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(54) AC TO DC POWER SUPPLY WITH PFC FOR LAMP

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Publication Classification

(51) **Int. Cl.**
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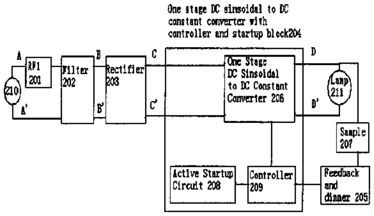
(52) **U.S. Cl.** **315/291**

(57) ABSTRACT

An AC-to-DC converter with PFC or without PFC generates an output constant voltage at any predetermined value (no matter less or more than input line peak voltage, or even equal to input line peak voltage) with an input line AC voltage with wide range (Typical sinusoidal 110 VAC, 60 Hz or 220 VAC, 50 Hz). It is mainly used as power supply for lamp. Previous power supply for lamp has low frequency component or high frequency component. (1) Low frequency light cause eyes pupil and crystalline lens will adjust 60 times, 120 or many times per second to cause eyes tired. Pupil open wide and crystalline lens adjust to collect more light to focus on retina for seeing clearly at weak light while pupil open narrow and crystalline lens adjust to collect less light to focus on retina at strong light to prevent retina from strong light harm and hurt. In the long run, muscles to control pupil and crystalline lens become very tired and become flabby. Then the muscle can't adjust pupil and crystalline according to distance and brightness so that myopia is caused. (2) High frequency voltage causes lamp brightness changes too fast. Eyes can not adjust fast enough to follow the brightness change of lamp for high frequency voltage. But high frequency large current on the secondary cause high EMI that has risk to harm people's health. High frequency light causes EMI issue. Peoples' eyes can't keep up with high frequency light. Peak strong light shine on the retina for pupil can't shrink at high frequency light. In the long run, retina will be harmed and affect eyesight is affected, cornea dryness or crystalline lens opacity is caused. My invention of power supply lamp has only DC constant voltage on lamp. Lamp's brightness is constant and has no low frequency or high frequency component Thus peoples' eyes and health are protected to maximum extent. The output voltage is regulated at predetermined DC constant value by feedback. You can adjust feedback potentiometer value to set output voltage. Potentiometer and resistor voltage divider with auxiliary winding, (opto-coupler, digital isolator or direct feedback) compose the dimming feedback circuit. It is convenient to adjust the brightness of lamp for eyes' comfort by adjusting the potentiometer resistance value. My invention can be used directly on second category lamp that doesn't need high voltage with ballast to start the lamp. Most of them use heat generated by filament or diode etc to create light. Such as Halogen, Incandescent, LED, PAR lamp, miniature sealed beam lamp, Projection lamp, automotive lamp, some stage and studio lamp, DC fluorescent lamp etc. The converter realized pulse-by-pulse or other current limit protection by sense the current sense resistor or signal transformer.

One stage DC sinusoidal to DC constant converter **206** can be implemented by all kinds of topologies other than the following topologies as long as they can convert DC sinusoidal voltage to DC constant voltage. Buck, Boost, Buck-boost, Noninverting buck-boost ,H-Bridge, Watkins-Johnson, Current-fed bridge, Inverse of Watkins-Johnson, Cuk, SEPIC, Inverse of SEPIC, Buck square, full bridge, half bridge, Forward, Two-transistor Forward, Push-pull, Flyback, Push-pull converter basedon Watkins-Johnson, Isolated SEPIC, Isolated Inverse SEPIC, Isolated Cuk, Two-transistor Flyback etc

One stage AC to DC converter **206** can be realized by discrete components without controller **209**, active startup circuit, feedback circuit or sample circuit. Main switch and active startup circuit can be integrated in IC controller. The AC to DC converter is not used only for lamp. It is can also be used for any device requires DC power supply in all the industrial areas. (Telecommunication, Storage, Personal computer, cell phone power supply and charger, video game etc) For example, Bus AC to DC converter, PFC converter, PFC converter for lighting Computer power supply, Monitor power supply, notebook adapter, LCD TV, AC/DC adapter, adjusted voltage charger, Power tool charger, Electronic ballast, Video game power supply etc.



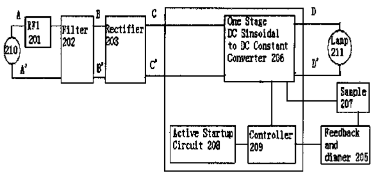


Figure 1

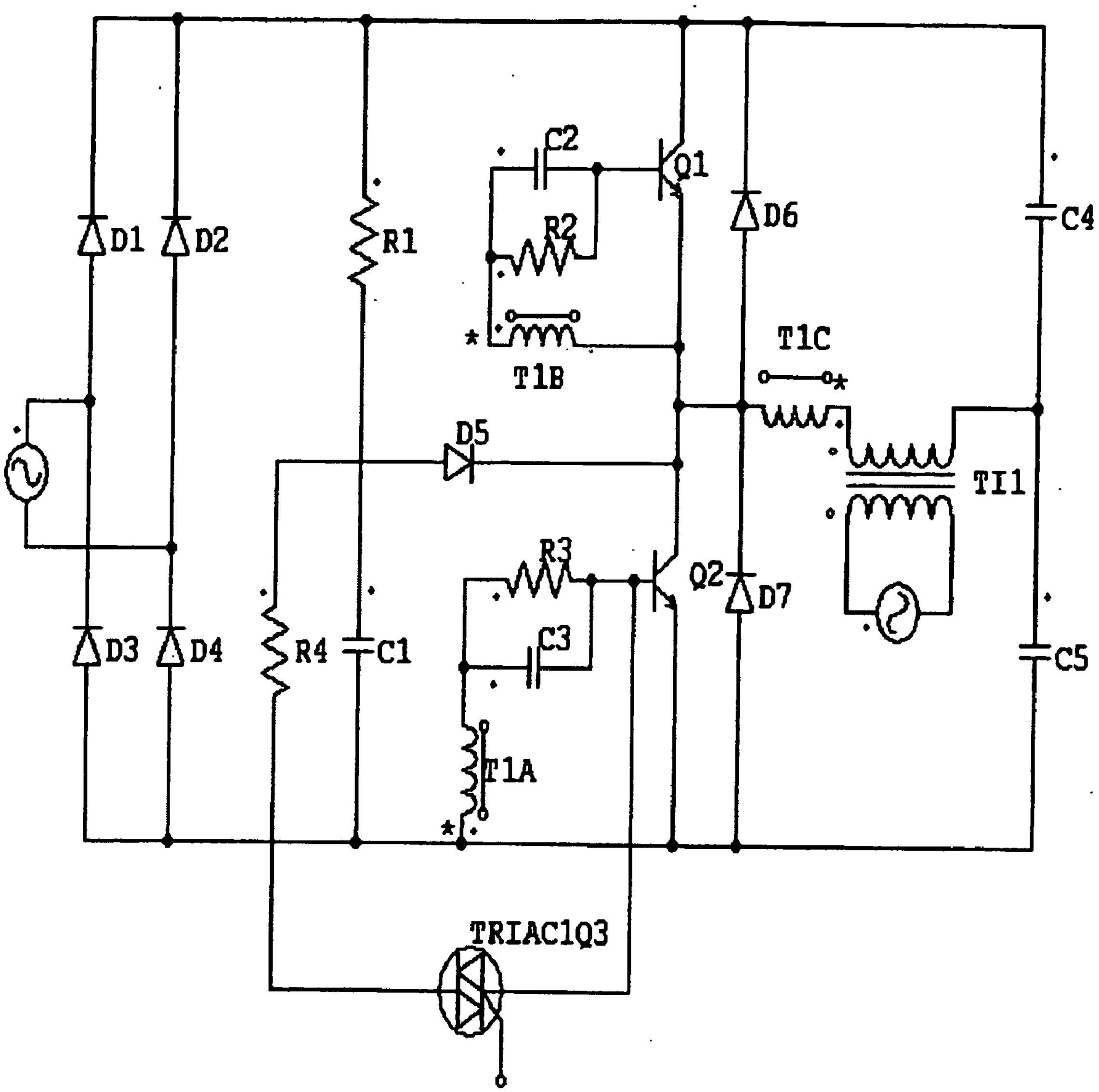
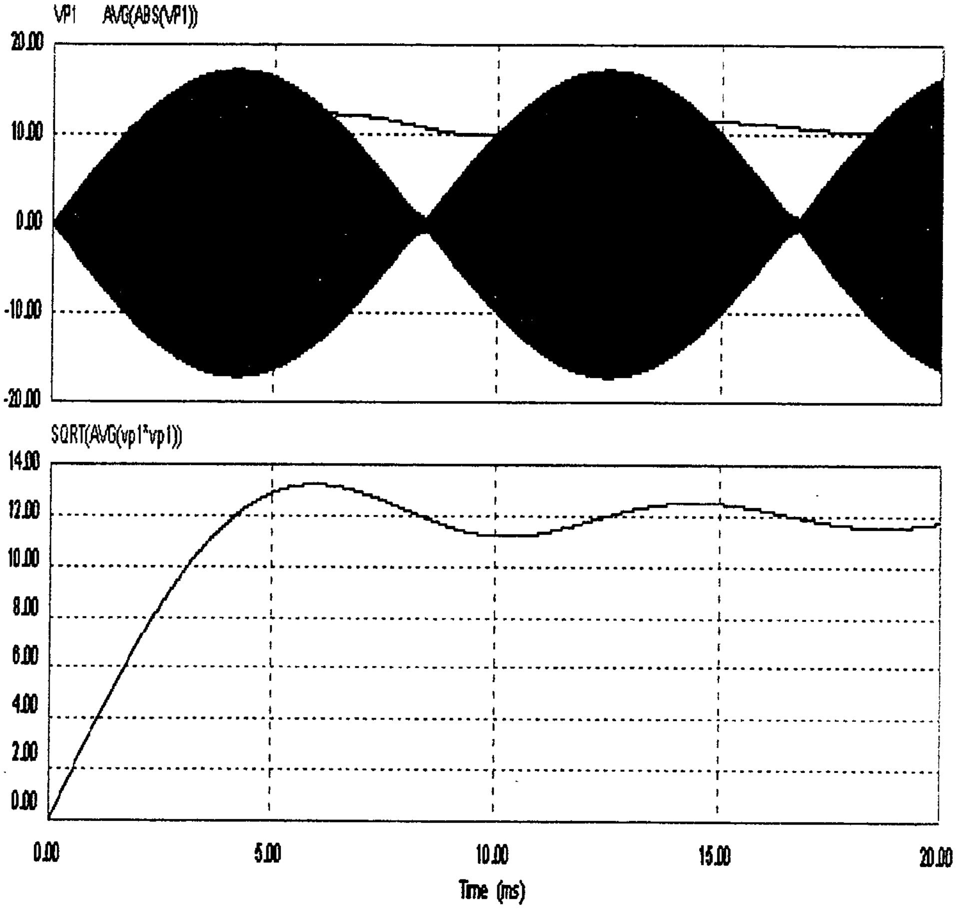
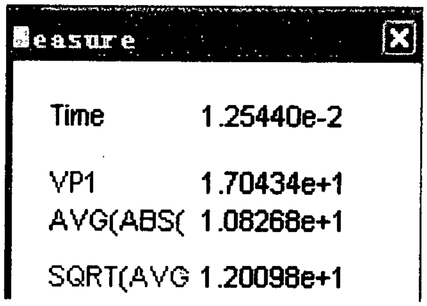

