configured to cycle through a repeating sequence that includes the first mode and the second mode. The controller is configured to synchronize the operation of the AC voltage generator and the electronic switch such that switching of the electronic switch to either the first mode or the second mode is restricted to windows of time that correspond to the first 5.7°, the middle 11.4°, and the last 5.7° of each 360° cycle of the AC voltage generator. ~~the instantaneous output of the AC voltage generator is less than 5 V in magnitude whenever the electronic switch switches to either the first mode or the second mode.~~ Within 20 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

[0022] In some embodiments of the fourth apparatus, the electronic switch is further configured to (c) operate in a third mode in which the output of the AC voltage generator is not routed to either the first power output or the second power output, and (d) cycle through the first mode, the second mode, and the third mode in the following repeating sequence (1) first mode, (2) third mode, (3) second mode, and (4) third mode. In some embodiments of the fourth apparatus, the controller is configured to synchronize the operation of the AC voltage generator and the electronic switch such that the instantaneous output of the AC voltage generator is less than 1 V in magnitude whenever the electronic switch switches to either the first mode or the second mode.

[0023] In some embodiments of the fourth apparatus, within 5 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage. In some embodiments of the fourth apparatus, within 1 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

[0024] In some embodiments of the fourth apparatus, the AC voltage generator continues to operate at its full steady-state AC output voltage during transitions of the electronic switch to either the first mode or the second mode.

[0025] In some embodiments of the fourth apparatus, the controller synchronizes the operation of the AC voltage generator and the electronic switch by controlling timing of

transitions of the electronic switch so that the transitions coincide with windows of time during which the instantaneous output of the AC voltage generator is less than 5 V in magnitude. In some embodiments of the fourth apparatus, the controller synchronizes the operation of the AC voltage generator and the electronic switch by controlling the AC voltage

WHAT IS CLAIMED IS:

1. An apparatus for generating AC electrical signals for application to a first pair of electrodes and a second pair of electrodes, the apparatus comprising:

an AC voltage generator having an output;

an electronic switch having an input that receives the output of the AC voltage generator, a first power output, and a second power output, wherein the electronic switch is configured to (a) operate in a first mode that routes the output of the AC voltage generator to the first power output, and (b) operate in a second mode that routes the output of the AC voltage generator to the second power output, and wherein the electronic switch is further configured to cycle through a repeating sequence that includes the first mode and the second mode; and

a controller configured to synchronize the operation of the AC voltage generator and the electronic switch such that switching of the electronic switch to either the first mode or the second mode is restricted to windows of time that correspond to the first 5.7°, the middle 11.4°, and the last 5.7° of each 360° cycle of the AC voltage generator,

wherein, within 20 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

2. The apparatus of claim 1, wherein the electronic switch is further configured to (c) operate in a third mode in which the output of the AC voltage generator is not routed to either the first power output or the second power output, and (d) cycle through the first mode, the second mode, and the third mode in the following repeating sequence (1) first mode, (2) third mode, (3) second mode, and (4) third mode.

3. The apparatus of claim 1, wherein the controller is configured to synchronize the operation of the AC voltage generator and the electronic switch such that switching of the electronic switch to either the first mode or the second mode is restricted to windows of time that correspond to the first 1.1°, the middle 2.2°, and the last 1.1° of each 360° cycle of the AC voltage generator.

4. The apparatus of claim 1, wherein, within 5 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

5. The apparatus of claim 1, wherein, within 1 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

6. The apparatus of claim 1, wherein the AC voltage generator continues to operate at its full steady-state AC output voltage during transitions of the electronic switch to either the first mode or the second mode.

7. The apparatus of claim 1, wherein the controller synchronizes the operation of the AC voltage generator and the electronic switch by controlling timing of transitions of the electronic switch so that the transitions coincide with windows of time that correspond to the first 5.7°, the middle 11.4°, and the last 5.7° of each 360° cycle of the AC voltage generator.

