DC/AC INVERTER

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ABSTRACT

A DC/AC inverter for transforming a DC power source to an AC power, which drives a load. The DC/AC inverter comprises a full-bridge switch circuitry, a resonant tank, a frequency generator and a driver circuit. The full-bridge switch circuitry is electrically connected to the DC power source to convert the DC voltage to a pulse signal. The full-bridge switch circuitry comprises a first power switch, a second power switch, a third power switch, and a fourth power switch. The resonant tank is electrically connected between the full-bridge switch circuitry and a load for boosting and filtering the pulse signal to generate an AC power supplied to the load. The frequency generator generates a pulse signal at one of at least two predetermined operating frequencies based on an operation state of the DC/AC inverter. The driver circuit is coupled to the frequency generator and provides four driving signals based on the pulse signal of the frequency generator for turning on and off the first power switch, the second power switch, the third power switch, and the fourth power switch respectively. The four driving signals have the same frequency, wherein the duty cycle of two of the four driving signals is smaller than 50% and the duty cycle of the other two of the four driving signals is larger than 50%.
Fig. 1A (PRIOR ART)

Fig. 1B (PRIOR ART)
DC/AC INVERTER
CROSS REFERENCE TO RELATED APPLICATIONS


BACKGROUND OF THE PRESENT INVENTION

[0002] 1. Field of Invention

[0003] The present invention relates to a DC/AC inverter for driving a cold cathode fluorescent lamp (CCFL) used as a backlight of a liquid crystal display (LCD), and more particularly to a DC/AC inverter for controlling a plurality of power switches to drive a plurality of fluorescent lamps.

[0004] 2. Description of Related Arts

[0005] As liquid crystal displays (LCDs) are thinner than conventional cathode ray tube (CRT) monitors, they are being used in more and more homes and public display. However, since LCD is operated by its optical rotation and optical characteristic to display image and text information, hence not illuminable, it requires an additional backlight source. An example of backlight source for LCD is a fluorescent lamp.

[0006] A typical DC/AC inverter utilizes a full-bridge inverter circuit, along with a resonant tank and a step-up transformer. A DC power input can be filtered and converted to a high AC voltage by the resonant tank and the step-up transformer, so as to drive the fluorescent lamp.

[0007] In order to stabilize the light emitted by the fluorescent lamp, and prevent a change in light intensity while there is a change in the power input voltage, most inverters are incorporated with negative feedback circuits for stabilizing the current in the fluorescent lamp. As the life-span of the fluorescent lamp is affected by the symmetry of the waveform of the current, it is most popular to use a full-bridge inverter to drive a fluorescent lamp.

[0008] Referring to FIG. 1A of the drawings, a conventional full-bridge inverter is illustrated. As shown in FIG. 1A, a full-bridge inverter 100 comprises a DC power source 101, a resonant tank 102, a fluorescent lamp 103, four NMOS power switches 104A, 104B, 104C and 104D. The resonant tank 102 comprises an inductor 105 and a resonant capacitor 106. The four NMOS power switches 104A, 104B, 104C and 104D are respectively driven by four driving signals V_G1, V_G2, V_G3 and V_G4 to control the conduction period and the non-conduction period of four power switches 104A, 104B, 104C and 104D. The DC power source 101 is electrically connected to the power switches 104A, 104B, 104C and 104D of the full-bridge switch circuitry 104. The NMOS power switches 104B, and 104C of the full-bridge switch circuit 104 are grounded. An output terminal A of the power switches 104A, 104B and an output terminal B of the power switches 104C, 104D are electrically connected to two input terminals of the resonant tank 102 respectively. An output terminal C of the resonant tank 102 is electrically connected to one end of the fluorescent lamp 103.

Conventional full-bridge inverter 100 is operated based on a high frequency alternative conduction between the four power switches 104A, 104B, 104C and 104D, such that the DC voltage V_DC output by the DC power source 101 is transformed to outputted as a high-frequency AC square wave, which is provided for being inputted to the resonant tank 102. The resonant tank 102 utilizes the filter characteristic of the inductor 105 and the capacitor 106 to transform the high-frequency AC square wave to a high frequency AC sine wave, which is supplied to the fluorescent lamp 103.

[0010] As mentioned before, the four NMOS power switches 104A, 104B, 104C and 104D are respectively driven by four driving signals V_G1, V_G2, V_G3 and V_G4 to control the conduction period and the non-conduction period of four NMOS power switches 104A, 104B, 104C and 104D. The four driving signals V_G1, V_G2, V_G3 and V_G4 are square waves, which have the same fixed frequency, the same duty cycle, but different phases. Generally speaking, the duty cycle of the four driving signals V_G1, V_G2, V_G3 and V_G4 is a little smaller than 50%. Conventional fixed-frequency phase-shift control technique shifts different phases of the four driving signals V_G1, V_G2, V_G3 and V_G4 to generate different power output. Referring to FIGS. 1B and 1C of the drawings, FIGS. 1B and 1C representative waveforms present in the circuit of FIG. 1A. The driving signals V_G1, V_G2 must keep 180° phase shift in order to avoid simultaneous conduction of the power switches 104A, 104B. Also, the driving signals V_G3, V_G4 must keep 180° phase shift in order to avoid simultaneous conduction of the power switches 104C, 104D. The phase shift between the driving signals V_G1, V_G3 as shown in FIG. 1B is smaller than the phase shift between the driving signals V_G2, V_G4 as shown in FIG. 1C, such that the output V_AB of the full-bridge switch circuitry 104 as shown in FIG. 1B has a greater duty cycle to generate more power output.

[0011] This conventional type of full-bridge inverter can stably control the current of a fluorescent lamp. But on liquid-crystal display application, the DC voltage supplied by the system only reaches to teen volts. However, The full-bridge inverter as shown in FIG. 1A needs a voltage of several hundred volts to start operating.

[0012] As shown in FIG. 1A, the full-bridge inverter 100 utilizes NMOSFETs as four power switches to convert the DC voltage V_DC to a high-frequency AC square wave, therefore, the driving signals V_G1 and V_G4 respectively with respect to the voltage at the output terminal A and the voltage at the output terminal B have to be appropriately increased in order to turn on the power switch 104A or the power switch 104D. As a result, an additional step-up circuit is required to boost the driving signals V_G1 or V_G4; however, circuit design is difficult and complicated.