C2
Q1
R2
D6
C4
D1
D2
R1
T1B
T1C
D5
TI1
R3
Q2
D7
D3
D4
R4
C1
C3
C5
T1A
TRIAC1Q3

Figure 2





Time	1.25440e-2
VP1	1.70434e+1
AVG(ABS(	1.08268e+1
SQRT(AVG	1.20098e+1

Figure 3

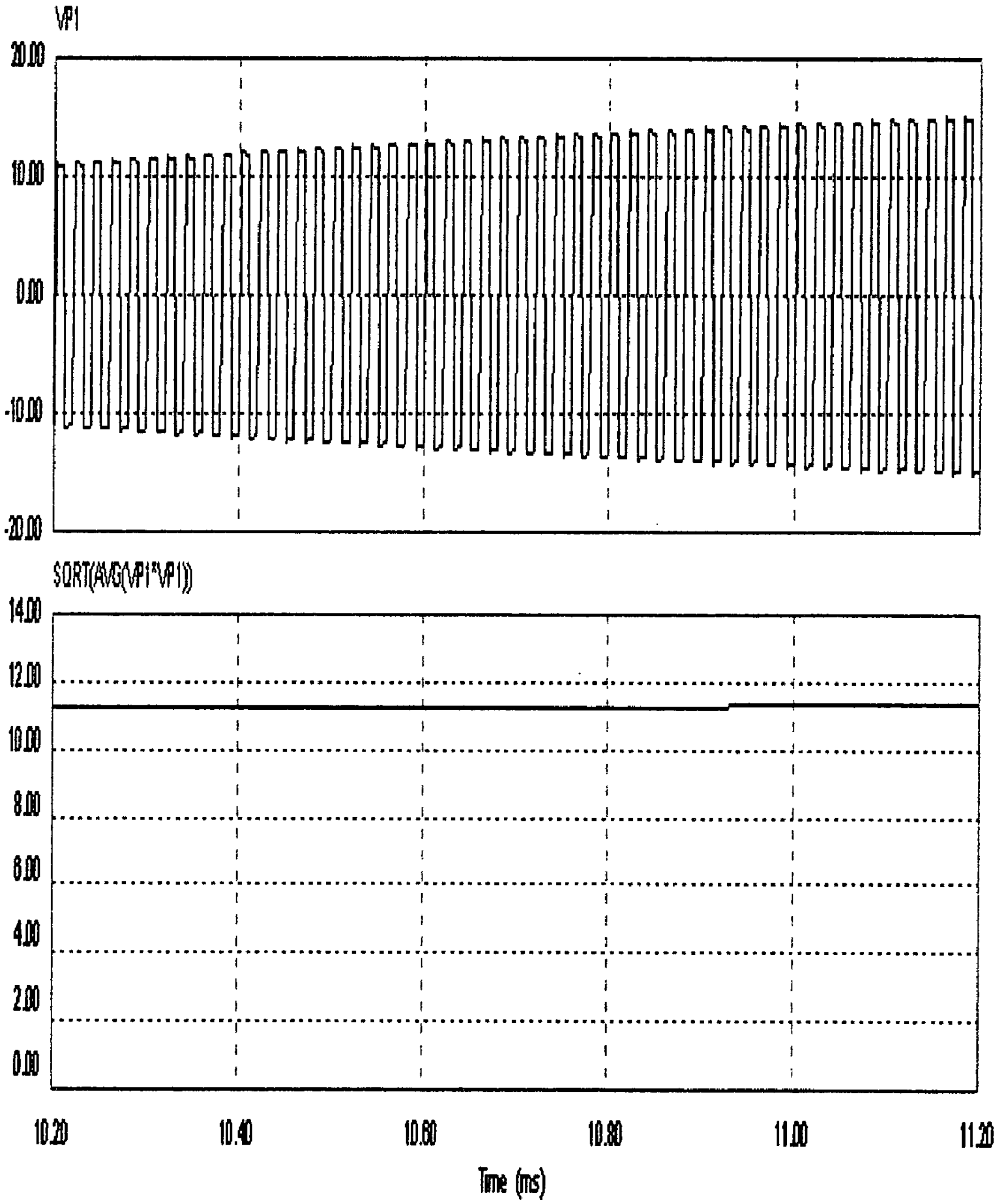
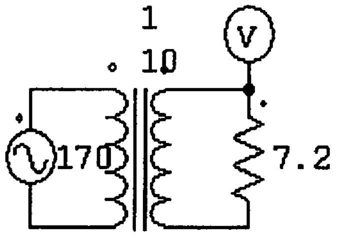
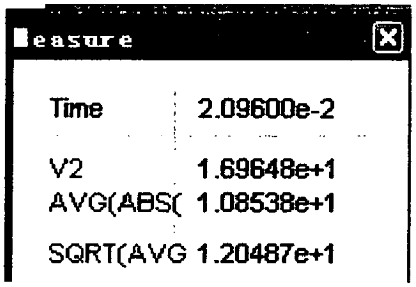

