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(54) **HYDROGEN GENERATION SYSTEM WITH A CONTROLLABLE REACTIVE CIRCUIT AND ASSOCIATED METHODS**

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C25B 1/04 (2006.01)
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(52) **U.S. Cl.**
CPC ***C25B 1/04*** (2013.01); ***C25B 1/02*** (2013.01); ***C25B 9/04*** (2013.01); ***C25B 9/06*** (2013.01); ***C25B 11/02*** (2013.01); ***C25B 15/02*** (2013.01)

(58) **Field of Classification Search**
CPC C25B 1/04; C25B 9/06; C25B 15/02
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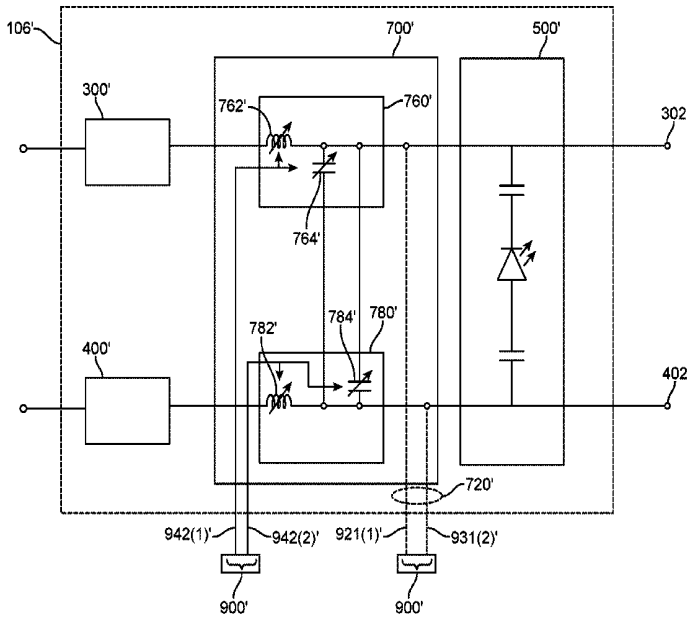
(57) **ABSTRACT**

A hydrogen generation system includes a pulsed drive signal generator to generate a pulsed drive signal, a hydrogen generation chamber to receive the pulsed drive signal and generate hydrogen from a feedstock material contained therein based on the pulsed drive signal and a controllable reactive circuit coupled between the pulsed drive signal generator and the hydrogen generation chamber. A hydrogen detection device is coupled to the hydrogen generation chamber to detect the generated hydrogen. A controller controls the controllable reactive circuit based on detection of the generated hydrogen.

25 Claims, 11 Drawing Sheets



Related U.S. Application Data

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(51) **Int. Cl.**

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C25B 9/06	(2006.01)
C25B 11/02	(2006.01)
C25B 15/02	(2006.01)

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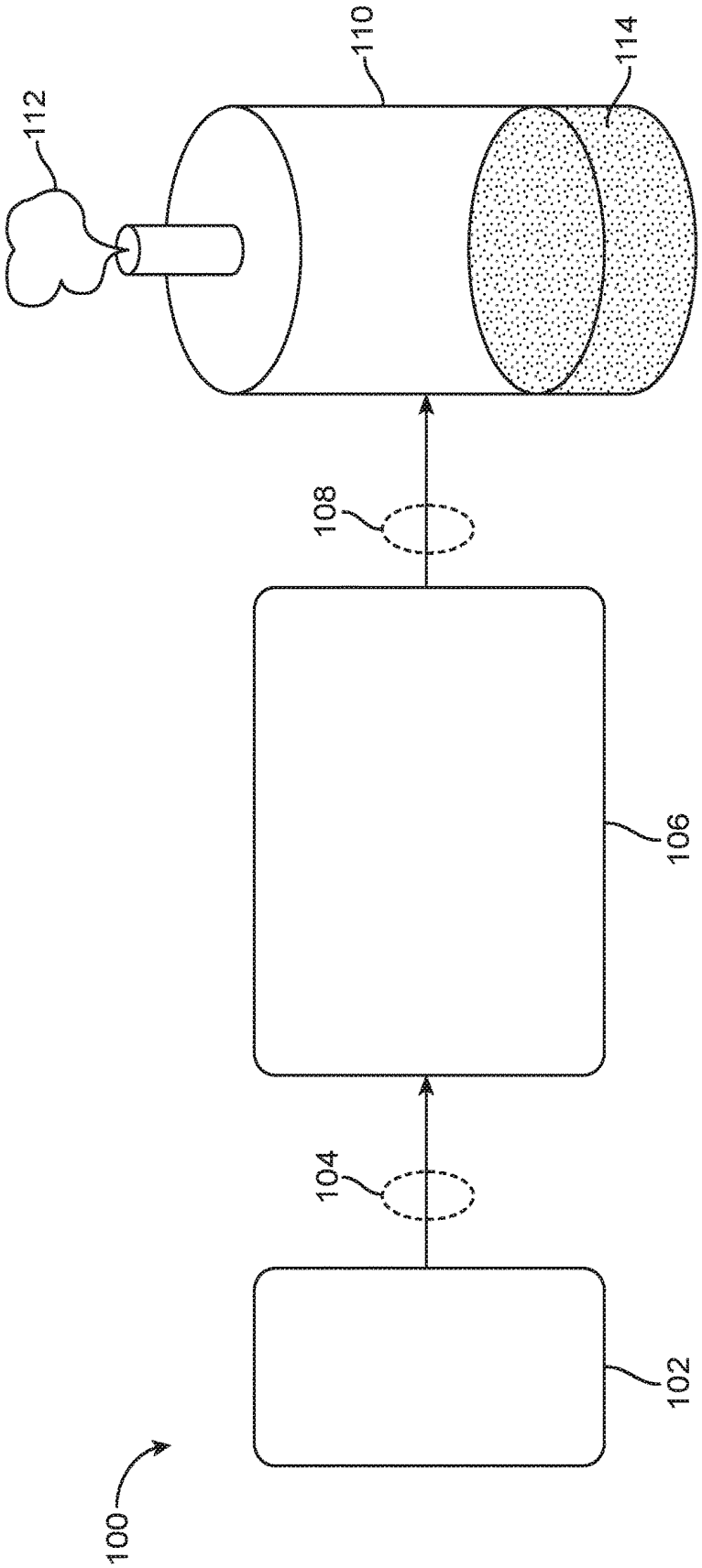


FIG. 1

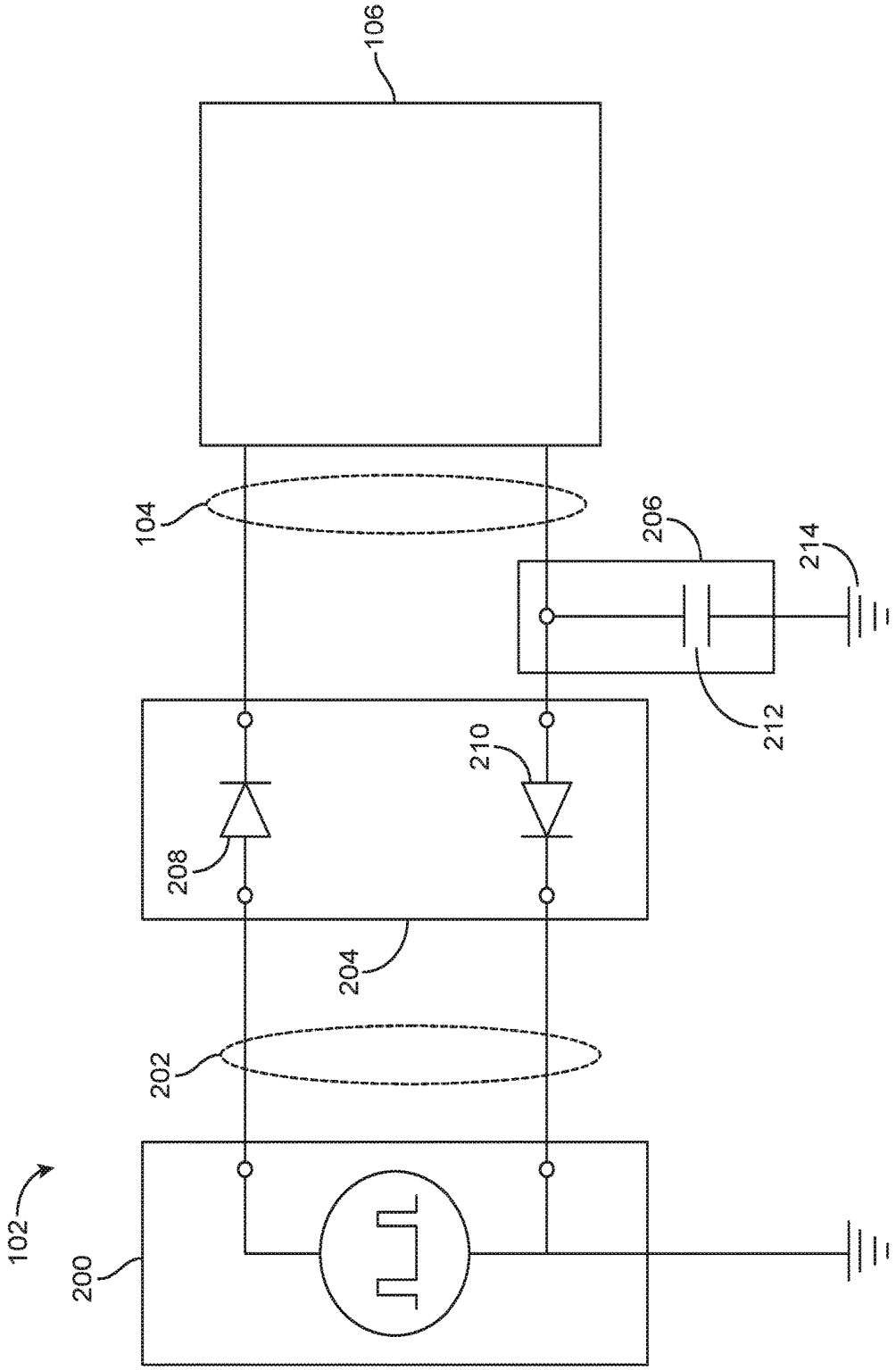
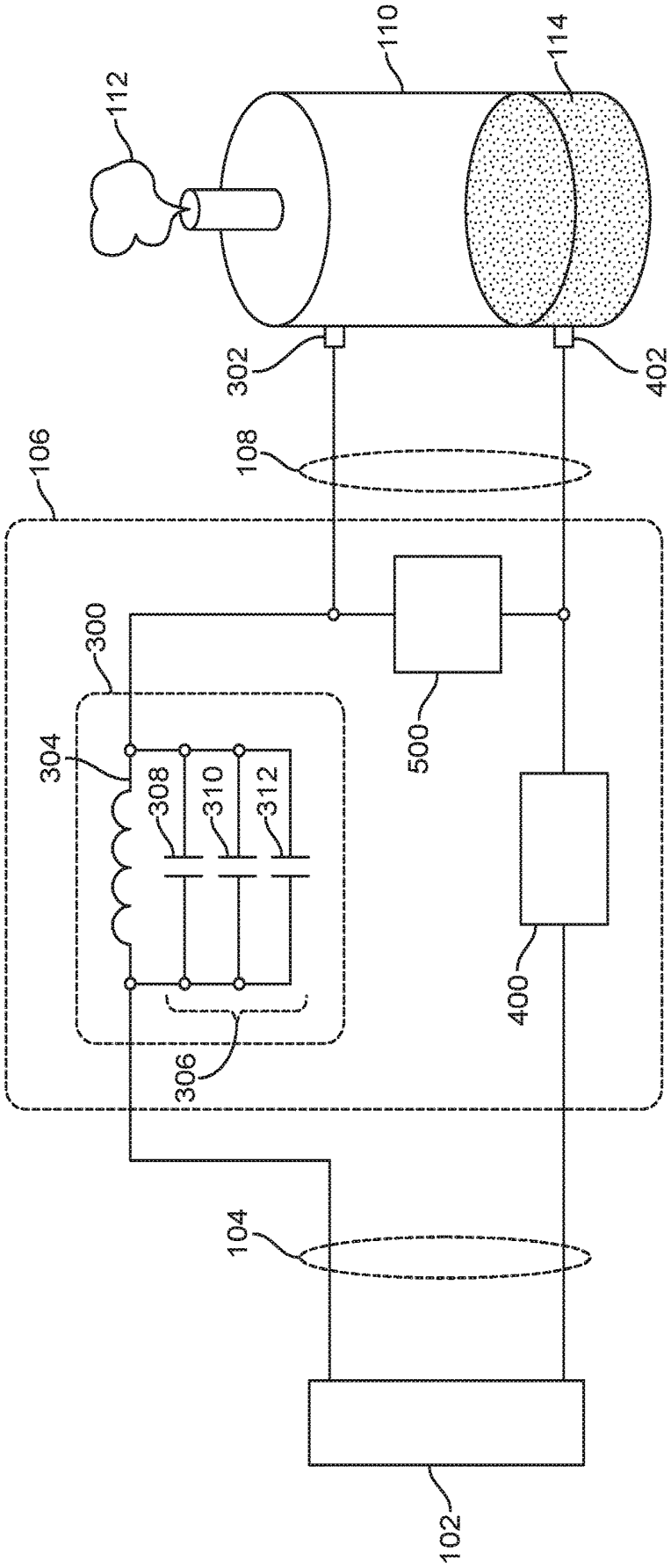