[0013] Therefore, the present invention is to provide a DC/AC driver apparatus for driving cold cathode fluorescent lamps.

SUMMARY OF THE PRESENT INVENTION

[0014] A main object of the present invention is to provide a DC/AC inverter for driving a backlight fluorescent lamp of a LCD, especially for a plurality of DC/AC inverters designed for driving a plurality of fluorescent lamps, wherein the DC/AC inverter utilizes a set of driving signals to alternatively turn on and off NMOS power switches and PMOS power switches for lowering DC voltage ripple and in turn lowering noise caused by system ripples.
Another object of the present invention is to provide a DC/AC inverter for driving a backlight fluorescent lamp of a LCD, especially for a plurality of DC/AC inverters designed for driving a plurality of fluorescent lamps, wherein the DC/AC inverter utilizes less power switches and a set of driving signals to alternatively turn on and off NMOS power switches and PMOS power switches for lowering DC voltage ripple, which in turn lowers noise caused by system ripples caused by switching of power switches.

Another object of the present invention is to provide a DC/AC inverter for driving a backlight fluorescent lamp of a LCD, which utilizes driving signals to directly drive power switches without step-up circuits. Therefore, the DC/AC inverter has advantages of easy circuit design and lower manufacturing cost.

Another object of the present invention is to provide a plurality of DC/AC inverters for driving a plurality of fluorescent lamps such that the DC/AC inverters can utilize a frequency generator to generate a plurality of driving signals having the same frequency but different phases, which are applied to a plurality of fluorescent lamps, such that the fluorescent lamps can be driven by the plurality of signals having the same frequency but different phases.

Another object of the present invention is to provide two sets of DC/AC inverters such that the DC/AC inverters can provide two sets of driving signals, which are applied to drive half-bridge power switch circuit and have the symmetric waveform of the duty cycle, such that two sets of the power switches would not be conducted simultaneously for lowering DC voltage ripple.

Accordingly, in order to accomplish the above objects, the present invention provides a DC/AC inverter for transforming a DC power source to a AC power source, which drives a load, the DC/AC inverter comprising:

- a full-bridge switch circuitry electrically connected to said DC power source being operative to convert said DC voltage to a pulse signal, said full-bridge switch circuitry comprising a first power switch, a second power switch, a third power switch, and a fourth power switch;
- a resonant tank electrically connected between said full-bridge switch circuitry and said load for being operative to boost said pulse signal to generate an AC power supplied to said load;
- a frequency generator for being operative to generate a pulse signal having at least two predetermined operating frequencies, wherein said frequency generator outputs said pulse signal having one of said predetermined operating frequencies based on an operation state of said DC/AC inverter; and
- a driver circuit coupled to said frequency generator and providing four driving signals based on said pulse signal of said frequency generator for turning on and off said first power switch, said second power switch, said third power switch, and said fourth power switch respectively, wherein said four driving signals have the same frequency, the duty cycle of two of said four driving signals is smaller than 50% and the duty cycle of the other two of said four driving signals is larger than 50%.

These and other objectives, features, and advantages of the present invention will become apparent from the following detailed description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A illustrates a conventional full-bridge inverter.

FIGS. 1B and 1C illustrate representative waveforms present in the circuit of FIG. 1A.

FIG. 2 illustrates the circuitry of the DC/AC inverter according to the preferred embodiment of the present invention.

FIG. 3 illustrates representative waveforms present in the circuit of FIG. 2.

FIG. 4 illustrates a circuitry of the driver circuit according to the above-preferred embodiment of the present invention.

FIG. 5 illustrates the timing diagram for the driver circuit according to the above-preferred embodiment of the present invention.

FIG. 6 illustrates a circuitry of a frequency generator used to be provided for driving N number of DC/AC inverters according to another preferred embodiment of the present invention.

FIG. 7 illustrates the circuitry of the DC/AC inverter according to another preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 2 of the drawings, a circuitry of a DC/AC inverter according to the preferred embodiment of the present invention is illustrated. As shown in the drawing, an inverter controller 200 comprises a DC power source 201, a set of MOS power switch 202, a resonant tank 203, a fluorescent lamp 204, a current detecting circuit 205, a voltage detecting circuit 206, a pulse width modulator 207, a frequency generator 208, a driver circuit 209, a protection circuit 210, a timer 211 and a dimming control circuit 212. The DC power source 201 is coupled to the power switch 202. An output of the set of power switch 202 is coupled to an input of the resonant tank 203. An output of the resonant tank 203 is coupled to one end of the fluorescent lamp 204. In this invention, the resonant tank 203 could be any type of the transformer such as Meg-transformer and Piezo-transformer but could not be limited to any type of the transformer. The resonant tank 203 further comprises a step-up transformer 221 and resonant capacitors 222, 223, and 224. In this preferred embodiment, the resonant tank 203 having a low Q factor can be used so as to provide easy designing of the circuitry.

Under such a circuitry design, the signals for driving the step-up transformer 221 and the fluorescent lamp 204 are neither pure square waves nor pure sine waves. The signals for driving the step-up transformer 221 and the fluorescent lamp 204 are quasi sine waves or quasi-square waves. FIG. 3 of the drawings illustrates the voltage wave-
forms at different positions under the power transfer route design according to the preferred embodiment.

[0035] In FIG. 3 of the drawings, S51 is the output signal of the power switches 202A, 202B of the set of power switch 202, 202S is the input signal of the step-up transformer 221, and S16 is the fluorescent lamp driving signal output by the step-up transformer 221.

[0036] The current detecting circuit 205 and the voltage detecting circuit 206 are coupled to the ends of the fluorescent lamp 204 respectively. The current detecting circuit 205 is also electrically connected to the pulse width modulator 207, wherein the pulse width modulator 207 is also electrically connected to the frequency generator 208 and the driver circuit 209. The driver circuit 209 is coupled to the set of power switch 202, forming a control loop connection.

[0037] The set of power switch 202 comprises four power switches 202A, 202B, 202C, and 202D. The power switches 202A and 202C could be PMOS power switches. The power switches 202B and 202D could be NMOS power switches. Nevertheless, the four power switches 202A, 202B, 202C, and 202D are not limited to MOS power switches. The four power switches 202A, 202B, 202C, and 202D also could be any type transistor switch such as NPN-type BJT or PNP-type BJT.