VP1
20.00
10.00
0.00
-10.00
-20.00
SQRT(AVG(VP1*VP1))
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
10.20
10.40
10.60
10.80
11.00
11.20
Time (ms)

Figure 4





Time 2.09600e-2

V2 1.69648e+1
AVG(ABS(1.08538e+1

SQRT(AVG 1.20487e+1

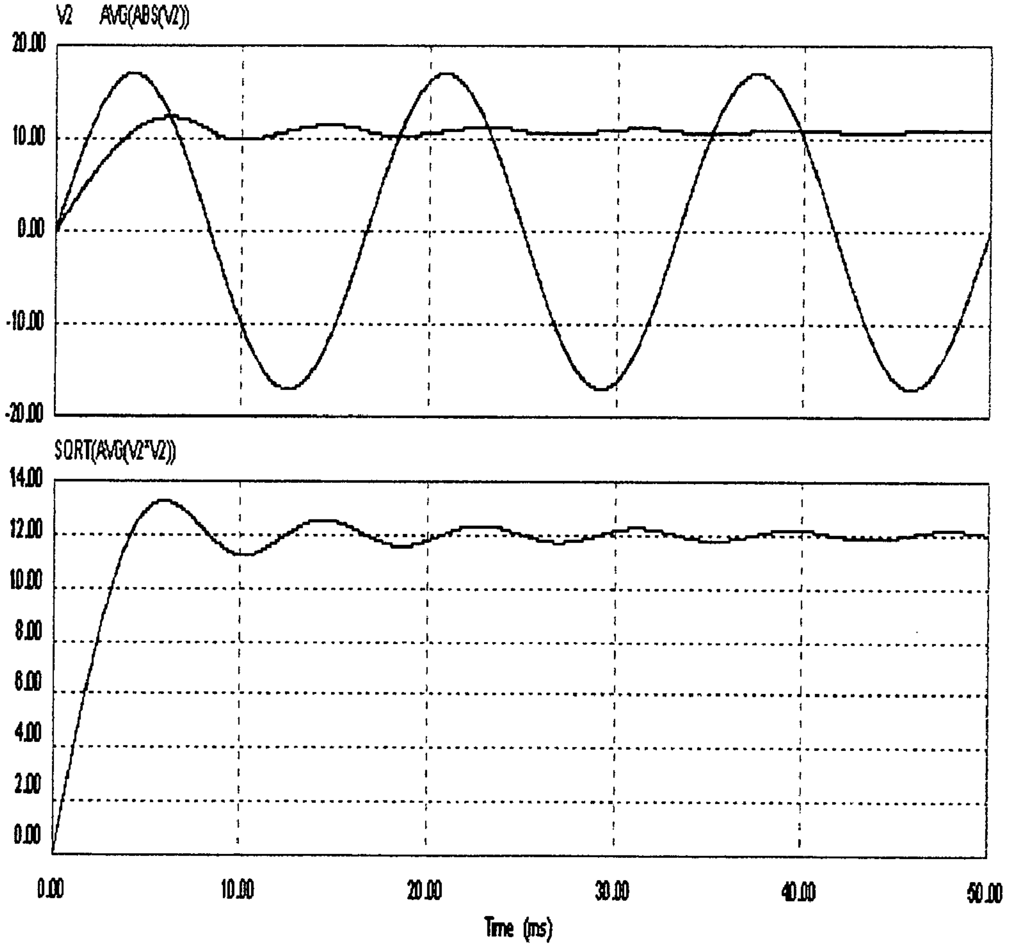


Figure 5

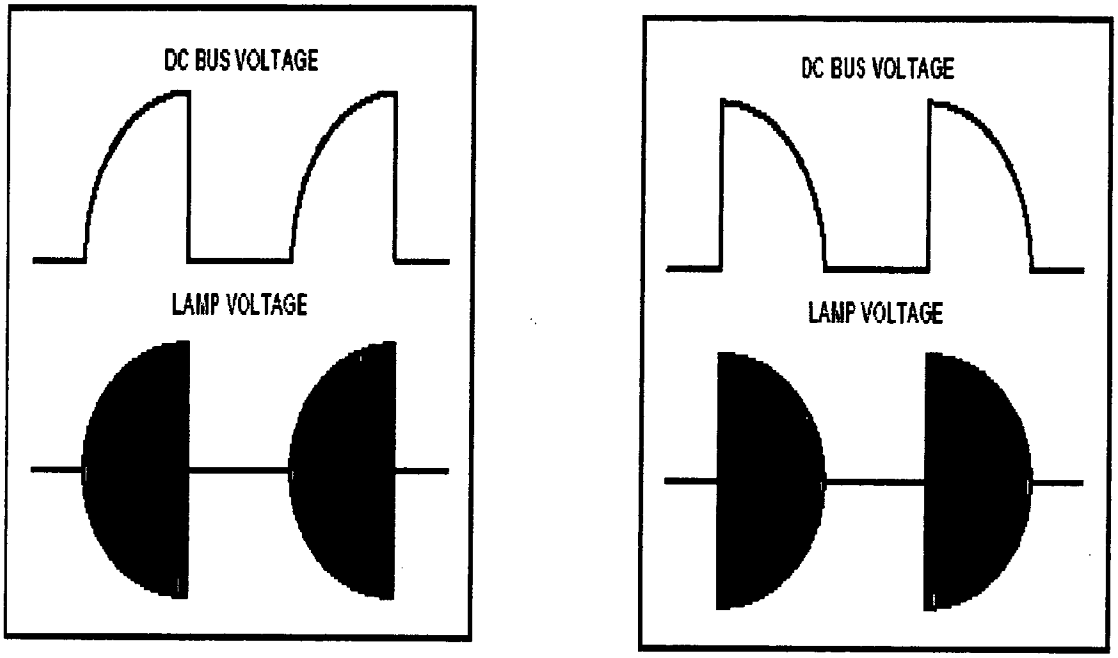


Figure 6

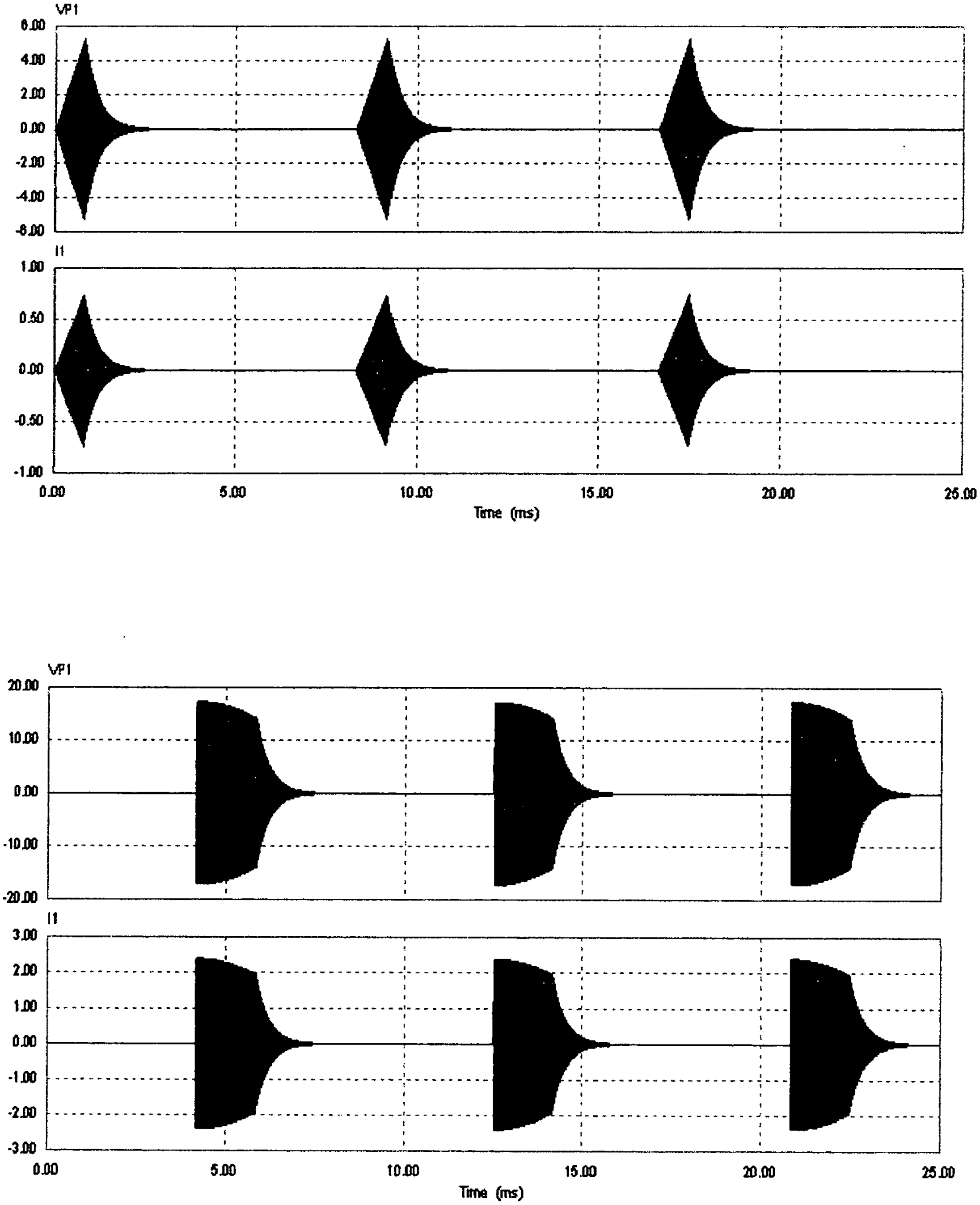

VP1
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
I1
1.00
0.50
0.00
-0.50
-1.00
0.00
5.00
10.00
15.00
20.00
25.00
Time (ms)
VP1
20.00
10.00
0.00
-10.00
-20.00
I1
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