FIG. 2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114
112
302
402
106
108
300
500
304
308
310
312
306
400
104
102

FIG. 3

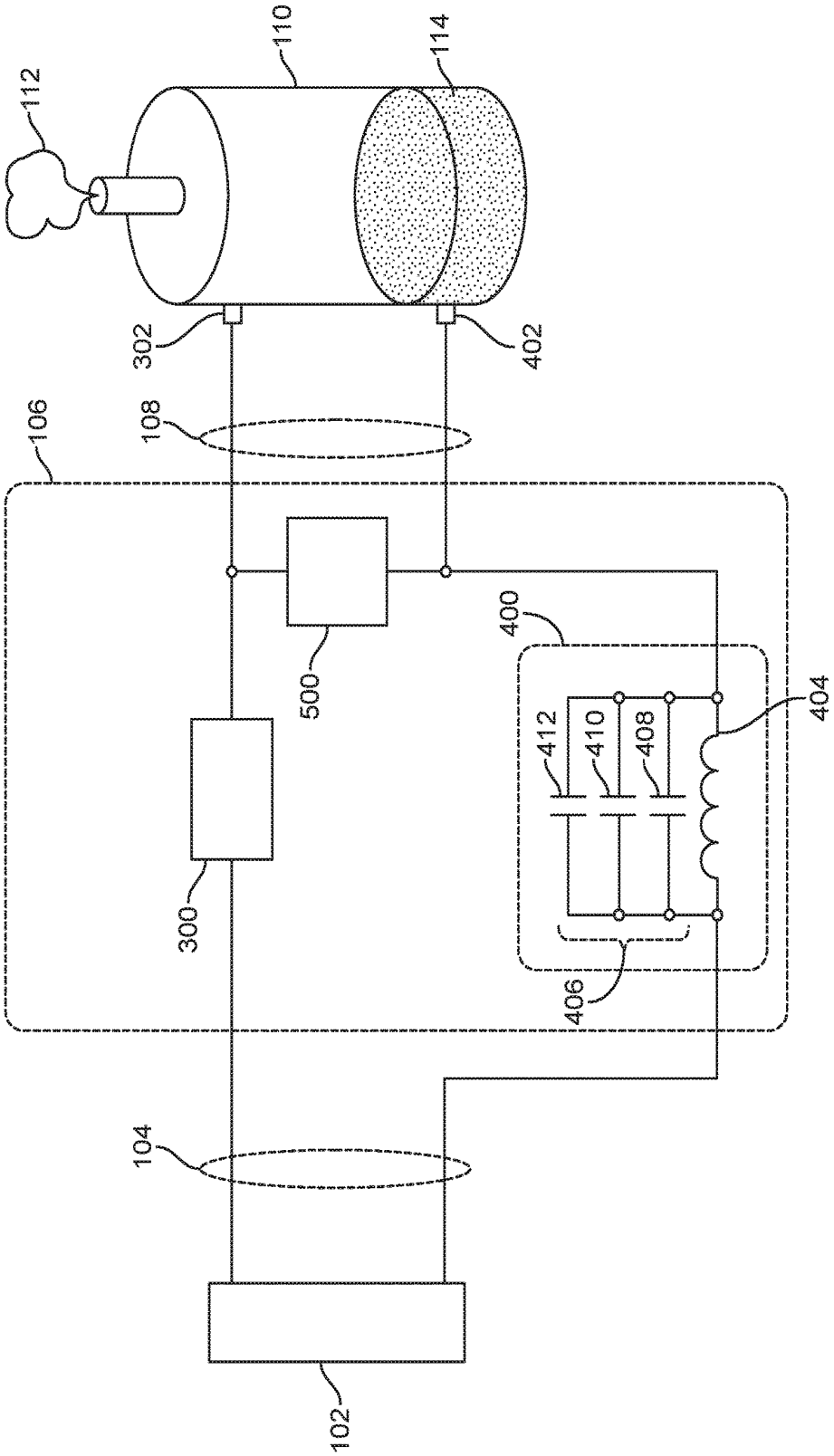
110
114
112
302
402
106
108
500
400
404
412
410
408
406
300
104
102