[0038] The frequency generator 208 generates a triangular wave signal S1 and a pulse signal S2, wherein both signals have the same frequency. However, the present invention is not limited to the use of triangular wave signals, where all ramp signals and sawtooth wave signals are applicable.

[0039] The current detecting circuit 205 is in series to the fluorescent lamp 204 to provide a signal S3 for indicating the conduction state of the fluorescent lamp 204 and to utilize a signal S4 to show the current value of the current flowing through the fluorescent lamp 204. The voltage detecting circuit 206 utilizes the resonant capacitors 223, 224 of the resonant tank 203 to obtain a signal S5 for indicating a terminal voltage of the fluorescent lamp 204.

[0040] The pulse width modulator 207 comprises an inverting integrator and a comparator 264, wherein the inverting integrator comprises an error amplifier 261, a resistor 262, and a capacitor 263. The pulse width modulator 207 also comprises a current controlled source 265, which is electrically connected to an inverting input of the error amplifier 261 through a switch 266.

[0041] The protection circuit 210 comprises a logic control circuit 272, wherein the protection circuit 210 receives the signal S3, the signal S5 and an output signal S6 of the error amplifier 261 in the pulse width modulator 207.

[0042] The timer 211 comprises two comparators 281 and 282, and a current source 283. The dimming control circuit 212 comprises a dimming frequency generator 291 for generating a dimming triangular signal S7. The dimming triangular signal S7 is transmitted to a non-inverting input of a comparator 293, and a dimming control voltage S8 is transmitted to an inverting input of the comparator 293. After comparison, a dimming pulse signal S9 is generated. The dimming control circuit 212 further comprises an OR gate 296. The outputting timing of a dimming voltage S20 to the pulse width modulator 207 is controlled through the switch 235 controlled by dimming pulse signal S9 and the switch 236.

[0043] The driver circuit 209 receives an output signal S15 of the pulse width modulator 207, the pulse signal S2 of the frequency generator 208, and an output signal S18 of the protection circuit 210 to generate four driving signals POUT1, POUT2, NOUT1, and NOUT2 so as to control the power switches 202A, 202B, 202C, and 202D respectively.

[0044] According to the preferred embodiment of the present invention, the timer 211 functions in a manner that a capacitor 284 is being charged by the current source 283, such that a capacitor voltage S12 of the capacitor 284 increases as time increases. Before the capacitor voltage S12 reaches a first reference voltage Vref1, a reset signal S11 is sent out. Furthermore, when the capacitor voltage S12 reaches a second reference voltage Vref2, a time out signal S10 will be sent out. The reset signal S11 could be utilized as a reset signal to reset any analog circuitry and digital circuitry of the system such as the pulse width modulator 207 and the logic control circuit 272 at a proper time.

[0045] The current source 283 is controlled by a power control signal S13, such that when the voltage 201 of the system is lower than a third reference voltage Vref3, the current source 283 will be cut off and the capacitor voltage of the capacitor 284 is grounded through a transistor 285 which is controlled by the power control signal S13. Through such design, when the system starts up the DC power source 201 from a zero voltage, the capacitor 284 of the timer 211 is always charged from zero voltage.

[0046] According to the preferred embodiment of the present invention, the frequency generator 208 is also controlled by a signal S14, indicating whether or not the fluorescent lamp is conducted. When the fluorescent lamp is conducted, an operating frequency is sent out. And when the fluorescent lamp is not conducted, a start-up frequency is sent out. An advantage of such design is that the system can be operated around the resonance frequency, whether or not the fluorescent lamp is conducted, such that the system is operated efficiently even though the resonance frequency of the resonant tank 203 is different due to the conduction state of the fluorescent lamp.

[0047] The signal S14 is determined by the signal S3 provided by the current detecting circuit 205, and a comparator 274 of the protection circuit 210, such that when the signal S3 exceeds a fourth reference voltage Vref4, the fluorescent lamp 204 is considered as being conducted.

[0048] Under normal circumstances, the detailed operation procedures according to the preferred embodiment of the present invention are as follows:

[0049] After starting up the system, the timer 211 starts to charge the capacitor 284. Before the capacitor voltage reaches the first reference voltage Vref1, the timer 211 sends out the reset signal S11 that passes through an OR gate 267 to turn on a switch 266. Therefore, the current source 265 is connected to the inverting input of the error amplifier 261, forcing an inverting input voltage of the error amplifier 261 to be higher than a fifth reference voltage Vref5, which in turn forces the output of the error amplifier 261 to be zero. As a result, the duty cycle of a pulse width modulation signal S15 outputted by the pulse width modulator 207 becomes zero. Once the duty cycle of a pulse width modulation signal S15 becomes zero and the pulse width modulation signal S15 is delivered to the driver circuit 209, the duty cycle of
the driving signals NOUT1 and NOUT2 become zero such that the corresponding power switches are turned off. When the driver circuit 209 is under normal operation, the duty cycle of two of the four power switches 202A, 202B, 202C, and 202D is smaller than 50% and the duty cycle of the other two of the power switches 202A, 202B, 202C, and 202D is greater than 50%. Under such design as shown in FIG. 4, the duty cycle of the power switches 202A and 202C is greater than 50% and the duty cycle of the power switches 202B and 202D is smaller than 50% such that the system ripple could be reduced and the duty cycles of the four driving signals are varied based on the conduction state of the load.

[0050] When the capacitor 284 continues to be charged and the capacitor voltage is greater than the first reference voltage Vref1, the power switch 266 will be turned off. Therefore, the pulse width modulator 207 is initialized, and because of the fluorescent lamp 204 is not conducted, the non-inverting input voltage of the error amplifier 261 will become lower than the fifth reference voltage Vref5. The output signal S6 outputted by the error amplifier 261 will increase under the negative feedback theory. Hence, after comparing the output signal S6 with the triangular wave signal S1, the comparator 264 of the pulse width modulator 207 outputs the pulse width modulation signal S15. The driver circuit 209 receives the pulse width modulation signal S15 and the pulse signal S2 so as to generate the driving signals POUT1, POUT2, NOUT1, and NOUT2 to drive the power switches 202A, 202B, 202C, and 202D respectively.

