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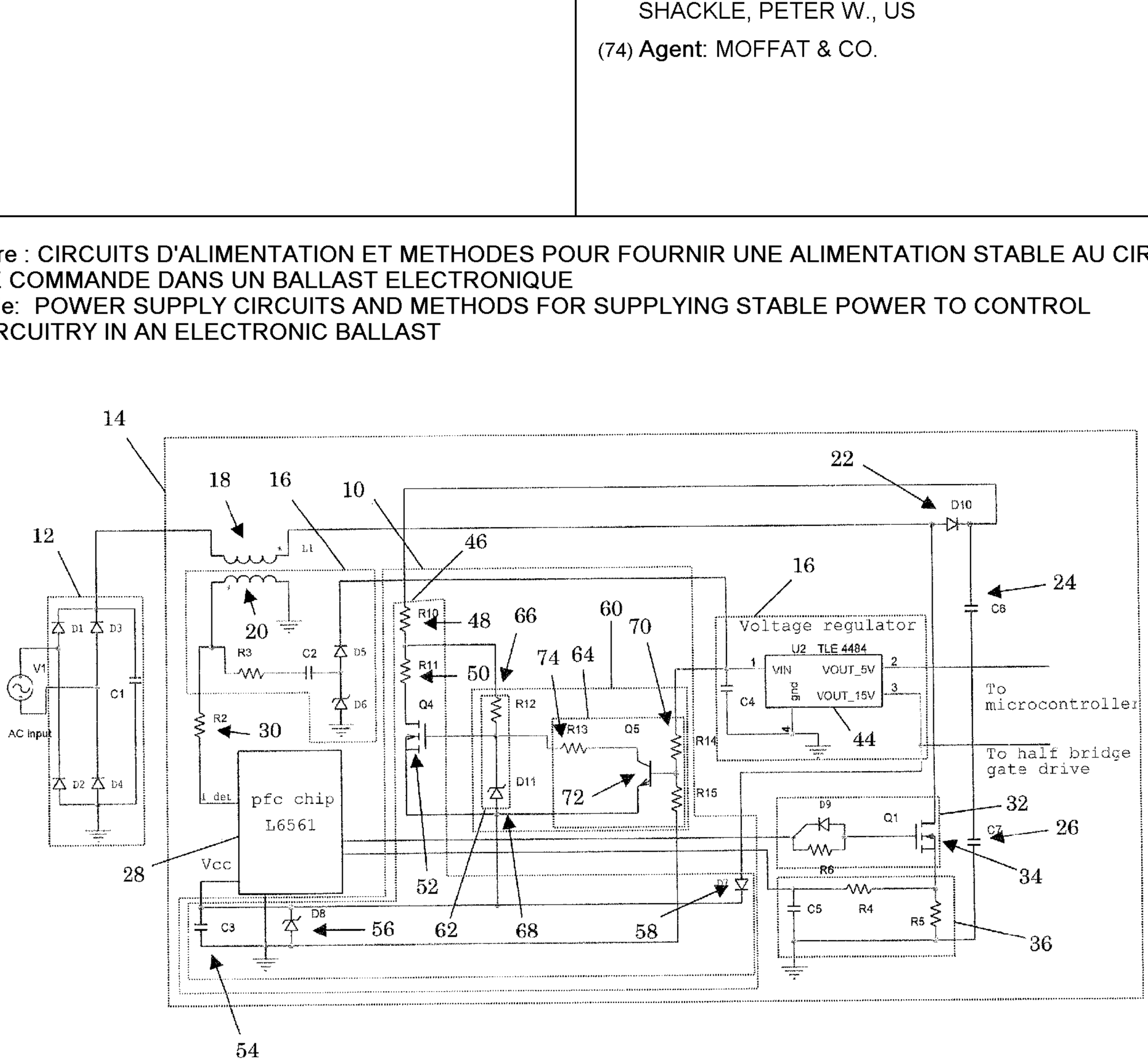
(54) Titre : CIRCUITS D'ALIMENTATION ET METHODES POUR FOURNIR UNE ALIMENTATION STABLE AU CIRCUIT DE COMMANDE DANS UN BALLAST ELECTRONIQUE

(54) Title: POWER SUPPLY CIRCUITS AND METHODS FOR SUPPLYING STABLE POWER TO CONTROL CIRCUITRY IN AN ELECTRONIC BALLAST



(57) Abrégé/Abstract:
Electronic ballast power supply/control circuits and methods that can be used to supply starting power to PFC control chips and that can be used to control ballasts so that PFC and inverter power supply circuits supply stable power to control circuitry even when the ballasts are performing advanced ballast functions. The circuits and methods supply starting power more quickly and efficiently than prior art starting circuits and control ballasts by either loading PFC circuits or inverter circuits included in the ballasts. The circuits load PFC circuits by connecting load resistors to the PFC circuits or by operating the inverter circuits at high frequencies that generate switching losses in the inverter transistors that load the PFC circuits. Inverter circuits are loaded by operating the inverter at frequencies that are much higher than preheating, igniting, and normal operating frequencies.

ABSTRACT OF THE DISCLOSURE

[0073] Electronic ballast power supply/control circuits and methods that can be used to supply starting power to PFC control chips and that can be used to control ballasts so that PFC and inverter power supply circuits supply stable power to control circuitry even when the ballasts are performing advanced ballast functions. The circuits and methods supply starting power more quickly and efficiently than prior art starting circuits and control ballasts by either loading PFC circuits or inverter circuits included in the ballasts. The circuits load PFC circuits by connecting load resistors to the PFC circuits or by operating the inverter circuits at high frequencies that generate switching losses in the inverter transistors that load the PFC circuits. Inverter circuits are loaded by operating the inverter at frequencies that are much higher than preheating, igniting, and normal operating frequencies.

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APPLICATION FOR

UNITED STATES LETTERS PATENT

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[0002] This application claims priority on co-pending U.S. Provisional Patent Application, Serial Number 60/526.640, filed December 3, 2003 and entitled "Low Loss Power Supply Management for Ballast with Microcontroller," which is hereby incorporated by reference.

[0003] Be it known that we, Qinghong Yu, a citizen of the United States, residing in Madison, Alabama, Christopher Radzinski, a citizen of the United States, residing in Madison, Alabama, and Peter W. Shackle, a citizen of the United States, residing in Madison, Alabama, have invented new and useful "Power Supply Circuits And Methods For Supplying Stable Power To Control Circuitry In An Electronic Ballast."

BACKGROUND OF THE INVENTION

[0004] The present invention relates generally to electronic ballasts that include control circuitry.

[0005] More particularly, this invention pertains to power supply circuits and methods for supplying stable power to control circuitry included in electronic ballasts.

[0006] Electronic ballasts that include control circuitry are known in the art. These devices typically include an AC/DC converter circuit, a power factor control (PFC) circuit including a PFC control chip, an inverter circuit, which includes an inverter gate drive chip, and a microcontroller. The control circuitry includes the PFC control chip, the inverter gate drive chip, and the microcontroller. The lossless power supply management circuitry is designed to ensure that these chips receive appropriate bias supply at all times.

[0007] The AC/DC converter is designed to convert low frequency AC voltage from an AC power source into rectified AC voltage and the PFC circuit is designed to convert the rectified AC voltage into an approximately constant DC voltage and to cause power drawn from the AC power source to have a desired power factor. The inverter circuit is designed to convert the approximately constant DC voltage into high frequency sinusoidal AC voltage and to use that voltage to supply current to a gas discharge lamp connected to the electronic ballast. When the electronic ballast is operating normally, the inverter circuit loads the PFC circuit and the gas discharge lamp loads the inverter circuit.

[0008] The microcontroller is responsible for controlling the inverter circuit and causing it to generate the high frequency sinusoidal AC voltage supplied to the gas discharge lamp. In addition to controlling the inverter circuit, the microcontroller is also usually capable of automatically detecting and igniting lamps that are connected to the electronic ballast and protecting the electronic ballast and lamps from being damaged by fault conditions occurring in the electronic ballast.

[0009] The microcontroller, the PFC control chip, and the inverter gate drive chip included in the control circuitry of prior art electronic ballasts are all digital control circuits that have relatively strict power supply requirements. Unlike analog integrated circuits, which can continue to operate properly if their input voltage drops briefly, these digital circuits will not continue to operate properly if their input voltage drops too low. This is particularly true for the microcontroller, which will reset and restart as if the electronic ballast had just been turned on if its input voltage drops below a certain level.

[0010] The prior art teaches the use of three different types of power supply circuits and methods to supply power to control circuitry in electronic ballasts: the starting power supply circuit, the PFC power supply circuit, and the inverter power supply circuit. However using these circuits to provide power to the chips when the ballast is shut down either in response to a dimming off command or while waiting for a replacement lamp will either

waste power or have other side effects such as producing undesired output voltages. In addition, the starting power supply circuit consumes unnecessary power, which reduces the efficiency of the ballast, and the alternative of limiting the amount of power consumed by it then causes electronic ballasts using this type of circuit to start slowly.

[0011] An example of a prior art starting power supply circuit is shown in Fig. 1 supplying power to a PFC control chip and includes a resistor R1 connected to the high DC voltage input of the PFC circuit, a capacitor C3 connected to the resistor R1, a Zener diode D8 connected across the capacitor C3, and a blocking diode D7 connected to the Zener diode D8. The resistor R1 converts the high DC voltage input into a starting current that is supplied to the PFC control chip and used to charge the capacitor C3, which generates the required starting voltage for the PFC circuit. The Zener diode D8 prevents the starting voltage from exceeding a maximum starting voltage level and protects the PFC control chip from excessively high input voltages, and the blocking diode D7 prevents current from flowing back into the voltage regulator circuit included in the PFC power supply circuit.

[0012] Due to high power losses generated by the resistor R1, this type of circuit only provides a very small fraction of the power required by the control circuitry to operate properly and is typically only used to supply the PFC control chip with power until a PFC power supply circuit or an inverter power supply circuit can do so. In addition, once the PFC or the inverter

power supply circuit begins supplying power to the PFC control chip, the starting power supply circuit continues to consume power even though it is no longer needed. This increases the amount of power consumed by, and reduces the efficiency of, electronic ballasts using this type of circuit. The high resistance of the resistor R1 also limits the amount of current that can flow in the circuit and increases the time required to start the PFC control chip.

[0013] An example of a prior art PFC power supply circuit is also shown in Fig. 1. This type of power supply circuit is widely used in the prior art and can be used to supply power to all of the electronic ballast control circuitry.