8. The apparatus of claim 1, wherein the controller synchronizes the operation of the AC voltage generator and the electronic switch by controlling the AC voltage generator so that the output of the AC voltage generator is turned off whenever a transition of the electronic switch occurs.

9. The apparatus of claim 1, wherein the controller synchronizes the operation of the AC voltage generator and the electronic switch by both (a) controlling timing of transitions of the electronic switch so that the transitions coincide with windows of time that correspond to the first 5.7°, the middle 11.4°, and the last 5.7° of each 360° cycle of the AC voltage generator and (b) controlling the AC voltage generator so that the output of the AC voltage generator is turned off whenever a transition of the electronic switch occurs.

10. The apparatus of claim 1, wherein the electronic switch is configured to cycle through the first mode and the second mode in the following repeating sequence (1) first mode, (2) second mode, and wherein the electronic switch is configured to switch directly from the first mode to the second mode and to switch directly from the second mode to the first mode.

11. An apparatus for generating AC electrical signals for application to a first pair of electrodes and a second pair of electrodes, the apparatus comprising:

an AC voltage generator having an output;

an electronic switch having an input that receives the output of the AC voltage generator, a first power output, and a second power output, wherein the electronic switch is configured to (a) operate in a first mode that routes the output of the AC voltage generator to the first power output, and (b) operate in a second mode that routes the output of the AC voltage generator to the second power output, and wherein the electronic switch is further configured to cycle through a repeating sequence that includes the first mode and the second mode; and

a controller configured to synchronize the operation of the AC voltage generator and the electronic switch such that whenever the electronic switch switches to either the first mode or the second mode, the instantaneous output of the AC voltage generator has a magnitude that is below a threshold at which a subject being treated begins to experience a perceptible sensation,

wherein, within 20 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

12. The apparatus of claim 11, wherein the electronic switch is further configured to (c) operate in a third mode in which the output of the AC voltage generator is not routed to either the first power output or the second power output, and (d) cycle through the first mode, the second mode, and the third mode in the following repeating sequence (1) first mode, (2) third mode, (3) second mode, and (4) third mode.

13. The apparatus of claim 11, wherein the controller is configured to synchronize the operation of the AC voltage generator and the electronic switch such that the instantaneous output of the AC voltage generator is less than 1 V in magnitude whenever the electronic switch switches to either the first mode or the second mode.

14. The apparatus of claim 11, wherein, within 5 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

15. The apparatus of claim 11, wherein, within 1 ms after the electronic switch switches to either the first mode or the second mode, the AC voltage generator's output voltage is at least 80% of the AC voltage generator's steady-state output voltage.

16. The apparatus of claim 11, wherein the AC voltage generator continues to operate at its full steady-state AC output voltage during transitions of the electronic switch to either the first mode or the second mode.

17. The apparatus of claim 11, wherein the controller synchronizes the operation of the AC voltage generator and the electronic switch by controlling timing of transitions of the electronic switch so that the transitions coincide with windows of time during which the instantaneous output of the AC voltage generator has a magnitude that is below the threshold.

18. The apparatus of claim 11, wherein the controller synchronizes the operation of the AC voltage generator and the electronic switch by controlling the AC voltage generator so that the output of the AC voltage generator is turned off whenever a transition of the electronic switch occurs.

19. The apparatus of claim 11, wherein the controller synchronizes the operation of the AC voltage generator and the electronic switch by both (a) controlling timing of transitions of the electronic switch so that the transitions coincide with windows of time during which the instantaneous output of the AC voltage generator has a magnitude that is below the threshold and (b) controlling the AC voltage generator so that the output of the AC voltage generator is turned off whenever a transition of the electronic switch occurs.

20. The apparatus of claim 11, wherein the electronic switch is configured to cycle through the first mode and the second mode in the following repeating sequence (1) first mode, (2) second mode, and wherein the electronic switch is configured to switch directly from the first mode to the second mode and to switch directly from the second mode to the first mode.