FIG. 4

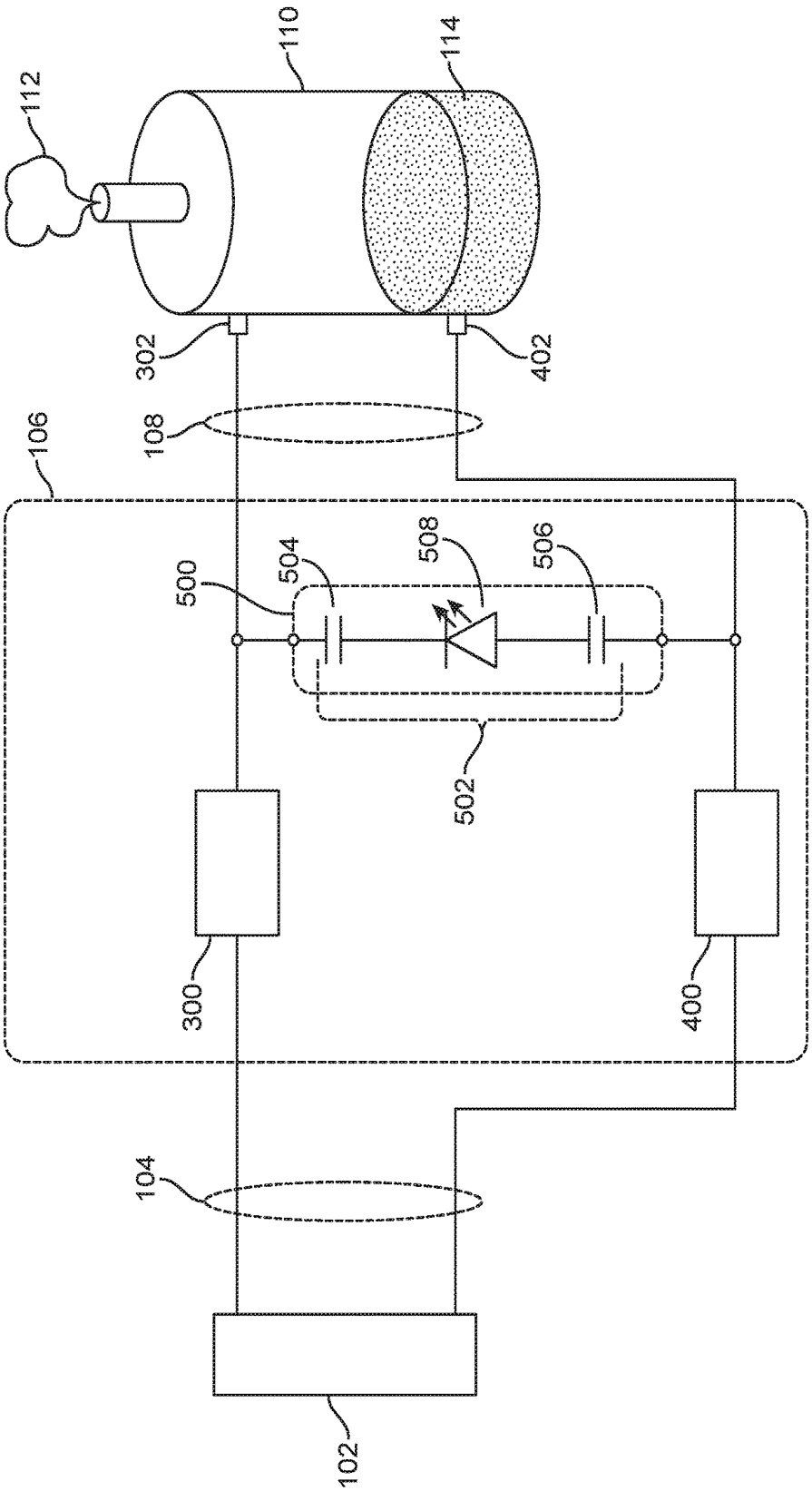

FIG. 5

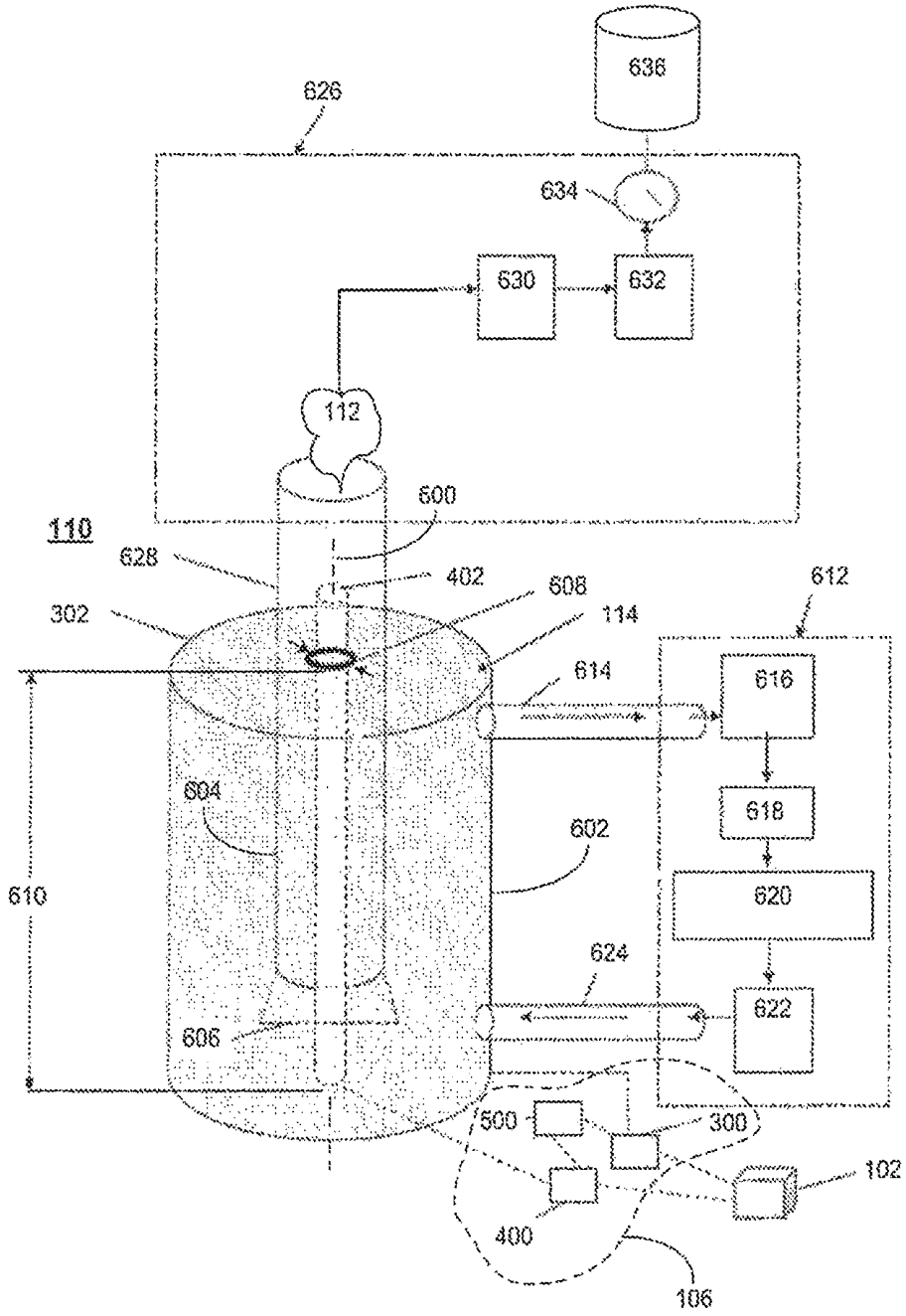
636
626
634
630
632
112
600
110
628
402
608
612
302
114
614
616
618
620
604
602
610
624
622
606
500
300
102
400
106

FIG. 6

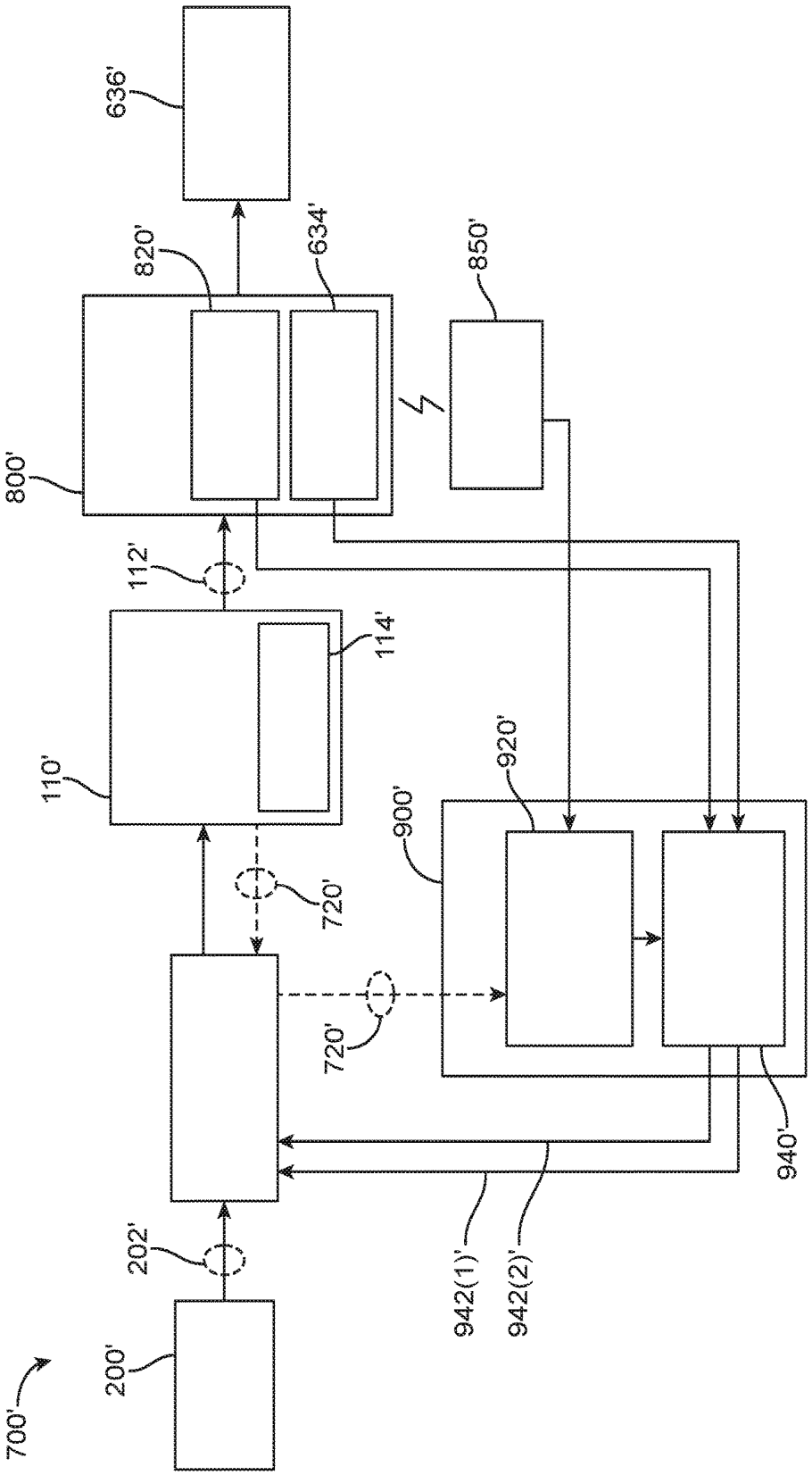
636'
820'
634'
850'
800'
112'
114'
110'
920'
900'
720'
720'
940'
942(1)'
942(2)'
202'
200'
700'