[0014] The PFC power supply circuit includes an auxiliary winding connected to a boost inductor L1, a charge pump connected to the auxiliary winding that includes R3, C2, D5, D6, and C4, and a voltage regulator circuit connected to the charge pump that includes the voltage regulator chip U2. The auxiliary winding generates and supplies a low voltage rectified AC voltage to the charge pump (the auxiliary winding is also used to provide zero current detection for transient mode operation of the PFC circuit), the charge pump uses this voltage to generate an input voltage that is supplied to the voltage regulator circuit, and the voltage regulator circuit uses the input voltage to generate and supply the required operating power to the control circuitry. More specifically, the voltage regulator circuit supplies a regulated

+5 volt voltage to the microcontroller circuit and a +15 volt voltage to the PFC control chip and the inverter gate drive chip. The connection between the PFC power supply circuit and the inverter gate drive chip is not shown in Fig. 1 in order to simplify that drawing.

[0015] When the PFC circuit shown in Fig. 1 is operating normally, that is, it is converting the rectified AC voltage supplied by the AC/DC converter circuit into the approximately constant DC voltage that is supplied to the inverter circuit, the PFC power supply circuit is capable of generating and supplying the operating power required by the control circuitry in the electronic ballast. When the PFC circuit is not operating normally, however, the voltages generated by this type of power supply circuit drop out and cannot be used to supply the required operating power to the control circuitry. As explained in more detail below, this typically occurs when the inverter circuit is not loading, i.e., drawing current from, the PFC circuit.

[0016] The prior art solution to the problem presented by the PFC power supply circuit is to connect a load resistor (R9 in Fig. 1) across the bulk capacitors included with the PFC circuit. The load resistor provides a load to the PFC circuit and causes it to remain active even when the inverter circuit is not running. While this solution does work, it reduces the efficiency of, and generates extra heat in, the electronic ballast because the load resistor constantly consumes power. For a four-lamp ballast, the typical loss on the load resistor is approximately 2.7 watts.

[0017] An example of a prior art inverter power supply circuit is shown in Fig. 4. As shown in that figure, the inverter power supply circuit is connected to a midpoint between the two power MOSFET transistors included with the inverter circuit. The inverter power supply circuit includes a charge pump and a voltage regulator circuit, both of which are similar to the charge pump and voltage regulator circuits shown in Fig. 1. The inverter power supply circuit does not include the auxiliary winding connected to the boost inductor used with the PFC power supply circuit.

[0018] When the inverter circuit shown in Fig. 4 is operating normally and converting the approximately constant DC voltage supplied by the PFC circuit into high frequency sinusoidal AC voltage and current that is supplied to the gas discharge lamp, the inverter power supply circuit is capable of generating and supplying operating power to the control circuitry. If the inverter circuit stops running for some reason, this power supply stops as well and the required operating voltages for the control circuitry drop out. The prior art does not teach a solution for this problem.

[0019] As a result of the disadvantages discussed above, the PFC and inverter power supply circuits discussed above cannot be used to supply stable power in an electronic ballast that includes a microcontroller that provides advanced functions which require prolonged periods of inactivity, such as when the ballast has shut down because a lamp has reached end of life and the ballast is waiting for relamping. When the microcontroller in

this type of electronic ballast senses that the ballast has been connected to a gas discharge lamp, it automatically causes the inverter circuit to attempt to ignite the lamp by turning the inverter circuit off and on for brief periods of time, i.e., flashing the lamp. More specifically, the microcontroller turns the inverter circuit off and on every two seconds for a 100 second time period causing the lamp to flash 50 times. During each 2 second time interval, the inverter circuit is on for approximately 10 milliseconds and off for the remainder of the interval. The duration of the flashes and the intervals between flashes are set by industrial regulations, such as Underwriters Laboratories (UL) regulation UL 935, and are designed to prevent the electronic ballast from presenting an electric shock hazard to a human being.

[0020] Unfortunately, the limitations on the flashing duration and interval make it impossible to feed current from the inverter circuit to the lamp during the flashing period. As a result, the inverter circuit turns off and no longer loads the bulk capacitors included in the PFC circuit. This, in turn, causes the PFC circuit to turn off.

[0021] When the inverter circuit turns off, the charge pump in the inverter power supply circuit turns off and the voltages generated by the inverter power supply circuit drop too low to be used to supply the required voltages to the control circuitry in the electronic ballast. In a similar manner, when the PFC circuit turns off, the charge pump in the PFC power supply circuit turns off and the voltages generated by the PFC power supply

circuit drop too low to be used to supply power to the electronic ballast control circuitry. Thus, neither of these types of power supply circuits can be used in electronic ballasts providing this type of advanced functionality.

[0022] What is needed, then, is a starting power supply circuit and method that can be used to supply starting power to a PFC control chip in an electronic ballast more quickly and that consumes less power and is more efficient than prior art starting power supply circuits. In addition, what is needed is PFC and inverter power supply circuits and methods that can be used to supply stable power to the control circuitry even when the ballast output is completely shut down.

SUMMARY OF THE INVENTION

[0023] Accordingly, one object of the present invention is to provide a starting power supply circuit and method that can be used to supply starting power to a PFC control chip in an electronic ballast more quickly and that consumes less power and is more efficient than prior art starting power supply circuits and methods.

[0024] Another object is to provide PFC and inverter power supply circuits and methods that can be used to supply stable power to the control circuitry even when the microcontroller is performing advanced functions, such as automatic lamp detection and relamping.

[0025] Still another object is to provide a PFC power supply circuit and method that can be used to supply stable power to the control circuitry even when the microcontroller is performing advanced functions and that is more efficient than the prior art method of connecting a load resistor to the PFC circuit.

[0026] These objects, and other objects that will become apparent to one skilled in the art practicing the present invention, are satisfied by the electronic ballast power supply circuits and methods of the present invention.

[0027] .According to one aspect, the present invention includes an electronic ballast power supply and control circuit that can be used to supply starting power to a PFC control chip in an electronic ballast and that can be used to control the electronic ballast so that an operating power supply circuit in the electronic ballast supplies stable operating power to the PFC control chip and other control circuitry included in the electronic ballast even when an inverter circuit included in the electronic ballast is not loading a PFC circuit included in the electronic ballast. The power supply and control circuit includes a starting power supply/loading circuit adapted to be connected to the PFC circuit and to the PFC control chip, and to convert power supplied by the PFC circuit into starting power for the PFC control chip and to supply the starting power to the PFC control chip.

[0028] The power supply and control circuit also includes a control

circuit connected to the starting power supply/loading circuit and adapted to be connected to the operating power supply circuit and the PFC control chip. The control circuit is also adapted to sense when the operating power supply circuit begins supplying stable operating power to the PFC control chip and to disconnect the starting power supply/loading circuit from the PFC control chip so that the starting power supply/loading circuit no longer supplies starting power to the PFC control chip. In addition, the control circuit is adapted to sense when the inverter circuit stops loading the PFC circuit and, in response, to connect the starting power supply/loading circuit to the PFC circuit in a manner that causes the PFC circuit to supply the operating power supply circuit with sufficient power to prevent the operating power being supplied by the operating power supply circuit to the PFC control chip and the other control circuitry from becoming unstable. Finally, the control circuit is further adapted to sense when the inverter circuit begins loading the PFC circuit again and, in response, to disconnect the starting power supply/loading circuit from the PFC circuit.

[0029] According to a second aspect, the present invention includes a method of supplying stable power to a PFC control chip and other control circuitry in an electronic ballast using a starting power supply/loading circuit that includes the steps of connecting the starting power supply/loading circuit to the PFC control chip, converting power supplied by a PFC circuit in the electronic ballast into starting power and supplying the starting power to the

PFC control chip using the starting power supply/loading circuit, sensing when an operating power supply circuit in the electronic ballast begins supplying stable operating power to the PFC control chip, and disconnecting the starting power supply/loading circuit from the PFC control chip so that the starting power supply/loading circuit no longer supplies starting power to the PFC control chip when the operating power supply circuit begins supplying stable operating power to the PFC control chip. The method further includes the steps of sensing when an inverter circuit included in the electronic ballast stops loading the PFC circuit, connecting the starting power supply/loading circuit to the PFC circuit in a manner that causes the PFC circuit to supply the operating power supply circuit with sufficient power to prevent the operating power being supplied by the operating power supply circuit to the PFC control chip and the other control circuitry from becoming unstable when the inverter circuit stops loading the PFC circuit, sensing when the inverter circuit begins loading the PFC circuit again, and disconnecting the starting power supply/loading circuit from the PFC circuit when the inverter circuit begins loading the PFC circuit again.

[0030] A third aspect of the present invention includes an electronic ballast control circuit that can be used to control an electronic ballast so that an operating power supply circuit in the electronic ballast supplies stable operating power to control circuitry in the electronic ballast. The control circuit includes a controllable load circuit adapted to be connected to a PFC

circuit included in the electronic ballast and to load the PFC circuit so that the PFC circuit supplies the operating power supply circuit with sufficient power to supply the control circuitry with stable operating power. The control circuit further includes a load control circuit connected to the load circuit and adapted to sense when an inverter circuit included in the electronic ballast stops loading the PFC circuit and, before the stable operating power being supplied by the operating power supply circuit can become unstable as a result of the inverter circuit not loading the PFC circuit, to connect the controllable load circuit to the PFC circuit so that the controllable load circuit loads the PFC circuit and causes the PFC circuit to supply the operating power supply circuit with sufficient power to prevent the stable operating power being supplied by the operating power supply circuit from becoming unstable. When the inverter circuit begins loading the PFC circuit again, the load control circuit senses this change and, in response, disconnects the controllable load circuit from the PFC circuit.

[0031] Still another aspect of the present invention includes a method of supplying stable power to control circuitry in an electronic ballast that includes the steps of sensing when an inverter circuit in the electronic ballast stops loading a PFC circuit in the electronic ballast and, in response, loading the PFC circuit so that the PFC circuit supplies an operating power supply circuit in the electronic ballast with sufficient power to supply the control circuitry with stable operating power. This method also includes the steps of

sensing when the inverter circuit begins loading the PFC circuit again and, in response, unloading the PFC circuit.

[0032] A fifth aspect of the present invention includes an electronic ballast control circuit that can be used to control an electronic ballast so that an operating power supply circuit in the electronic ballast supplies stable operating power to control circuitry in the electronic ballast. This control circuit includes a microcontroller adapted to be connected to the operating power supply circuit and an inverter circuit in the electronic ballast. The microcontroller is further adapted to sense when a lamp connected to the electronic ballast stops loading the inverter circuit and, in response, to load the inverter circuit in a manner that causes the inverter circuit to supply the operating power supply circuit with sufficient power to supply the control circuitry with stable operating power and that prevents the inverter circuit from supplying a lamp output included with the electronic ballast with sufficient power to create an electric shock hazard to humans. The microcontroller is still further adapted to unload the inverter circuit when the microcontroller senses that the lamp is beginning to load the inverter circuit again.