[0051] Before the fluorescent lamp 204 being struck to conduct, a voltage of the fluorescent lamp driving signal S16 will increase due to the duty cycle of the pulse width modulation signal S15 being increased. Once the protection circuit 210 senses the signal S5 exceeding a sixth reference voltage Vref6, the protection circuit 210 sends out an over-voltage signal S17. The over-voltage signal S17 turns on the switch 266 of the current source 265 via the OR gate 267, so as to increase the voltage of the inverting input of the error amplifier 261 and reduce the output signal S6 of the error amplifier 261. Hence, the duty cycle of the pulse width modulation signal S15 is decreased to decrease the amount of electrical power input to the fluorescent lamp.

[0052] If the signal S5 is less than the sixth reference voltage Vref6 due to the amount of electrical power inputted to the fluorescent lamp being decreased, the switch 266 will be turned off again to increase the output signal S6 of the error amplifier 261. Accordingly, the fluorescent lamp driving signal S16 is stably adjusted under such a negative feedback control.

[0053] As soon as the fluorescent lamp is struck to conduct by a sufficient fluorescent lamp driving signal S16 for an enough time, according to the characteristic of the fluorescent lamp, the fluorescent lamp driving signal S16 will drop to less than half the original voltage of the fluorescent lamp driving signal S16, such that the voltage detecting circuit 206 loses its function due to a non-detection of a higher voltage.

[0054] At the same time, the current detecting circuit 205 sends out the signal S3 to the protection circuit 210 and the signal S4 to the pulse width modulator 207. When the signal S3 is higher than the fourth reference voltage, the signal S14 alters the output frequency of the frequency generator 208. The signal S4 could stabilize the current flowing through the fluorescent lamp on a pre-determined value through the negative feedback control.

[0055] The protection circuit 210 according to this embodiment can function to prevent from damage caused by disconnection of fluorescent lamp, the damage of fluorescent lamp, the power leakage of the transformer, etc. The operation of the protection circuit 210 is described in detail as follows:

[0056] When the fluorescent lamp is not connected, the signal S5 will be continuously sent out to the logic control circuit 272 for indicating that the terminal voltage of the fluorescent lamp exceeds the sixth reference voltage Vref6. The logic control circuit 272 will take no action until the time out signal S10 is inputted. Once the time out signal S10 is sent to the logic control circuit 272, and in the condition of the terminal voltage of the fluorescent lamp exceeds the sixth reference voltage Vref6, a digital timer in the logic control circuit 272 starts to count time with the pulse signal S2 produced by the frequency generator 208. If the terminal voltage of the fluorescent lamp still exceeds the sixth reference voltage Vref6 over a predetermined period of time, a terminating signal S18 will be outputted by the logic control circuit 272 to the driver circuit 209, so as to cut off the conduction of the NMOS power switches 202B and 202D.

[0057] If the fluorescent lamp is damaged during operation, a current detecting circuit 205 will transmit the signal S3 for indicating the non-conduction state of the fluorescent lamp 204. Then the comparator 274 of the protection circuit 210 sends out the signal S14, indicating that the fluorescent lamp is not conducted, to the logic control circuit 272. Similarly, the logic control circuit 272 will not take any action until the receiving the time out signal S10. When the logic control circuit 272 receives the time up signal S10, the logic control circuit 272, under the condition of the signal S14 indicating that the fluorescent lamp is not conducted, counts time with pulse signal S21 produced by the low frequency dimming control circuit 212 by a digital timer thereof.

[0058] If the fluorescent lamp still is not conducted over a predetermined period of time, the logic control circuit 272 will output the terminating signal S18 to the driver circuit 209, so as to cut off the conduction of the power switches 202B and 202D.

[0059] Also, when the step-up transformer 221 encounters serious damages, such as an overloading condition due to power leakage, the entire system will be overloaded. Under such conditions, the error amplifier 261 will continue to increase the outputting level of the output signal S6 for providing a sufficient power to stabilize the current of the fluorescent lamp. And if the maximum power provided by the system could not cover the power leakage, the output signal S6 of the error amplifier 261 will definitely exceed the peak value of the triangular wave signal S1. The protection circuit 210 compares the output signal S6 of the error amplifier 261 with a reference voltage Vref7 whose value is slightly higher than the peak value of the triangular wave signal S1, to obtain an overloading signal S19, indicating whether or not the system is overloaded.

[0060] Similarly, when the overloading signal S19 indicates that the system is overloaded and the protection circuit
210 is started by the time up signal S10 of the timer 211, the logic control circuit 272 will count time with the pulse signal S2 produced by the frequency generator 208. When the counted time also exceeds the predetermined period of time, the logic control circuit 272 then outputs the terminating signal S18 to the driver circuit 209, cutting off the conduction of the power switches 202B and 202D.

[0061] According to the preferred embodiment of the present invention, the inverter further has the dimming control circuit 212 provided for controlling the power to the fluorescent lamp. The dimming control circuit 212 controls the timing to deliver power to the fluorescent lamp with a frequency signal S7 that is lower than the operation frequency of the fluorescent lamp, so as to adjust the brightness of the fluorescent lamp. And, in order to avoid generating flicker due to low frequency, the dimming frequency is normally above 200 Hz.

[0062] The dimming control circuit 212 is controlled by two signals, the first one being the signal S14 indicating whether or not the fluorescent lamp is struck and the second one being the time out signal S10 of the timer 211. Only when the signal S14 indicates that the fluorescent lamp is struck or the time out signal S10 of the timer 211 is received, a switch S36 will be turned on so as to output the dimming control signal.

[0063] A dimming control voltage S20 of the dimming control circuit 212 is higher than the reference voltage Vref. When the dimming control voltage S20 passes through the dimming control switches 235, 236 and a resistor 234 to the pulse width modulator 207, the output signal S6 of the error amplifier 261 of the pulse width modulator 207 is decreased to stop delivering power to the fluorescent lamp. When the dimming control switch 235 is turned off by the dimming signal S9, the dimming voltage S20 could not be sent to the pulse width modulator 207, and so the power will be restarted delivering to the fluorescent lamp again.