FIG. 7

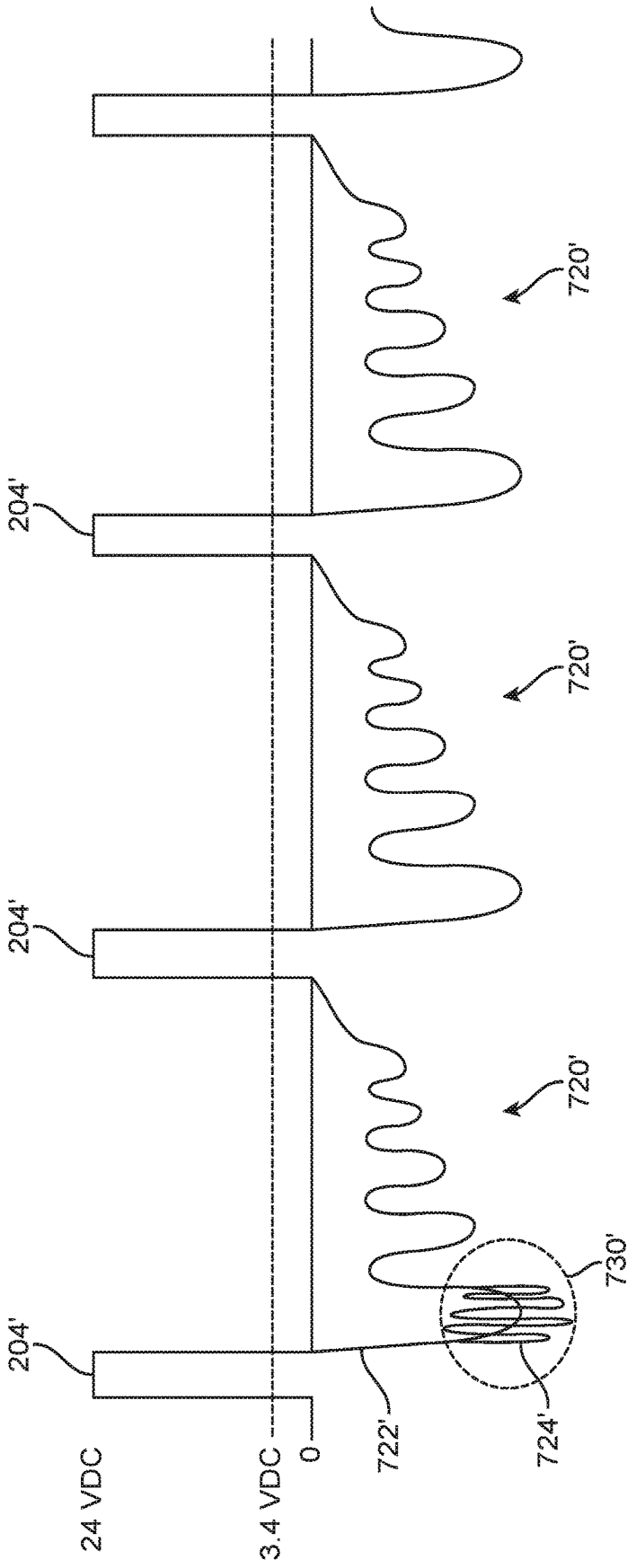

FIG. 8

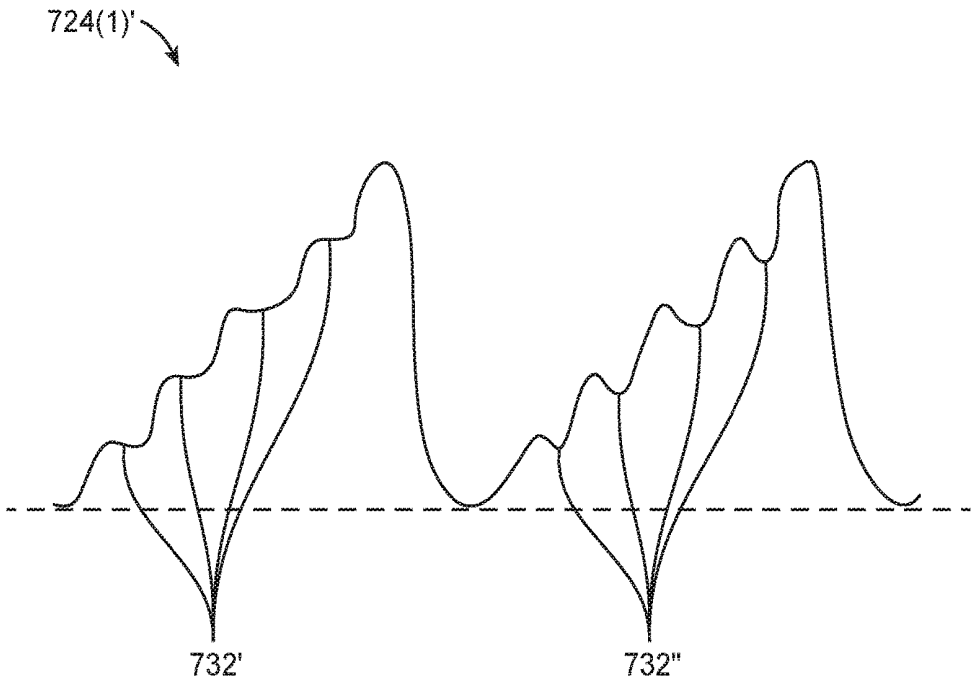

FIG. 9

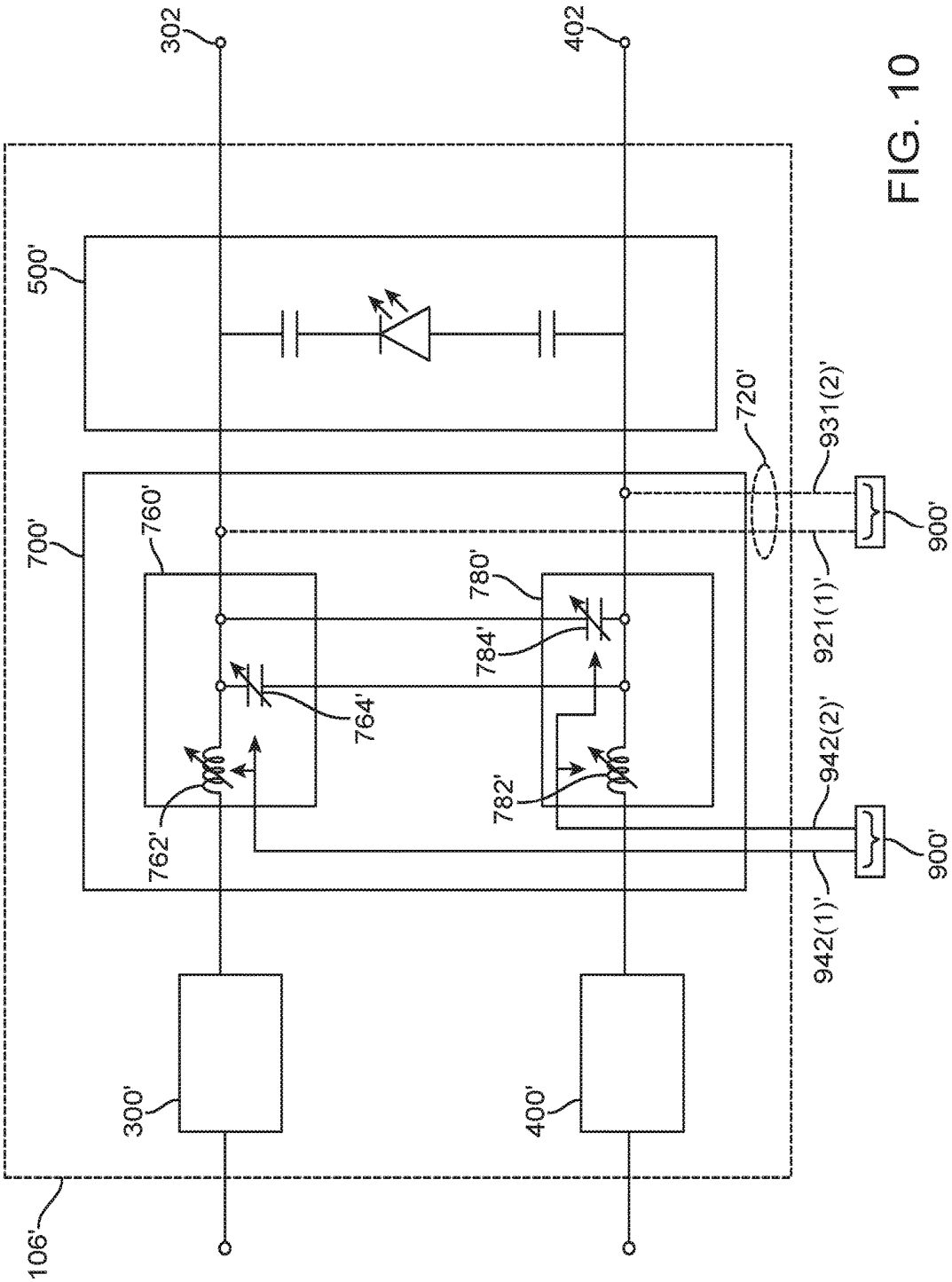
302
402
500'
720'
931(2)'
700'
760'
780'
900'
921(1)'
784'
764'
942(2)'
782'
762'
900'
942(1)'
300'
400'
106'

FIG. 10

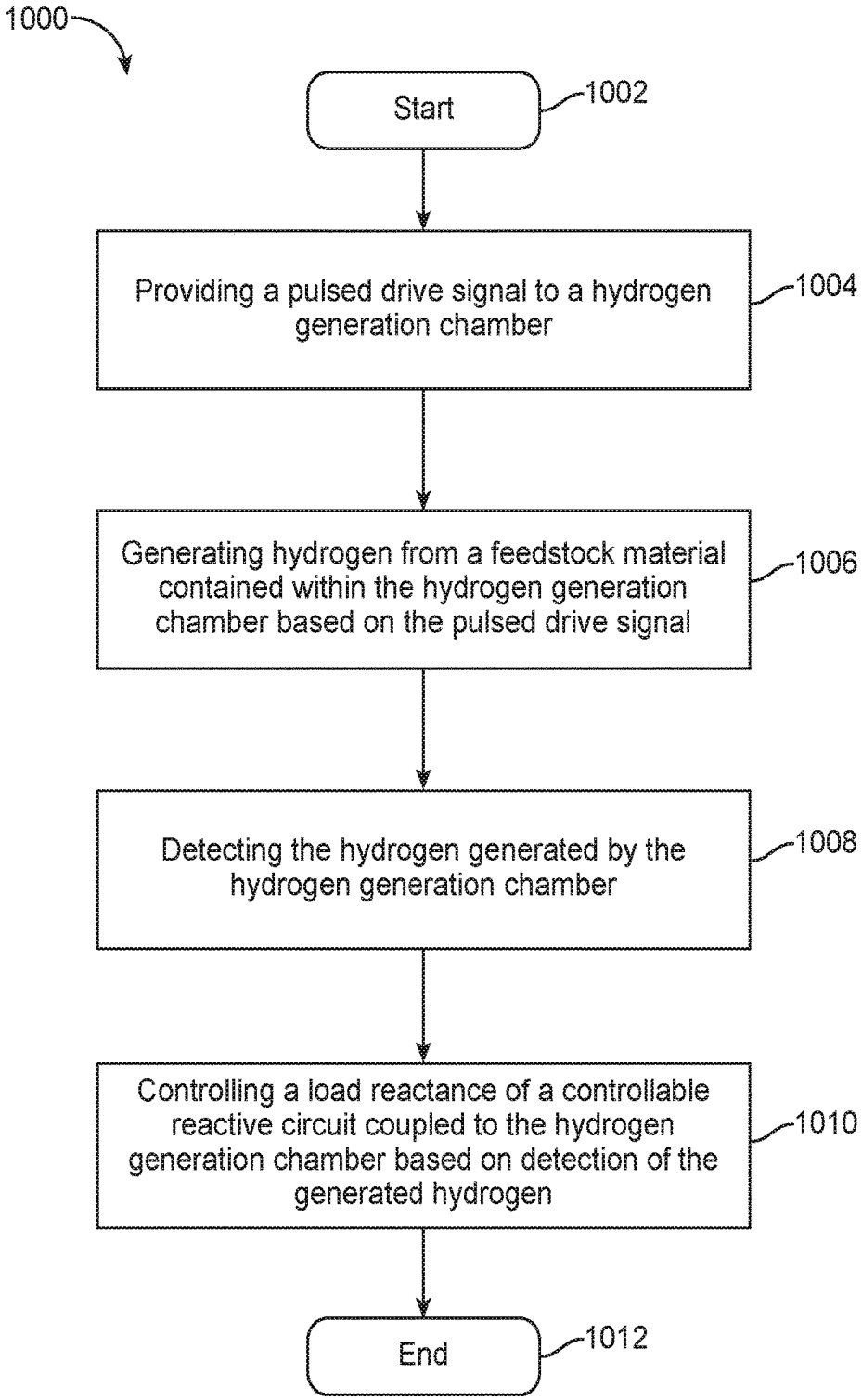
1000
Start
1002
Providing a pulsed drive signal to a hydrogen generation chamber
1004
Generating hydrogen from a feedstock material contained within the hydrogen generation chamber based on the pulsed drive signal
1006
Detecting the hydrogen generated by the hydrogen generation chamber
1008
Controlling a load reactance of a controllable reactive circuit coupled to the hydrogen generation chamber based on detection of the generated hydrogen
1010
End
1012

FIG. 11

HYDROGEN GENERATION SYSTEM WITH A CONTROLLABLE REACTIVE CIRCUIT AND ASSOCIATED METHODS

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 14/852,695 filed Sep. 14, 2015, which is continuation-in-part of U.S. patent application Ser. No. 14/616,851 filed Feb. 9, 2015, which claims the benefit of U.S. Provisional Application Ser. No. 62/091,702 filed Dec. 15, 2014, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to the field of hydrogen generation systems, and more particularly, to a hydrogen generation system with a controllable reactive circuit to generate hydrogen from feedstock, and associated methods.

BACKGROUND

Currently, the majority of the energy consumed by the developed world has its origins in fossil fuels. Unfortunately, there are many well-documented problems associated with over-reliance upon energy generated from fossil fuels. These problems include pollution and climate change caused by the emission of greenhouse gases, the finite nature of fossil fuels and the dwindling reserves of such carbon-based energy sources and the concentration of control of petroleum-based energy supplies by various volatile countries and OPEC.

Accordingly, there is a need for alternative sources of energy. One such alternative energy source includes hydrogen generation systems that produce hydrogen via hydrolysis. Ideally, such hydrogen generation systems would be capable of producing hydrogen gas without the presence of oxygen, wherein such hydrogen may be used for industrial, commercial and residential purposes.

For example, when greater than 99% pure, hydrogen may be used in generator cooling, steel production, glass production, and semiconductor and photovoltaic cell production. When less than 99% pure, hydrogen may be used in various industries, such as the aerospace industry, the animal feed industry, the automotive industry, the baking industry, the chemical industry, the ethanol industry, the food processing industry, the dairy industry, the meat industry, the manufacturing industry, the medical industry, the hospitality industry, the laundry/uniform industry, the marine and offshore industry, the military and defense industry, the mining industry, the oil and gas industry, the paper/corrugating industry, the pharmaceutical industry, the rubber industry, the steel and metals industry, the tobacco industry, the transportation industry, the wire and cable industry and the education industry.

Unfortunately, there are a number of significant hurdles that prevent the widespread use of hydrogen in commercial, industrial, and residential applications. These hurdles include cost, efficiency, and safety. First and foremost, creating hydrogen gas in a traditional manner is inefficient and costly, or even environmentally harmful when produced via reformation (i.e., the primary commercial method). Secondly, hydrogen's very low mass and energy density makes it challenging to get enough mass of hydrogen gas safely in one place to be of practical value to a user. The result is that hydrogen has been prohibitively expensive to

produce, compress, cryogenically cool, maintain (at pressure and temperature), contain (due to its very small molecule structure) and transport. Accordingly, pressure, temperature, flammability, explosiveness and low ignition energy requirement are all significant safety issues concerning the widespread use of hydrogen.

SUMMARY

A hydrogen generation systems comprises: a pulsed drive signal generator to generate a pulsed drive signal; a hydrogen generation chamber to receive the pulsed drive signal and generate hydrogen from a feedstock material contained therein based on the pulsed drive signal; and a controllable reactive circuit coupled between the pulsed drive signal generator and the hydrogen generation chamber. A hydrogen detection device may be coupled to the hydrogen generation chamber to detect the generated hydrogen. A controller may control the controllable reactive circuit based on detection of the generated hydrogen.

