power supplies, the control circuitry is configured to determine at least one of a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance, wherein the control circuitry is configured to determine the frequency based on the amperage parameter and at least one of the pulse peak current time, the pulse peak current percentage, the pulse background current time, the

pulse background current percentage, the AC waveform type, or the weld circuit inductance.
(37) In some example welding-type power supplies, each cycle of the pulse waveform comprises a peak current and a background current. In some example welding-type power supplies, the control circuitry is configured to determine the range of frequencies of the AC waveform or the pulse waveform based on a selected one of a plurality of predetermined relationships between the frequency and the amperage parameter.
(38) Some disclosed example welding-type power supplies include: power conversion circuitry configured to convert input power to welding-type power having at least one of an alternating current (AC) waveform or a pulse waveform, an interface configured to receive an input representative of a selected amperage, and control circuitry configured to: determine a frequency of the AC waveform or the pulse waveform; based on the frequency of the AC waveform or the pulse waveform, determine an amperage range; control the interface to output an indication of the selected amperage with respect to the determined amperage range; and control the power conversion circuitry to output the welding-type power at the selected amperage and based on the frequency.
(39) In some examples, each cycle of the AC waveform comprises an electrode negative portion and an electrode positive portion. In some example welding-type power supplies, the amperage parameter includes at least one of an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive peak current, or an electrode positive commutation current.
(40) In some example welding-type power supplies, the interface is configured to receive the frequency. In some example welding-type power supplies, the control circuitry is configured to limit the selection of the amperage via the operator interface, based on at least one of an upper amperage limit or a lower amperage limit. Some example welding-type power supplies further include an output device configured to output a notification in response to determining that a difference between the selected amperage and an amperage limit is less than a threshold difference.
(41) In some example welding-type power supplies, the control circuitry is configured to determine an inductance of a welding-type circuit to which the power conversion circuitry is coupled to output the welding-type power, and the control circuitry is configured to determine the amperage based on the frequency and the determined inductance. In some example welding-type power supplies, the control circuitry is configured to determine at least one of a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance, wherein the control circuitry is configured to determine the amperage based on the frequency and at least one of the pulse peak current time, the pulse peak current percentage, the pulse background current time, the pulse background current percentage, the AC waveform type, or the weld circuit inductance.
(42) In some example welding-type power supplies, each cycle of the pulse waveform comprises a peak current and a background current. In some example welding-type power supplies, the control circuitry is configured to determine the amperage range of the AC waveform or the pulse waveform based on a selected one of a plurality of predetermined relationships between the frequency and the amperage parameter.
(43) Turning now to the drawings, FIG. **1**A is a block diagram of an example welding system **100** having a welding-type power supply **102**, a remote interface **104**, and a welding torch **106**. The welding system **100** powers, controls, and/or supplies consumables to a welding application. In the example of FIG. **1**, the power supply **102** directly supplies welding-type output power to the welding torch **106**. The welding torch **106** is configured for gas tungsten arc welding (GTAW), which may be used to perform welding processes involving DC welding-type current, pulsed DC welding-type current waveforms, and/or AC waveforms. Example DC pulse waveforms that may be output by the power supply **102** have a peak phase at a peak current and a background phase at a background current, and one pulse cycle includes one peak phase and one background phase.

(44) The power supply **102** receives primary power **108** (e.g., from the AC power grid, an engine/generator set, a battery, or other energy generating or storage devices, or a combination thereof), conditions the primary power, and provides an output power to one or more welding devices in accordance with demands of the system **100**. The primary power **108** may be supplied from an offsite location (e.g., the primary power may originate from the power grid). The power supply **102** includes power conversion circuitry **110**, which may include transformers, rectifiers, switches, and so forth, capable of converting the AC input power to AC and/or DC output power as dictated by the demands of the system **100** (e.g., particular welding processes and regimes). The power conversion circuitry **110** converts input power (e.g., the primary power **108**) to welding-type power based on a target amperage (e.g., a weld current setpoint) and outputs the welding-type power via a weld circuit.

(45) The power supply **102** includes control circuitry **112** to control the operation of the power supply **102**. The power supply **102** also includes a user interface **114**. The control circuitry **112** receives input from the user interface **114**, through which a user may choose a process and/or input desired parameters (e.g., a voltage, a current, a frequency, pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, an AC balance, a weld circuit inductance, etc.). The user interface **114** may receive inputs using one or more input devices **115**, such as via a keypad, keyboard, physical buttons, switches, knobs, a mouse, a keyboard, a keypad, a touch screen (e.g., software buttons), a voice activation system, a wireless device, etc. Furthermore, the control circuitry **112** controls operating parameters based on input by the user as well as based on other current operating parameters. Specifically, the user interface **114** may include a display **116** for presenting, showing, or indicating, information to an operator.

(46) Similarly, the example remote interface **104** may include a user interface **134** having one or more input device(s) **135** and a display **136**. The user interface **134**, the input device(s) **135**, and/or the display **136** may be similar, identical, or different than the user interface **114**, the input device(s) **115**, and/or the display **116**.

(47) The control circuitry **112** may also include interface circuitry for communicating data to other devices in the system **100**, such as the remote interface **104**. For example, in some situations, the power supply **102** wirelessly communicates with the remote interface **104**. Further, in some situations, the power supply **102** communicates with the remote interface **104** using a wired connection, such as by using a network interface controller (NIC) to communicate data via a network (e.g., ETHERNET, 10baseT, 10base100, etc.), and/or. In some examples, the control circuitry **112** communicates with the remote interface **104** via the weld circuit.

(48) The control circuitry **112** includes at least one controller or processor **120** that controls the operations of the power supply **102**. The control circuitry **112** receives and processes multiple inputs associated with the performance and demands of the system **100**. The processor **120** may include one or more microprocessors, such as one or more “general-purpose” microprocessors, one or more special-purpose microprocessors and/or ASICS, and/or any other type of processing device. For example, the processor **120** may include one or more digital signal processors (DSPs).

(49) The example control circuitry **112** includes one or more storage device(s) **123** and one or more memory device(s) **124**. The storage device(s) **123** (e.g., nonvolatile storage) may include ROM, flash memory, a hard drive, and/or any other suitable optical, magnetic, and/or solid-state storage medium, and/or a combination thereof. The storage device **123** stores data (e.g., data corresponding to a welding application), instructions (e.g., software or firmware to perform welding processes), and/or any other appropriate data. Examples of stored data for a welding application include predetermined relationships between frequency and amperage, such as one or more look up tables, as described in more detail below.