0.00
5.00
10.00
15.00
20.00
25.00
Time (ms)

Figure 7

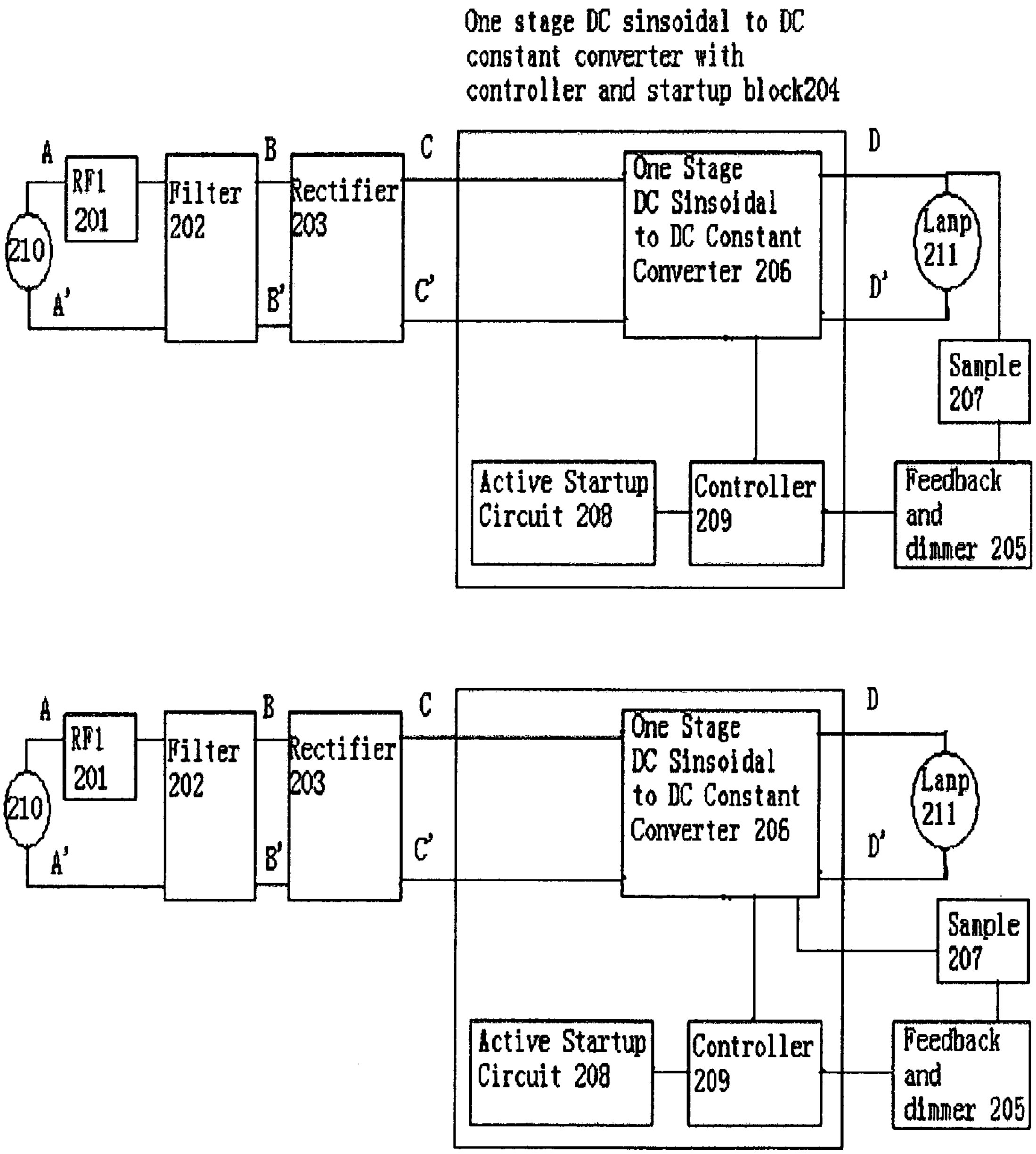

One stage DC sinsoidal to DC constant converter with controller and startup block204
A
A'
B
B'
C
C'
D
D'
210
RF1 201
Filter 202
Rectifier 203
One Stage DC Sinsoidal to DC Constant Converter 206
Lamp 211
Sample 207
Active Startup Circuit 208
Controller 209
Feedback and dimmer 205
A
A'
B
B'
C
C'
D
D'
210
RF1 201
Filter 202
Rectifier 203
One Stage DC Sinsoidal to DC Constant Converter 206
Lamp 211
Sample 207
Active Startup Circuit 208
Controller 209
Feedback and dimmer 205