[0064] Brightness adjusting effect can be achieved by a low frequency to control the ratio between the stopping and the restarting of providing electrical power of each cycle. In order to ensure that the fluorescent lamp has sufficient and continuous electrical power so as to be struck in a predefined period of time, the dimming control circuit 212 starts to operate after the fluorescent lamp 204 is struck to conduct.

[0065] In order to provide a symmetric alternating current to drive the fluorescent lamp 204, according to the preferred embodiment of the present invention, the circuit design of the driver circuit 209 is shown in FIG. 4. Referring to FIG. 4 of the drawings, the input signal of the input terminal PWM is corresponding to the pulse width modulation signal S15 as shown in FIG. 2. A clock pulse is corresponding to the pulse signal S2 as shown in FIG. 2. The input signal of the input terminal PS (protection signal) is corresponding to the output signal S18 of the protection circuit 210. The detailed operation according to the preferred embodiment of the present invention is shown in FIG. 5. FIG. 5 is the timing diagram for the driver circuit 209 according to the invention. When the pulse width of the pulse width modulation signal S15 is changed, the pulse widths of the driving signals POUT1, POUT2, NOUT1 and NOUT2 are altered. As a result, the simultaneously conducted periods of the power switches 202B and 202C controlled by the driving signal NOUT1 and POUT2 are changed. Similarly, the simultaneously conducted periods of the power switches 202D and 202A controlled by the driving signal NOUT1 and POUT2 are changed. The dashed portion of FIG. 5 shows the change in operation periods of the driving signals POUT1, NOUT1 and POUT2, NOUT2. Under normal operation, while the two NMOS power switches 202B and 202D are turned off, the two PMOS power switches 202A and 202C are simultaneously turned on.

[0066] Under conventional fixed-frequency phase-shift control, operations of the PMOS power switches simultaneously being conducted and NMOS power switches simultaneously being conducted exist at the same period and the conductions of PMOS and NMOS power switches are asymmetric conduction. On the contrary, both NMOS power switches and PMOS power switches are applied to this DC/AC inverter in this invention and the power is stopped to provide to the fluorescent lamp. Under this design, the two PMOS power switches are turned on. Such design could avoid a floating in the set of power switch 202 regardless of under normal operation and protection operation (i.e.: the terminating signal S18 is sent out to the driver circuit 209).

[0067] On the other hand, when the power is stopped to provide to the fluorescent lamp, the present invention could be modified to that the NMOS power switches 202B and 202D are turned on the two PMOS power switches 202A and 202C are turned off. Such design also has the same function of avoiding floating.

[0068] The present invention employs a frequency generator that generates different phase signals at the same frequency as a frequency source to drive the fluorescent lamps for more than two fluorescent lamps.

[0069] Referring to FIG. 6 of the drawings, a frequency generator used to be provided for driving N number of DC/AC inverters according to this alternative embodiment of the present invention is illustrated. The frequency generator 601 is utilized to replace the function of the frequency generator 208 and the dimming control circuit 212 so as to drive a plurality of fluorescent lamps. The input of the frequency generator 601 can be an external clock pulse 602, which can be any one frequency relative to the control signal of the LCD controller of the LCD display. The other input of the frequency generator 601 is a frequency control signal 603.

[0070] As shown in FIG. 6, the frequency control signal 603 utilizes an AND gate 604 and an OR gate 605 to control the changing of the operating frequency of the fluorescent lamps, according to the conduction confirmation signals 606, 607, 608 . . . N (referring to the fourth signal S14 as shown in FIG. 2), confirming whether or not all the N number of fluorescent lamps are conducted, or upon the outputting of a timer signal 609 (referring to the time out signal S10 as shown in FIG. 2) by the timer.

[0071] Each of the triangular wave signals 610 (referring to the triangular wave signal S1 as shown in FIG. 2) output by the frequency generator 601 to each of the pulse width modulator has the same frequency but different phase.

[0072] Each of the pulse signals 611 (referring to the pulse signal S2 as shown in FIG. 2) output to each of the driver circuits, such as full-bridge driver circuit, half-bridge driver circuit, push-pull driver circuit, Royer driver circuit and any
switching type, has the same frequency as and in phase with the triangular wave signals 610, respectively.

[0073] Such the frequency generator 601 can be achieved by a conventional micro control unit (MCU) 621 and a direct digital synthesizer (DDS) 622.

[0074] The micro control unit (MCU) 621 could provide a pulse signal 636 (referring to the pulse signal S21 as shown in FIG. 2) or a plurality of pulse signals having the same frequency but different phases. The pulse signal 636 could be utilized to be a synchronized signal for the inner circuitry of the micro control unit (MCU) 621 and the frequency generator 601 in order to implement the external brightness control. After another dimming control input 631 (referring to the dimming control voltage S8 as shown in FIG. 2) is input into the micro control unit (MCU) 621 of the frequency generator 601, the micro control unit 621 produces a dimming control signal 632 having the same frequency with the pulse signal 636. The frequency control signal 603 controls the conduction state of the switch 633, so as to control the outputting time of the dimming control signal 632 to each of the DC/AC inverters. A plurality of fluorescent lamps could utilize the common dimming control signal 632 (or a plurality of dimming control signals having the same frequency but different phases) to make each of the fluorescent lamps have the same dimming frequency. The dimming control signal 632 controlled by the switch 633 is delivered to each pulse width modulator through each diode 637 and each resistor 638. The diode 637 is utilized to avoid the feedback interference caused by other pulse width modulators. The diode 637 could be neglected.

[0075] In addition, the micro control unit (MCU) 621 also provides N sets of pulse signals 611 having the same frequency but different phases to the direct digital synthesizer (DDS) 622 and external circuits. The direct digital synthesizer (DDS) 622 receives the N sets of pulse signals 611 to generate N sets of the triangular wave signals 610 having the same frequency and the corresponding phase with the pulse signal 611 to external circuits. The above-mentioned pulse signals 611 and triangular wave signals 610 could be generated according to the external clock pulse 602. For example, the external clock pulse 602 could be one frequency of display, the frequency of the pulse signals 611 and the triangular wave signals 610 could be the multiple frequency of the external clock pulse 602 such that the interference from optical beam frequencies could be avoided to display on the display so as to improve the quality of the display.

