

AIR IONIZER ELECTRODE DRIVE CIRCUIT AND METHOD

FIELD OF THE INVENTION

The invention relates generally to the generation of negative ions in the air. More specifically, the invention concerns an electrode drive circuit and method for use in controlling the level of negative ion generation in an air ionizer.

BACKGROUND OF THE INVENTION

Over the last few decades negative air ions have been found to be an essential component of good air quality. These negative ions have been shown to have beneficial physiological effects on plants, animals and humans. Extensive research has concluded that abundant negative ions in an environment can enhance mood, improve metabolic activity, accelerate healing and increase performance in athletes. In addition, negative ions have been shown to have important air cleaning functions, such as removing harmful dust particles, remove odors and kill various micro-organisms.

An air ionizer may include an electrode assembly of the general kind seen, for example, in United States patent US 7,365,956 B2, in which two electrodes are respectively disposed in close proximity on either side of a barrier of dielectric material. Negative ions are generated by the application of a high AC voltage of the order of a few kV. Other examples of ionizer electrode assemblies, having novel electrode structures for enhancing ion generation, are disclosed in the Applicant's international patent application PCT/SG2008/000497 filed 23 December 2008, the content of which is hereby incorporated by reference. The present invention, however, is not confined in its applicability to any particular

form of electrode assembly, provided there are at least two electrodes, of any configuration, that are separated by a dielectric material.

In conventional air ionizers, the level of negative ions produced was usually controlled by varying the amplitude of the AC voltage applied to the electrodes. The voltage across the two electrodes correlates to the rate of ion production. Generally, the higher the voltage, the higher the rate of ion production. However, this method has two major problems. First, if the applied voltage is lower than a specific excitation threshold for the particular electrode/dielectric configuration, there will be very few or no ions produced. Second, if the applied voltage exceeds a specific excitation threshold for the particular electrode/dielectric configuration, corona discharge may occur resulting in escalation of ozone generation. Excessive ozone generation may have negative implications for health.

These two major problems restrict the available variation of ion production rate to a very narrow range and call for accurate control of the applied voltage. However, if the voltage control is provided by a potentiometer in the electrode drive circuit, the tolerance on the resistance of the potentiometer may easily be +/- 20% or more. This leads to serious problems in achieving predictable and reliable performance of a mass-produced ionizer.

United States patent application publication US 2009/0047183 A1 discloses an air cleaner apparatus that well illustrates how the applied voltage can tip the balance between ion generation and ozone generation. This document discloses a negative ion generator and an ozone gas generator that are driven by a common inverter circuit. The AC voltage amplitude output by the inverter is switched between a first value that is sufficient to drive the ion generator but below the excitation threshold of the ozone generator, and a

second value that is sufficient to activate both generators. A control circuit generates a pulse-width modulated signal whose duty cycle determines the AC voltage amplitude of the electrode drive output from a transformer.

There is an unfulfilled need for an air ionizer electrode drive circuit and method that can be used to produce an ample and controllable quantity of negative ions with lower chance of unintentionally generating ozone. The present invention was developed in consideration of this need.

SUMMARY OF THE INVENTION

In a first aspect, the invention provides an air ionizer electrode drive circuit adapted to generate a drive voltage for application to the electrodes of an air ionizer, the drive circuit comprising:

a high voltage generator that generates an AC high voltage of a predetermined constant amplitude; and

a controller that generates a control signal which is supplied to the high voltage generator;

wherein the control signal has a repeating waveform that switches the high voltage generator on and off, to produce the drive voltage, according to one of a plurality of predetermined duty cycles so as to control the ion production by controlling the amount of negative ions produced during each period of the waveform.

In a second aspect, the invention provides an air ionizer comprising an electrode assembly having at least a pair of electrodes separated by dielectric

material, and a drive circuit according to the first aspect of the invention for driving the electrodes so as to produce negative ions at any one of a plurality of predetermined levels selectable by a user.

In a third aspect, the invention provides a method of driving the electrodes of an air ionizer having at least a pair of electrodes separated by dielectric so as to produce negative ions, the method comprising applying to the electrodes an AC high voltage of a predetermined constant amplitude that is pulse width modulated according to one of a plurality of predetermined duty cycles so as to control the ion production by controlling the amount of negative ions produced during each pulse width modulation waveform period.