[0033] According to a sixth aspect, the present invention includes a method of supplying stable operating power to control circuitry in an electronic ballast that includes the steps of sensing when a lamp connected to the electronic ballast stops loading an inverter circuit included in the

electronic ballast and, in response, loading the inverter circuit in a manner that causes the inverter circuit to supply an operating power supply circuit in the electronic ballast with sufficient power to supply the control circuitry with stable operating power and that prevents the inverter circuit from supplying a lamp output included with the electronic ballast with sufficient power to create an electric shock hazard to humans. In addition, this method also includes the steps of sensing when the lamp begins loading the inverter circuit again and, in response, unloading the inverter circuit.

[0034] According to still another aspect, the present invention includes a power resistor which connects from one of the high voltage power nodes of the ballast through an electronic switch to an auxiliary power rail of the system which provides power for the integrated circuits present. If the voltage on the auxiliary power rail falls below the desired level then the switch is briefly closed until the desired voltage is achieved. The loading of the boost stage achieved by connecting the resistor prompts the boost to start up and supply power to the auxiliary power rail, and in addition the charge which is being removed from the high voltage power rail is being deposited directly into the auxiliary power rail

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] Fig. 1 is a simplified schematic of a prior art ballast with a

microcontroller and active PFC stage.

[0036] Fig. 2 is a schematic showing one embodiment of the electronic ballast power supply and control circuit of the present invention.

[0037] Fig. 3 is a schematic showing one embodiment of the electronic ballast control circuit of the present invention.

[0038] Fig. 4 is schematic showing another embodiment of the electronic ballast control circuit of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0039] Referring to Fig. 2, one embodiment of the electronic ballast power supply and control circuit 10 of the present invention is shown connected to a conventional electronic ballast. The electronic ballast includes an AC/DC converter circuit 12, a PFC circuit 14, and a PFC power supply circuit 16. The AC/DC converter circuit 12 is a conventional AC/DC converter circuit and is operable to convert AC input voltage provided by an AC power source into rectified AC voltage. The AC/DC converter circuit 12 includes a full bridge rectifier, which converts the AC input voltage into the rectified AC voltage, and a filter capacitor, which prevents high frequency switching noise created by switching in the PFC circuit 14 from being passing back through the AC/DC converter circuit 12 to the AC voltage source.

[0040] The PFC circuit 14 is a conventional PFC circuit and is operable

to convert rectified AC voltage supplied by the AC/DC converter circuit 12 into approximately constant DC voltage and to cause power drawn from the AC power source to have a desired power factor. The PFC circuit 14 includes a PFC boost inductor 18 with an auxiliary winding 20, a boost diode 22, two bulk capacitors 24, 26, a PFC control chip 28, a zero current detection resistor 30, a PFC transistor circuit 32, which includes a PFC transistor 34, a gate resistor, and a gate diode, and a current sensing circuit 36, which includes a current sense resistor and a low pass filter circuit. The low pass filter circuit includes a low pass resistor connected to a low pass capacitor. The connection between the boost diode 22 and an inverter circuit (not shown in Fig. 2, but see Fig. 3) is referred to as a high voltage rail.

[0041] The PFC circuit 14 also includes an output voltage sensing circuit (not shown) that is used to sense the DC voltage that develops across the bulk capacitors 24, 26 and to send a voltage feedback signal representative of this voltage back to the PFC control chip 28. The PFC control chip 28 uses this feedback signal to adjust the operation of the PFC circuit 14 so that the DC voltage developed across the bulk capacitors 24, 26 remains approximately constant. When an inverter circuit 38 (an example of which is shown in Fig. 3) draws current from the bulk capacitors 24, 26, the DC voltage across these capacitors begins to drop. The PFC control chip 28 senses this drop and increases the switching of the PFC transistor 34 to prevent the voltage from dropping to low. In addition, when the inverter

circuit 38 is not drawing current from the bulk capacitors 24, 26, the DC voltage across the bulk capacitors 24, 26 remains approximately constant. The PFC control chip 28 senses this fact as well and stops switching the PFC transistor 34 so that the DC voltage does not rise above a desired maximum value.

[0042] The PFC power supply circuit 16 is a conventional PFC power supply circuit that is operable to convert a low voltage, rectified AC voltage ("the LV rectified AC voltage") that develops across the auxiliary winding 20 connected to the PFC boost inductor 18 into low voltage, voltage regulated, DC voltages ("the LVVR DC voltages") that can be supplied to the PFC control chip 28, a microcontroller 40 (not shown in Fig. 2, but see Fig. 3), and a half bridge gate drive chip 42 (not shown in Fig. 2, but see Fig. 3). In Fig. 2, the LVVR DC voltages are +5 and +15 volt DC voltages. The +5 volt DC voltage is supplied to the microcontroller 40 and the +15 volt voltage is supplied to both the PFC control chip 28 and the half bridge gate drive 42.

[0043] The PFC power supply circuit 16 includes a charge pump, which converts the LV rectified AC voltage into a low voltage DC input voltage ("the LV DC input voltage"), and a voltage regulator chip 44, which converts the LV DC input voltage into the LVVR DC voltages (in alternative embodiments the voltage regulator chip may be replaced with a voltage regulating Zener diode instead). The charge pump includes a charge pump resistor, a charge pump input capacitor, a charge pump Zener diode, a charge pump diode, and

a charge pump output capacitor. The connection between the charge pump diode and the charge pump output capacitor is referred to as a low voltage rail.

[0044] The LV rectified AC voltage only develops across the auxiliary winding 20 when the PFC transistor 34 is switched off and on by the PFC control chip 28. In other words, the LV rectified AC voltage only develops when the PFC circuit 14 is operating normally. When the PFC circuit 14 stops operating, the LV rectified AC voltage is not developed across the auxiliary winding 20 and cannot be converted into the LVVR DC output voltages.

[0045] The electronic ballast power supply and control circuit 10 is operable to supply the PFC control chip 28 with starting and operating power until the PFC power supply circuit 16 begins operating properly. Once the PFC power supply circuit 16 begins supplying power, the electronic ballast power supply and control circuit 10 stops supplying power to the PFC control chip 28. Importantly, and unlike prior art starting circuits, the electronic ballast power supply and control circuit 10 of the present invention also reduces the amount of power consumed by the electronic ballast power supply and control circuit 10 after the PFC power supply circuit 16 begins supplying power to the PFC control chip 28. As a result, the electronic ballast power supply and control circuit 10 of the present invention consumes less power and is more efficient than prior art starting circuits.

[0046] To supply starting and operating power to the PFC control chip 28, the electronic ballast power supply and control circuit 10 includes a starting power supply/loading circuit 46 that is operable to convert the rectified AC voltage supplied by the AC/DC converter circuit 12 into starting and operating power for the PFC control chip 28. The starting power supply/loading circuit 46 includes two starting/loading resistors 48, 50, a starting/loading transistor 52, a starting capacitor 54, a starting Zener diode 56, and a blocking diode 58.

[0047] The starting/loading resistors 48, 50 are connected to the output of the PFC circuit 14 and, more particularly, to the boost diode 22 and the bulk capacitors 24, 26 in the PFC circuit 14, and in series with the starting/loading transistor 52. The starting capacitor 54 and starting Zener 56 are connected in parallel with one another, to the PFC control chip 28, to circuit ground, and in series with the starting/loading transistor 52. The blocking diode 58 is connected to the starting capacitor 54 and the starting Zener 56, the PFC control chip 28, and the +15 volt output of the voltage regulator chip 44 in the PFC power supply circuit 16. The connection between the blocking diode 58 and the PFC control chip 28 is referred to as an auxiliary power supply rail.

[0048] The starting/loading resistors 48, 50 limit the starting and operating current flowing to the PFC control chip 28 and prevent those currents from reaching levels that can damage the PFC control chip 28. The

starting/loading transistor 52 is operable to connect and disconnect the starting/loading resistors 48, 50 from the PFC control chip 28 based on control voltages received from a control circuit discussed in more detail below. The starting capacitor 54 is operable to convert the starting and operating currents into starting and operating voltages, respectively, for the PFC control chip 28. The starting Zener diode 56 is operable to limit the starting and operating voltages to levels that will not harm the PFC control chip 28. The blocking diode 58 prevents starting and operating current from flowing into the +15 volt output of the voltage regulator chip 44 in the PFC power supply circuit 16.

[0049] To determine when to supply power to the PFC control chip 28, the electronic ballast power supply and control circuit 10 includes a control circuit 60 that is operable to sense when the PFC power supply circuit 16 is and is not supplying power to the PFC control chip 28. When the control circuit 60 senses that the PFC power supply circuit 16 is not supplying power, the control circuit 60 connects the starting power supply/loading circuit 46 to the PFC control chip 28 so that it can supply starting and operating power to the PFC control chip 28. Similarly, when the control circuit 60 senses that the PFC power supply circuit 16 is supplying power to the PFC control chip 28, the control circuit 60 disconnects the starting power supply/loading circuit 46 from the PFC control chip 28. The control circuit 60 includes a starting/loading connecting circuit 62 ("the connecting circuit 62")

and a starting/loading disconnecting circuit 64 ("the disconnecting circuit 64") for performing these functions.

[0050] The connecting circuit 62 is connected to the output of the PFC circuit 14, and more specifically, to the boost diode 22 in the PFC circuit 14, (it could be connected to other high voltage nodes as well, for example the rectified ac power line voltage at the input) and is operable to convert the rectified AC voltage generated by the AC/DC converter circuit 12 into a starting/loading transistor turn on voltage and to supply this voltage to the starting/loading transistor 52. In response to this voltage, the starting/loading transistor 52 turns on and connects the starting/loading resistors 48, 50 to the PFC control chip 28, the starting capacitor 54, the starting Zener 56, and the blocking diode 58, and the starting power supply/loading circuit 46 supplies power to the PFC control chip 28. The power drain from the rail drops the rail voltage a little, stimulating the PFC to run and generate power for the 5/15V regulator 44 and the other chips in the system. As an alternative to this configuration, the charge bled off from the power rail could also be delivered to the input pin 1 of the voltage regulator 44, with a suitably different switching control circuit.

[0051] The connecting circuit 62 includes a connecting resistor 66 connected in series with a connecting Zener diode 68. The connecting resistor 66 is connected to a point between the two starting/loading resistors 48, 50 and to the gate of the starting/loading transistor 52. The connecting Zener 68

is connected to the connecting resistor 66, the gate of the starting/loading transistor 52, the drain of the starting/loading transistor 52, the blocking diode 58, the starting Zener 56, the starting capacitor 54, and the PFC control chip 28.

[0052] The disconnecting circuit 64 is connected to the LV DC input voltage input of the voltage regulator chip 44 and is operable to convert the LV DC input voltage applied to this input into a starting/loading transistor turn off voltage and to supply this voltage to the starting/loading transistor 52. In response to this voltage, the starting/loading transistor 52 turns off and disconnects the starting/loading resistors 48, 50 from the PFC control chip 28, the starting capacitor 54, the starting Zener 56, and the blocking diode 58.