Purity and production rate of the generated hydrogen as determined by the hydrogen detection device may be used to measure performance of the hydrogen generation chamber. The controllable reactive circuit is advantageously used to improve performance of the hydrogen generation system by presenting a varying reactive load to damped sine waves generated within the hydrogen generation chamber.

The hydrogen detection device may comprise a mass spectrometer to determine the purity of the generated hydrogen and wherein the controller may be configured to control the controllable reactive circuit based on the purity of the generated hydrogen.

The hydrogen detection device may comprise a hydrogen flow meter to determine the production rate of the generated hydrogen and wherein the controller may be configured to control the controllable reactive circuit based on the production rate of the generated hydrogen.

The damped sine waves are generated within the hydrogen generation chamber based on interaction between the pulsed drive signal and the feedstock material and wherein the controller may control the controllable reactive circuit so as to present a varying load reactance to the damped sine waves.

The controller may be configured to control the controllable reactive circuit based on detection of the generated hydrogen and the damped sine waves. The damped sine waves may include a DC signal with a plurality of embedded interactive chamber signals with at least one of the embedded interactive chamber signals corresponding to the hydrogen being generated. The controller may be further configured to analyze the at least one embedded interactive chamber signal corresponding to the hydrogen being generated.

The controllable reactive circuit may comprise: a first variable load reactance circuit coupled between a first terminal of the pulsed drive signal generator and a first terminal of the hydrogen generation chamber; and a second variable load reactance circuit coupled between a second terminal of the pulsed drive signal generator and a second terminal of the hydrogen generation chamber. The variable load reactance circuits may be cross-coupled to one another.

Another aspect is directed to a hydrogen generation system comprising a pulsed drive signal generator configured to generate a pulsed drive signal and a hydrogen generation chamber configured to receive the pulsed drive signal and generate hydrogen from a feedstock material contained therein, with damped sine waves being generated

within the hydrogen generation chamber based on interaction between the pulsed drive signal and the feedstock material. A controllable reactive circuit having a controllable load reactance may be coupled between the pulsed drive signal generator and the hydrogen generation chamber. A hydrogen detection device may be coupled to the hydrogen generation chamber and configured to detect the generated hydrogen. A controller may be configured to control the load reactance in the controllable reactive circuit based on detection of the generated hydrogen and the damped sine waves.

Yet another aspect is directed to a method for operating the hydrogen generation system as described above. The method comprises detecting the hydrogen generated by the hydrogen generation chamber, and controlling a load reactance of the controllable reactive circuit based on detection of the generated hydrogen.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic view of a hydrogen generation system in accordance with the disclosure;

FIG. **2** is a diagrammatic view of a signal generation system included within the hydrogen generation system of FIG. **1**;

FIG. **3** is a diagrammatic view of a positive reactive circuit included within the hydrogen generation system of FIG. **1**;

FIG. **4** is a diagrammatic view of a negative reactive circuit included within the hydrogen generation system of FIG. **1**;

FIG. **5** is a diagrammatic view of a feedback circuit included within the hydrogen generation system of FIG. **1**;

FIG. **6** is a diagrammatic view of a hydrogen generation chamber included within the hydrogen generation system of FIG. **1**;

FIG. **7** is a diagrammatic view of a hydrogen generation system with a controllable reactive circuit in accordance with the disclosure;

FIG. **8** is a graph illustrating damped sine waves generated as a negative latch between pulses of the pulsed drive signal in accordance with the disclosure;

FIG. **9** is a graph illustrating one of the embedded interactive chamber signals included within the damped sine waves illustrated in FIG. **8**;

FIG. **10** is a more detailed diagrammatic view of the signal processing system with the controllable reactive circuit in accordance with the disclosure; and

FIG. **11** is a flowchart illustrating a method for operating the hydrogen generation system with a controllable reactive circuit as illustrated in FIG. **7**.

DETAILED DESCRIPTION

Exemplary embodiments will be described more fully hereinafter with reference to the accompanying drawings. These embodiments should not be construed as limited to those illustrated and described herein as other forms and are provided so that this disclosure will be thorough and complete and convey the scope to those skilled in the art. Like numbers refer to like elements throughout, and prime notations are used to indicate alternate embodiments.

Hydrogen Generation System Overview

Referring to FIG. **1**, there is shown hydrogenation generation system **100**. Hydrogen generation system **100** may include signal generation system **102** configured to generate a driver signal **104**. An example driver signal **104** may include but is not limited to a pulsed DC signal. Driver signal **104** may be provided to signal processing system **106**, wherein signal processing system **106** may be configured to process driver signal **104** and generate a chamber excitation signal **108**.

Hydrogen generation system **100** may include hydrogen generation chamber **110** that may be configured to receive chamber excitation signal **108** and generate hydrogen **112** (e.g., gaseous hydrogen) from feedstock **114** contained within hydrogen generation chamber **110**.

As discussed above, hydrogen **112** produced by hydrogen generation system **100** may be used with various industries, such as the aerospace industry, the animal feed industry, the automotive industry, the baking industry, the chemical industry, the ethanol industry, the food processing industry, the dairy industry, the meat industry, the manufacturing industry, the medical industry, the hospitality industry, the laundry/uniform industry, the marine and offshore industry, the military, the mining industry, the oil and gas industry, the paper/corrugating industry, the pharmaceutical industry, the rubber industry, the steel and metals industry, the tobacco industry, the transportation industry, the wire and cable industry and the education industry.

As discussed above, hydrogen generation system **100** may generate hydrogen **112** (e.g., gaseous hydrogen) from feedstock **114** contained within hydrogen generation chamber **110**. One example of feedstock **114** may include but is not limited to sea water. Accordingly and in certain implementations, hydrogen generation system **100** may be positioned proximate a source of feedstock **114**. Alternatively, feedstock **114** may be provided to hydrogen generation system **100** via a delivery network, not shown.

Hydrogen generation chamber **110**, when filled with an electrolytic fluid (e.g., feedstock **114**), may react like a variable capacitive load with corresponding variable impedance values. When a Pulsed DC signal (e.g., chamber excitation signal **108**) is applied to hydrogen generation chamber **110**, the result may be a reactive load. Hydrogen generation chamber **110** may complete the closed circuit path that forms the load factor during the ON Cycle Pulse (OCP) of chamber excitation signal **108**.

The electrolytic fluid (e.g., feedstock **114**) may change state both chemically and electronically during the OCP of chamber excitation signal **108**. These changes may affect the charge state of feedstock **114**, changing the above-described capacitive and impedance values, which may be monitored via a differential potential voltage measurement across the anode and cathode of hydrogen generation chamber **110**.

Signal processing system **106** may provide impedance matching and capacitive balancing during the OCP of chamber excitation signal **108**. Balancing of signal processing system **106** may accomplish multiple functions, including but not limited to lowering reactive circuit current demand while directing chamber excitation signal **108** with a given base frequency across the electrodes of hydrogen generation chamber **110**.

During the OFF Cycle Pulse (OFCP) of chamber excitation signal **108**, the inductive and capacitive sections of signal processing system **106** may receive energy from hydrogen generation chamber **110** as hydrogen generation chamber **110** discharges.

Signal Generation System Configuration

Referring to FIG. **2**, there is shown one implementation of signal generation system **102**. Signal generation system **102**

may include pulsed DC source **200** configured to generate pulsed DC source signal **202**. Signal generation system **102** may include mono-directional blocking circuit **204** configured to receive pulsed DC source signal **202** and generate driver signal **104**. Signal generation system **102** may also include filter circuit **206** configured to filter driver signal **104** and remove AC components.

Mono-directional blocking circuit **204** may include at least one asymmetrically conductive component, an example of which includes but is not limited to a diode (e.g., a Schottky diode), such as a 1N4003G diode available from ON Semiconductor configured to function as blocking diodes. In a typical configuration, mono-directional blocking circuit **204** may include two asymmetrically conductive components **208**, **210**. Filter circuit **206** may include capacitor **212** coupled to ground **214** that is sized to remove any undesirable AC signal components. An example of capacitor **212** may include a 470 microfarad capacitor available from Mouser Electronics.

One implementation of driver signal **104** generated by signal generation system **102** may be a driver signal that has a duty cycle of less than 25%. Specifically and in a preferred embodiment, driver signal **104** may have a duty cycle between 6.5% and 13%, wherein during 6.5%-13% of the waveform of driver signal **104**, driver signal **104** has an amplitude of 4.5 to 10 VDC and during 87%-93.5% of the waveform of driver signal **104**, driver signal **104** has an amplitude of 0 VDC. The above-described implementations of driver signal **104** are intended to be illustrative and not all inclusive. Accordingly, these are intended to be merely examples of the various driver signals that be utilized by signal generation system **102**.

Operation of the Signal Generation System

Concerning driver signal **104** generated by signal generation system **102**, the rise time of driver signal **104** may be critical to the overall function and performance of hydrogen generation chamber **110**. Accordingly, a rise time as close to instantaneous as possible (e.g., as close to a truly vertical sweep) may result in the most efficient operation of hydrogen generation chamber **110**. Further, the amplitude of driver signal **104** may be increased/decreased to vary the performance of hydrogen generation chamber **110** and the quantity of hydrogen **112** produced.

Signal generation system **102** may be configured to provide for adjustments in the pulse width and/or duty cycle of driver signal **104**. Any pulse width and/or duty cycle adjustments may be based on the desired chamber performance. The timing of the duty cycle of driver signal **104** may establish a base frequency for driver signal **104**. In a preferred embodiment, the pulse base frequency of driver signal **104** may range from 100 hertz to 10 kilohertz (however, frequencies outside of this range may also be utilized).

The diodes (e.g., asymmetrically conductive components **208**, **210**) utilized in mono-directional blocking circuit **204** may perform several functions. Typically, Schottky diodes have forward biases of approximately 1 mA in the range 0.15 to 0.46 volts. This lower forward voltage may provide for higher switching speeds and better system efficiency, wherein Schottky diodes are considered to have essentially instant reverse recovery time.

The two diodes (e.g., asymmetrically conductive components **208**, **210**) may provide a first stage voltage clamp that may enhance rise time and forward current build up, which may be important during each startup of the OCP. The blocking diodes (e.g., asymmetrically conductive components **208**, **210**) may provide transient voltage suppression during initial charging of hydrogen generation chamber **110**. This may allow hydrogen generation chamber **110** to reach full voltage amplitude in the least amount time.

The two diodes (e.g., asymmetrically conductive components **208**, **210**) may also prevent voltage returned from hydrogen generation chamber **110** from interfering with pulsed DC source signal **202**, thus isolating the downstream circuit (e.g., signal processing system **106**) during the off cycle while the reactive part of this circuit is in the recovery phase and exposed to a return voltage in the range of 0.90 VDC to 4.5 VDC.

Positive Reactive Circuit Configuration

Referring to FIG. **3**, there is shown one implementation of signal processing system **106**, wherein signal processing system **106** is shown to include positive reactive circuit **300**. Positive reactive circuit **300** may be coupled to anode **302** of hydrogen generation chamber **110**.

In one implementation, positive reactive circuit **300** may include inductive component **304** and capacitive component **306**. One example of inductive component **304** may include a 10 microhenry inductor available from Mouser Electronics. Inductive component **304** may be in parallel with capacitive component **306**. Capacitive component **306** may be sized based, at least in part, upon one or more physical characteristics of hydrogen generation chamber **110** (e.g., size, shape, electrode type, configuration and dimensions) and/or one or more physical characteristics of feedstock **114** (e.g., feedstock type and contents included therein) contained within hydrogen generation chamber **110**.