(50) The memory device **124** may include a volatile memory, such as random access memory (RAM), and/or a nonvolatile memory, such as read-only memory (ROM). The memory device **124**

and/or the storage device(s) **123** may store a variety of information and may be used for various purposes. For example, the memory device **124** and/or the storage device(s) **123** may store processor executable instructions **125** (e.g., firmware or software) for the processor **120** to execute. In addition, one or more control regimes for various welding processes, along with associated settings and parameters, may be stored in the storage device **123** and/or memory device **124**.

(51) In some examples, a gas supply **128** provides shielding gases, such as argon, helium, carbon dioxide, and so forth, depending upon the welding application. The shielding gas flows to a valve **130**, which controls the flow of gas, and if desired, may be selected to allow for modulating or regulating the amount of gas supplied to a welding application. The valve **130** may be opened, closed, or otherwise operated by the control circuitry **112** to enable, inhibit, or control gas flow (e.g., shielding gas) through the valve **130**. Shielding gas exits the valve **130** and flows through a cable **138** (which in some implementations may be packaged with the welding power output) to the welding torch **106**, which provides the shielding gas to the welding application. In some examples, the welding system **100** does not include the gas supply **128**, the valve **130**, and/or the cable **138**.

(52) In the example of FIG. **1**, the power supply **102** includes a communications transceiver **118**, and the remote interface **104** includes a communications transceiver **119**. The communications transceivers **118**, **119** each include a corresponding receiver circuit **121** and a corresponding transmitter circuit **122**. The example communications transceivers **118**, **119** enable the remote interface **104** to transmit commands to the power supply **102** and/or receive information from the power supply **102**. Example commands may include commands to set parameters and/or otherwise configure the power supply **102**. The remote interface **104** may receive information about the configuration of the power supply **102**.

(53) The remote interface **104** further includes control circuitry **132**, which may include one or more processor(s) **120**, one or more storage device(s) **123**, and/or memory **124**, and/or may store and execute machine readable instructions **125**. The control circuitry **132**, the processor(s) **120**, the storage device(s) **123**, and/or the memory **124** may be similar, identical, or different than the control circuitry **112**, the processor(s) **120**, the storage device(s) **123**, and/or the memory **124** of the power supply **102**.

(54) The welding torch **106** delivers the welding power and/or shielding gas for a welding application. The welding torch **106** is used to establish a welding arc between the welding torch **106** and a workpiece **146**. A welding cable **140** couples the torch **106** to the power conversion circuitry **110** to conduct current to the torch **106**. A work cable **148** couples the workpiece **146** to the power supply **102** (e.g., to the power conversion circuitry **110**) to provide a return path for the weld current (e.g., as part of the weld circuit). The example work cable **148** is attachable and/or detachable from the power supply **102** for ease of replacement of the work cable **148**. The work cable **148** may be terminated with a clamp **150** (or another power connecting device), which couples the power supply **102** to the workpiece **146**.

(55) In some examples, one or more sensors **147** are included with or connected to the welding torch **106** to monitor one or more welding parameters (e.g., power, voltage, current, inductance, impedance, etc.) to inform the control circuitry **132** and/or **112** during the welding process.

(56) To aid a weld operator in configuring the welding-type power supply **102** appropriately (e.g., welding parameters) for an AC waveform or DC pulse process, the example storage device(s) **123** may store tables **126** or other data representative of relationships between frequency and amperage. The tables **126** may define the relationships for different values of other parameters, such as welding circuit inductance, waveform characteristics (e.g., AC waveform shape, peak and/or background current and/or dwell time for pulse, etc.), and/or any other variables. The example tables **126** may be populated based on empirical testing using different combinations of welding parameters.

(57) FIG. **2**A is an example user interface **200** that may implement the user interface **114**, **134** of FIG. **1** to enable an operator to adjust one or more parameters of a welding-type output waveform,

and/or to output an indication of a selected parameter with respect to a determined range of parameters. The example user interface **200** of FIG. **2**A includes a display **202**, input buttons **204***a*-**204***e*, **206**, **208**, **210**, and an input knob **212**. The example buttons **204***a*-**204***e*, **206**, **208**, **210**, and the input knob **212** may implement the input devices **115**, **135** of FIG. **1**.

(58) The example buttons **204***a*-**204***e* enable an operator to select one or more weld parameters for adjustment or recall (e.g., by recalling a weld schedule or stored set of parameters). Once a parameter is selected, the example knob **212** receives inputs to change the value of the parameter, such as by increasing (e.g., incrementing) or decreasing (e.g., decrementing) a value of a parameter and/or selecting between discrete values of a parameter. For example, an operator may turn the knob **212** to select an AC waveform or a DC pulse process, to change a welding amperage, change an AC or DC pulse frequency, and/or to change any other parameters.

(59) The button **208** may be selected to confirm a selected parameter. The button **208** enables navigation, such as by canceling a parameter change and/or reverting to a prior menu.

(60) The example button **210** may be selected to enable or disable an automatic configuration mode, in which the control circuitry **112**, **132** automatically configures one or more parameters in response to changes in one or more other parameters. For example, when the automatic configuration mode is selected, the control circuitry **112**, **132** may respond to changes in an amperage parameter (e.g., received via the knob **212**) with corresponding changes to a frequency for AC and/or DC pulse processes. Similarly, the control circuitry **112**, **132** may respond to changes in the frequency parameter by automatically configuring the amperage. To determine automatic changes, the example control circuitry **112**, **132** accesses a predetermined relationship stored in the storage device(s) **123** and/or memory **124**, such as a relationship between amperage and frequency. The predetermined relationship may be selected from multiple predetermined relationships based on other selected parameters, such as the type of welding process (e.g., AC, DC pulse), measured inductance, and/or any other parameters. The operator may be permitted to change the parameter from the automatically configured value, or may be prevented from making changes to an automatically configured value without disabling the automatic configuration mode.

(61) When the automatic configuration mode is disabled (or deselected), the control circuitry **112**, **132** permits the parameters specified in the predetermined relationships to be set independently. For example, the control circuitry **112**, **132** does not change the frequency based on changes to the amperage, and does not change the amperage based on changes to the frequency.

(62) In the example of FIG. **2**A, the display **202** presents a graphic **214** that indicates the selected value of a parameter (e.g., the frequency) with respect to a range of frequencies. The example graphic **214** includes an indicator **216** within a trapezoid **218** representing the range of values. The center portion **220** of the trapezoid represents a preferred or optimal value of the parameter, according to the selected predetermined relationship. The left portion **222** and the right portion **224** of the trapezoid **218** represent deviations of the parameter value from the value represented by the center portion **220**. As the value of the parameter is modified (e.g., via the knob **212**), the control circuitry **112**, **132** updates the graphic **214** to move the indicator **216** within the trapezoid **218** based on the value of the parameter with respect to the range.