The invention provides an effective solution to the above-mentioned two major problems of the prior art approach to controlling ion production. In the invention, an AC high voltage of predetermined constant amplitude is output by a high voltage generator for application to the ionizer electrodes. The level of ions produced is then controlled by the ion production time using a controller that switches the voltage generator on and off in a repeating manner. The duty cycle, i.e. on-off ratio, at which the voltage generator operates then determines the average ion production rate. This method allows control of the ion production level from 0 to 100% of the range.

A plurality of different predetermined duty cycles is available from the controller for the user to set different levels of ion output within such range. Therefore, one embodiment of the electrode drive circuit further comprises user-operable input means for selecting one of the plurality of predetermined duty cycles. The input means may comprise a push-button in association with one or more status indicators such as LEDs.

The plurality of predetermined duty cycles may consist of three duty cycles corresponding to low, medium and high levels of ion production. These three settings will normally be sufficient in an air ionizer for domestic use. However, a different number of settings is equally possible and within the scope of the invention. The capability of accurately controlling the production of ions, based on timing instead of voltage level, allows the invention to be scaled up from a basic residential application to commercial applications where the demand can be quite different.

In an embodiment, the AC high voltage has a frequency higher than the frequency of the control signal. The AC high voltage may have a frequency in the range of 10kHz to 100kHz. The control signal may have a frequency in the range of 0.1Hz to 500Hz.

In another embodiment of the electrode drive circuit, the high voltage generator comprises an oscillator and a transformer that multiplies the voltage output from the oscillator.

The control signal may switch the oscillator on and off. In an embodiment, the oscillator operates at a supply voltage of about 12V, and suitably in the range of about 11.5V to about 12.6V.

The controller may comprise a processor, such as a microprocessor or microcontroller. This can be used to control other features of the air ionizer.

An optimum predetermined constant amplitude of the AC high voltage may be established empirically for the particular electrode assembly to which the voltage will be applied. It will be such that the applied voltage exceeds the specific excitation threshold and is below the specific breakdown threshold.

The predetermined constant amplitude of the AC high voltage is in the range of 1kV to 10kV. In one embodiment, the AC high voltage is in the range of about 2.5kV to about 3.5kV.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated, though not limited, by the following description of preferred embodiments thereof, when taken in conjunction with the accompanying drawings.

In the accompanying drawings, like reference numerals are used to denote like parts throughout the several views.

Fig. 1 is a block diagram of an air ionizer electrode drive circuit according to an embodiment;

Fig. 2 is a block diagram of a high voltage generator used in the circuit of Fig. 1;

Figs. 3 (a) – (c) shows a first set of exemplary waveforms for the control signal and electrode drive voltage for three different levels of ion generation according to one embodiment;

Figs. 4 (a) – (c) show a second set of exemplary waveforms for the control signal and electrode drive voltage for three different levels of ion generation according to another embodiment;

Fig. 5 shows an example of an electrode assembly with which the electrode drive circuit of Fig. 1 may be used, so as to realize in combination an air ionizer device; and

Fig. 6 is a set of graphs comparing the controllability of ion generation according to the invention and the prior art.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig. 1 is a block diagram of an air ionizer electrode drive circuit according to an embodiment. The drive circuit has two main components: controller 12 and high voltage generator 16. Controller 12 is at the core of the drive circuit and suitably is a microcontroller or microprocessor having a Central Processing Unit (CPU) 14 and associated support circuits such as program memory, data memory, oscillator, timer and watchdog in one integrated circuit package.

User input is made via one or more button switches 11 to control the ionizer's functions. The button switches are connected to controller 12 through digital input interface 13. In this embodiment, the functions to be controlled include the ion output level, booster fan operating time, and different combinations thereof. The status and operating mode of the ionizer are suitably shown by function indicators such as LEDs that are driven by controller 12 through digital output interface 15.

Controller 12 further provides signals for driving a booster fan and decorative lighting through the interface 15. The booster fan is used to propel and increase the throughput of the ions generated by the electrode module. The decorative lighting may comprise a set of LEDs that is used to enhance the physical appearance of the ionizer.

High voltage generator 16 serves to generate the required AC high voltage 19 for driving the electrodes of the ionizer for negative ion production. It is controlled by controller 12 through digital output interface 15 that provides control signal 17. The high voltage generator 16 receives a regulated DC low voltage input from voltage regulator 18, from which the AC high voltage is generated.