[0053] The disconnecting circuit 64 only generates the starting/loading transistor turn off voltage when the LV DC input voltage applied to the voltage regulator chip 44 rises above a minimum LV DC input voltage level that can be converted by the voltage regulator chip 44 into the power required by the PFC control chip 28 to operate properly. Prior to this time, the voltage regulator chip 44 cannot supply the PFC control chip 28 with sufficient power to operate properly and the starting power supply/loading circuit 46 must be used to supply power to the PFC control chip 28.

[0054] The disconnecting circuit 64 includes a disconnecting voltage

divider 70, a disconnecting transistor 72, and a disconnecting resistor 74. The disconnecting voltage divider 70 is connected to the LV DC input voltage input of the voltage regulator chip 44 and to circuit ground, and includes two voltage divider resistors. The disconnecting transistor 72 includes a base connected to a point between the two voltage divider resistors, a collector connected to the disconnecting resistor 74, and an emitter connected to the connecting Zener diode 68, the blocking diode 58, the starting Zener 56, the starting capacitor 54, and the PFC control chip 28. The disconnecting resistor 74 is connected to the connecting resistor 66, the gate of the starting transistor, and the connecting Zener diode 68.

[0055] The disconnecting voltage divider 70 converts the LV DC input voltage applied to the voltage regulator chip 44 into a disconnecting control voltage that can be used to turn the disconnecting transistor 72 on and off. When the LV DC input voltage is below the minimum LV DC input voltage level that can be converted by the voltage regulator chip 44 into the power required by the PFC control chip 28 to operate properly, the disconnecting control voltage developed across the disconnecting voltage divider 70 is too small to turn the disconnecting transistor 72 on. As a result, the connecting circuit 62 generates and supplies the starting/loading transistor turn on voltage to the starting/loading transistor 52 and the starting/loading transistor 52 stays on.

[0056] When the LV DC input voltage rises below the minimum LV DC

input voltage level, the disconnecting voltage divider 70 generates a disconnecting control voltage that causes the disconnecting transistor 72 to turn on. When this happens, the disconnecting resistor 74 connects in parallel with the connecting Zener diode 68 and causes the starting/loading transistor turn on voltage to drop below a level that causes the starting/loading transistor 72 to turn on. This, in turn, causes the starting/loading transistor 52 to turn off and disconnect the starting/loading resistors 48, 50 from the PFC control chip 28, the starting capacitor 54, the starting Zener 56, and the blocking diode 58. As a result, power is no longer supplied to the PFC control chip 28 by the electronic ballast power supply and control circuit 10.

[0057] It should be noted that the connecting circuit 62 does consume power after the starting power supply/loading circuit 46 is disconnected from the PFC control chip 28. By sizing the connecting resistor 66 so that the current flowing through the connecting circuit 62 is very small, i.e., by choosing a connecting resistor 66 that has a large resistance, the amount of power dissipated in the connecting circuit 62 can be minimized and reduced to a level that is lower than the power consumed by prior art starting circuits that are constantly connected to the PFC control chip 28. This causes the starting power supply/loading circuit 46 of the present invention to be more efficient than constantly connected prior art starting circuits. In addition, by selecting starting/loading resistors 48, 50 that have a very small resistance,

the electronic ballast power supply and control circuit 10 can be designed so that it generates and supplies the starting power required by the PFC control chip 28 more quickly than prior art starting circuits.

[0058] The electronic ballast power supply and control circuit 10 is also operable to regulate the operation of the PFC circuit 14 so that the LVVR DC voltages generated by the PFC power supply circuit 16 remain approximately constant even when an inverter circuit 38 (such as the one shown in Fig. 3) is not loading the PFC circuit 14. To perform this function, the electronic ballast power supply and control circuit 10 senses when the inverter circuit 38 is not loading the PFC circuit 14 and, in response, loads the PFC circuit 14 so that it supplies the PFC power supply circuit 16 with sufficient voltage to generate the required LVVR DC voltages. When the electronic ballast power supply and control circuit 10 senses that the inverter circuit 38 is once again loading the PFC circuit 14 in a manner that allows the PFC power supply circuit 16 to supply the required LVVR DC voltages, the circuit stops loading the PFC circuit 14.

[0059] By loading and unloading the PFC circuit 14 in this manner, the electronic ballast power supply and control circuit 10 of the present invention consumes less power than prior art load circuits that constantly load the PFC circuit 14 and consume power. This causes electronic ballasts using the electronic ballast power supply and control circuit 10 of the present invention to be more efficient than prior art electronic ballasts using load circuits that

constantly load the PFC circuit 14.

[0060] Turning now to Fig. 3, one embodiment of the electronic ballast control circuit 94 of the present invention is shown connected to a conventional electronic ballast similar to the one shown in Fig. 2. In this case the microprocessor, which includes an A/D circuit for measuring voltage, is used to directly measure the voltage on pin 1 of the voltage regulator and uses one of its output pins to directly drive the FET 82. All other aspects of the operation are unchanged.

[0061] In a variation of the embodiment shown in Fig. 3, the microcontroller 40 does not sense the LV DC input voltage supplied to the voltage regulator chip 44 in the PFC power supply circuit 16. Instead, the microcontroller 40 simply monitors itself to determine if it is sending control signals to the inverter circuit 38 that cause the inverter circuit 38 to load the PFC control chip 28, i.e., the microcontroller 40 simply senses if the inverter circuit 38 is running. If not, the microcontroller 40 generates a control signal that causes the load transistor 82 to turn on and connect the load resistor 80 to circuit ground. When the microcontroller 40 begins generating control signals that cause the inverter circuit 38 to begin loading the PFC circuit 14 again, the microcontroller 40 generates a control signal that causes the load transistor 82 to turn off and disconnect the load resistor 80 from circuit ground.

[0062] The circuit shown in Fig. 3 and described above is an alternative method for providing the load to the PFC circuit 14 in which the load transistor 82 is directly controlled by the microcontroller 40. The microcontroller 40 turns on the load transistor 82 to provide a load to the PFC circuit 14 when the inverter is not running or when it detects that the low voltage power supply is dropping off.

[0063] Although the circuits shown in Figs. 2 and 3 work as indicated above, they do require the use of high voltage transistors. This may be undesirable in some applications. Accordingly, in another variation of the embodiment shown in Fig. 3, the controllable load circuit 76 is excluded and the microcontroller 40 is modified to include software that causes the microcontroller 40 to switch the inverter transistors 84, 86 at a switching frequency that generates switching losses in the inverter transistors 84, 86. These losses load the PFC circuit 14 and prevent the LV DC input voltage to the voltage regulator 44 from dropping below the minimum LV DC input voltage level that can be converted into the LVVR DC voltages required by the electronic ballast control circuitry.

[0064] In this embodiment, the microcontroller 40 senses the LV DC input voltage supplied to the voltage regulator chip 44 included in the PFC power supply circuit 16 and, when this voltage drops below the LV DC voltage level generated when the inverter circuit 38 is loading the PFC circuit 14, the microcontroller 40 generates control signals that cause the inverter

gate drive 42 to switch the inverter transistors 84, 86 on and off at a switching frequency that causes switching losses to develop in the inverter transistors 84, 86. When the LV DC input voltage rises back above the LV DC voltage level generated when the inverter circuit 38 is loading the PFC circuit 14, the microcontroller 40 stops generating controls signals that cause switching losses to develop in the inverter transistors 84, 86.

[0065] In alternative embodiments, the microcontroller 40 does not sense the LV DC input voltage supplied to the voltage regulator chip 44 in the PFC power supply circuit 16. Instead, the microcontroller 40 simply monitors itself to determine if it is sending control signals to the inverter circuit 38 that cause the inverter circuit 38 to load the PFC control chip 28. If not, it generates control signals that cause the inverter circuit 38 to operate at a switching frequency that causes switching losses in the inverter transistors 84, 86. When the microcontroller 40 begins generating control signals that cause the inverter circuit 38 to begin loading the PFC circuit 14 again, the microcontroller 40 stops generating the control signals that cause switching losses to develop in the inverter transistors 84, 86.

[0066] Loading the PFC circuit 14 by creating switching losses in the inverter transistors 84, 86 is possible because the resonant output circuit 88 of the inverter circuit 38, which includes resonant output inductor 90 and capacitor 92, provides a high impedance when the inverter frequency is much higher, for example, more than approximately 200 kHz, than the resonant

frequency of the resonant output circuit 88. When the inverter circuit 38 is operating at this frequency, the voltage developed across the resonant output circuit capacitor 92 is very small and there is no electric shock risk to human beings.

[0067] When the ballast is shut down or merely flashing a lamp, and the low voltage power supply begins to drop off, the microcontroller 40 can operate the inverter circuit 38 in between flashes at a frequency that is much higher than normal in order to create losses in the inverter switches 84, 86. With the power supply voltage monitored, this high frequency running of the inverter is controlled to avoid excessive stress on the inverter switches 84, 86, while simultaneously creating enough load on the output of the PFC circuit 14 to activate it to provide enough power to the PFC power supply circuit 16.

[0068] Such a mode of operation is shown in Fig. 4. In this embodiment when the ballast is temporarily shut down, the microprocessor simply turns on the output at a harmless but power dissipating high frequency in order to load the boost stage and cause it to run and generate bias power for the chips.

[0069] The output stage can also be used to generate bias power for the chips directly, and this is the particular configuration shown in Fig. 4. Instead of the controlled loading of the PFC circuit 14 discussed above, this embodiment uses a charge pump approach that is implemented using software that causes the inverter circuit 38 to operate at a very high

frequency that prevents voltage high enough to present an electric shock hazard from developing on the resonant output circuit capacitor. In this embodiment, the charge pump should be connected to the inverter circuit 38 as shown in Fig. 4.

[0070] The inverter power supply circuit shown in Fig. 4 is the same type of circuit that is typically used in the prior art and connected to an inverter circuit 38 in an electronic ballast. In this case, however, the power supply is secured mainly by software. When the inverter circuit 38 is not running at preheating, lamp ignition, or normal operating frequencies, and the lamp cannot be the load of the inverter circuit 38, software in the microcontroller 40 causes the microcontroller 40 to operate the inverter circuit 38 in short pulses at a frequency that is much higher then the lamp preheating frequency. The inductor in the resonant output circuit, or resonant tank, prevents current from flowing to the lamp because of the higher frequency of the inverter circuit 38. The charge pump input capacitor, on the other hand, allows sufficient power to pass through to the charge pump to allow the inverter power supply circuit to operate properly. Thus, even when the inverter circuit 38 runs only in short pulses, there is enough power provided through this charge pump to maintain the power supply for the microcontroller 40.

[0071] In both of the approaches described above that require the inverter circuit 38 to operate at a switching frequency that is much higher

than normal, the switching frequency is limited by the parameters of the inverter circuit 38. In each case, the resonant tank circuit should be designed to provide enough attenuation to avoid electric shock at the lamp output and the switching device should be able to operate at a high frequency with acceptable losses on the inverter switches 84, 86.