(63) In the example of FIG. **2**A, the left portion **222** and the right portion **224** may have different characteristics, such as different colors or patterns, to indicate the relative advantages or disadvantages of the corresponding parameter range. For example, the right portion **224** representing a higher frequency for a given amperage may be colored a color associated with caution or disadvantage to indicate that the right portion **224** represents a disadvantageous frequency range. Conversely, the left portion **222** representing a lower frequency for the given amperage may be colored a color associated with acceptability to indicate that, while not the preferred range, the left portion **222** represents an acceptable range.

(64) In addition to the graphic **214**, the example display **202** may also display the selected value of the parameter numerically, and/or may display information to guide the operator to make changes

to the selected value (e.g., increase parameter for thinner materials, decrease parameter for thicker materials).
(65) The range of frequencies represented by the graphic **214** may be determined based on another parameter (e.g., amperage) specified in the stored predetermined relationships. For example, when the amperage parameter is selected, the control circuitry **112**, **132** automatically determines a range of frequencies. The range of frequencies may include only preferred frequencies, or may include less preferred, but acceptable frequencies.
(66) In the example of FIG. **2**A, the determined range does not include frequencies that have been set in the stored predetermined relationships. In some examples, an operator may be prevented by the control circuitry **112**, **132** from setting the value of the frequency parameter outside of the acceptable range.
(67) FIG. **2**B illustrates the example user interface **200** in response to a change in the frequency for a selected amperage, such as an operator input to change the frequency via the knob **212**. The example user interface **200** may similarly represent a change in the amperage for a selected frequency.
(68) In some examples, the control circuitry **112** may update the graphic **214** representative of the frequency value and the frequency range based on changes to the amperage, or vice versa. For example, while the indicator **216** of FIG. **2**B is in the right portion **224** of the graphic **214** for a given amperage, a change to the amperage will cause the control circuitry **112** to recalculate the frequency range, change the frequency ranges represented by the graphic **214** and the portions **220**, **222**, **224**, and display the indicator **216** with respect to the graphic **214** based on the updated range.
(69) FIG. **2**C is another example user interface **230** that may implement the user interface **114**, **134** of FIG. **1** to enable an operator to adjust one or more parameters of a welding-type output waveform, and/or to output another type of indication of a selected parameter with respect to a determined range of parameters. The example user interface **230** of FIG. **2**B includes the display **202**, the buttons **204*a*-204*e***, **206-210** and the knob **212** of FIG. **2**A.
(70) In the example of FIG. **2**C, the display **202** presents an amperage value **232** and a frequency value **234** (e.g., pulses per second for DC pulses processes). The display **202** further presents an indication **236** of the frequency value **234** with respect to a determined range of values. In the example of FIG. **2**C, the indication **236** includes an indicator graphic **238** and an text explanation **240** of the frequency value, such as “above ideal range,” in which changes to the frequency above the determined frequency range may result in a limited ability of the power supply **102** to provide the specified pulse shape at the configured amperage. When the selected frequency is below the determined frequency range, the indication **236** may include a text explanation that changes to the frequency below the determined frequency range has a limited effect relative to changes to the frequency within the determined range.
(71) FIG. **2**D is another example user interface **250** that may implement the user interface **114**, **134** of FIG. **1** to output an indication of a selected frequency with respect to a determined range of frequencies. Additionally or alternatively, the user interface **250** may output an indication of a selected amperage with respect to a determined range of amperage.
(72) The example user interface **250** includes output displays **252**, **254**, which output the selected amperage and the selected frequency. However, the displays **252**, **254** may be configured to output a value for any parameter that is being configured by the operator, change to outputting a value and/or an identification of a selected parameter in response to selection of the parameter by the operator, and/or output values of default parameters in response to a lack of input (e.g., for a threshold time).
(73) The example user interface **250** further includes indicators **256**, **258**, **260** to provide an indication to the operator of the value of the amperage or frequency with respect to a determined range of values for the parameter. The example indicator **256** is a visual indicator (e.g., a light, an LED, etc.) that is lit when the selected frequency is considered a preferred (or ideal) value

determined based on the selected amperage. Additionally or alternatively, the indicator **256** may be configured to output the indication when the selected frequency is within a preferred (or ideal) range of frequencies determined by the control circuitry **112** based on the selected amperage.

(74) The example indicator **258** is a visual indicator (e.g., a light, an LED, etc.) that is lit when the selected frequency has reached (e.g., is equal to) an upper limit on the frequency, where the upper limit is determined based on the amperage. Similarly, the example indicator **260** is a visual indicator (e.g., a light, an LED, etc.) that is lit when the selected frequency has reached (e.g., is equal to) a lower limit on the frequency, where the lower limit is determined based on the amperage. In some examples, the control circuitry **112** controls the respective indicator **258**, **260** to light when the corresponding limit is reached by the operator selecting the frequency (e.g., by incrementing or decrementing the frequency via the knob **212**).

(75) The limits triggering the indicators **258**, **260** may be selected to be the limits of a preferred range and/or the limits of one or more acceptable ranges. When the limits of a preferred range is used, the control circuitry **112** may treat the limits as “soft” limits that may be exceeded (e.g., the operator may be permitted to select frequency values outside of the range represented by the limits), while continuing to output the indication via the corresponding indicator **258**, **260**. In some examples, when the limits of an acceptable range is used, the control circuitry **112** may treat the limits as “hard” limits that may not be exceeded, and output the indication via the corresponding indicator **258**, **260** while the selected frequency is equal to the corresponding lower or upper frequency limit. However, a preferred range of frequencies may be treated as “hard” limits and/or an acceptable range of frequencies may be treated as “soft” limits.

(76) While example indicators **256**, **258**, **260** are illustrated in FIG. **2**D, additional and/or alternative indicators may be used. For example, indicators may be included for both “hard” and “soft” limits and/or for different ranges (e.g., a preferred range vs. an acceptable range).

(77) While FIG. **2**D is described above with reference to selecting frequency and limits on the frequency based on the selected amperage, the example user interface **250** may additionally or alternatively operate the indicators **256**, **258**, **260** based on a selected amperage relative to an amperage range that is based on a selected frequency.