~~21. An apparatus for generating a sinusoid at a frequency f, the apparatus comprising:~~

~~a DC power source having a voltage-control input that sets an output voltage of the DC power source;~~

a transformer having a primary and a secondary;

a power switch having a control input, wherein the power switch is configured to apply the output of the DC power source to the primary of the transformer in a first direction when a first control signal is applied to the control input, apply the output of the DC power source to the primary of the transformer in a second direction when a second control signal is applied to the control input, and remain off when neither the first control signal nor the second control signal is applied to the control input, wherein the second direction is opposite to the first direction;

a controller programmed to (a) apply the first control signal to the control input for a duration of T/3, then (b) wait for a duration of T/6, then (c) apply the second control signal to the control input for a duration of T/3, and then (d) wait for a duration of T/6, then continuously repeat the sequence (a), (b), (c), and (d), wherein T is the reciprocal of the frequency f; and

an output filter connected to the secondary of the transformer, wherein the output filter passes the frequency f and attenuates frequencies above a cut-off frequency,

wherein the controller is further programmed to control an amplitude of the sinusoid at the frequency by adjusting a third control signal that is applied to the voltage-control input of the DC power source, and wherein the controller is further programmed to prevent adjustments of the third control signal from occurring when either the first control signal or the second control signal is being applied to the control input.

22. The apparatus of claim 21, wherein the cut-off frequency is between 2f and 4f and wherein the output filter has a transfer function with a zero at 5f.

23. An apparatus for generating a sinusoid at a frequency f, the apparatus comprising:

n DC power sources, each of the n DC power sources having a voltage-control input that sets an output voltage of the respective power source, wherein n is a positive integer;

a power switch having output terminals and a control input, wherein the power switch is configured to either (a) route the output of a selected one of the n DC power sources to the output terminals with a selected polarity in response to 2n states of a control signal that is applied to the control input or (b) remain off in response to an additional state of the control signal;

a controller programmed to control the generation of an oversampled version of a sine wave that is sampled N times per cycle using evenly-spaced samples that include a sampling

point at 0°, where N=2+4n, by setting the output voltages of the n DC power sources to levels that are present on the oversampled version of the sine wave, and then sequencing the control signal through the 2n states and the additional state, so that each of the n DC power sources is routed to the output terminals of the power switch with the selected polarity at appropriate times in a sequence so as to generate the oversampled version of the sine wave; and

an output filter that filters current arriving from the output terminals of the power switch, wherein the output filter passes the frequency f and attenuates frequencies above a cut-off frequency,

wherein the controller is programmed to control an amplitude of the sinusoid by adjusting the output voltages of the n DC power sources via the voltage control inputs, and wherein the controller is further programmed not to adjust the output voltage of a DC power source while its output is being routed to the output terminals of the power switch.

24. The apparatus of claim 23, further comprising a transformer having a primary connected to the output terminals of the power switch and a secondary connected to the output filter, configured so that the current from the output terminals of the power switch arrives at the output filter via the transformer.

25. The apparatus of claim 23, wherein n=1, which means that there is only a single DC power source, and

wherein, the controller is programmed to control the generation of the oversampled version of the sine wave by (a) applying a first control signal to the control input for a duration of T/3 in order to cause the power switch to route the output of the single DC power source to the output terminals with a first polarity, then (b) waiting for a duration of T/6, then (c) applying a second control signal to the control input for a duration of T/3 in order to cause the power switch to route the output of the single DC power source to the output terminals with a second polarity that is opposite to the first polarity, and then (d) waiting for a duration of T/6, then continuously repeating the sequence (a), (b), (c), and (d), wherein T is the reciprocal of the frequency f.

26. The apparatus of claim 25, wherein the cut-off frequency is between 2f and 4f, and wherein the output filter has a transfer function with a zero at 5f.