[0076] Of course, it is not necessary that each pulse signal 611 has the different phase, and so do the triangular wave signals 610. However, it just needs that the pulse signals 611 and triangular wave signals 610 could be divided into at least two sets of driving signals to reduce a voltage ripple of the system caused by alternative conduction of power switches. As a result, the frequency generator generates a plurality of driving signals having the same frequency but different phases for lowering the voltage ripple caused by switching of power switches. Furthermore, the operating frequency is synchronized with the display so as to reduce the visual noise caused by the interference of the beat frequency.

[0077] In this present invention, the frequency generator generating the signals with the same frequency but different phases could not be limited to apply to a full-bridge DC/AC converter which has four power switches. Under at least two sets of fluorescent lamp conditions, such technique also could apply to a half-bridge power supply circuit or another power supply circuit having the same operating frequency such that the voltage ripple and the visual noise could be reduced. Additionally, the timer and the protection circuit in this present invention could also be applied to any kind of power supply circuit but not limited to DC/AC converter. Furthermore, in this invention the fluorescent lamps are used for an example, but any kind of discharge lamps or loads could be applied with the technique disclosed by the invention.

[0078] Referring to FIG. 7 of the drawings, a circuitry of a DC/AC inverter according to another preferred embodiment of the present invention is illustrated, wherein the DC/AC inverter is a half-bridge DC/AC inverter. As shown in the drawing, an inverter controller 700 comprises a DC power source 201, a half-bridge switch circuitry 702, a resonant tank 203, a fluorescent lamp 204, a current detecting circuit 205, a voltage detecting circuit 206, a pulse width modulator 207, a frequency generator 208, a driver circuit 209, a protection circuit 210, a timer 211 and a dimming control circuit 212. The half-bridge switch circuitry 702 is electrically connected to the DC power source 201. An output terminal of the half-bridge switch circuitry 702 is electrically connected to an input terminal of the resonant tank 203. An output terminal of the resonant tank 203 is electrically connected to one end of the fluorescent lamp 204. The resonant tank 203 further comprises a step-up transformer 221 and resonant capacitors 222, 223, and 224.

The series connection of the half-bridge switch circuitry 702, the resonant tank 203 and the fluorescent lamp 204 is a typical example of a power transfer connection.

[0079] The operation principle of the preferred embodiment of the present invention as shown in FIG. 7 is similar to that as shown in FIG. 2. Therefore, some of the elements or components in FIG. 7 use the same label in FIG. 2. The following description is for the purposes of illustrating the functional and structural principles in FIG. 7 that is not mentioned in FIG. 2.

[0080] In this embodiment, the half-bridge switch circuitry 702 comprises two power switches 702A and 702B. The power switch 702A which is a PMOS power switch is electrically connected to a power line. The power switch 702B which is a NMOS power switch is electrically connected to the ground. Nevertheless, the two power switches 702A and 702B are not limited to MOS power switches. The two power switches 702A and 702B also could be any type transistor switch such as NPN-type BJT or PNP-type BJT.

[0081] In order to provide an AC current with good symmetry to drive the fluorescent lamp 204, in this embodiment, when the system operates steadily, two power switches 702A and 702B of the half-bridge switch circuitry 702 are alternately conducted with the same duty cycle but shifted by 180 degrees. In other words, the driver circuit 709 outputs two sets of driving signals with the same duty cycle but shifted by 180 degrees.

[0082] One skilled in the art will understand that the embodiment of the present invention as shown in the drawings and described above is exemplary only and not intended to be limiting.

[0083] It will thus be seen that the objects of the present invention have been fully and effectively accomplished. It
embodiments have been shown and described for the purposes of illustrating the functional and structural principles of the present invention and is subject to change without departure from such principles. Therefore, this invention includes all modifications encompassed within the spirit and scope of the following claims.

What is claimed is:

1. A DC/AC inverter for transforming a DC power source to an AC power source, which drives a load, said DC/AC inverter comprising:
   a full-bridge switch circuitry electrically connected to said DC power source for being operative to convert said DC voltage to a pulse signal, said full-bridge switch circuitry comprising a first power switch, a second power switch, a third power switch, and a fourth power switch;
   a resonant tank electrically connected between said full-bridge switch circuitry and said load for being operative to boost and filter said pulse signal to generate an AC power supplied to said load;
   a frequency generator for being operative to generate a pulse signal at one of at least two predetermined operating frequencies based on an operation state of said DC/AC inverter; and
   a driver circuit coupling to said frequency generator and providing four driving signals based on said pulse signal of said frequency generator for turning on and off said first power switch, said second power switch, said third power switch, and said fourth power switch respectively, wherein said four driving signals have the same frequency, the duty cycle of two of said four driving signals is smaller than 50% and the duty cycle of the other two of said four driving signals is larger than 50%.

2. The DC/AC inverter, as recited in claim 1, further comprising a protection circuit electrically connected to said driver circuit in which said protection circuit comprises at least two timers for being operative to selectively alter said driving signals depending on a conduction state of said load and an output of said timers.

3. The DC/AC inverter, as recited in claim 2, further comprising a pulse width modulator electrically connected to said driver circuit for providing a pulse width modulation signal to said driver circuit to generate said driving signals.

4. The DC/AC inverter, as recited in claim 3, wherein said frequency generator is electrically connected to said pulse width modulator and said driver circuit and provides a triangular wave signal and a pulse signal, both of which have the same frequency, to said pulse width modulator and said driver circuit respectively such that said pulse width modulator generates said pulse width modulation signal depending on said triangular wave signal.

5. The DC/AC inverter, as recited in claim 3, wherein said pulse width modulator comprises:
   an error amplifier;
   a resistor electrically connected an inverting input of said error amplifier; a capacitor having one end electrically connected to said resistor and said inverting input of said error amplifier to form an inverting integrator;
   a comparator having a non-inverting input electrically connected to an output terminal of said error amplifier and the other end of said capacitor; a switch; and
   a current controlled source electrically connected to said inverting input of said error amplifier through said switch.

6. The DC/AC inverter, as recited in claim 3, further comprising a dimming control circuit electrically connected to said pulse width modulator for providing a dimming pulse signal to control whether said pulse width modulator provides said pulse width modulation signal.