Fig. 2 is a block diagram of the high voltage generator 16. It has a low voltage oscillator 21 that generates a low voltage AC signal, and a transformer 22 that provides voltage multiplication up to the required voltage 19 to drive the ionizer electrodes. The oscillator is powered by regulated voltage from voltage regulator 18 via switch logic 23 that is controlled by control signal 17. The switch logic may comprise a simple transistor switch that is biased by the control signal to switch the power supply to oscillator 21 on and off according to the level of the control signal.

The AC high voltage 19 output by generator 16 has a predetermined constant amplitude that is optimized for ion generation as explained in the introduction. In the present embodiment, the voltage has a magnitude a range of about 2.5kV to about 3.5kV. More generally, the voltage may have a magnitude in the range of 1kV to 10kV. The actual value chosen will depend on the nature of the electrodes and intervening dielectric layer, such as their size, thickness, and the materials of which they are made. In the high voltage generator 16, the final output voltage magnitude is determined by the magnitude of the AC signal output by the low voltage oscillator 21 and the turns ratio of the transformer 22. The AC frequency is suitably in the range of 1kHz to 10kHz.

The novel control technique for ion generation in accordance with the present invention will now be explained with reference to two example schemes.

The control signal 17 that is used to switch the high voltage generator on and off has the form of a pulse width modulated (PWM) waveform of fixed period. In the examples that follow, the period is 0.25 second. The frequency of the control signal is thus 4Hz. More generally, the frequency of the control signal may be, for example, in the range of 1Hz to 10Hz but in any event is lower than the AC signal frequency. The controller 12 turns the high voltage generator on and off at this frequency to control the level of ion production. The on/off time ratio during the PWM period is set at one of several predetermined values by the controller. The desired level is selected by the user operating the control switch(es) 11 (Fig. 1).

Figs. 3 (a)-(c) show a first control scheme in which the PWM period is divided into 10 sub-periods each of 0.025 second duration. The upper graph in each figure shows the control signal waveform, whereas the lower graph shows the applied AC high voltage, as modulated by the control signal. This example has three levels of control corresponding to High, Medium and Low.

Fig. 3(a) shows the High setting in which the control signal is high for all 10 sub-periods, i.e. it is a constant DC level. The AC high voltage is accordingly also constant and this naturally corresponds to maximum ion production.

Fig. 3(b) shows the Medium setting in which the control signal is high for 8 out of 10 sub-periods and low for the remaining 2 sub-periods. The AC high voltage is thus applied to the ionizer electrodes at this duty cycle. Negative ions are then generated at 80% of the full rate available under the High setting.

Fig. 3(c) shows the Low setting in which the control signal is high for 6 out of 10 sub-periods and low for the remaining 4 sub-periods. The AC high

voltage is thus applied to the ionizer electrodes at this duty cycle. Negative ions are then generated at 60% of the full rate available under the High setting.

Figs. 4 (a)-(c) show a second control scheme in which the PWM period is divided into 5 sub-periods each of 0.05 second duration. Again, the upper graph in each figure shows the control signal waveform, whereas the lower graph shows the applied AC high voltage, as modulated by the control signal. This example also has three levels of control corresponding to High, Medium and Low.

Fig. 4(a) shows the High setting in which the control signal is high for all 5 sub-periods, i.e. it is a constant DC level. The AC high voltage is accordingly also constant and this naturally corresponds to maximum ion production.

Fig. 4(b) shows the Medium setting in which the control signal is high for 4 out of 5 sub-periods and low for the remaining 1 sub-period. The AC high voltage is thus applied to the ionizer electrodes at this duty cycle. Negative ions are then generated at 80% of the full rate available under the High setting.

Fig. 4(c) shows the Low setting in which the control signal is high for 3 out of 5 sub-periods and low for the remaining 2 sub-periods. The AC high voltage is thus applied to the ionizer electrodes at this duty cycle. Negative ions are then generated at 60% of the full rate available under the High setting.

Needless to say, the above two example schemes are not limiting. The duration of the PWM period, number of sub-periods, and the number of different ion production levels available can all be varied according to the degree of control desired for any particular application.

Fig. 5 illustrates, by way of example only, an exploded view of an ionizer electrode module 50 suitable for being driven by the drive circuit of Fig. 1. The module 50 includes the components of inner electrode 52, outer electrode 54 and dielectric barrier 53, arranged in parallel and encased in a modular casing 51, 55. The AC high voltage 19 is applied across the electrodes 52, 54.