[0072] Thus, although there have been described particular embodiments of the present invention of a new and useful Power Supply Circuits And Methods For Supplying Stable Power To Control Circuitry In An Electronic Ballast, it is not intended that such references be construed as limitations upon the scope of this invention except as set forth in the following claims.

Attorney Docket No. N8226
Customer No. 23456

CLAIMS

I claim:

1. A electronic ballast control circuit, comprising:

a first resistor connected in series with a first electronic switch the first electronic switch including a pair of first switch terminals;

a voltage limiter connected to the pair of first switch terminals;

a second resistor connected in series with the voltage limiter and having a first end connected to one of the first switch terminals and a second end connected to the first resistor; and

a third resistor connected in series with a second electronic switch to form a series combination and wherein the series combination is connected in parallel with the voltage limiter.

2. The circuit of claim 1, wherein:

the second electronic switch includes a second switch terminal; and

the circuit further includes a voltage divider connected to the second switch terminal.

3. The circuit of claim 2, wherein:

the first and second electronic switches are transistors; and

the voltage limiter is a Zener diode.

4. The circuit of claim 3, wherein:

the first electronic switch is a field effect transistor (FET); and

the second electronic switch is a bipolar junction transistor (BJT).

5. The circuit of claim 4,wherein:

the FET includes a gate terminal and a source terminal; and

the pair of first switch terminals are the gate and source terminals of the FET.

6. The circuit of claim 5, wherein

the BJT includes a base terminal; and

the second switch terminal is the base terminal of the BJT.

7. The circuit of claim 6, wherein:

the voltage divider includes a fourth and fifth resistor connected in series at a junction point; and

the junction point is connected to the base terminal of the BJT.

8. A circuit for an electronic ballast, comprising:

a sensing circuit adapted to sense a reference voltage associated with an auxiliary power supply included in an electronic ballast;

a control circuit adapted to adjust the operation of the electronic ballast by activating a power factor control circuit included in the electronic ballast so that the reference voltage associated with the auxiliary power supply increases when the reference voltage drops below a predetermined voltage level.

9. The circuit of claim 8, wherein the control circuit activates the power factor control circuit by connecting a resistor to the power factor control circuit.

10. The circuit of claim 8, wherein the control circuit activates the power factor control circuit by causing switching losses to develop in an inverter circuit included in the electronic ballast.

11. The circuit of claim 10, wherein the control circuit causes switching losses to develop in the inverter circuit by operating the inverter circuit at an inverter switching frequency that prevents the electronic ballast from creating an electric shock hazard at a lamp output included with the electronic ballast.

12. The circuit of claim 8, wherein the sensing circuit includes a microcontroller.

13. The circuit of claim 8 wherein the control circuit includes:

a resistor connected in series with an electronic switch, and

a microcontroller connected to the electronic switch and adapted to adjust the operation of the electronic ballast by turning the electronic switch off and on.

14. The circuit of claim 8, wherein both the sensing circuit and the control circuit are implemented using a microcontroller.

15. The circuit of claim 8, wherein the reference voltage is an input voltage for a voltage regulator circuit included in the auxiliary power supply.

16. A circuit for an electronic ballast, comprising:

a sensing circuit adapted to sense a reference voltage associated with an auxiliary power supply included in an electronic ballast;

a control circuit adapted to adjust the operation of the electronic ballast by activating an inverter circuit included in the electronic ballast so that the reference voltage associated with the auxiliary power supply increases when the reference voltage drops below a predetermined voltage level

17. The circuit of claim 16, wherein the control circuit causes the inverter circuit to operate at an inverter frequency that prevents the electronic ballast from outputting an output voltage sufficient to ignite a lamp.

18. A method of operating an electronic ballast, comprising:

sensing an input reference voltage associated with an auxiliary power supply included in an electronic ballast; and

adjusting the operation of the electronic ballast so that the input reference voltage associated with the auxiliary power supply increases when the input reference voltage drops below a predetermined voltage level.

19. The method of claim 18, wherein the step of sensing an input reference voltage includes the step of sensing an input voltage to a voltage regulator circuit included in the auxiliary power supply.

20. The method of claim 18, wherein the step of adjusting the operation of the electronic ballast includes the step of turning on a power factor control circuit included in the auxiliary power supply circuit and the power factor control circuit causes the reference voltage to increase.

21. The method of claim 20, wherein the step of turning on the power factor control circuit includes the step of turning on an electronic switch.

22. The method of claim 20, wherein the step of turning on the power factor control circuit includes the step of connecting a resistor to the power factor control circuit.

23. The method of claim 18, wherein the step of adjusting the operation of the electronic ballast includes the step of turning on an inverter circuit included in the auxiliary power supply circuit and the inverter circuit causes the reference voltage to increase.

24. The method of claim 23, wherein the step of turning on the inverter circuit includes the step of turning on the inverter circuit at an inverter operating frequency that prevents the electronic ballast from generating an output voltage sufficient to ignite a lamp.

25. A starting power circuit for a ballast control circuit in an electronic ballast, comprising:

a starting circuit adapted to supply starting power to the ballast control circuit; and

a starting control circuit adapted to cause the starting circuit to stop supplying starting power to the ballast control circuit when an auxiliary power supply circuit included in the electronic ballast begins supplying power to the ballast control circuit.

26. The circuit of claim 26, wherein the starting circuit supplies starting power to the ballast control circuit by connecting a resistor to the ballast control circuit.

27. The circuit of claim 26, wherein the starting circuit supplies starting power to the ballast control circuit by activating an electronic switch included in the starting circuit.

28. The circuit of claim 26, wherein the starting control circuit causes the starting circuit to stop supplying starting power by deactivating an electronic switch included in the starting circuit.

29. The circuit of claim 29, wherein the starting control circuit deactivates the electronic switch in the starting circuit by activating a second electronic switch in the starting control circuit.

30. The circuit of claim 26, wherein the starting control circuit senses when the auxiliary power supply begins supplying power to the ballast control circuit by sensing a reference voltage associated with the auxiliary power supply.

31. The circuit of claim 31, wherein the reference voltage is an input voltage to a voltage regulator circuit included in the auxiliary power supply.

32. An electronic ballast, comprising:

a high voltage power rail;

an auxiliary power supply rail; and

a first resistor connected in series with a first electronic switch between the high voltage power rail and the auxiliary power supply rail.

33. The ballast of claim 32, wherein:

the first electronic switch includes a pair of first switch terminals; and

the ballast includes a voltage limiter connected to the pair of first switch terminals.

34. The ballast of claim 33, wherein the ballast further includes:

a second resistor connected in series with the voltage limiter and having a first end connected to one of the first switch terminals and a second end connected to the first resistor; and

a third resistor connected in series with a second electronic switch to form a series combination and wherein the series combination is connected in parallel with the voltage limiter.

35. The ballast of claim 34, wherein:

the second electronic switch includes a second switch terminal; and

the ballast further includes a voltage divider connected to the second switch terminal.

36. A method of operating an electronic ballast including a high voltage rail, a low voltage rail, and an auxiliary power supply rail, comprising the steps of:

sensing a reference voltage associated with the low voltage rail; and

when the reference voltage drops below a predetermined voltage level,

supplying power from the high voltage rail to the auxiliary power supply rail.

37. The method of claim 36, wherein the step of supplying power from the high voltage rail includes the step of turning on a first electronic switch connected between the high voltage rail and the auxiliary power supply rail.

38. The method of claim 37, wherein the step of turning on the first electronic switch includes the step of turning off a second electronic switch connected to the first electronic switch.

39. The method of claim 36, wherein the step of supplying power from the high voltage rail includes the step of connecting a resistor between the high voltage rail and the auxiliary power supply rail.

40. An electronic ballast, comprising:

a high voltage rail;

a low voltage rail;

an auxiliary power supply rail, and

a control circuit connected to the high voltage, low voltage, and auxiliary power supply rails, the control circuit being adapted to sense a reference voltage associated with the low voltage rail and, when the reference voltage drops below a predetermined voltage level, to supply power from the high voltage rail to the auxiliary power supply rail.

41. A method of operating an electronic ballast including a high voltage rail and a low voltage rail, comprising the steps of:

sensing a reference voltage associated with the low voltage rail; and

when the reference voltage drops below a predetermined voltage level,

activating an electronic switch included in the electronic ballast that causes the reference voltage to increase.

42. A method of operating an electronic ballast including a high voltage rail and a low voltage rail, comprising the steps of:

sensing a reference voltage associated with the low voltage rail; and

when the reference voltage drops below a predetermined voltage level, activating an electronic switch included in the electronic ballast that causes power to be supplied to the low voltage rail.

43. An electronic ballast power supply and control circuit that can be used to supply starting power to a PFC control chip in an electronic ballast and that can be used to control the electronic ballast so that an operating power supply circuit in the electronic ballast supplies stable operating power to the PFC control chip and other control circuitry included in the electronic ballast even when an inverter circuit included in the electronic ballast is not loading a PFC circuit included in the electronic ballast, comprising:

a starting power supply/loading circuit adapted to be connected to the PFC circuit and to the PFC control chip, the starting power supply/loading circuit being further adapted to convert power supplied by the PFC circuit into starting power for the PFC control chip and to supply the starting power to the PFC control chip; and

a control circuit connected to the starting power supply/loading circuit and adapted to be connected to the operating power supply circuit and the PFC control chip, the control circuit being further adapted to sense when the operating power supply circuit begins supplying stable operating power to the PFC control chip and to disconnect the starting power supply/loading circuit from the PFC control chip so that the starting power supply/loading circuit no longer supplies starting power to the PFC control chip;

the control circuit being still further adapted to sense when the inverter circuit stops loading the PFC circuit and, in response, to connect the starting power supply/loading circuit to the PFC circuit in a manner that causes the PFC circuit to supply the operating power supply circuit with sufficient power to prevent the operating power being supplied by the operating power supply circuit to the PFC control chip and the other control circuitry from becoming unstable;

the control circuit being yet further adapted to sense when the inverter circuit begins loading the PFC circuit again and, in response, to disconnect the starting power supply/loading circuit from the PFC circuit.

44. The circuit of claim 43, wherein the starting power supply/loading circuit includes:

a pair of starting/loading resistors connected in series with a starting/loading transistor;

a starting capacitor connected in parallel with a starting Zener diode, the starting capacitor and starting Zener diode being further connected in series with the series connection of the starting/loading resistors and the starting/loading transistor; and

a blocking diode connected to a point between the series connection of the starting/loading resistors and the starting/loading transistor and the parallel connection of the starting capacitor and the starting Zener diode.

45. The circuit of claim 43, wherein the control circuit includes:

a starting/loading connecting circuit; and

a starting/loading disconnecting circuit connected to the starting/loading connecting circuit.

46. The circuit of claim 45, wherein the starting/loading connecting circuit includes a connecting resistor connected in series with a connecting Zener diode.