Inductive component **304** may be constructed of/formed from several individual inductors that may be arranged (in a parallel and/or series configuration) to achieve the desired inductance value. Additionally (and as will be discussed below), capacitive component **306** may be constructed of/formed from several individual capacitors that are arranged (in a parallel and/or series configuration) to achieve the desired capacitive value.

In one implementation, capacitive component **306** may include a plurality of discrete capacitors. For example, capacitive component **306** may include three discrete capacitors (e.g., capacitors **308**, **310**, **312**) arranged in parallel to form a parallel capacitor circuit. In one particular implementation, capacitor **308** may be a 45 microfarad capacitor available from Mouser Electronics, capacitor **310** may be a 1 picofarad capacitor available from Mouser Electronics, and capacitor **312** may be a 5 nanofarads capacitor available from Mouser Electronics. This parallel capacitor circuit (e.g., the parallel combination of capacitors **308**, **310**, **312**) may be coupled in parallel with inductive component **304**, wherein the output of the parallel capacitor circuit (e.g., the parallel combination of capacitors **308**, **310**, **312**) and inductive component **304** may be provided to anode **302** of hydrogen generation chamber **110**.

In this particular implementation, positive reactive circuit **300** may be configured as a band-stop filter. As is known in the art and in signal processing, a band-stop filter (or band-rejection filter) is a filter that passes most frequencies unaltered (i.e., unattenuated), while attenuating those frequencies that are within a defined range. As with any other LC filter, the particular range of frequencies that are attenuated may be defined based upon the value of the capacitors

(e.g., capacitors **308**, **310**, **312**) and inductors (e.g., inductive component **304**) included within positive reactive circuit **300**.

Negative Reactive Circuit Configuration

Referring to FIG. **4**, there is shown one implementation of signal processing system **106**, wherein signal processing system **106** is shown to include negative reactive circuit **400**. Negative reactive circuit **400** may be coupled to cathode **402** of hydrogen generation chamber **110**.

In one implementation, negative reactive circuit **400** may include inductive component **404** and capacitive component **406**. One example of inductive component **404** may include a 100 microhenry inductor available from Mouser Electronics. Inductive component **404** may be in parallel with capacitive component **406**. Capacitive component **406** may be sized based, at least in part, upon one or more physical characteristics of hydrogen generation chamber **110** (e.g., size, shape, electrode type, configuration and dimensions) and/or one or more physical characteristics of feedstock **114** (e.g., feedstock type and contents included therein) contained within hydrogen generation chamber **110**.

Inductive component **404** may be constructed of/formed from several individual inductors that may be arranged (in a parallel and/or series configuration) to achieve the desired inductance value. Additionally (and as will be discussed below), capacitive component **406** may be constructed of/formed from several individual capacitors that are arranged (in a parallel and/or series configuration) to achieve the desired capacitive value.

In one implementation, capacitive component **406** may include a plurality of discrete capacitors. For example, capacitive component **406** may include three discrete capacitors (e.g., capacitors **408**, **410**, **412**) arranged in parallel to form a parallel capacitor circuit. In one particular implementation, capacitor **408** may be a 1 microfarad capacitor available from Mouser Electronics, capacitor **410** may be a 1 picofarad capacitor available from Mouser Electronics and capacitor **412** may be a 5 nanofarads capacitor available from Mouser Electronics. This parallel capacitor circuit (e.g., the parallel combination of capacitors **408**, **410**, **412**) may be coupled in parallel with inductive component **404**, wherein the output of the parallel capacitor circuit (e.g., the parallel combination of capacitors **408**, **410**, **412**) and inductive component **304** may be provided to cathode **402** of hydrogen generation chamber **110**.

In this particular implementation, negative reactive circuit **400** may be configured as a band-stop filter. As is known in the art and in signal processing, a band-stop filter (or band-rejection filter) is a filter that passes most frequencies unaltered (i.e., unattenuated), while attenuating those frequencies that are within a defined range. As with any other LC filter, the particular range of frequencies that are attenuated may be defined based upon the value of the capacitors (e.g., capacitors **408**, **410**, **412**) and inductors (e.g., inductive component **404**) included within negative reactive circuit **400**.

Feedback Circuit Configuration

Referring to FIG. **5**, there is shown one implementation of signal processing system **106**, wherein signal processing system **106** is shown to include feedback circuit **500**. Feedback circuit **500** may be configured to couple anode **302** of hydrogen generation chamber **110** to cathode **402** of hydrogen generation chamber **110**.

In one implementation, feedback circuit **500** may include capacitive component **502**. Capacitive component **502** may be sized based, at least in part, upon one or more physical characteristics of hydrogen generation chamber **110** (e.g., size, shape, electrode type, configuration and dimensions) and/or one or more physical characteristics of feedstock **114** (e.g., feedstock type and contents included therein) contained within hydrogen generation chamber **110**.

Capacitive component **502** may include two discrete capacitors (e.g., capacitors **504**, **506**). In one particular implementation, capacitor **504** may be a 1 microfarad capacitor available from Mouser Electronics and capacitor **506** may be a 1 microfarad capacitor available from Mouser Electronics. A first of the discrete capacitors (e.g., capacitor **504**) may be coupled to anode **302** of hydrogen generation chamber **110**. A second of the discrete capacitors (e.g., discrete capacitor **506**) may be coupled to cathode **402** of hydrogen generation chamber **110**.

Feedback circuit **500** may include asymmetrically conductive component **508**, wherein asymmetrically conductive component **508** may be positioned between the two discrete capacitors (e.g., capacitors **504**, **506**). One example of asymmetrically conductive component **508** may include, but is not limited to, a diode (e.g., a light emitting diode), such as a RED/diffused T-1 (3 mm) 696-SSL-LX3044ID available from Mouser Electronics.

Operation of the Signal Processing System

Concerning the reactive circuits (e.g., positive reactive circuit **300** and negative reactive circuit **400**), these circuits may incorporate an inductor in parallel with a plurality of capacitors (as discussed above). Upon the initiation of the OCP, these inductors may oppose any rise in current. This opposition may be part of the electronic clamp during the rise time of the OCP. The capacitors in parallel with the inductor may start to charge during the rise time of the OCP and provide a path for electron flow in the direction of the hydrogen generation chamber **110**.

These capacitors may not be able to overcome the voltage amplitude of hydrogen generation chamber **110** and, therefore, may not be able to discharge during the OCP time. As these capacitors may be relatively small and may reach full charge status during the rise time of OCP and may remain charged during the duration of the OCP.

The slight opposition to current change (by the inductor) during the OCP rise time may quickly dissipate, wherein the inductor opposes current change based upon magnetically induced resistance to the current flow.

Hydrogen generation chamber **110** may function as a load for signal processing system **106**, wherein hydrogen generation chamber **110** may have a varying internal resistance and a varying voltage amplitude. Hydrogen generation chamber **110** may behave similarly to an inductive/capacitive electronic component, wherein variations may occur based upon varying electrolytic conditions that can vary dramatically during the rise time of the OCP. These varying conditions may continue during the length of the duty cycle and may be in the form of a charge ion state triggering charging of hydrogen generation chamber **110**. The electron density within hydrogen generation chamber **110** may increase dramatically within hydrogen generation chamber **110**. This electron density may be at its greatest at a circumference slightly larger than the outer diameter of cathode **402**.

The ON cycle rise time and duration of the duty cycle may cause a molecular polarity shift within the electrolytic fluid

(e.g., feedstock **114**). This molecular polarity shift may have a corresponding electromagnetic/electrostatic component. Due to the shape and geometry of hydrogen generation chamber **110** and without a defined electron flow pathway, the electromagnetic component will have a chaotic characteristic, wherein this chaotic characteristic may assist in the molecular splitting of gas atoms from the water molecules within the electrolytic fluid (e.g., feedstock **114**) due to a constant molecular charge imbalance.

The OFF cycle of signal processing system **106** may start at the beginning of the OFCP. The blocking diodes (e.g., asymmetrically conductive components **208**, **210**) are in the cutoff state which may isolate signal generation system **102** from signal processing system **106**. A pulsed DC input base signal set to one kilohertz may reach the cutoff state one-thousand times per second. During the OFF cycle, the electrolytic fluid (e.g., feedstock **114**) in hydrogen generation chamber **110** may change from a charge state to a reset discharge cycle. During this OFF cycle, all electronic interactions may be energized from energy recovered (or harvested) from hydrogen generation chamber **110**.

The charge amplitude of hydrogen generation chamber **110** may have a characteristic fast decline from greater than 3.5 VDC to less than 1.4 VDC. The decline curve sweep angle may be dependent on the pulsed DC input frequency and the configuration of the reaction circuits (e.g., positive reaction circuit **300** and negative reaction circuit **400**).

During the cutoff initiation, the first decline sequence to occur is the collapse of the electron density column surrounding cathode **402**. This high density electron column may be held in place by the induced magnetic field that is a result of the OCP. This collapse may cause an electronic flashback (or rapid energy release) from hydrogen generation chamber **110** to the reactive circuit (e.g., positive reaction circuit **300** and/or negative reaction circuit **400**), which is similar to an electrostatic discharge and may provide the electrolytic fluid (e.g., feedstock **114**) with a pathway to start a change in state of polarity releasing additional stored energy.

Once the electron column proximate cathode **402** starts to collapse, there is a fast rise in potential on negative reactive circuit **402**. At this point, there may be an imbalance with positive reactive circuit **302**. The inductor within negative reactive circuit **402** may have a rise in potential imposing an impedance value that may allow the parallel capacitors to discharge in the opposite direction to the charge state during the OCP. This situation may create a latching circuit potential through hydrogen generation chamber **110** as the pathway for electron flow.

The return energy from hydrogen generation chamber **110** may be a DC signal with embedded AC components, wherein these AC components may be relatively small in amplitude. The AC components may be driven by the molecular polarity shift after the cutoff sequence is initiated and the imbalance of the charge state of hydrogen generation chamber **110**. The DC component produced by hydrogen generation chamber **110** may be clamped to swing the AC wave into the positive range.

The capacitors in the reactive circuits (e.g., positive reaction circuit **300** and/or negative reaction circuit **400**) may stabilize after the electrostatic release from the DC component. The inductors may provide timing sequences and preload for capacitor charge/discharge sequence while minimizing circuit resistance at peak input values. The capacitors may subsequently discharge under the influence of the AC components. The result may be an amplification of the embedded frequency waves providing a charge/discharge cycle at these given frequencies. This sequence may continue until the molecular polarity rotation of hydrogen generation chamber **110** is stabilized or the charge imbalance of the reactive circuit (e.g., positive reaction circuit **300** and/or negative reaction circuit **400**) is diminished.

Feedback circuit **500** may be configured in reverse polarity to signal generation system **102** and signal processing system **106**. Feedback circuit **500** may function as a secondary load to the reset reaction of hydrogen generation chamber **110**. The capacitors (e.g., capacitors **504**, **506**) of feedback circuit **500** may collect electrons during the electrostatic discharge cycle, which may then be discharged through the light emitting diode (i.e., asymmetrically conductive component **508**).

Feedback circuit **500** may assist in minimizing the electrostatic discharge impact on other portions of the reactive circuit (e.g., positive reaction circuit **300** and/or negative reaction circuit **400**), which may result in the regulation of the timing of ON, OFF and Cutoff sequences. The light emitting diode (i.e., asymmetrically conductive component **508**) may minimize electrostatic interference, thus assisting in maintaining peak charge amplitudes during the reset sequence of hydrogen generation chamber **110**.