(78) Any of the example interfaces **200**, **230**, **250** may provide other indications of a frequency determined based on a selected amperage, or indications of an amperage determined based on a selected frequency. For example, the control circuitry **112** may control the determined parameter (e.g., frequency, amperage) to provide a visual or other indication (e.g., flashing, color, etc.) on a display or other output device that a displayed value of the parameter (e.g., frequency, amperage) has been automatically selected based on one or more other parameters (e.g., amperage, frequency, etc.).

(79) FIG. **3**A is a chart **300** representative of an example table or function that may be used by the welding-type power supply **102** of FIG. **1** to determine a frequency parameter, a frequency range, an amperage parameter, and/or an amperage range. The example chart **300** may be stored as one or more data structures, data points, and/or any other format in the storage devices **123** and/or memory **124** of FIG. **1**.

(80) The example chart **300** includes relationship **302**, which may be stored as one or more functions and/or data points. If the control circuitry **112**, **132** has enabled an automatic configuration mode, the control circuitry **112**, **132** may respond to a selection of the amperage parameter by determining a corresponding frequency according to the relationship **302**.

(81) The example chart **300** further illustrates ranges **304**, **306**, **308** representative of combinations of amperage and frequency values. The example range **304** is representative of preferred or optimal values of frequency for each amperage value or, conversely, preferred or optimal values of amperage for each frequency. The example range **306** is representative of secondary (e.g., less preferred, sub-optimal) values of frequency for each amperage value (or vice-versa), and the example range **308** is representative of performance-limited values of frequency for each amperage

value (or vice-versa).
(82) In some examples, the control circuitry **112** enables the operator to select a modified relationship **310** as a function of the relationship **302** (e.g., via the user interface **114** and/or the input device(s) **115**). For example, the control circuitry **112** may substitute a relationship **310** for the relationship **302** when automatically selecting frequency values or amperage values. The relationship **310** may be defined using, for example, a selected percentage deviation or by a fixed deviation. An example percentage deviation may include adjusting the frequency or amperage higher or lower than the value specified by the relationship **302** by a selected percentage of the frequency or amperage value. Other example percentage deviations may include adjusting the frequency or amperage higher or lower than the value specified by the relationship **302** by a selected percentage of the difference between the upper and lower limit values of the preferred range **304** (or a combination of the ranges **304**, **306**, and/or **308**), or a selected percentage of the difference between the value specified by the relationship **302** and the upper or lower limit value of the preferred range **304**. An example fixed deviation may include a set frequency or amperage difference, such as X Hz or X pulses per second higher or lower than the frequency specified by the relationship **302**.
(83) FIG. **3**B is a chart **320** representative of another example table or function that may be used by the welding-type power supply **102** of FIG. **1** to determine a frequency parameter, a frequency range, an amperage parameter, and/or an amperage range. The example chart **320** may be stored as one or more data structures, data points, and/or any other format in the storage devices **123** and/or memory **124** of FIG. **1**.
(84) Like the chart **300** of FIG. **3**A, the example chart **320** includes a preferred range **322** representative of preferred or optimal values of frequency for each amperage value, a secondary range **324** representative of secondary values of frequency for each amperage value, and a range **326** representative of performance-limited values. In contrast with the predetermined ranges of FIG. **3**A, which have upper and lower frequency limits that change with the amperage, the example ranges **322**, **324**, **326** have upper and lower frequency limits that change at predetermined amperage thresholds. For example, the ranges **322**, **324**, **326** have constant respective upper and lower frequency limits from 0 Amperes to 125 Amperes, from 125 Amperes to 266 Amperes, and from 266 Amperes to 425 Amperes. However, other amperage limits may be used.
(85) The portions of the chart outside the ranges **322**, **324**, **326** may indicate combinations of frequency and amperage that are not permitted by the control circuitry **112**, **132**. For example, for an output current of 100 Amperes, the control circuitry **112**, **132** may not increase the frequency beyond 350 Hz despite receiving inputs via the knob **212** to further increase the frequency. While the example range **324** includes lower frequency limits, in some examples the lower frequency limits of the range **324** is near 0 Hz, or the lowest frequency that the power supply **102** is capable of outputting AC or DC pulse welding power.
(86) In some examples, if a frequency is selected (e.g., via the operator interface **114**, **134**) that is within a threshold difference from the upper frequency limit or lower frequency limit, the control circuitry **112**, **132** outputs an notification to the operator, such as to indicate that the frequency is approaching the frequency limit. In other examples, the control circuitry **112**, **132** outputs an notification to the operator when the upper frequency limit or the lower frequency limit is reached.
(87) FIG. **3**C is a chart **340** representative of another, multi-dimensional table or function that may be used by the welding-type power supply **102** of FIG. **1** to determine a frequency parameter, a frequency range, an amperage parameter, and/or an amperage range, based on one or more additional parameters. The example chart **340** includes pulse peak time as a third parameter, though other parameters may be used.
(88) Like the example chart **300** of FIG. **3**A, the chart **340** includes a relationship **342** that may be used in an automatic configuration mode. The chart **340** further includes a preferred range **344** representative of preferred or optimal values of frequency for each amperage value, a secondary