Figure 8

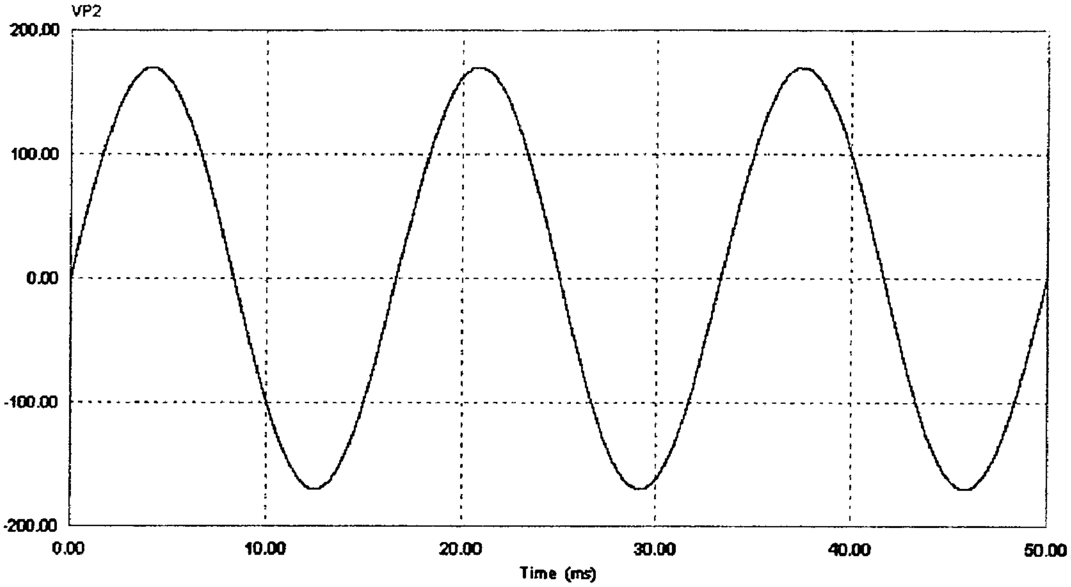


Figure 9

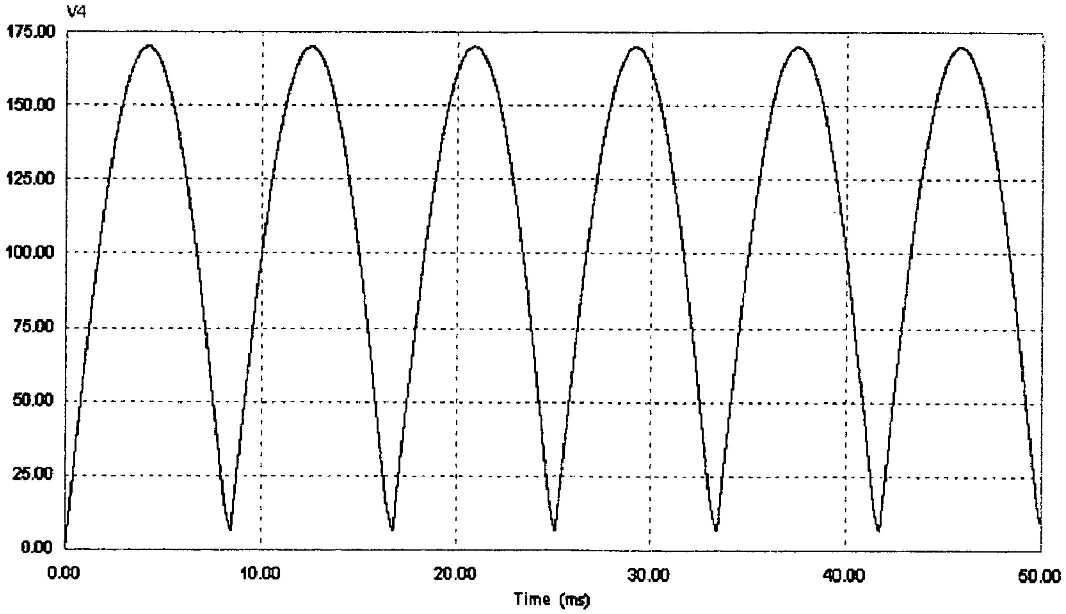


Figure 10

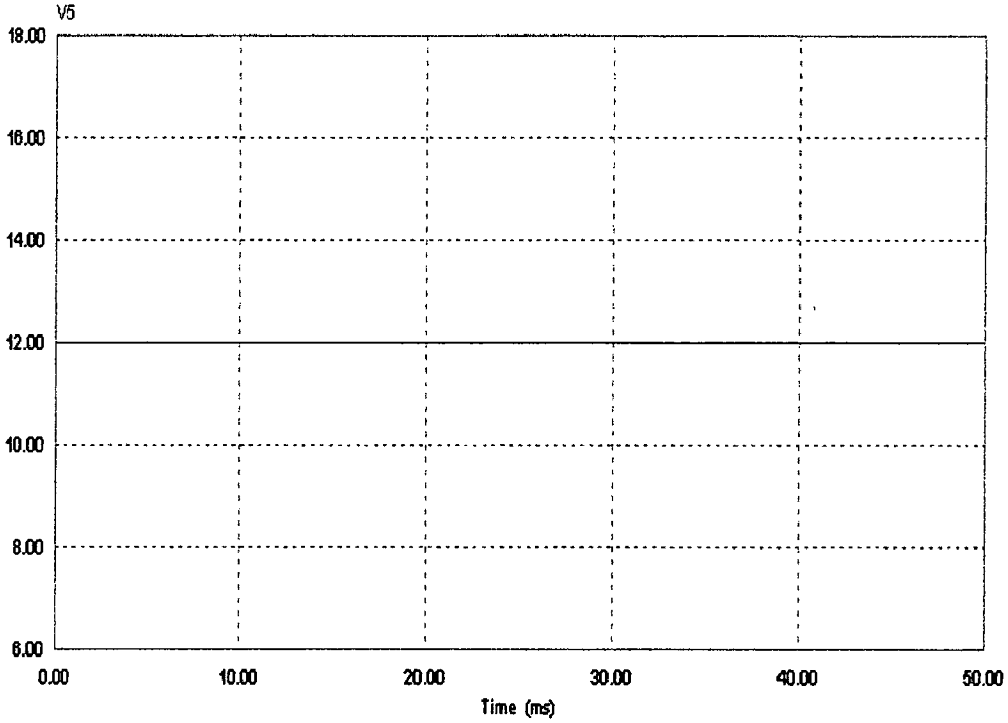


Figure 11

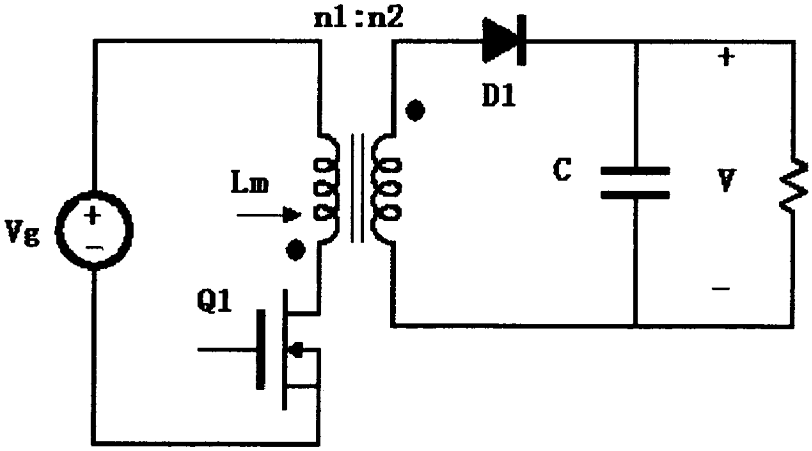


Figure 12

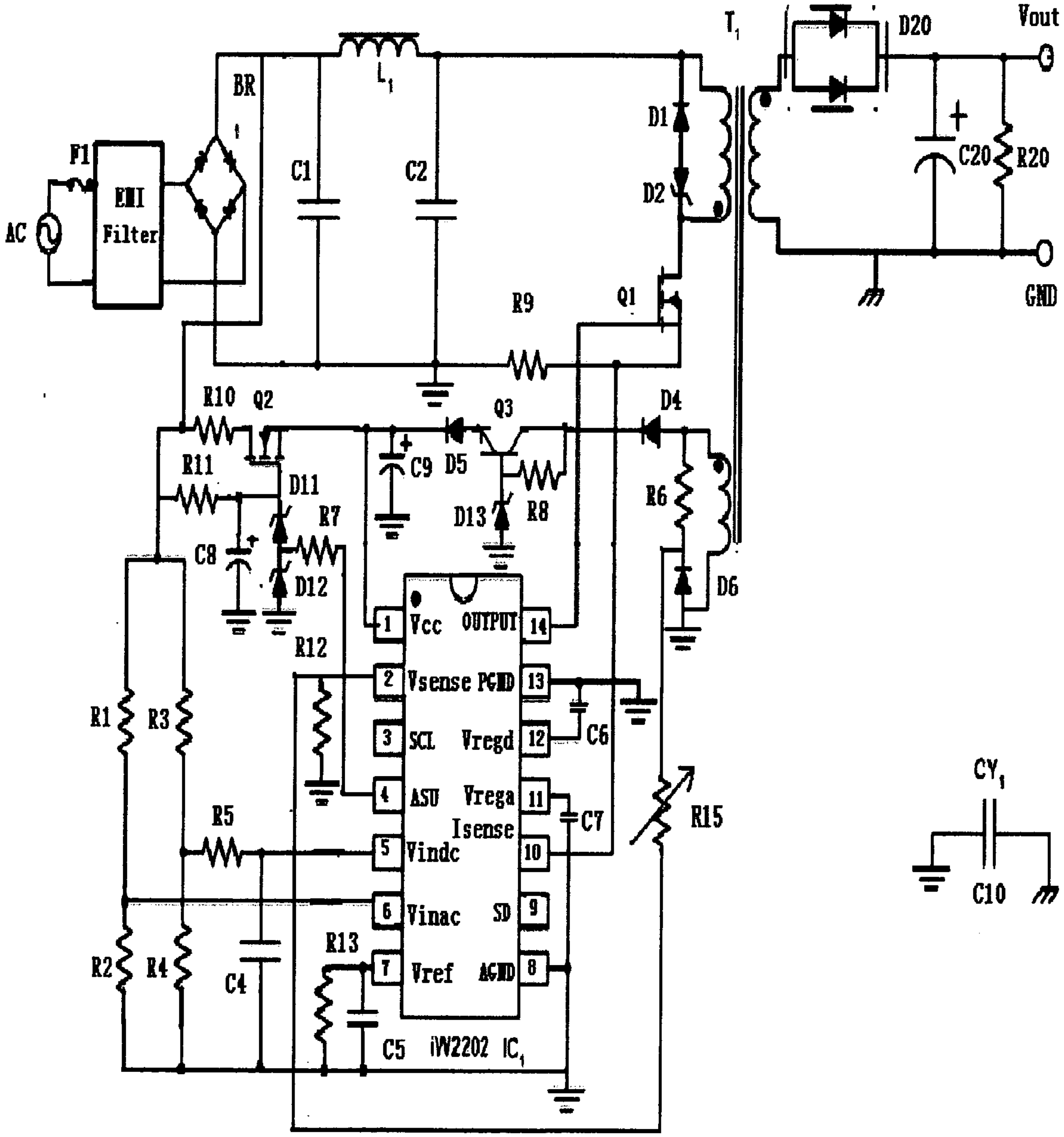

T1
D20
Vout
L1
BR
F1
EMI Filter
AC
C1
C2
D1
D2
C20
R20
GND
R9
Q1
R10
Q2
Q3
D4
R11
C9
D5
D11
R7
D13
R8
R6
C8
D12
D6
R12
1 Vcc
OUTPUT 14
2 Vsense
PGND 13
3 SCL
Vregd 12
C6
4 ASU
Vrega 11