7. The DC/AC inverter, as recited in claim 6, wherein said dimming control circuit comprises:
   a dimming frequency generator being operative of providing a triangular wave signal; and
   a comparator having a non-inverting input electrically connected to said dimming frequency generator for receiving said triangular wave signal and an inverting input electrically connected a dimming control voltage such that said comparator compares said dimming control voltage with said triangular wave signal to generate said dimming pulse signal.

8. The DC/AC inverter, as recited in claim 1, further comprising a timer and a pulse width modulator in which said pulse width modulator is coupled to said timer and said driver circuit for providing a pulse width modulation signal to said driver circuit to generate said driving signals, said timer comprises:
   a current source;
   a capacitor electrically connected to said current source for being charged by said current source; and
   a comparator electrically connected to said capacitor and a reference voltage, wherein said timer delivers a reset signal to reset said pulse width modulator when a voltage of said capacitor is lower than said reference voltage and said pulse width modulator starts to work when said voltage of said capacitor is higher than said reference voltage.

9. The DC/AC inverter, as recited in claim 1, further comprising a current detecting circuit electrically connected to said load for being operative to providing a signal indicative of a conduction state of said load and another signal indicative of a current passing through said load.

10. The DC/AC inverter, as recited in claim 9, further comprising a voltage detecting circuit electrically connected to said load for providing a signal indicative of a terminal voltage of said load.

11. The DC/AC inverter, as recited in claim 10, further comprising a protection circuit being capable of receiving said signal indicative of said conduction state of said load and said signal indicative of said terminal voltage of said load, in which said protection circuit comprises a control circuit having a timing control function, in which said protection circuit generates an indicative signal to said control circuit when said voltage or said current of said load is within a predetermined state and delivers a altering signal.
to said driver circuit wherein said driver circuit outputs a signal to alter an output of said driver circuit while said indicative signal remains for a predetermined period.

12. The DC/AC inverter, as recited in claim 11, wherein said driver circuit receives said altering signal to control said full-bridge switch circuitry not to provide the power of said DC voltage to said resonant tank.

13. The DC/AC inverter, as recited in claim 11, wherein said protection circuit further comprises a comparator which receives said signal indicative of said conduction state of said load to provide a control signal to said frequency generator such that said frequency generator determines said pulse signal operated at one of said predetermined operating frequencies depending on said control signal.

14. A controller comprises:

a frequency generator for being operative to generate a pulse signal at one of at least one predetermined operating frequencies depending on a control signal of said controller;

a pulse width modulator coupled to said frequency generator for providing a pulse width modulation signal based on said pulse signal;

a driver circuit coupled to said pulse width modulator for providing at least one driving signals based on said pulse width modulation signal;

a protection circuit electrically connected to said driver circuit comprising a timing circuit, wherein said protection circuit receives at least one external signals and a result of said timers to selectively alter said driving signals.

15. The controller, as recited in claim 14, wherein said timing circuit has at least two timers to provide a reset signal and a time out signal in which said resets signal enables any circuit receiving said reset signal to reset said circuit and said time out signal enables any circuit receiving said time out signal to start said circuit.

16. The controller, as recited in claim 14, wherein said driver circuit provides four driving signals having the same frequency in which the duty cycle of two of said four driving signals is smaller than 50% and the duty cycle of the other two of said four driving signals is larger than 50%.

17. A timer applied to a power supply circuit comprising a driver circuit, a protection circuit, and a detection circuit, said timer comprises:

a voltage generator generating a voltage varying with time; and

at least two comparators, each of said two comparators electrically connected to a reference voltage and said voltage varying with time respectively to generate a comparative signal to at least one circuits of said power supply circuit, wherein a first comparative signal of said comparative signal is a reset signal such that any circuit receiving said reset signal is enabled to be reset.

18. The timer, as recited in claim 17, wherein said power supply circuit further comprises a pulse width modulation circuit, a power switch circuitry, and a resonant tank in which said pulse width modulation circuit provides a pulse width modulation signal to said driver circuit to control said power switch circuitry and said power switch circuitry is electrically connected to said resonant tank.

19. The timer, as recited in claim 18, wherein said at least one circuits receiving said reset signal is one of said protection circuit, said pulse width modulation circuit, and a combination thereof.

20. The timer, as recited in claim 17, wherein said second comparative signal of said comparative signal is a time out signal such that any circuit receiving said time out signal is enabled to be started.

21. The timer, as recited in claim 20, wherein said protection circuit receives said time out signal.

22. The timer, as recited in claim 17, wherein said voltage generator comprises a capacitor and a current source in which a voltage across said capacitor is charged by said current source such that said voltage across said capacitor is varying with time.

23. The timer, as recited in claim 22, further comprises a switch in parallel with said capacitor such that said switch is turned on to discharges of said capacitor when a power source supplying power to said power supply circuit is lower than a predetermined value.

24. A protection circuit applied to a power supply circuit comprising a timer, a driver circuit, and a detection circuit, comprises:

a logic control circuit being started after receiving a time out signal generated by said timer; and

at least one comparators, each of said comparators coupling to at least one circuits of said power supply circuit and a reference voltage for comparing a electrical signal of said at least one circuits with said reference voltage to generate a comparative signal to said logic control circuit, wherein said logic control circuit outputs a stopping output signal to said driver circuit to control a power switch circuitry stopping an output of a power source when said comparative signal is an indicative signal of a predetermined state.

25. The protection circuit, as recited in claim 24, wherein said power supply circuit further comprises a resonant tank, a pulse width modulation circuit, a power switch circuitry, and a frequency generator in which said frequency generator generates a pulse signal to said pulse width modulator, said pulse width modulator provides a pulse width signal to said driver circuit to control said power switch circuitry, and said power switch circuitry is electrically connected to said resonant tank.

26. The protection circuit, as recited in claim 25, wherein said frequency generator alters an operating frequency of said pulse signal after receiving said indicative signal to indicate a predetermined state.

27. The protection circuit, as recited in claim 24, wherein said logic control circuit receives at least one pulse signals generated by a frequency generator such that said logic control circuit delivers out said stopping output signal when said comparative signal is said indicative signal to indicate a predetermined state for a duration counted with operating frequency of said pulse signal for a predetermined period.

28. The protection circuit, as recited in claim 24, wherein said timer further generates a reset signal such that said protection circuit receives said reset signal to be reset.