range **346** representative of secondary values of frequency for each amperage value, and a range **348** representative of performance-limited values.
(89) In some examples, the preferred range includes all frequencies (or all frequencies that the power conversion circuitry is capable of outputting or configured to output) that are less than a threshold current. For example, low currents below a threshold current do not create distortion, regardless of the frequency used by the power conversion circuitry.
(90) FIG. **4** is a flowchart illustrating example machine readable instructions **400** which may be executed by the welding-type power supply **102** of FIG. **1** to select and control a frequency of an output waveform. The example instructions **400** may be stored in the storage device **123** and/or the memory **124**, and executed by the processor(s) **120**. The instructions **400** are discussed below with reference to the power supply **102** and the user interface **200** of FIG. **2**A. However, blocks **402-414** may be performed by the example remote interface **104** of FIG. **1**.
(91) At block **402**, the control circuitry **112** determines an amperage parameter for welding-type power to be output by the power conversion circuitry **110**. For example, the control circuitry **112** may receive a selection of an amperage parameter via the knob **212** of the user interface **200**. The amperage parameter may be a current setpoint, an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive peak current, or an electrode positive commutation current, and/or any other current.
(92) At block **404**, the control circuitry **112** determines whether the welding-type output is configured for an AC waveform, a DC pulse waveform, or a different welding process. For example, the control circuitry **112** may be capable of controlling the power conversion circuitry using different welding processes, including DCEN, DCEP, AC, and/or DC pulse waveforms, among others. If the welding-type output is not configured for either an AC waveform or a DC pulse waveform (block **404**), control returns to block **402**.
(93) If the welding-type output is configured for either an AC waveform or a DC pulse waveform (block **404**), at block **406** the control circuitry **112** determines whether automatic parameter configuration is selected (e.g., enabled). For example, the control circuitry **112** may determine whether the automatic configuration button **210** is selected on the user interface **200**.
(94) If automatic parameter configuration is selected (block **406**), at block **408** the control circuitry **112** determines a frequency of the waveform based on the amperage parameter. For example, the control circuitry **112** may access a predetermined relationship, such as the relationship **302** of FIG. **3**A, to determine a frequency that corresponds to the determined amperage parameter. The predetermined relationship may be fixed, or may be selected from multiple predetermined relationships based on one or more other parameter values. For example, parameter values that may be used to select a predetermined relationship may include a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance.
(95) In some examples, the control circuitry **112** determines an inductance of a welding-type circuit to which the power conversion circuitry **110** is coupled to output the welding-type power. For example, the control circuitry **112** may measure, calculate, and/or estimate the inductance of the weld circuit, and/or the inductance may be input by the user (e.g., via the user interface **114**, **134**). The control circuitry **112** may then be used to select an appropriate predetermined relationship (e.g., a three-dimensional lookup table or function, similar to the chart **340** of FIG. **3**C) to determine the frequency based on the amperage parameter and the determined inductance.
(96) Additionally or alternatively, the control circuitry **112** may identify (e.g., via a current sensor) when the current does not reach the peak current level or the background current level during a DC pulse process, which indicates that the inductance is too high for the selected amperage and frequency. In such examples, the control circuitry **112** may output a warning or alert that the current is not reaching to the intended level, or does not reach the intended level within the expected time,

due to detected high inductance and/or detected wave shape variations. Additionally or alternatively, the control circuitry **112** may automatically adjust the frequency in response to detecting that the expected wave shape is not obtained for a threshold number of pulses or cycles.
(97) At block **410**, the control circuitry **112** sets the frequency of the waveform to the determined frequency.
(98) After setting the frequency (block **410**), or if automatic parameter configuration is not selected (block **406**), at block **412** the control circuitry **112** determines whether an input has been received to modify the frequency. For example, the control circuitry **112** may permit changes to an automatically configured frequency, or the frequency may not be automatically configured. An example input to modify the frequency may be received via the input devices **115**, **135**, such as the knob **212** of FIGS. **2**A and/or **2**B.
(99) If an input to modify the frequency has been received (block **412**), at block **414** the control circuitry **112** determines whether a frequency modification is acceptable. For example, the control circuitry **112** may compare the selected frequency to one or more ranges of frequencies based on the amperage parameter, to determine whether the combination of amperage and frequency will lead to an acceptable weld condition. An example method to determine whether a frequency modification is acceptable is disclosed below with reference to FIG. **5**.
(100) If the frequency modification is acceptable (block **416**), at block **418** the control circuitry **112** sets the frequency of the waveform to the modified frequency. In some examples, the control circuitry **112** may output an indication of the modified frequency with respect to the range and/or with respect to a value that would be automatically configured (e.g., a preferred or optimal value), such as via the graphic **214** of FIG. **2**A. Conversely, if the frequency modification is not acceptable (block **416**), the control circuitry **112** outputs a notification that the modified frequency is outside of the frequency range. For example, the control circuitry **112** may output an indication such as the example indication illustrated in FIG. **2**B. After setting the frequency (block **418**) or outputting the notification (block **420**), control returns to block **412**.
(101) If an input to modify the frequency is not received (e.g., the user confirms that the frequency is acceptable) (block **412**), at block **420** the control circuitry **112** determines whether welding is active. For example, the control circuitry **112** may determine whether welding current is flowing or if there is an output voltage corresponding to an arc. If welding is active (block **422**), at block **424** the control circuitry **112** controls the power conversion circuitry **110** to output the welding-type power using the set frequency. The set frequency may be, for example, the automatically set frequency (block **410**) or the modified frequency (block **418**). Control iterates to block **422** to continue welding. If welding is not active (block **422**), control returns to block **402**.
(102) FIG. **5** is a flowchart illustrating example machine readable instructions **500** which may be executed by the welding-type power supply **102** of FIG. **1** to determine whether a frequency modification is acceptable based on one or more predetermined relationships. The example instructions **500** may be executed by the control circuitry **112**, **132** of FIG. **1** to implement block **414** of FIG. **4**. The example instructions **500** may enter from block **412** of FIG. **4**.
(103) At block **502**, the control circuitry **112** determines one or more frequency ranges based on the determined amperage parameter. For example, the control circuitry **112** may look up a predetermined relationship stored in the tables **126**. Example ranges are illustrated in FIGS. **3**A, **3**B, and **3**C. At block **504**, the control circuitry **112** determines whether the selected frequency (e.g., selected at block **412** of FIG. **4**) is within a preferred frequency range. For example, the control circuitry **112** may determine whether the selected frequency is in a respective preferred frequency range **304**, **322**, or **344** of FIG. **3**A, **3**B, or **3**C, based on the selected predetermined relationship, or any other range that is stored as a preferred or optimal range.
(104) If the selected frequency is not within a preferred frequency range (block **504**), at block **506** the control circuitry **112** determines whether the selected frequency is within an allowable frequency range. For example, the control circuitry **112** may determine whether the selected

frequency is in a respective acceptable or limited frequency range **306**, **308**, **324**, **326**, **346**, or **348** of FIG. **3**A, **3**B, or **3**C, based on the selected predetermined relationship, or any other range that is stored as a permissible or acceptable range for the power conversion circuitry **110** to implement.

(105) If the selected frequency is within a preferred frequency range (block **504**), or the selected frequency is within an allowable frequency range (block **506**), at block **508** the control circuitry **112** determines that the selected frequency is acceptable, or that the operator will be permitted to perform a welding operation using the selected frequency and amperage.

(106) Conversely, if the selected frequency is not within either of a preferred frequency range (block **504**) or an allowable frequency range (block **506**), at block **510** the control circuitry **112** determines that the selected frequency is not acceptable, or that the operator will not be permitted to perform a welding operation using the selected frequency and amperage.

(107) After determining that the selected frequency is acceptable (block **508**) or not acceptable (block **510**), the example instructions **500** end and return control to block **416** of FIG. **4**.