C7
R1
R3
R5
Isense
5 Vindc
10
R15
CY1
6 Vinac
SD 9
C10
R13
R2
R4
C4
7 Vref
AGND 8
C5
iW2202 IC1

Figure 13

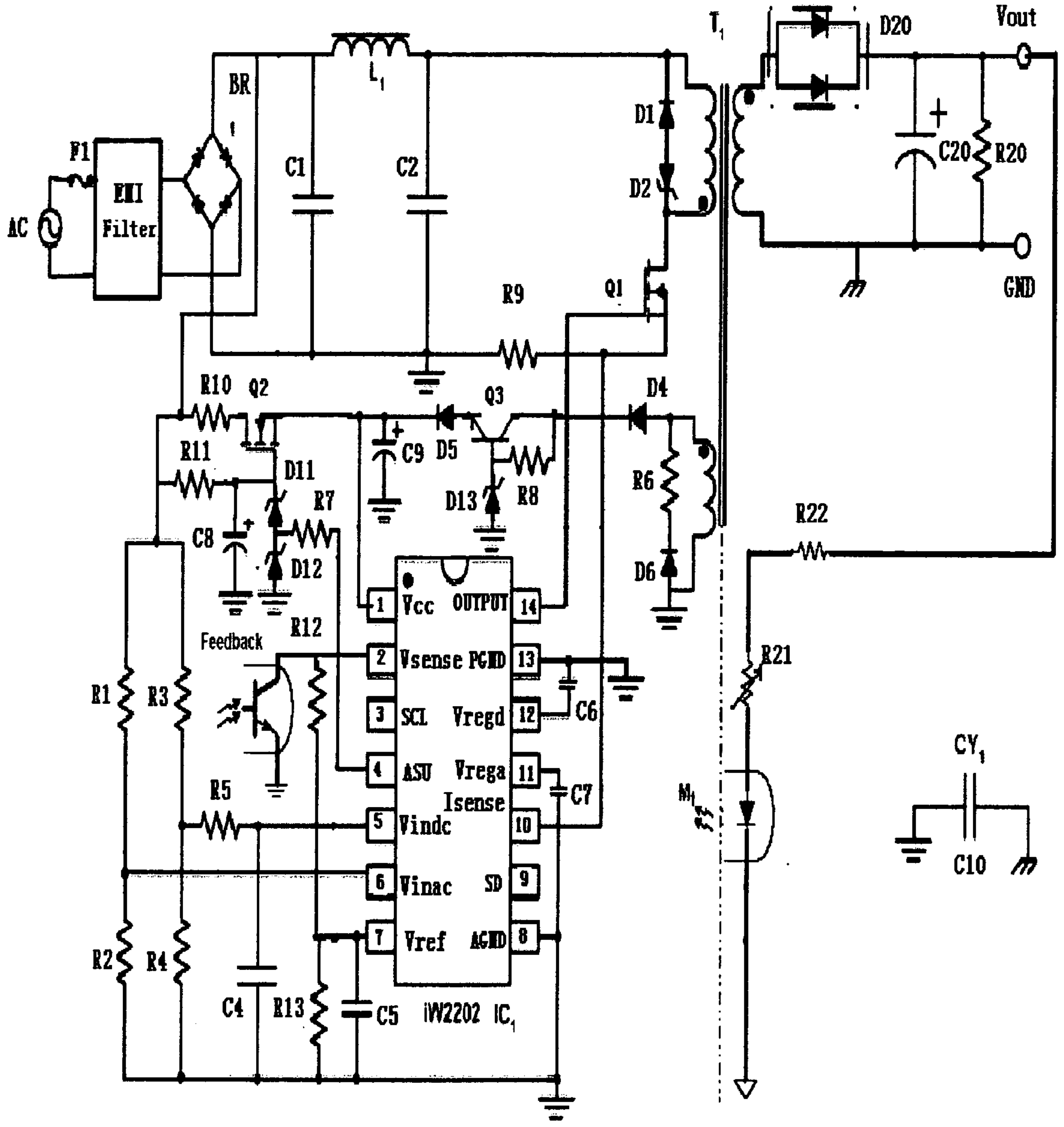

T1
D20
Vout
BR
L1
D1
D2
F1
EMI Filter
AC
C1
C2
C20
R20
GND
R9
Q1
R10
Q2
Q3
D4
R11
C9
D5
D11
R7
D13
R8
R6
C8
D12
R22
D6
Feedback
R12
1 Vcc
OUTPUT 14
2 Vsense
PGND 13
3 SCL
Vregd 12
4 ASU
Vrega 11
Isense
5 Vindc
10
6 Vinac
SD 9
7 Vref
AGND 8
R21
C6
C7
R1
R3
R5
M1
CY1
C10
R2
R4
C4
R13
C5
iW2202 IC1