Specifically, the electrostatic charge may find a secondary pathway through the light emitting diode (i.e., asymmetrically conductive component **508**). The light emitting diode (e.g., asymmetrically conductive component **508**) may have a characteristic that allows static electricity to pass through while minimizing resistive load characteristics. This pathway may help regulate the discharge timing sequence while dissipating the accumulated charge on the capacitors (e.g., capacitors **504**, **506**). The switching or blocking characteristics of the light emitting diode (i.e., asymmetrically conductive component **508**) may also minimize current loss during the OCP.

Due to the reverse polarity of feedback circuit **500**, a portion of the recovered energy may be applied to the riding frequency during the cut off discharge sequence to assist in increasing the frequency amplitude. Further, the secondary electrostatic charge release may assist in the percentage of the desired gas output of hydrogen **112**. The electrostatic charge energy may only be recoverable during a given time interval, wherein if the time interval is too long, the electrostatic charge may interfere with the proper sequencing of the OCP and OFCP. Accordingly, the values of capacitors **504**, **506** may be adjusted to optimize the timing sequence.

Hydrogen Generation Chamber Configuration

Referring to FIG. **6**, there is shown one implementation of hydrogen generation chamber **110**. Hydrogen generation chamber **110** may include at least one hollow cylindrical anode **302** configured to contain feedstock **114**. At least one cathode **402** may be positioned within hollow cylindrical anode **302**. Cathode **402** may be positioned along a longitudinal centerline (i.e., longitudinal centerline **600**) of hollow cylindrical anode **302**. Accordingly, hydrogen generation chamber **110** may be configured as a coaxial hydrogen generation chamber, as cathode **402** and hollow cylindrical anode **302** share a common centerline (namely longitudinal centerline **600**).

Cathode **402** may be constructed, at least in part, of tungsten. For example, cathode **402** may be a tungsten rod. Hollow cylindrical anode **302** may be constructed, at least in part, of graphite. For example, hollow cylindrical anode **302** may be machined from a block of graphite.

Hollow cylindrical anode **302** may have an outer surface **602** and an inner surface **604**, wherein the inside diameter (e.g., inside diameter **606**) of hollow cylindrical anode **302** is 2,400% to 2,600% of (i.e., 24-26 times larger than) an outside diameter (e.g., outside diameter **608**) of cathode **402** positioned within hollow cylindrical anode **302**. For example and in a preferred embodiment, hollow cylindrical anode **302** may have an inside diameter (i.e., inside diameter **606**) of 25.0 millimeters and cathode **402** positioned within hollow cylindrical anode **302** may have an outside diameter (e.g., outside diameter **608**) of 1.0 millimeter.

Cathode **402** positioned within hollow cylindrical anode **302** may have a longitudinal length (i.e., longitudinal length **610**) that is 190% to 210% of (i.e., 1.9-2.1 times longer than) inside diameter **606** of hollow cylindrical anode **302**. For example and in a preferred embodiment, cathode **402** positioned within hollow cylindrical anode **302** may have a longitudinal length of 50.0 millimeters (when hollow cylindrical anode **302** has an inside diameter (i.e., inside diameter **606**) of 25.0 millimeters).

Hydrogen generation chamber **110** may include feedstock recirculation system **612**. For example and in this particular illustrative embodiment, feedstock **114** may be drawn through first conduit **614** and gas contractor **616** and into fuel reservoir **618**. Fuel reservoir **618** may serve as a preconditioning zone to maintain feedstock and catalyst concentrations at desired levels. Feedstock **114** may be pulled through circulation pump **620** and then through heat exchanger **622** (to e.g., maintain a desired temperature for feedstock **114**) and returned to hydrogen generation chamber **110** via conduit **624**.

Gas collection system **626** may be coupled to hydrogen generation chamber **110** and may be configured to collect hydrogen **112** generated by hydrogen generation chamber **110** from feedstock **114**. In this particular illustrative example, hydrogen **112** may be drawn through conduit **628** by vacuum pump **630**, which then may pass through cold trap **632** and flow meter **634** and into e.g., storage container **636**.

In certain implementations, hydrogen generation chamber **110** may include a plurality of discrete chambers. Accordingly, hollow cylindrical anode **600** may include a plurality of hollow cylindrical anodes **606** configured to contain feedstock **114** and cathode **602** may include plurality of cathodes **608** that may be positioned within plurality of hollow cylindrical anodes **606**. Specifically, hydrogen generation chamber **110** may be configured so as to include multiple anode/cathode pair, thus increasing the production of hydrogen **112**.

Controllable Reactive Circuit Configuration

Referring now to FIG. **7**, another aspect of the disclosure is directed to a hydrogen generation system **100'** with a controllable reactive circuit **700'**. As will be discussed in greater detail below, the reactive circuit **700'** includes inductive and capacitive values that may be selectively varied. When the inductive and capacitive values are selectively varied, this causes the load reactance on the hydrogen generation system **100'** to vary. Varying the load reactance is advantageously used to adjust performance of the hydrogen generation system **100'**.

The hydrogen generation system **100'** includes a pulsed drive signal generator **200'** to generate a pulsed drive signal **202'**, and a hydrogen generation chamber **110'** to receive the pulsed drive signal and generate hydrogen **112'** from a feedstock material **114'** contained therein based on the pulsed drive signal **202'**.

The controllable reactive circuit **700'** is coupled between the pulsed drive signal generator **200'** and the hydrogen generation chamber **110'**. A hydrogen detection device **800'** is coupled to the hydrogen generation chamber **110'** to detect the generated hydrogen **112'**. A controller **900'** is coupled between the hydrogen detection device **800'** and the controllable reactive circuit **700'** to control the controllable reactive circuit **700'** based on detection of the generated hydrogen **112'**.

Hydrogen generated by the hydrogen generation chamber **110'** may be detected in terms of purity and production rate, for example. The hydrogen detection device **800'** may be a mass spectrometer **820'** to determine the purity of the generated hydrogen **112'**. Alternatively or in addition, the hydrogen detection device **800'** may be a hydrogen flow meter **634'** to determine the production rate of the generated hydrogen **112'**.

Purity and production rate of the generated hydrogen as determined by the hydrogen detection device **800'** may be used to measure performance of the hydrogen generation chamber **110'**. The controllable reactive circuit **700'** is advantageously used to adjust performance of the hydrogen generation system **100'** by presenting a varying load reactance to damped sine waves **720'** (as illustrated in FIG. **8**) generated within the hydrogen generation chamber **110'**. As the name implies, a damped sine wave **720'** is a sinusoidal function whose amplitude approaches zero as time increases.

The damped sine waves **720'** generated within the hydrogen generation chamber **110'** are based on interactions between the pulsed drive signal **202'** and the feedstock material **114'**. The damped sine waves **720'** are received by the controllable reactive circuit **700'** as well as by the controller **900'**. By the controller **900'** selectively varying the load reactance within the controllable reactive circuit **700'** subsequently formed damped sine waves **720'** are re-energized which in turn can be used to improve performance of the hydrogen generation system **100'**. Re-energized waves or signals in the general sense refer to electrical characteristic values, such as voltage, current, frequency, and/or waveform shapes being altered so as to have an enhanced effect within the hydrogen generation system **100'**.

With the addition of the controllable reactive circuit **700'** performance of the hydrogen generation system **100'** is improved over that of a typical electrolytic cell. As an example, the purity of the generated hydrogen **112'** may increase from a 0.7 range to a mid/upper 0.9 range when a varying load reactance is selectively presented to the damped sine waves **720'** generated within the hydrogen generation chamber **110'**. Similarly, the production rate of the generated hydrogen **112'** increases significantly from a 0.7/0.8 Coefficient of Performance (COP) to greater than four times the COP (>400%).

The COP measurement used herein is defined as follows: a ratio of power consumption of the circuitry (measured in electrical watts) to the hydrogen gas production (measured in thermal watts). The power analysis is based on using a low heating value for hydrogen (i.e., 120 MJ/kg) to assess its energy content. Support for this value may be found in http://www.h2data.de, for example. Power analysis results are calculated using the following relationship: thermal watts (Wt) of hydrogen produced divided by electrical watts (We) consumed.

Since the controllable reactive circuit **700'** is used to tune or adjust the damped sine waves **720'** generated within the hydrogen generation chamber **110'** to improve performance of the hydrogen generation system **100'**, the hydrogen generation chamber **110'** may be considered to function as an antenna. In this case, the cathode **402'** may be characterized as an emitter and the anode **302'** may be characterized as a reflector. For discussion purposes, the cathode **402'** may also be referred to as a first terminal and the anode **302'** may also be referred to as a second terminal.

The hydrogen generation system **100'** may further include a passive receive antenna **850'** adjacent the hydrogen generation chamber **110'** that is configured to receive transmissions from the chamber. The transmissions are in response to the hydrogen generation chamber **110'** receiving the pulse drive signal **202'**. The received transmissions are provided to the controller **900'** for analysis so as to confirm that the hydrogen generation system **100'** is operating correctly.

The pulsed drive signal **202'** generated by the pulsed drive signal generator **200'** is a pulsed DC drive signal. As an example, the pulsed DC drive signal entering the hydrogen generation chamber **110'** may be set to one kilohertz and may have a peak voltage of 24 VDC with a 2% duty cycle. However, the voltage within the hydrogen generation chamber **110'** is maintained at a lower level as discussed above, such as 3.4 VDC, for example.

The damped sine waves **720'** occur between the DC pulses **204'**, as illustrated in FIG. **8**. More particularly, the damped sine waves **720'** occur as a negative latch between the DC pulses **204'**. Each damped sine wave **720'** includes a DC signal **722'** with a plurality of low-level embedded interactive chamber signals **724'**. The low-level embedded interactive chamber signals **724'** are only shown within section **730'** of the DC signal **722'** so as to simplify the illustration. Certain ones of these low-level embedded interactive chamber signals **724'** may correlate with chemical reactions that occur within the hydrogen generation chamber **110'**.

Interactions between the pulsed DC drive signal **202'** and the feedstock material **114'** may be attributed to an electromagnetic pulse (EMP) occurring within the hydrogen generation chamber **110'**. As readily understood by those skilled in the art, an EMP is a short burst of electromagnetic energy, and orientation of a pulse may occur as an electromagnetic field, for example. The EMP may be partially absorbed by the chamber materials, and may be partially reflected so that interfering patterns of EMP constructive and destructive nodes are created within the chamber. The interaction of the chamber and the EMP is reflected in the damped sine waves **720'** detected from the chamber **110'** between the DC pulses **204'**.

An underlying theory of one embodiment of the present disclosure is that the generated electromagnetic field has an influence on the electrons within the hydrogen generation chamber **110'**. This influence leads to the damped sine waves **720'** having the embedded interactive chamber signals **724'** which are low-level and chaotic in nature but may be correlated with the chemical reactions that occur within the hydrogen generation chamber **110'**. The chemical reactions that are of interest are those that have an impact on the purity or production rate of the hydrogen **112'** generated within the hydrogen generation chamber **110'**.

In addition to the controllable reactive circuit **700'** receiving the damped sine waves **720'**, the controller **900'** also receives the damped sine waves **720'**. The controller **900'** includes an interactive chamber signal analyzer **920'** to analyze the embedded interactive chamber signals **724'** carried by the damped sine waves **720'**. In one embodiment, an oscilloscope may be one such signal analyzer.

An example interactive chamber signal **724'** may be found around 1420 MHz. Another example interactive chamber signal **724'** may be found around 24.5 MHz. Yet another interactive chamber signal **724'** may be found around 33.3 MHz. These example frequencies are not to be limiting.