47. The circuit of claim 45, wherein the starting/loading disconnecting circuit includes:

a disconnecting voltage divider;

a disconnecting transistor connected to the disconnecting voltage divider; and

a disconnecting resistor connected to the disconnecting transistor.

48. The circuit of claim 43, wherein the starting power supply/loading circuit includes:

a pair of starting/loading resistors connected in series with one another and a starting/loading transistor; and

a connecting resistor connected in series with a connecting Zener diode, the connecting resistor being further connected to a point between the pair of starting/loading resistors and a gate associated with the starting/loading transistor, and the connecting Zener diode being connected to the gate associated with the starting/loading transistor and source associated with the starting/loading transistor.

49. The circuit of claim 48, wherein the starting power supply/loading circuit further includes:

a disconnecting resistor connected to the connecting resistor, the gate of the starting/loading transistor, and the connecting Zener diode;

a pair of disconnecting voltage divider resistors; and

a disconnecting transistor having a base, a collector, and an emitter, the collector being connected to the disconnecting resistor, the emitter being connected to the connecting Zener, and the base being connected to a point in between the disconnecting voltage divider resistors.

50. The circuit of claim 49, wherein the starting power supply/loading circuit still further includes:

a starting capacitor connected in parallel with a starting Zener diode, the parallel connection of the starting capacitor and starting Zener diode being further connected in series with the series connection of the starting/loading resistors and the starting/loading transistor; and

a blocking diode connected to a point between the series connection of the starting/loading resistors and the starting/loading transistor and the parallel connection of the starting capacitor and the starting Zener diode.

51. A method of supplying stable power to a PFC control chip and other control circuitry in an electronic ballast using a starting power supply/loading circuit, comprising the steps of:

connecting the starting power supply/loading circuit to the PFC control chip;

converting power supplied by a PFC circuit in the electronic ballast into starting power and supplying the starting power to the PFC control chip using the starting power supply/loading circuit;

sensing when an operating power supply circuit in the electronic ballast begins supplying stable operating power to the PFC control chip;

disconnecting the starting power supply/loading circuit from the PFC control chip so that the starting power supply/loading circuit no longer supplies starting power to the PFC control chip when the operating power supply circuit begins supplying stable operating power to the PFC control chip;

sensing when an inverter circuit included in the electronic ballast stops loading the PFC circuit;

connecting the starting power supply/loading circuit to the PFC circuit in a manner that causes the PFC circuit to supply the operating power supply

circuit with sufficient power to prevent the operating power being supplied by the operating power supply circuit to the PFC control chip and the other control circuitry from becoming unstable when the inverter circuit stops loading the PFC circuit;

sensing when the inverter circuit begins loading the PFC circuit again; and

disconnecting the starting power supply/loading circuit from the PFC circuit when the inverter circuit begins loading the PFC circuit again.

52. The method of claim 51, wherein the step of connecting the starting power supply/loading circuit includes the steps of:

converting the power supplied by the PFC circuit into a starting/loading transistor turn on voltage; and

supplying the transistor turn on voltage to a starting/loading transistor included in the starting power supply/loading circuit thereby causing the starting/loading transistor to turn on and connect the starting power supply/loading circuit to the PFC control chip.

53. The method of claim 51, wherein the step of converting the power supplied by the PFC circuit includes the steps of:

converting the power supplied by the PFC circuit into a starting current by applying the power to starting/loading resistors;

converting the starting current into starting voltage by supplying the starting current to a starting capacitor; and

limiting the starting voltage to a predetermined maximum starting voltage level using a starting Zener diode.

54. The method of claim 51, wherein the step of sensing when the operating power supply circuit begins supplying stable operating power includes the step of sensing when a reference voltage in the operating power supply circuit exceeds a reference voltage level generated when the operating power supply circuit is supplying stable operating power to the PFC control chip.

55. The method of claim 51, wherein the step of disconnecting the starting power supply/loading circuit includes the step of turning off a starting/loading transistor in the starting power supply/loading circuit.

56. The method of claim 55, wherein the step of turning off the starting/loading transistor includes the steps of:

converting a reference voltage in the starting power supply/loading circuit into a starting/loading transistor turn off voltage; and

supplying the starting/loading transistor turn off voltage to the starting/loading transistor thereby causing the starting/loading transistor to turn off.

57. The method of claim 56, wherein the step of converting the reference voltage into the starting/loading transistor turn off voltage includes the steps of:

converting the reference voltage into a disconnecting transistor turn on voltage; and

supplying the disconnecting transistor turn on voltage to a disconnecting transistor included in the starting power supply/loading circuit, thereby causing the disconnecting transistor to turn on and generate the starting/loading transistor turn off voltage.

58. The method of claim 57, wherein, when the disconnecting transistor turns on, the disconnecting transistor connects a disconnecting resistor to a gate and drain associated with the starting/loading transistor.

59. The method of claim 51, wherein the step of sensing when the inverter circuit stops loading the PFC circuit includes the step of sensing when a reference voltage in the operating power supply circuit drops below a reference voltage level generated in the operating power supply circuit when the inverter circuit is loading the PFC circuit.

60. The method of claim 51, wherein the step of connecting the starting power supply/loading circuit to the PFC circuit includes the step of turning on a starting/loading transistor in the starting power supply/loading circuit.

61. The method of claim 51, wherein the step of sensing when the inverter circuit begins loading the PFC circuit again includes the step of sensing when a reference voltage in the operating power supply circuit rises above a reference voltage level generated in the operating power supply circuit when the starting power supply/loading circuit is connected to the PFC control chip.

62. An electronic ballast control circuit that can be used to control an electronic ballast so that an operating power supply circuit in the electronic ballast supplies stable operating power to control circuitry in the electronic ballast, comprising:

a controllable load circuit adapted to be connected to a PFC circuit included in the electronic ballast and to load the PFC circuit so that the PFC circuit supplies the operating power supply circuit with sufficient power to supply the control circuitry with stable operating power; and

a load control circuit connected to the load circuit and adapted to sense when an inverter circuit included in the electronic ballast stops loading the PFC circuit and, before the stable operating power being supplied by the operating power supply circuit can become unstable as a result of the inverter circuit not loading the PFC circuit, to connect the controllable load circuit to the PFC circuit so that the controllable load circuit loads the PFC circuit and causes the PFC circuit to supply the operating power supply circuit with sufficient power to prevent the stable operating power being supplied by the operating power supply circuit from becoming unstable, the load control circuit being further adapted to sense when the inverter circuit begins loading the PFC circuit again and, in response, to disconnect the controllable load circuit from the PFC circuit.

63. The circuit of claim 62, wherein the controllable load circuit includes a load resistor connected in series with a load transistor.

64. The circuit of claim 62, wherein the load control circuit includes a microcontroller.

65. A method of supplying stable power to control circuitry in an electronic ballast, comprising the steps of:

sensing when an inverter circuit in the electronic ballast stops loading a PFC circuit in the electronic ballast and, in response, loading the PFC circuit so that the PFC circuit supplies an operating power supply circuit in the electronic ballast with sufficient power to supply the control circuitry with stable operating power; and

sensing when the inverter circuit begins loading the PFC circuit again and, in response, unloading the PFC circuit.

66. The method of claim 65, wherein:

the step of loading the PFC circuit includes the step of connecting a load resistor to the PFC circuit; and

the step of unloading the PFC circuit includes the step of disconnecting the load resistor from the PFC circuit.

67. The method of claim 66, wherein:

the step of connecting the load resistor to the PFC circuit includes the step of turning on a transistor; and

the step of disconnecting the load resistor from the PFC circuit includes the step of turning off the transistor.

68. The method of claim 65, wherein the steps of loading and unloading the PFC circuit are implemented using a microcontroller.

69. The method of claim 65, wherein the step of loading the PFC circuit includes the step of operating inverter switches in an inverter circuit connected to the PFC circuit at a switching frequency that causes switching losses in the inverter switches to develop and load the PFC circuit.

70. The method of claim 69, wherein the step of operating the inverter switches at a switching frequency that causes switching losses includes the

step of operating the inverter switches at a switching frequency that prevents the inverter circuit from creating an electric shock hazard at a lamp output of the electronic ballast.

71. The method of claim 70, wherein the step of operating the inverter switches at a switching frequency that prevents the inverter circuit from creating an electric shock hazard at a lamp output of the electronic ballast includes the step of operating the inverter switches at a switching frequency that prevents the inverter circuit from supplying sufficient current to the lamp output of the electronic ballast to create an electric shock hazard.

72. An electronic ballast control circuit that can be used to control an electronic ballast so that an operating power supply circuit in the electronic ballast supplies stable operating power to control circuitry in the electronic ballast, comprising:

a microcontroller adapted to be connected to the operating power supply circuit and an inverter circuit in the electronic ballast, the microcontroller being further adapted to sense when a lamp connected to the electronic ballast stops loading the inverter circuit and, in response, to load the inverter circuit in a manner that causes the inverter circuit to supply the

operating power supply circuit with sufficient power to supply the control circuitry with stable operating power and that prevents the inverter circuit from supplying a lamp output included with the electronic ballast with sufficient power to create an electric shock hazard to humans;

the microcontroller being still further adapted to sense when the lamp begins loading the inverter circuit again and, in response, to unload the inverter circuit.

73. The circuit of claim 72, wherein the microcontroller is adapted to sense when the lamp stops loading the inverter circuit by sensing when a reference voltage in the operating power supply circuit drops below a reference voltage level generated when the lamp is loading the inverter circuit.

74. The circuit of claim 72, wherein the microcontroller is adapted to load the inverter circuit by operating the inverter circuit at an inverter switching frequency that causes the inverter circuit to supply the operating power supply circuit with sufficient power to prevent the stable operating power from becoming unstable and that prevents the inverter circuit from supplying the lamp output with sufficient power to create an electric shock hazard to humans.

75. The circuit of claim 72, wherein the microcontroller is adapted to sense when the lamp begins loading the inverter circuit again by sensing when a reference voltage in the operating power supply circuit rises above a reference voltage level generated when the lamp is loading the inverter circuit.