(108) FIG. **6** is a flowchart illustrating example machine readable instructions **600** which may be executed by the welding-type power supply **102** of FIG. **1** to control an interface to output an indication of a selected frequency with respect to a determined range, based on one or more predetermined relationships. The example instructions **600** may be stored in the storage device **123** and/or the memory **124**, and executed by the processor(s) **120**. The instructions **600** are discussed below with reference to the power supply **102** and the user interface **200** of FIG. **2**A. However, blocks **602-616** may be performed by the example remote interface **104** of FIG. **1**.

(109) At block **602**, the control circuitry **112** determines an amperage parameter for welding-type power to be output by the power conversion circuitry **110**. For example, the control circuitry **112** may receive a selection of an amperage parameter via the knob **212** of the user interface **200**. The amperage parameter may be a current setpoint, an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive peak current, or an electrode positive commutation current, and/or any other current.

(110) At block **604**, the control circuitry **112** determines whether the welding-type output is configured for an AC waveform, a DC pulse waveform, or a different welding process. For example, the control circuitry **112** may be capable of controlling the power conversion circuitry using different welding processes, including DCEN, DCEP, AC, and/or DC pulse waveforms, among others. If the welding-type output is not configured for either an AC waveform or a DC pulse waveform (block **604**), control returns to block **602**.

(111) If the welding-type output is configured for either an AC waveform or a DC pulse waveform (block **604**), at block **606** the control circuitry **112** determines a frequency range based on the amperage parameter. For example, the control circuitry **112** may determine a frequency range based on a predetermined relationship corresponding to one or more weld parameters, such as a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance. The determined frequency range may be selected from one or more sub-ranges, such as preferred ranges, acceptable ranges, and/or limited performance ranges, such as the ranges **304-308**, **322-326**, and **344-348** of FIGS. **3**A, **3**B, and **3**C. In some examples, the determined frequency range is limited to the preferred range specified in the tables **126**. In other examples, the determined frequency range may include an acceptable range, or an acceptable range and a limited performance range.

(112) At block **608**, the control circuitry **112** determines whether a selection of an AC or pulse frequency has been received. An example input to select the frequency may be received via the input devices **115**, **135**, such as the knob **212** of FIGS. **2**A and/or **2**B. If a frequency selection has been received (block **608**), at block **610** the control circuitry **112** compares the selected frequency to the determined frequency range.

(113) At block **612**, the control circuitry **112** outputs an indication of the selected frequency with respect to the determined range of frequencies. For example, the control circuitry **112** may output the graphic **214** of FIG. **2**A, the indicator graphic **258** and/or the text explanation **260** of FIG. **2**B, a visual alert, alarm, display, or graphic, an audible alert, alarm, or message, a communications notification (e.g., a phone alert, email, text message, etc.) and/or any other indication (e.g., message, alert, alarm, notification, etc.) that represents the value of the selected frequency with reference to the determined range of frequencies.

(114) At block **614**, the control circuitry **112** determines whether the selected frequency is within the determined frequency range. If the selected frequency is not within the determined frequency range (block **614**), at block **616** the control circuitry **112** outputs a notification (e.g., via the user interface **114**) that the selected frequency is outside of the determined frequency range. The notification may be in addition to or implemented into the indication of block **612**. Conversely, if the selected frequency is within the determined frequency range (block **614**), at block **618** the control circuitry **112** sets the frequency of the output waveform to the selected frequency.

(115) If a frequency selection has not been made (block **608**), after outputting the notification (block **616**), or after setting the frequency (block **618**), at block **620** the control circuitry **112** determines whether welding is active. For example, the control circuitry **112** may determine whether welding current is flowing or if there is an output voltage corresponding to an arc. If welding is active (block **620**), at block **622** the control circuitry **112** controls the power conversion circuitry **110** to output the welding-type power using the set frequency. Control iterates to block **620** to continue welding. If welding is not active (block **620**), control returns to block **602**.

(116) FIG. **7** is a flowchart illustrating example machine readable instructions **700** which may be executed by the welding-type power supply **102** of FIG. **1** to select and control an amperage parameter of an output waveform. The example instructions **700** may be stored in the storage device **123** and/or the memory **124**, and executed by the processor(s) **120**. The instructions **700** are discussed below with reference to the power supply **102** and the user interface **200** of FIG. **2**A. However, blocks **702-718** may be performed by the example remote interface **104** of FIG. **1**.

(117) At block **702**, the control circuitry **112** determines a frequency parameter for welding-type power to be output by the power conversion circuitry **110**. For example, the control circuitry **112** may receive a selection of a frequency parameter via the knob **212** of the user interface **200**. The frequency parameter may be number of pulses per second (e.g., for DC pulse operations) or a number of cycles per second (e.g., for AC operations).

(118) At block **704** the control circuitry **112** determines whether automatic parameter configuration is selected (e.g., enabled). For example, the control circuitry **112** may determine whether the automatic configuration button **210** is selected on the user interface **200**.

(119) If automatic parameter configuration is selected (block **704**), at block **706** the control circuitry **112** determines an amperage of the waveform based on the determined frequency. For example, the control circuitry **112** may access a predetermined relationship, such as the relationship **302** of FIG. **3**A, to determine an amperage that corresponds to the determined frequency. The predetermined relationship may be fixed, or may be selected from multiple predetermined relationships based on one or more other parameter values. For example, parameter values that may be used to select a predetermined relationship may include a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance. At block **708**, the control circuitry **112** sets the amperage parameter for the welding operation to the determined amperage.

(120) After setting the frequency (block **708**), or if automatic parameter configuration is not selected (block **704**), at block **710** the control circuitry **112** determines whether an input has been received to modify the amperage. For example, the control circuitry **112** may permit changes to an automatically configured amperage, or the amperage may not be automatically configured. An example input to modify the amperage may be received via the input devices **115**, **135**, such as the