Fig. 6 is a set of graphs that illustrate the advantage of the invention in terms of a highly linear relationship between a control setting and the amount of ions generated. These results were generated by testing on an electrode assembly of the kind shown in Fig. 5.

Referring to Fig. 6, the long-dash graph reflects the results when a conventional AC voltage amplitude control technique is employed. It shows a non-linear relationship where at the higher setting (i.e. higher voltage) the ion production flattens out as the breakdown voltage is reached and the generation of ozone occurs. The short-dash graph reflects the results when the constant voltage control technique of the invention is employed with the PWM period divided into 5 sub-periods. Finally, the solid-line graph reflects the results when the constant voltage control technique of the invention is employed with the PWM period divided into 10 sub-periods.

Similar results were obtained by the applicant when other electrode assemblies were tested. It will thus be seen that the invention achieves a consistent highly linear control of the ion generation.

The embodiments in accordance with the invention can be scaled to a size to suit the application of the user. The electrode drive circuit may be incorporated in an electronic module and connected in use to one or more electrode modules of the kind shown in Fig. 5 or as described more fully in the

Applicant's international patent application PCT/SG2008/000497. The electrode drive circuit of the invention can alternatively be integral to an ion generating product.

It will be appreciated that the present invention allows consistent and effective control over the level of ion generation based on repetitive switching on and off of a constant voltage applied to the ionizer electrodes according to a timing scheme that is readily accurately governed by electronics. In other words, negative ions are generated intermittently at a fixed rate. Therefore, the problems associated with possible under-generation of ions or unintended production of ozone are eliminated.

Furthermore, although the invention was developed initially for use with an ion generator, the electrode drive circuit and method of the invention can just as equally be applied to an ozone generator with the same good results, simply by setting the predetermined constant amplitude AC high voltage to a suitably higher level.

The invention may also be embodied in many ways other than those specifically described herein, without departing from the scope thereof.

CLAIMS

1. An air ionizer electrode drive circuit adapted to generate a drive voltage for application to the electrodes of an air ionizer, the drive circuit comprising:

a high voltage generator (16) that generates an AC high voltage of a predetermined constant amplitude; and

a controller (12) that generates a control signal which is supplied to the high voltage generator;

wherein the control signal (17) has a repeating waveform that switches the high voltage generator (16) on and off, to produce said drive voltage, according to one of a plurality of predetermined duty cycles so as to control the ion production by controlling the amount of negative ions produced during each period of said waveform.

2. An air ionizer electrode drive circuit according to claim 1, further comprising user-operable input means (11) for selecting one of said plurality of predetermined duty cycles.

3. An air ionizer electrode drive circuit according to claim 1 or claim 2, wherein said plurality of predetermined duty cycles consists of three duty cycles corresponding to low, medium and high levels of ion production.

4. An air ionizer electrode drive circuit according to any one of claims 1 to 3, wherein said AC high voltage has a frequency higher than the frequency of said control signal.

5. An air ionizer electrode drive circuit according to claim 4, wherein said AC high voltage has a frequency in the range of 10kHz to 100kHz.

6. An air ionizer electrode drive circuit according to claim 4 or claim 5, wherein said control signal has a frequency in the range of 0.1Hz to 500Hz.

7. An air ionizer electrode drive circuit according to any one of the preceding claims, wherein said high voltage generator comprises an oscillator (21) and a transformer (22) that multiplies the voltage output from the oscillator.

8. An air ionizer electrode drive circuit according to claim 7, wherein said control signal (17) switches the oscillator on and off.

9. An air ionizer electrode drive circuit according to any one of the preceding claims, wherein said controller comprises a processor (14).

10. An air ionizer electrode drive circuit according to any one of the preceding claims, wherein the predetermined constant amplitude of said AC high voltage exceeds an excitation threshold of the electrodes in said air ionizer and is below a breakdown threshold of the electrodes in said air ionizer.

11. An air ionizer electrode drive circuit according to any one of the preceding claims, wherein the predetermined constant amplitude of said AC high voltage is in the range of 1kV to 10kV.

12. A method of driving the electrodes of an air ionizer having at least a pair of electrodes (52, 54) separated by dielectric (53) so as to produce negative ions, the method comprising applying to the electrodes an AC high voltage of a predetermined constant amplitude that is pulse width modulated

according to one of a plurality of predetermined duty cycles so as to control the ion production by controlling the amount of negative ions produced during each pulse width modulation waveform period.