29. A frequency generator applied to a power supply circuit, comprises:

a micro control unit being capable of generating at least one sets of a plurality of first pulse signals having the same frequency but different phases according to a
frequency control signal and generating at least one adjustable pulse signals according to a pulse width modulation signal;
a direct digital synthesizer being capable of receiving said first pulse signals to generate corresponding signals; and

a switch electrically coupled to said micro control unit for controlling an output of said at least one adjustable pulse signals.

30. The frequency generator as recited in claim 29, wherein said micro control unit further receives an external timing signal to generate said first pulse signals at a frequency that is a multiple of a frequency of said external timing signal.

31. The frequency generator as recited in claim 30, wherein said signals generated by said direct digital synthesizer are one of triangular waves, ramp waves, and sawtooth waves.

32. The frequency generator as recited in claim 30, wherein said signals generated by said direct digital synthesizer are provided to corresponding power supplies or pulse width modulators.

33. The frequency generator as recited in claim 29, wherein said first pulse signals are provided to corresponding power supplies or driver circuits.

34. The frequency generator as recited in claim 29, wherein said control signal is outputted from an output terminal of an OR gate, wherein an AND gate receives plural state signals and said OR gate receives an output signal of said AND gate and a time out signal.

35. The frequency generator as recited in claim 29, wherein said micro control unit further generates at least one set of second pulse signals having the same operating frequency with a operating frequency of said adjustable pulse signals to be a frequency reference for a circuit which is electrically connected to said frequency generator.

36. A DC/AC inverter for transforming a DC power source to a AC power source, which drives a load, said DC/AC inverter, comprising:

a half-bridge switch circuitry electrically connected to said DC power source for being operative to convert said DC voltage to a pulse signal;
a resonant tank electrically connected between said half-bridge switch circuitry and said load for transforming said pulse signal to said AC power supplied to said load;
a controller comprising a protection circuit having at least two timers and generating a pulse signal having at one of least two predetermined operating frequencies based on an operation state of said DC/AC inverter, and altering pulse wide of said pulse signal based on said timers, and

a driver circuit coupling to said controller for being operative to providing two driving signals for turning on and off said half-bridge switch circuitry in which the duty cycles of said two driving signals are varied based on said pulse signal provided by said controller.

37. The DC/AC inverter as recited in claim 36, wherein two driving signals have the same duty cycle but 180° phase shift.

38. The DC/AC inverter as recited in claim 36, wherein a power switch of said half-bridge switch circuitry which is electrically connected to said DC power source is a PMOS power switch and another power switch of said half-bridge switch circuitry is a NMOS power switch.

39. The DC/AC inverter as recited in claim 38, further comprising a protection circuit electrically connected to said driver circuit in which said protection circuit comprises at least two timers for being operative to alter said driving signals depending on a conduction state of said load and an output of said timers.

40. The DC/AC inverter as recited in claim 39, further comprising a pulse width modulator electrically connected to said driver circuit for providing a pulse width modulation signal and said driver circuit generating said driving signals according to said pulse width modulation signal.

41. The DC/AC inverter as recited in claim 40, wherein said frequency generator electrically connected to said pulse width modulator and said driver circuit for providing a triangular wave signal and a pulse signal to said pulse width modulator and said driver circuit respectively such that said pulse width modulator generates said pulse width modulation signal depending on said triangular wave signal.

42. The DC/AC inverter, as recited in claim 40, wherein said pulse width modulator comprises:

an error amplifier;
a resistor electrically connected an inverting input of said error amplifier;
a capacitor having one end electrically connected to said resistor and said inverting input of said error amplifier to form an inverting integrator;
a comparator having a non-inverting input electrically connected to an output terminal of said error amplifier and the other end of said capacitor;
a switch; and

a current controller source electrically connected to said inverting input of said error amplifier through said switch.

43. The DC/AC inverter, as recited in claim 40, further comprising a dimming control circuit electrically connected to said frequency generator for providing a dimming pulse signal to control whether said pulse width modulator provides said pulse width modulation signal.

44. The DC/AC inverter, as recited in claim 43, wherein said dimming control circuit comprises:

a dimming frequency generator being operative of providing a triangular wave signal; and

a comparator having a non-inverting input electrically connected to said dimming frequency generator for receiving said triangular wave signal and an inverting input electrically connected a dimming control voltage such that said comparator compares said dimming control voltage with said triangular wave signal to generate said dimming pulse signal.

45. The DC/AC inverter, as recited in claim 44, further comprising a timer and a pulse width modulator in which said pulse width modulator is coupled to said timer and said driver circuit for providing a pulse width modulation signal to said driver circuit to generate said driving signals, said timer comprises:
a current source;

a capacitor electrically connected to said current source for being charged by said current source; and

a comparator electrically connected to said capacitor and a first reference voltage, wherein said timer delivers a reset signal to reset said pulse width modulator when a voltage of said capacitor is lower than said first reference voltage and said pulse width modulator starts to work when said voltage of said capacitor is high than said first reference voltage.

46. The DC/AC inverter, as recited in claim 36, further comprising a current detecting circuit electrically connected to said load for being operative to providing a signal indicative of a conduction state of said load and another signal indicative of a current passing through said load.

47. The DC/AC inverter, as recited in claim 46, further comprising a voltage detecting circuit electrically connected to said load for providing a signal indicative of a terminal voltage of said load.

48. The DC/AC inverter, as recited in claim 47, further comprising a protection circuit being capable of receiving said signal indicative of said conduction state of said load and said signal indicative of said terminal voltage of said load, in which said protection circuit comprises a control circuit having a timing control function, in which said protection circuit generates an indicative signal to said control circuit when said voltage or said current of said load is within a predetermined state and delivers a altering signal to said driver circuit wherein said driver circuit outputs a signal to alter an output of said driver circuit when said indicative signal remains for a predetermined period.

49. The DC/AC inverter, as recited in claim 48, wherein said driver circuit receives said altering signal to control said half-bridge switch circuitry not to provide the power of said DC voltage to said resonant tank.

50. The DC/AC inverter, as recited in claim 48, wherein said protection circuit further comprises a comparator which receives said signal indicative of said conduction state of said load to provide a control signal to said frequency generator such that said frequency generator determines said pulse signal operated at which one of said predetermined operating frequencies depending on said control signal.