knob **212** of FIGS. **2**A and/or **2**B.
(121) If an input to modify the amperage has been received (block **710**), at block **712** the control circuitry **112** determines whether an amperage modification is acceptable. For example, the control circuitry **112** may compare the selected amperage to one or more ranges of amperages based on the frequency, to determine whether the combination of amperage and frequency will lead to an acceptable weld condition. An example method to determine whether an amperage modification is acceptable is disclosed below with reference to FIG. **5**.
(122) If the amperage modification is not acceptable (block **714**), at block **716** the control circuitry **112** sets the amperage of the waveform to the modified amperage. In some examples, the control circuitry **112** may output an indication of the modified amperage with respect to the range and/or with respect to a value that would be automatically configured (e.g., a preferred or optimal value), such as via the graphic **214** of FIG. **2**A. Conversely, if the amperage modification is not acceptable (block **714**), the control circuitry **112** outputs a notification that the modified amperage is outside of the amperage range. For example, the control circuitry **112** may output an indication such as the example indication illustrated in FIG. **2**B. After setting the amperage (block **716**) or outputting the notification (block **718**), control returns to block **710**.
(123) If an input to modify the amperage is not received (e.g., the user confirms that the amperage is acceptable) (block **710**), at block **720** the control circuitry **112** determines whether welding is active. For example, the control circuitry **112** may determine whether welding current is flowing or if there is an output voltage corresponding to an arc. If welding is active (block **422**), at block **424** the control circuitry **112** controls the power conversion circuitry **110** to output the welding-type power using the set amperage. The set amperage may be, for example, the automatically set amperage (block **708**) or the modified frequency (block **716**). Control iterates to block **720** to continue welding. If welding is not active (block **720**), control returns to block **702**.
(124) FIG. **8** is a flowchart illustrating example machine readable instructions **800** which may be executed by the welding-type power supply **102** of FIG. **1** to determine whether an amperage modification is acceptable based on one or more predetermined relationships. The example instructions **800** may be executed by the control circuitry **112**, **132** of FIG. **1** to implement block **712** of FIG. **7**. The example instructions **800** may enter from block **710** of FIG. **7**.
(125) At block **802**, the control circuitry **112** determines one or more amperage ranges based on the determined frequency. For example, the control circuitry **112** may look up a predetermined relationship stored in the tables **126**. Example ranges are illustrated in FIGS. **3**A, **3**B, and **3**C. At block **804**, the control circuitry **112** determines whether the selected amperage (e.g., selected at block **412** of FIG. **4**) is within a preferred amperage range. For example, the control circuitry **112** may determine whether the selected amperage is in a respective preferred range **304**, **322**, or **344** of FIG. **3**A, **3**B, or **3**C, based on the selected predetermined relationship, or any other range that is stored as a preferred or optimal range.
(126) If the selected amperage is not within a preferred range (block **804**), at block **806** the control circuitry **112** determines whether the selected amperage is within an allowable amperage range. For example, the control circuitry **112** may determine whether the selected amperage is in a respective acceptable or limited range **306**, **308**, **324**, **326**, **346**, or **348** of FIG. **3**A, **3**B, or **3**C, based on the selected predetermined relationship, or any other range that is stored as a permissible or acceptable range for the power conversion circuitry **110** to implement.
(127) If the selected amperage is within a preferred amperage range (block **804**), or the selected frequency is within an allowable frequency range (block **806**), at block **808** the control circuitry **112** determines that the selected frequency is acceptable, or that the operator will be permitted to perform a welding operation using the selected frequency and amperage.
(128) Conversely, if the selected frequency is not within either of a preferred frequency range (block **804**) or an allowable frequency range (block **806**), at block **810** the control circuitry **112** determines that the selected frequency is not acceptable, or that the operator will not be permitted

to perform a welding operation using the selected frequency and amperage.

(129) After determining that the selected frequency is acceptable (block **808**) or not acceptable (block **810**), the example instructions **800** end and return control to block **714** of FIG. **4**.

(130) FIG. **9** is a flowchart illustrating example machine readable instructions **900** which may be executed by the welding-type power supply **102** of FIG. **1** to control an interface to output an indication of a selected amperage with respect to a determined range, based on one or more predetermined relationships. The example instructions **900** may be stored in the storage device **123** and/or the memory **124**, and executed by the processor(s) **120**. The instructions **900** are discussed below with reference to the power supply **102** and the user interface **200** of FIG. **2**A. However, blocks **902-916** may be performed by the example remote interface **104** of FIG. **1**.

(131) At block **902**, the control circuitry **112** determines an AC or DC pulse frequency parameter for welding-type power to be output by the power conversion circuitry **110**. For example, the control circuitry **112** may receive a selection of a frequency via the knob **212** of the user interface **200**. The frequency parameter may be number of pulses per second (e.g., for DC pulse operations) or a number of cycles per second (e.g., for AC operations).

(132) At block **904**, the control circuitry **112** determines an amperage range based on the frequency. For example, the control circuitry **112** may determine an amperage range based on a predetermined relationship corresponding to one or more weld parameters, such as a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance. The amperage parameter may be a current setpoint, an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive peak current, or an electrode positive commutation current, and/or any other current.

(133) The determined amperage range may be selected from one or more sub-ranges, such as preferred ranges, acceptable ranges, and/or limited performance ranges, such as the ranges **304-308**, **322-326**, and **344-348** of FIGS. **3**A, **3**B, and **3**C. In some examples, the determined amperage range is limited to the preferred range specified in the tables **126**. In other examples, the determined amperage range may include an acceptable range, or an acceptable range and a limited performance range.

(134) At block **906**, the control circuitry **112** determines whether a selection of an amperage has been received. An example input to select the amperage may be received via the input devices **115**, **135**, such as the knob **212** of FIGS. **2**A and/or **2**B. If an amperage selection has been received (block **906**), at block **908** the control circuitry **112** compares the selected amperage to the determined amperage range.

(135) At block **910**, the control circuitry **112** outputs an indication of the selected amperage with respect to the determined amperage range. For example, the control circuitry **112** may output the graphic **214** of FIG. **2**A, the indicator graphic **258** and/or the text explanation **260** of FIG. **2**B, and/or any other indication (e.g., message, alert, alarm, notification, etc.) that represents the value of the selected amperage with reference to the determined amperage range.

(136) At block **912**, the control circuitry **112** determines whether the selected amperage is within the determined amperage range. If the selected amperage is not within the determined amperage range (block **912**), at block **914** the control circuitry **112** outputs a notification (e.g., via the user interface **114**) that the selected amperage is outside of the determined amperage range. The notification may be in addition to or implemented into the indication of block **910**. Conversely, if the selected amperage is within the determined amperage range (block **912**), at block **916** the control circuitry **112** sets the amperage of the output waveform to the selected amperage.

(137) If an amperage selection has not been made (block **906**), after outputting the notification (block **914**), or after setting the amperage (block **916**), at block **918** the control circuitry **112** determines whether welding is active. For example, the control circuitry **112** may determine whether welding current is flowing or if there is an output voltage corresponding to an arc. If

welding is active (block **918**), at block **920** the control circuitry **112** controls the power conversion circuitry **110** to output the welding-type power using the set amperage. Control iterates to block **918** to continue welding. If welding is not active (block **918**), control returns to block **902**.