76. A method of supplying stable operating power to control circuitry in an electronic ballast, comprising the steps of:

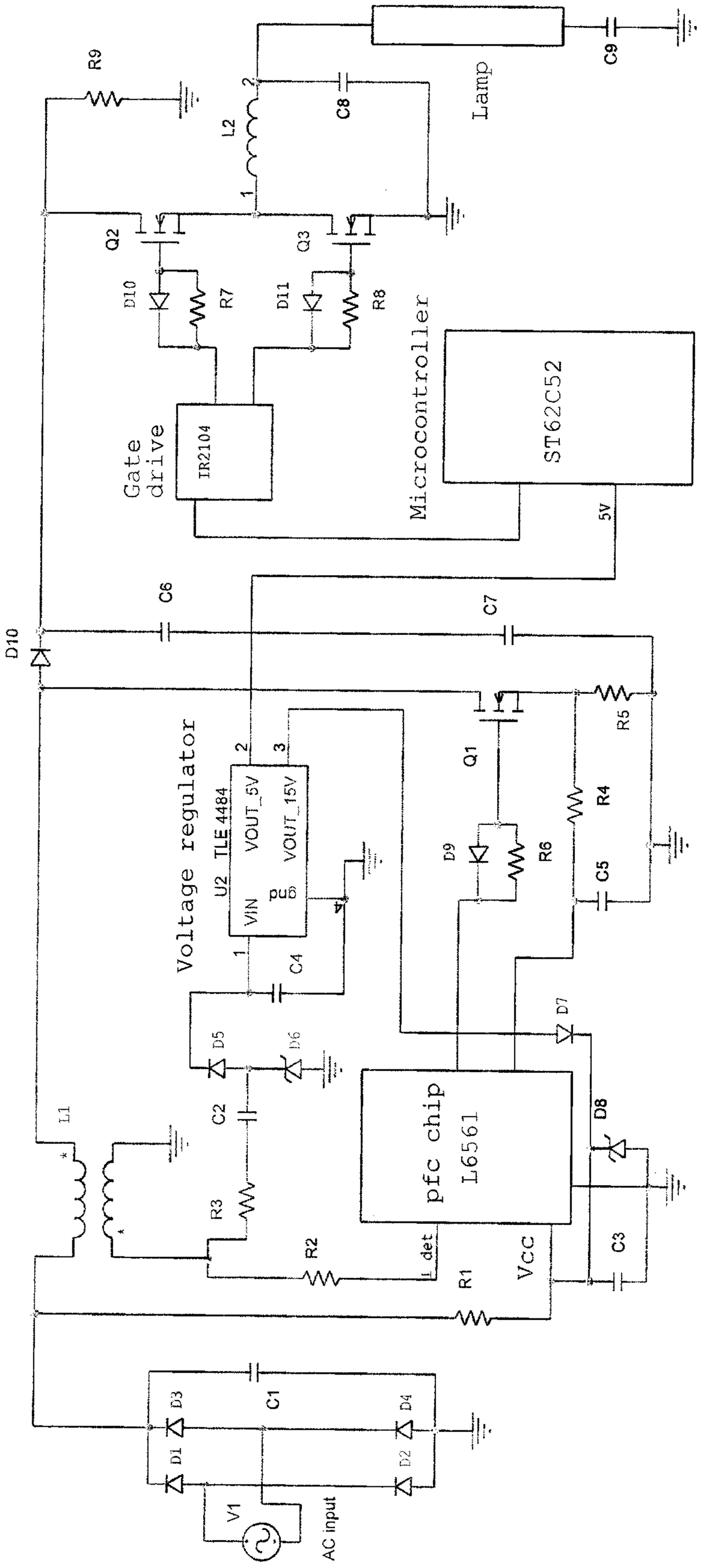
sensing when a lamp connected to the electronic ballast stops loading an inverter circuit included in the electronic ballast and, in response, loading the inverter circuit in a manner that causes the inverter circuit to supply an operating power supply circuit in the electronic ballast with sufficient power to supply the control circuitry with stable operating power and that prevents the inverter circuit from supplying a lamp output included with the electronic ballast with sufficient power to create an electric shock hazard to humans; and

sensing when the lamp begins loading the inverter circuit again and, in response, unloading the inverter circuit.

77. The method of claim 76, wherein the step of sensing when the lamp stops loading the inverter circuit includes the step of sensing when a reference voltage in the operating power supply circuit drops below a reference voltage level generated when the lamp is loading the inverter circuit.

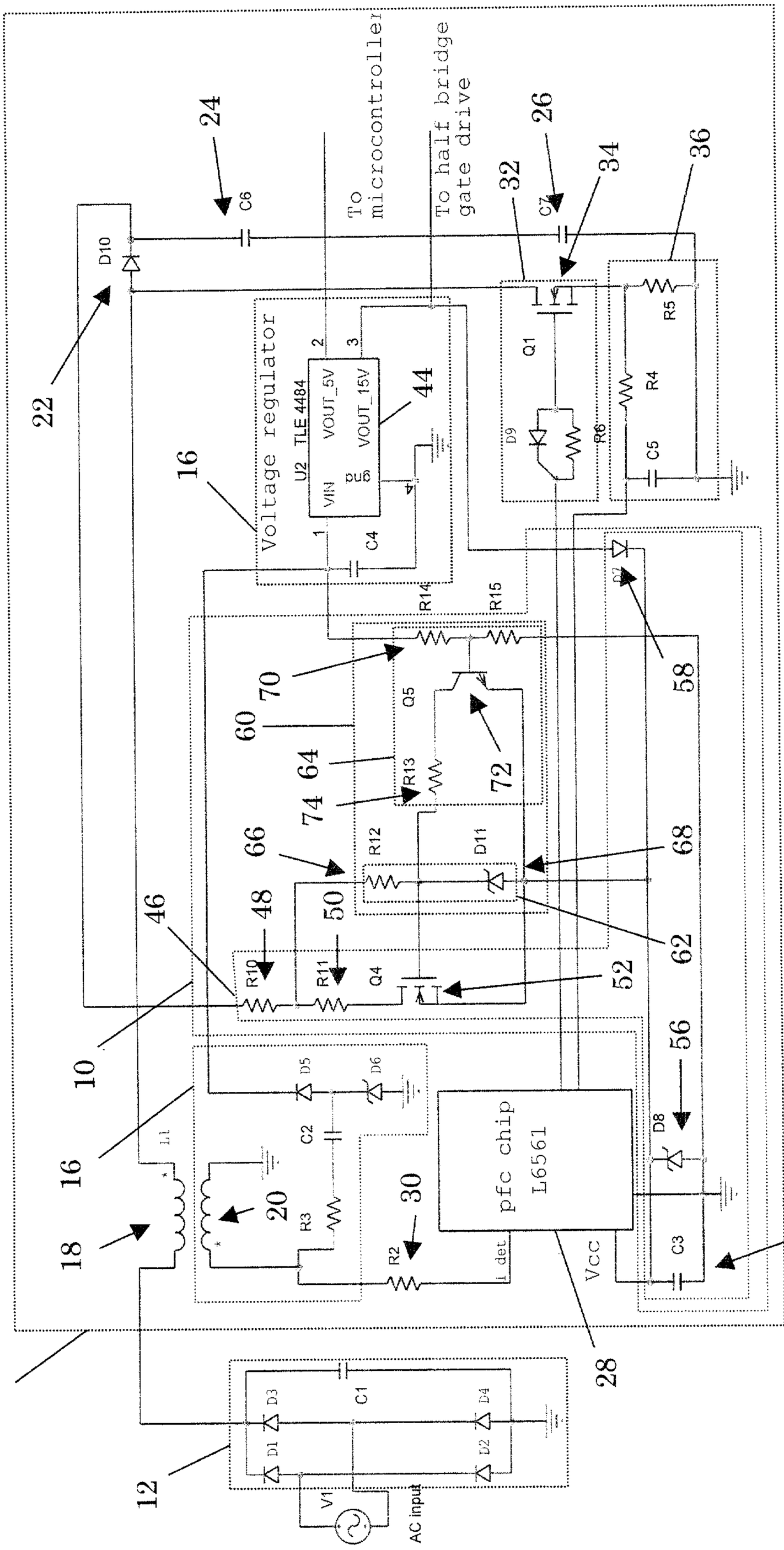
78. The method of claim 76, wherein the step of loading the inverter circuit includes the step of operating the inverter circuit at an inverter switching frequency that causes the inverter circuit to supply the operating power supply circuit with sufficient power to prevent the stable operating power from becoming unstable and that prevents the inverter circuit from supplying the lamp output with sufficient power to create an electric shock hazard to humans.

79. The method of claim 76, wherein the step of sensing when the lamp begins loading the inverter circuit again includes the step of sensing when a reference voltage in the operating power supply circuit rises above a reference voltage level generated when the lamp is loading the inverter circuit.



(PRIOR ART)

FIG. 1


12
14
16
18
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22
24
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28
30
32
34
36
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
To microcontroller
To half bridge gate drive
Voltage regulator
U2 TLE4484
VIN
GND
VOUT_5V
VOUT_15V
C4
C5
C6
C7
D9
D10
Q1
R4
R5
R6
D7
R14
R15
Q5
R13
R12
D11
R10
R11
Q4
D5
D6
C2
R3
R2
L1
pfc chip
L6561
i_det
Vcc
D8
C3
D1
D2
D3
D4
C1
V1
AC input