The controller **900'** may include a reactive load adjustment algorithm **940'** that compares or correlates the output from the hydrogen detection device **800'** to characteristics of one or more of the embedded interactive chamber signals **724'** as determined by the interactive chamber signal analyzer **920'**. Waveform shapes of the embedded interactive chamber signal **724'** being analyzed is one of the characteristics used by the reactive load adjustment algorithm **940'** when determining how to vary the reactive load within the controllable reactive circuit **700'**. The reactive load adjustment algorithm **940'** may operate as a lookup table when determining the reactive load by comparing the analyzed waveform characteristics with the purity or production rate of the generated hydrogen **112'**.

Referring now to FIG. **9**, a waveform shape of the 1420 MHz embedded interactive chamber signal **724(1)'** will be discussed as an example. When the waveform shape of the 1420 MHz embedded interactive chamber signal **724(1)'** being analyzed by the interactive chamber signal analyzer **920'** has a stair-stepped shape, as indicated by reference **732'**, then the purity or flow rate of the generated hydrogen **112'** has begun to decrease, then the load reactance of the controllable reactive circuit **700'** is adjusted so that the waveform shape of subsequent 1420 MHz embedded interactive chamber signals **724(1)'** has a more rounded or non-stair-stepped shape, as indicated by the more rounded stair **732"**.

Adjustment of the reactive load in the controllable reactive circuit **700'** is made in terms of re-energizing generation of subsequent damped sine waves **720'**. The above noted embedded interactive chamber signals **724'** may be considered as event characteristics, and when these event characteristics are triggered by changing the load reactance of the controllable reactive load circuit **700'**, then the purity and/or production rate of the hydrogen **112'** generated by the hydrogen generation chamber **110'** may be adjusted.

More particularly, the controllable reactive circuit **700'** is used to adjust the timing of subsequent embedded interactive chamber signals **724'**. Adjusting the timing increases the slope or slant range of a sinusoidal stair-stepped waveform shape of subsequent embedded interactive chamber signals **724'**. By varying the load reactance, the electronic speed is decreased to slow electron speed to form a retarded stair-stepped waveform shape **732"**. As the electron speed is decreased, the frequency of the embedded interactive chamber signals **724'** being analyzed may be adjusted. This in turn provides more energy within the hydrogen generation chamber **110'** which results in an improvement of the hydrogen generation system **100'**.

Referring now to FIG. **10**, Controllable Reactive Circuit **700'** includes the positive reactive circuit **300'**, the negative reactive circuit **400'**, and the feedback circuit **500'**.

In one implementation, the controllable reactive circuit **700'** includes a first variable load reactance circuit **760'** between the positive reactive circuit **400'** and the feedback circuit **500'** and a second variable load reactance circuit **780'** between the negative reactive circuit **400'** and the feedback circuit **500'**.

The first variable load reactance circuit **760'** includes a variable inductive component **762'** and a variable capacitive

component **764'** coupled to the variable inductive component **762'**. Similarly, the second variable load reactance circuit **780'** includes a variable inductive component **782'** and a variable capacitive component **784'** coupled to the variable inductive component **782'**. The variable capacitive components **764'**, **784'** are cross-coupled to one another between the first and second variable load reactance circuits **760'**, **780'**.

In operation, the controller **900'** is configured to adjust the variable inductive and capacitive components **762'**, **764'** in the first variable load reactance circuit **760'** via signal path **942(1)'** and to adjust the variable inductive and capacitive components **782'**, **784'** in the second variable load reactance circuit **780'** via signal path **942(2)'**.

The damped sine waves **720'** as received by the controllable reactive circuit **700'** are also received by the controller **900'** via signal paths **921(1)'**, **921(2)'**. By the controller **900'** selectively varying the load reactance within the controllable reactive circuit **700'** via the signal paths **942(1)'**, **942(2)'** subsequently formed damped sine waves **720'** are re-energized which in turn can be used to improve performance of the hydrogen generation system **100'**.

Referring now to the flowchart **1000** in FIG. **11**, another aspect of the disclosure is directed to a method for operating the above-described hydrogen generation system **100'**. From the start (Block **1002**), the method includes providing a pulsed drive signal **202'** to a hydrogen generation chamber **110'** at Block **1004**. Hydrogen **112'** is generated from a feedstock material **114'** contained within the hydrogen generation chamber **110'** based on the pulsed drive signal **202'** at Block **1006**. Hydrogen **112'** generated by the hydrogen generation chamber **110'** is detected at Block **1008**. The method further includes controlling a load reactance of a controllable reactive circuit **700'** coupled to the hydrogen generation chamber **110'** based on detection of the generated hydrogen **112'** at Block **1010**. The method ends at Block **1012**.

GENERAL

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed.

What is claimed is:

1. A hydrogen generation system comprising:

a pulsed drive signal generator configured to generate a pulsed drive signal;

a hydrogen generation chamber configured to receive the pulsed drive signal and generate hydrogen from a feedstock material contained therein based on the pulsed drive signal;

a controllable reactive circuit coupled between said pulsed drive signal generator and said hydrogen generation chamber;

a hydrogen detection device coupled to said hydrogen generation chamber and configured to detect the generated hydrogen; and

a controller configured to control said controllable reactive circuit based on detection of the generated hydrogen.

2. The hydrogen generation system according to claim **1** wherein said hydrogen detection device comprises a mass spectrometer to determine a purity of the generated hydrogen; and wherein said controller is configured to control said controllable reactive circuit based on the purity of the generated hydrogen.

3. The hydrogen generation system according to claim **1** wherein said hydrogen detection device comprises a hydrogen flow meter to determine a production rate of the generated hydrogen; and wherein said controller is configured to control said controllable reactive circuit based on the production rate of the generated hydrogen.

4. The hydrogen generation system according to claim **1** wherein damped sine waves are generated within said hydrogen generation chamber based on interaction between the pulsed drive signal and the feedstock material; and wherein said controller controls said controllable reactive circuit so as to present a varying load reactance to the damped sine waves.

5. The hydrogen generation system according to claim **4** wherein said controller is configured to control said controllable reactive circuit based on detection of the generated hydrogen and the damped sine waves.

6. The hydrogen generation system according to claim **5** wherein the damped sine waves include a DC signal with a plurality of embedded interactive chamber signals, with at least one of the embedded interactive chamber signals corresponding to the hydrogen being generated; and wherein said controller is further configured to analyze the at least one embedded interactive chamber signal corresponding to the hydrogen being generated.

7. The hydrogen generation system according to claim **6** wherein said controller analyzes a waveform shape of the at least one embedded interactive chamber signal corresponding to the hydrogen being generated, and varies the load reactance in said controllable reactive circuit based on the waveform shape.

8. The hydrogen generation system according to claim **4** wherein said pulsed drive signal generator generates a DC pulsed drive signal; and wherein the damped sine waves are generated between pulses of the DC pulsed drive signal.

9. The hydrogen generation system according to claim **1** wherein said controllable reactive circuit comprises:

a first variable load reactance circuit coupled between a first terminal of said pulsed drive signal generator and a first terminal of said hydrogen generation chamber; and

a second variable load reactance circuit coupled between a second terminal of said pulsed drive signal generator and a second terminal of said hydrogen generation chamber, wherein said first and second variable load reactance circuits are cross-coupled to one another.

10. The hydrogen generation system according to claim **9** wherein said first variable load reactance circuit comprises at least one variable inductive component, and at least one variable capacitive component; and wherein said second

variable load reactance circuit comprises at least one variable inductive component, and at least one variable capacitive component.

11. A hydrogen generation system comprising:

a pulsed drive signal generator configured to generate a pulsed drive signal;

a hydrogen generation chamber configured to receive the pulsed drive signal and generate hydrogen from a feedstock material contained therein, with damped sine waves being generated within said hydrogen generation chamber based on interaction between the pulsed drive signal and the feedstock material;

a controllable reactive circuit having a controllable load reactance coupled between said pulsed drive signal generator and said hydrogen generation chamber;

a hydrogen detection device coupled to said hydrogen generation chamber and configured to detect the generated hydrogen; and

a controller configured to control the load reactance in said controllable reactive circuit based on detection of the generated hydrogen and the damped sine waves.

12. The hydrogen generation system according to claim **11** wherein said hydrogen detection device comprises a mass spectrometer so that detection of the generated hydrogen corresponds to a purity of the generated hydrogen.

13. The hydrogen generation system according to claim **11** wherein said hydrogen detection device comprises a hydrogen flow meter so that detection of the generated hydrogen corresponds to a production rate of the generated hydrogen.

14. The hydrogen generation system according to claim **11** wherein the damped sine waves include a DC signal with a plurality of embedded interactive chamber signals, with at least one of the embedded interactive chamber signals corresponding to the hydrogen being generated; and wherein said controller is further configured to analyze the at least one embedded interactive chamber signal corresponding to the hydrogen being generated.

15. The hydrogen generation system according to claim **14** wherein said controller analyzes a waveform shape of the at least one embedded interactive chamber signal corresponding to the hydrogen being generated, and varies the load reactance in said controllable reactive circuit based on the waveform shape.

16. The hydrogen generation system according to claim **11** wherein said pulsed drive signal generator generates a DC pulsed drive signal; and wherein the damped sine waves are generated between pulses of the DC pulsed drive signal.

17. The hydrogen generation system according to claim **11** wherein said controllable reactive circuit comprises:

a first variable load reactance circuit coupled between a first terminal of said pulsed drive signal generator and a first terminal of said hydrogen generation chamber; and

a second variable load reactance circuit coupled between a second terminal of said pulsed drive signal generator and a second terminal of said hydrogen generation chamber, wherein said first and second variable load reactance circuits are cross-coupled to one another.

18. A method for operating a hydrogen generation system comprising a pulsed drive signal generator to generate a pulsed drive signal, a hydrogen generation chamber to receive the pulsed drive signal and generate hydrogen from a feedstock material contained therein based on the pulsed drive signal, and a controllable reactive circuit coupled between the pulsed drive signal generator and the hydrogen generation chamber, the method comprising:

detecting the hydrogen generated by the hydrogen generation chamber; and

controlling a load reactance of the controllable reactive circuit based on detection of the generated hydrogen.

19. The method according to claim **18** wherein the hydrogen detection device comprises a mass spectrometer so that detection of the generated hydrogen corresponds to a purity of the generated hydrogen.

20. The method according to claim **18** wherein the hydrogen detection device comprises a hydrogen flow meter so that detection of the generated hydrogen corresponds to a production rate of the generated hydrogen.

21. The method according to claim **18** wherein damped sine waves are generated within the hydrogen generation chamber based on interaction between the pulsed drive signal and the feedstock material; and wherein the load reactance of the controllable reactive circuit is controlled to present a varying load reactance to the damped sine waves.

22. The method according to claim **21** wherein the damped sine waves include a DC signal with a plurality of embedded interactive chamber signals, with at least one of the embedded interactive chamber signals corresponding to the hydrogen being generated; and wherein controlling the load reactance of the controllable reactive circuit is further based on analyzing the at least one embedded interactive chamber signal corresponding to the hydrogen being generated.

23. The method according to claim **22** wherein the analyzing comprises analyzing a waveform shape of the at least one embedded interactive chamber signal corresponding to the hydrogen being generated.

24. The method according to claim **21** wherein the pulsed drive signal generator generates a DC pulsed drive signal; and wherein the damped sine waves are generated between pulses of the DC pulsed drive signal.

25. The method according to claim **18** wherein the controllable reactive circuit comprises a first variable load reactance circuit coupled between a first terminal of the pulsed drive signal generator and a first terminal of the hydrogen generation chamber, and a second variable load reactance circuit coupled between a second terminal of the pulsed drive signal generator and a second terminal of the hydrogen generation chamber, with the first and second variable load reactance circuits being cross-coupled to one another.

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