(138) The present methods and systems may be realized in hardware, software, and/or a combination of hardware and software A typical combination of hardware and software may include one or more application specific integrated circuits and/or chips. Some implementations may comprise a non-transitory machine-readable (e.g., computer readable) medium (e.g., FLASH memory, optical disk, magnetic storage disk, or the like) having stored thereon one or more lines of code executable by a machine, thereby causing the machine to perform processes as described herein. As used herein, the term “non-transitory machine-readable medium” is defined to include all types of machine readable storage media and to exclude propagating signals.

(139) As utilized 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, “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”. As utilized herein, the term “exemplary” means serving as a non-limiting example, instance, or illustration. As utilized herein, the terms “e.g.,” and “for example” set off lists of one or more non-limiting examples, instances, or illustrations. As utilized herein, circuitry is “operable” to perform a function whenever the circuitry comprises the necessary hardware and code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or not enabled (e.g., by a user-configurable setting, factory trim, etc.).

(140) While the present method and/or system has 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 method and/or system. 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. For example, block and/or components of disclosed examples may be combined, divided, re-arranged, and/or otherwise modified. Therefore, the present method and/or system are not limited to the particular implementations disclosed. Instead, the present method and/or system will include all implementations falling within the scope of the appended claims, both literally and under the doctrine of equivalents.

Claims

1. A welding-type power supply, comprising: power conversion circuitry configured to convert input power to welding-type power having at least one of an alternating current (AC) waveform or a pulse waveform; an interface configured to receive an input representative of a selected frequency of the AC waveform or the pulse waveform; and control circuitry configured to: determine a value of an amperage parameter of the welding-type power; based on the value of the amperage parameter, determine a range of frequencies of the AC waveform or the pulse waveform; control the interface to output a representation of the selected frequency with respect to representations of an upper frequency limit and a lower frequency limit of the determined range of frequencies; in response to a change in the selected frequency, control the interface to update the representation of the selected frequency with respect to the representations of the upper frequency limit and the

lower frequency limit of the range of frequencies; and control the power conversion circuitry to output the welding-type power at the selected frequency and based on the amperage parameter.
2. The welding-type power supply as defined in claim 1, wherein each cycle of the AC waveform comprises an electrode negative portion and an electrode positive portion.
3. The welding-type power supply as defined in claim 2, wherein the amperage parameter comprises at least one of an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive peak current, or an electrode positive commutation current.
4. The welding-type power supply as defined in claim 1, wherein the interface is configured to receive the value of the amperage parameter.
5. The welding-type power supply as defined in claim 4, wherein the control circuitry is configured to limit the selection of the frequency via the operator interface, based on at least one of the upper frequency limit or the lower frequency limit.
6. The welding-type power supply as defined in claim 5, further comprising an output device configured to output a notification in response to determining that a difference between the selected frequency and a frequency limit is less than a threshold difference.
7. The welding-type power supply as defined in claim 1, wherein the control circuitry is configured to determine an inductance of a welding-type circuit to which the power conversion circuitry is coupled to output the welding-type power, wherein the control circuitry is configured to determine the frequency based on the value of the amperage parameter and the determined inductance.
8. The welding-type power supply as defined in claim 1, wherein the control circuitry is configured to determine at least one of a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance, wherein the control circuitry is configured to determine the frequency based on the value of the amperage parameter and at least one of the pulse peak current time, the pulse peak current percentage, the pulse background current time, the pulse background current percentage, the AC waveform type, or the weld circuit inductance.
9. The welding-type power supply as defined in claim 1, wherein each cycle of the pulse waveform comprises a peak current and a background current.
10. The welding-type power supply as defined in claim 1, wherein the control circuitry is configured to determine the range of frequencies of the AC waveform or the pulse waveform based on a selected one of a plurality of predetermined relationships between the frequency and the value of the amperage parameter.
11. A welding-type power supply, comprising: power conversion circuitry configured to convert input power to welding-type power having at least one of an alternating current (AC) waveform or a pulse waveform; an interface configured to receive an input representative of a selected amperage; and control circuitry configured to: determine a frequency of the AC waveform or the pulse waveform; based on the frequency of the AC waveform or the pulse waveform, determine an amperage range; control the interface to output a representation of the selected amperage with respect to representations of an upper amperage limit and a lower amperage limit of the determined amperage range; in response to a change in the selected frequency, control the interface to update the representation of the selected amperage with respect to the representations of the upper amperage limit and the lower amperage limit of the determined amperage range; and control the power conversion circuitry to output the welding-type power at the selected amperage and based on the frequency.
12. The welding-type power supply as defined in claim 11, wherein each cycle of the AC waveform comprises an electrode negative portion and an electrode positive portion.
13. The welding-type power supply as defined in claim 12, wherein the selected amperage comprises at least one of an average current, a root-mean-square (RMS) current, a peak current, an electrode negative peak current, an electrode negative commutation current, an electrode positive

peak current, or an electrode positive commutation current.
14. The welding-type power supply as defined in claim 11, wherein the interface is configured to receive a selection of the frequency.
15. The welding-type power supply as defined in claim 14, wherein the control circuitry is configured to limit the selection of the amperage via the operator interface, based on at least one of the upper amperage limit or the lower amperage limit.
16. The welding-type power supply as defined in claim 15, further comprising an output device configured to output a notification in response to determining that a difference between the selected amperage and an amperage limit is less than a threshold difference.
17. The welding-type power supply as defined in claim 11, wherein the control circuitry is configured to determine an inductance of a welding-type circuit to which the power conversion circuitry is coupled to output the welding-type power, wherein the control circuitry is configured to determine the amperage based on the frequency and the determined inductance.
18. The welding-type power supply as defined in claim 11, wherein the control circuitry is configured to determine at least one of a pulse peak current time, a pulse peak current percentage, a pulse background current time, a pulse background current percentage, an AC waveform type, or a weld circuit inductance, wherein the control circuitry is configured to determine the amperage based on the frequency and at least one of the pulse peak current time, the pulse peak current percentage, the pulse background current time, the pulse background current percentage, the AC waveform type, or the weld circuit inductance.
19. The welding-type power supply as defined in claim 11, wherein each cycle of the pulse waveform comprises a peak current and a background current.
20. The welding-type power supply as defined in claim 11, wherein the control circuitry is configured to determine the amperage range of the AC waveform or the pulse waveform based on a selected one of a plurality of predetermined relationships between the frequency and the amperage parameter.