FIG. 2

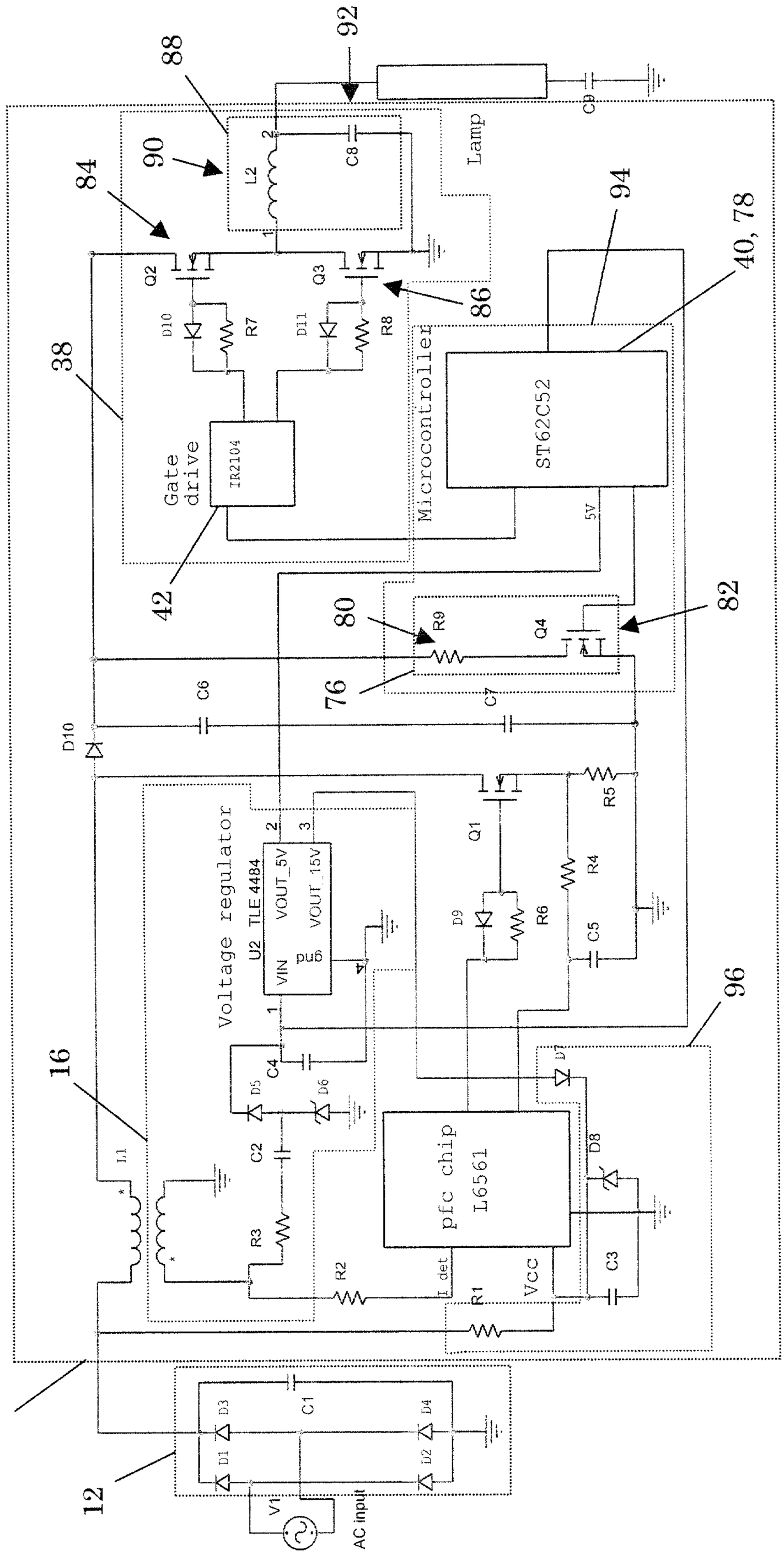

92
88
90
84
L2
C8
Lamp
Cp
94
40, 78
Q2
Q3
86
D10
R7
D11
R8
38
Microcontroller
ST62C52
Gate drive
IR2104
42
5V
80
R9
Q4
82
76
C6
C7
D10
R5
Q1
R4
U2 TLE 4484
VOUT_5V
VOUT_15V
VIN
gnd
Voltage regulator
D9
R6
C5
16
C4
D5
D6
D7
96
L1
C2
pfc chip
L6561
D8
R3
R2
I det
R1
Vcc
C3
14
C1
D3
D4
12
D1
D2
V1
AC input

FIG. 3

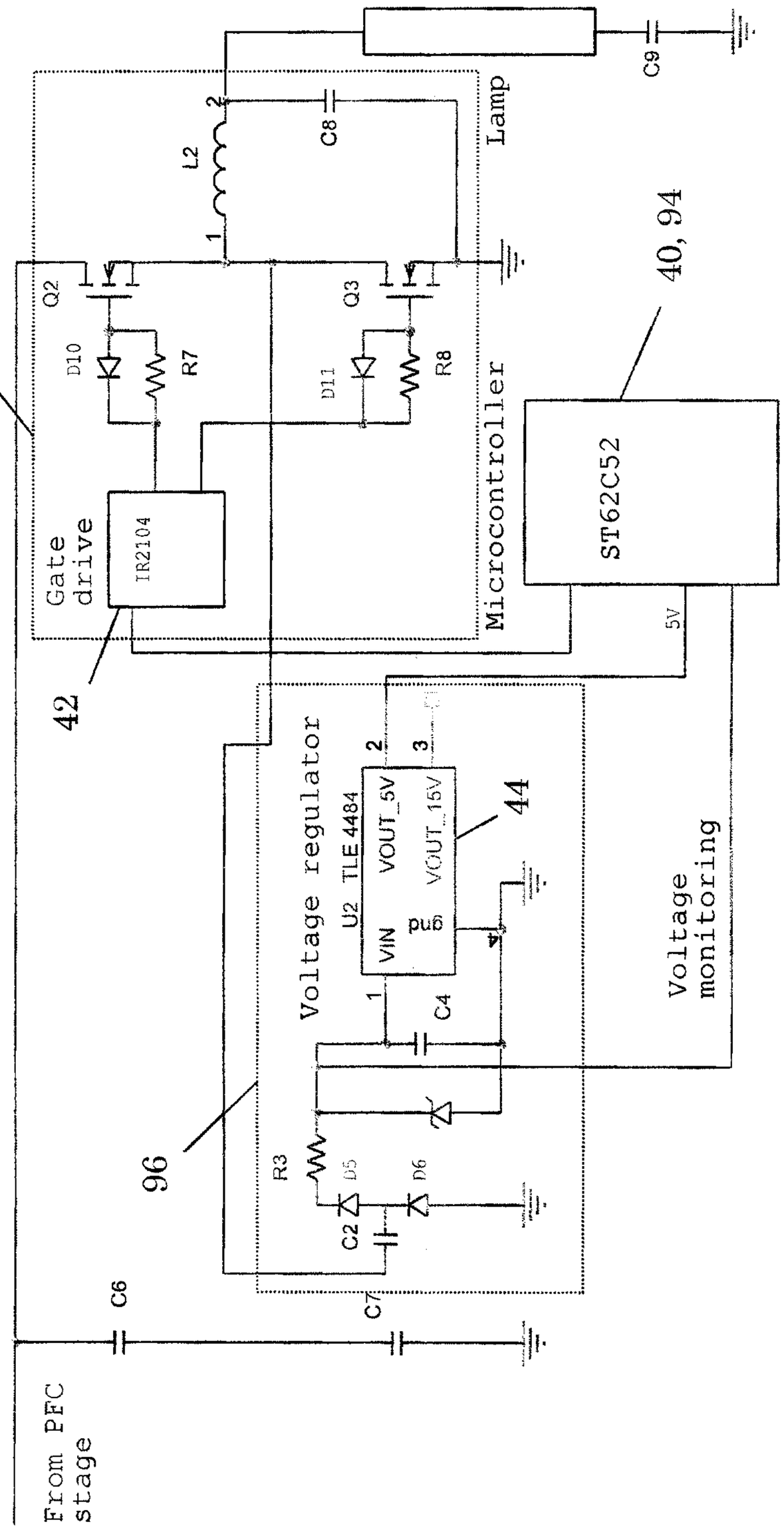
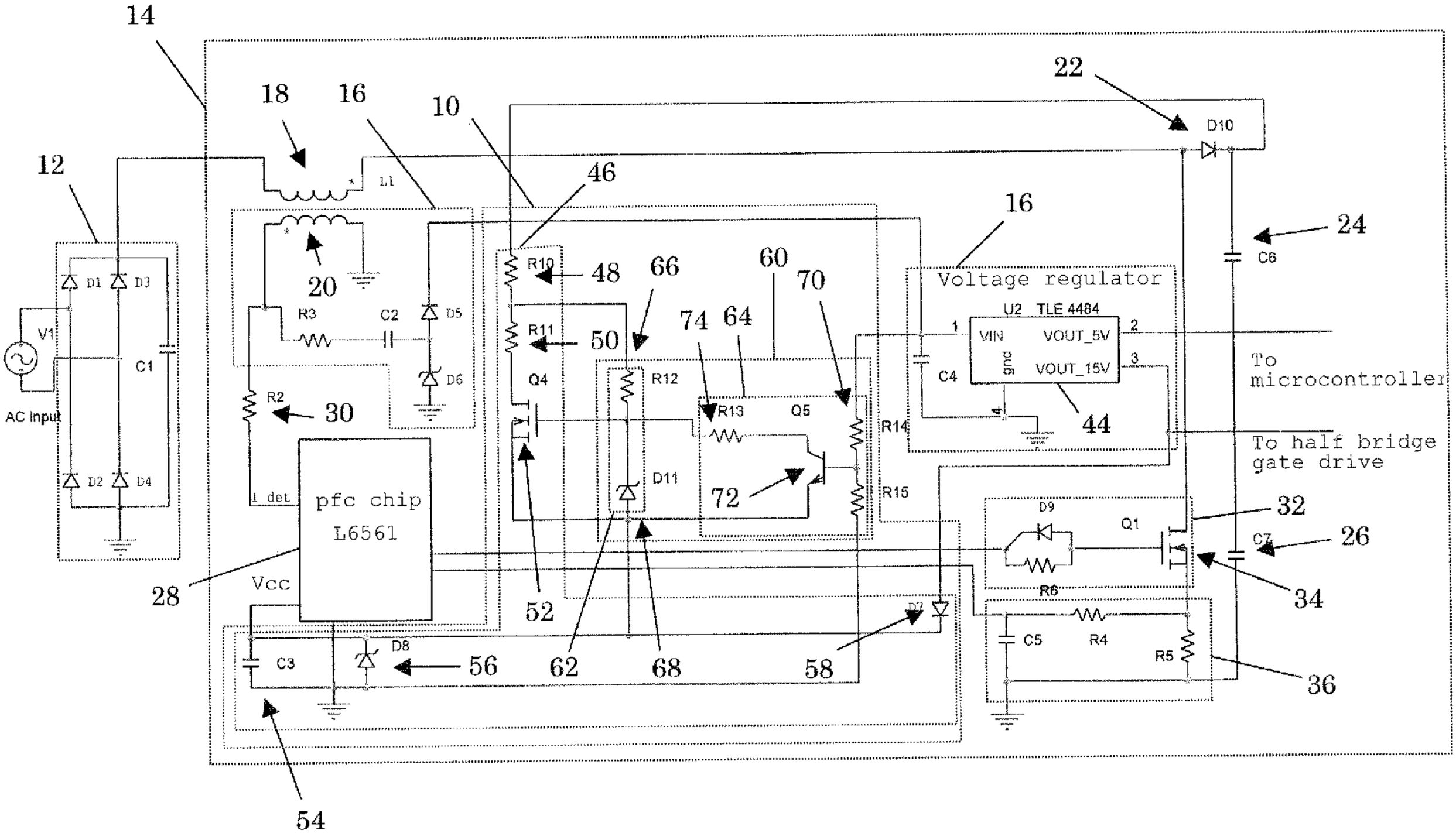

From PFC stage
C6
C7
96
Voltage regulator
R3
D5
D6
C2
U2 TLE 4484
VIN
VOUT_5V
VOUT_15V
GND
C4
44
Voltage monitoring
38
Gate drive
IR2104
42
Microcontroller
ST62C52
5V
Q2
Q3
D10
D11
R7
R8
L2
C8
C9
Lamp
40, 94

FIG. 4


14
18
16
10
22
12
46
16
24
D10
L1
20
R10
48
66
60
70
Voltage regulator
C6
D1
D3
R3
C2
D5
U2 TLE 4484
74
64
50
V1
C1
Q4
R12
1
VIN
VOUT_5V
2
To microcontroller
D6
C4
gnd
VOUT_15V
3
R2
30
R13
Q5
R14
44
To half bridge gate drive
AC input
D2
D4
D11
72
R15
I_det
pfc chip
L6561
D9
Q1
32
C7
26
28
Vcc
52
R6
34
D7
C5
R4
R5
C3
D8
56
62
68
58
36
54