27. The apparatus of claim 23, wherein n>1, and

wherein the controller is further programmed to control an amplitude of the sinusoid by adjusting the output voltages of the n DC power sources via the voltage control inputs, while maintaining a fixed ratio between the output voltages of each of the n DC power sources.

28. The apparatus of claim 27, wherein the output filter has a transfer function with a zero at a frequency where a harmonic of the frequency f is expected to contain power.

29. A method for generating a sinusoid at a frequency f, the method comprising:

setting n DC power sources to respective output voltages, wherein n is a positive integer;

generating an oversampled version of a sine wave that is sampled N times per cycle using evenly spaced samples that include a sampling point at 0°, where N=2+4n, by setting the output voltages of the n DC power sources to levels that are present on the oversampled version of the sine wave, and then switching the outputs of the n DC power sources to an output in a controlled sequence such that each of the n DC power sources is switched to the output in each direction at appropriate times in the sequence so as to generate the oversampled version of the sine wave; and

filtering the oversampled version of the sine wave to pass the frequency f and attenuate frequencies above a cut-off frequency, wherein the filtering implements a transfer function with a zero at a frequency where a harmonic of the frequency f is expected to contain power,

wherein the amplitude of the sinusoid is controlled by adjusting the output voltages of the n DC power sources, and adjustment of the output voltage of any given one of the DC power sources is prevented while the given one of the DC power sources is switched to the output.

30. The method of claim 29, wherein n = 1, which means that there is only a single DC power source, and wherein adjustment of the output voltage of the single DC power source only occurs during such times when the output of the single DC power source is not being switched to the output.

31. The method of claim 29, wherein the filtering implements a transfer function with a zero at a frequency where a harmonic of the frequency f is expected to contain power.

32. An apparatus for generating an output waveform at a frequency f, the apparatus comprising:

a first DC power source having a first voltage-control input that sets an output voltage of the first DC power source;

a second DC power source having a second voltage-control input that sets an output voltage of the second DC power source;

a power switch having output terminals and a control input, wherein the power switch is configured to (a) route the output of the first DC power source to the output terminals with a first polarity in response to a first state of the control input, (b) route the output of the first DC power source to the output terminals with a second polarity in response to a second state of the control input, (c) route the output of the second DC power source to the output terminals with the first polarity in response to a third state of the control input, (d) route the output of the second DC power source to the output terminals with the second polarity in response to a fourth state of the control input, and (e) remain off in response to an additional state of the control input, wherein the second polarity is opposite to the first polarity;

an output filter that filters current arriving from the output terminals of the power switch, wherein the output filter passes the frequency f and attenuates frequencies above a cut-off frequency; and

a controller programmed to operate in a first mode in which the controller sets the control input to the first and second states in an alternating sequence while holding the first voltage-control input constant, wherein the controller is further programmed to operate in a second mode in which the controller sets the control input to the third and fourth states in an alternating sequence while holding the second voltage-control input constant,

wherein the controller is further programmed so that if the controller is operating in the first mode, the controller brings about changes in amplitude of the output waveform by adjusting the second voltage-control input and subsequently switching the controller to the second mode, and

wherein the controller is further programmed so that if the controller is operating in the second mode, the controller brings about changes in amplitude of the output waveform by adjusting the first voltage-control input and subsequently switching the controller to the first mode.

33. The apparatus of claim 32, wherein the output waveform is a sinusoid,

wherein the setting of the control input to the first and second states in the alternating sequence comprises (a) placing the control input in the first state for a duration of T/3, then (b) waiting for a duration of T/6, then (c) placing the control input in the second state for a duration of T/3, and then (d) waiting for a duration of T/6, then continuously repeating the sequence (a), (b), (c), and (d),

wherein the setting of the control input to the third and fourth states in the alternating sequence comprises (e) placing the control input in the third state for a duration of T/3, then (f) waiting for a duration of T/6, then (g) placing the control input in the fourth state for a duration of T/3, and then (h) waiting for a duration of T/6, then continuously repeating the sequence (e), (f), (g), and (h), and

wherein T is the reciprocal of the frequency f.