Figure 14

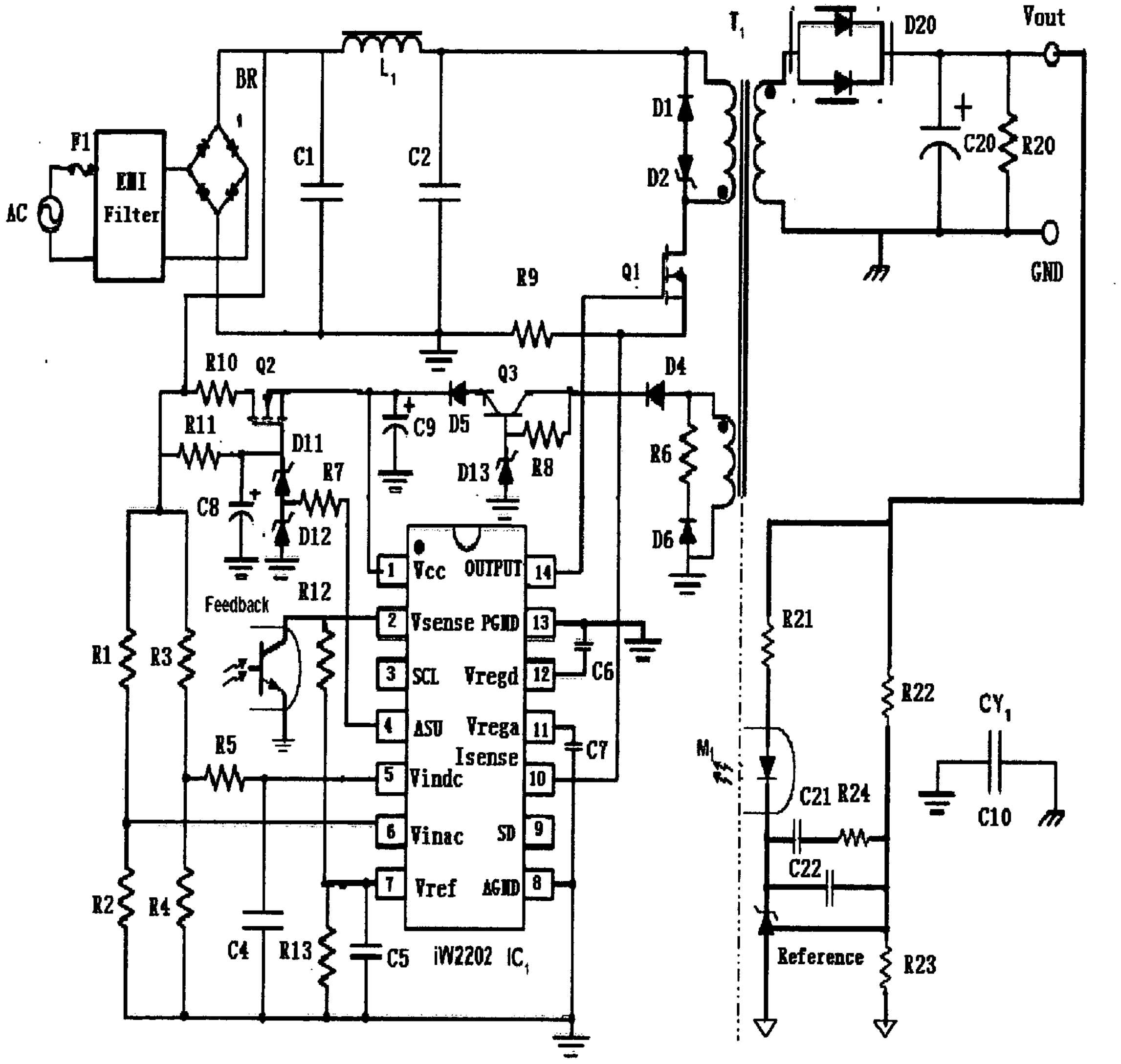

T1
D20
Vout
BR
F1
EMI
Filter
AC
C1
L1
C2
D1
D2
+
C20
R20
GND
R9
Q1
R10
Q2
Q3
D4
R11
C9
D5
D11
R8
R6
R7
D13
C8
D12
D6
1
Vcc
OUTPUT
14
Feedback
R12
2
Vsense
PGND
13
R1
R3
3
SCL
Vregd
12
C6
R21
R22
CY1
4
ASU
Vrega
11
C7
Isense
R5
5
Vindc
10
M1
C21
R24
C10
6
Vinac
SD
9
C22
7
Vref
AGND
8
R2
R4
C4
R13
C5
iW2202 IC1
Reference
R23

Figure 15

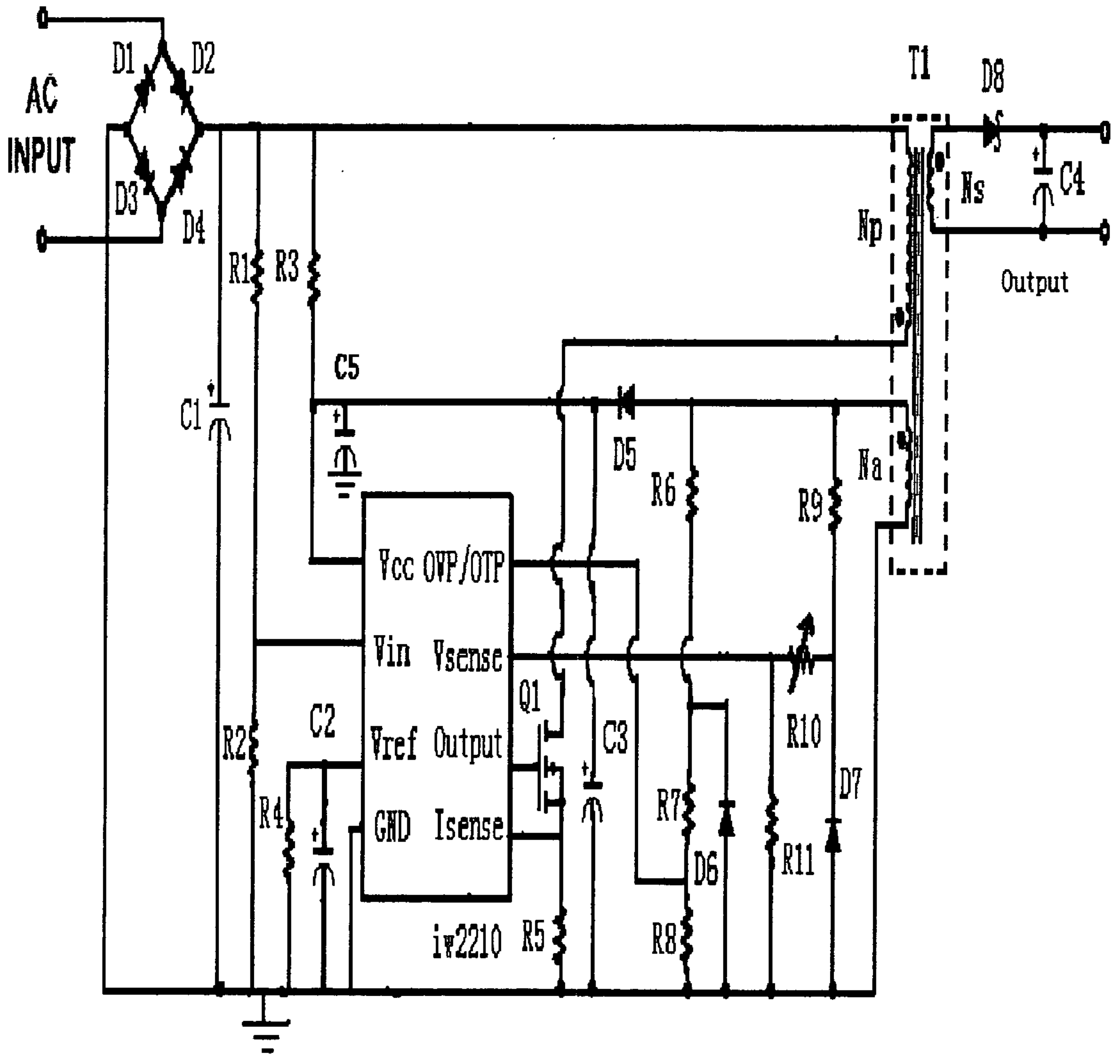

AC INPUT
D1
D2
D3
D4
R1
R3
R2
R4
C1
C2
C5
T1
D8
Ns
C4
Np
Output
Na
D5
R6
R9
Vcc
OVP/OTP
Vin
Vsense
Vref
Output
GND
Isense
Q1
C3
R10
D7
R7
D6
R11
R8
R5
iw2210