34. The apparatus of claim 32, wherein the controller is further programmed so that if the controller is operating in the first mode, the controller brings about changes in amplitude of the output waveform by adjusting the second voltage control input at least 1 ms before switching the controller to the second mode, and

wherein the controller is further programmed so that if the controller is operating in the second mode, the controller brings about changes in amplitude of the output waveform by adjusting the first voltage control input at least 1 ms before switching the controller to the first mode.

35. The apparatus of claim 32, further comprising a transformer having a primary connected to the output terminals of the power switch and a secondary connected to the output filter, configured so that the current from the output terminals of the power switch arrives at the output filter via the transformer.

36. The apparatus of claim 35, wherein the power switch is configured to (a) route the output of the first DC power source to the primary of the transformer in a first direction in response to the first state of the control input, (b) route the output of the first DC power source to the primary of the transformer in a second direction in response to the second state of the control input, (c) route the output of the second DC power source to the primary of the transformer in the first direction in response to the third state of the control input, (d) route the output of the second DC power source to the primary of the transformer in the second

direction in response to the fourth state of the control input, and (e) remain off in response to a fifth state of the control input, wherein the second direction is opposite to the first direction.

37. The apparatus of claim 32, wherein the cut-off frequency is between 2f and 4f, and wherein the output filter has a transfer function with a zero at 5f.

38. A method for generating an output waveform at a frequency f, the method comprising:

routing an output of a first DC power source to output terminals of a power switch with a first polarity in response to a first state of a control input of the power switch, (b) routing the output of the first DC power source to the output terminals with a second polarity in response to a second state of the control input, (c) routing the output of a second DC power source to the output terminals with the first polarity in response to a third state of the control input, (d) routing the output of the second DC power source to the output terminals with the second polarity in response to a fourth state of the control input, and (e) remaining off in response to an additional state of the control input, wherein the second polarity is opposite to the first polarity;

filtering current arriving from the output terminals of the power switch, wherein the filtering comprises passing the frequency f and attenuating frequencies above a cut-off frequency;

operating in a first mode in which the control input is set to the first and second states in an alternating sequence while holding the output voltage of the first DC power source constant; and

operating in a second mode in which the control input is set to the third and fourth states in an alternating sequence while holding the output voltage of the second DC power source constant,

wherein in the first mode, changes in amplitude of the output waveform are brought about by adjusting the output voltage of the second DC power source and subsequently switching to the second mode, and

wherein in the second mode, changes in amplitude of the output waveform are brought about by adjusting the output voltage of the first DC power source and subsequently switching to the first mode.

~~39. The method of claim 38, wherein the output waveform is a sinusoid,~~

~~wherein the control input is set to the first and second states in the alternating sequence by (a) placing the control input in the first state for a duration of T/3, then (b) waiting for a duration of T/6, then (c) placing the control input in the second state for a duration of T/3, and then (d) waiting for a duration of T/6, then continuously repeating the sequence (a), (b), (c), and (d),~~

~~wherein the control input is set to the third and fourth states in the alternating sequence by (e) placing the control input in the third state for a duration of T/3, then (f) waiting for a duration of T/6, then (g) placing the control input in the fourth state for a duration of T/3, and then (h) waiting for a duration of T/6, then continuously repeating the sequence (e), (f), (g), and (h), and~~

~~wherein T is the reciprocal of the frequency f.~~

~~40. The method of claim 38, wherein in the first mode, changes in amplitude of the output waveform are brought about by adjusting the output voltage of the second DC power source at least 1 ms before switching to the second mode, and~~

~~wherein in the second mode, changes in amplitude of the output waveform are brought about by adjusting the output voltage of the first DC power source at least 1 ms before switching to the first mode.~~