Figure 16

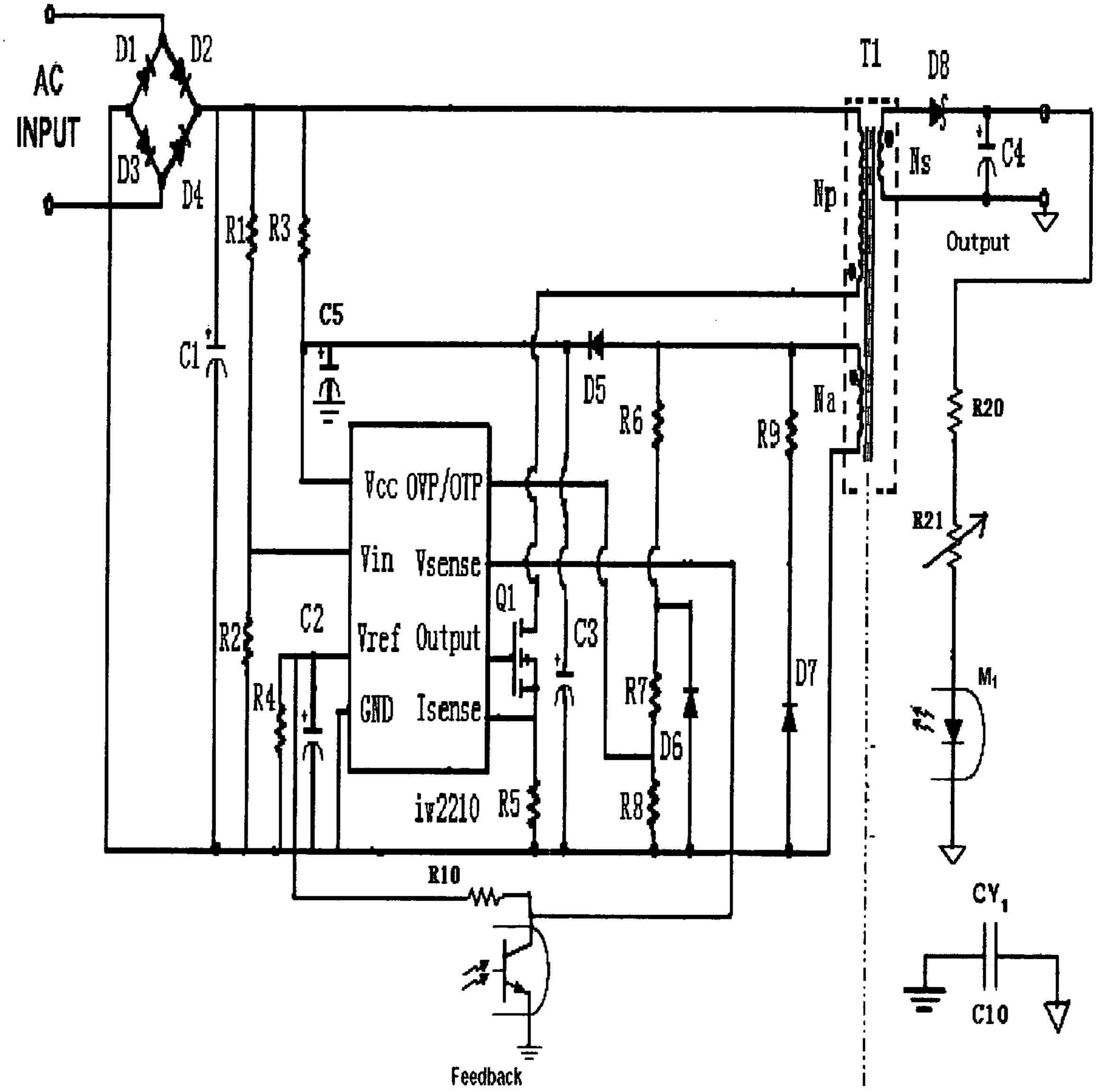

AC
INPUT
D1
D2
D3
D4
R1
R3
C1
C5
D5
R6
R9
Na
Np
T1
D8
Ns
C4
Output
R20
R21
M1
Vcc OVP/OTP
Vin Vsense
Vref Output
GND Isense
Q1
C2
C3
R2
R4
R7
D6
D7
R5
R8
iw2210
R10
Feedback
CY1
C10

Figure 17

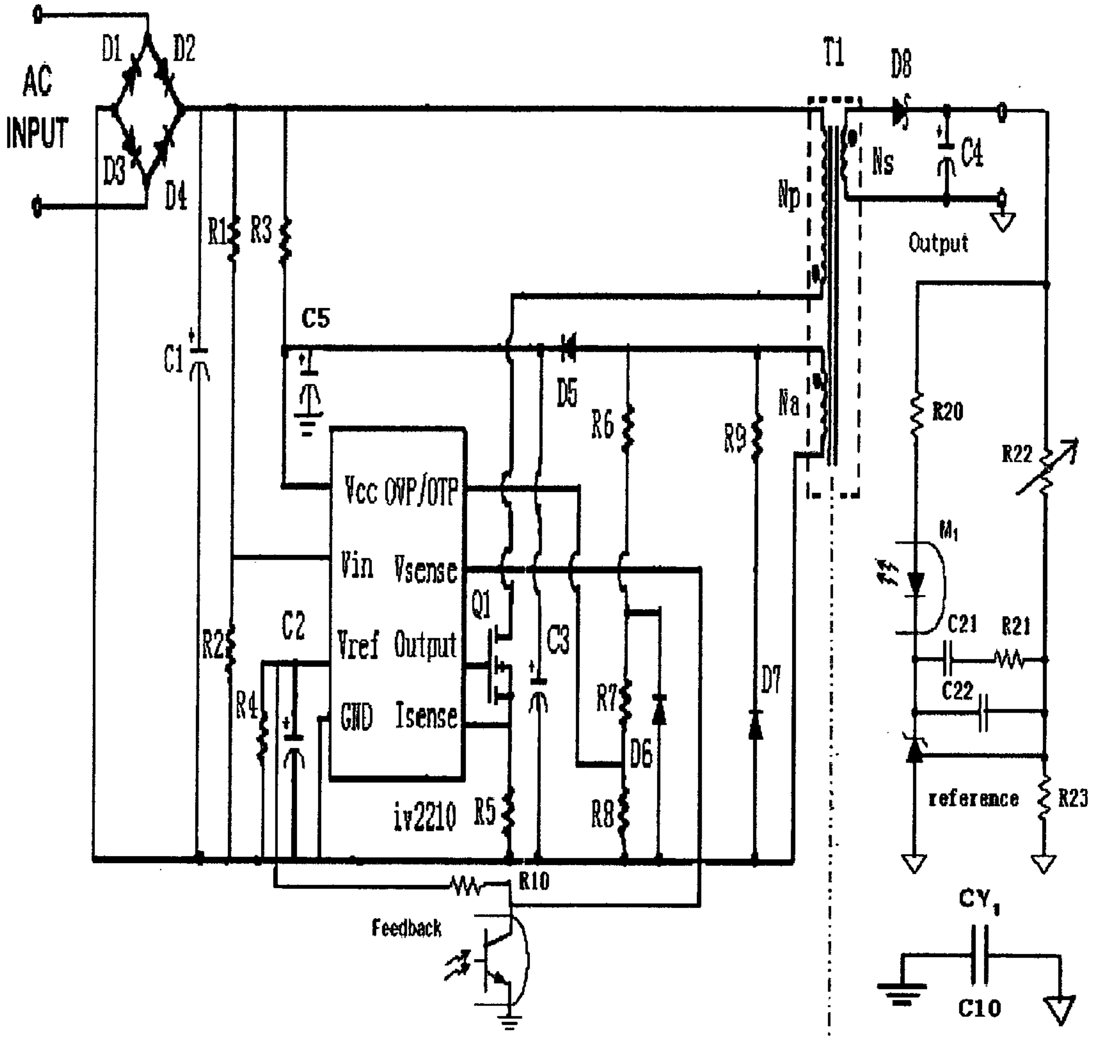

AC
INPUT
D1
D2
D3
D4
R1
R3
C1
C5
R2
C2
R4
Vcc
OVP/OTP
Vin
Vsense
Vref
Output
GND
Isense
iv2210
Q1
C3
D5
R5
R6
R7
D6
R8
R9
D7
R10
Feedback
T1
Np
Na
Ns
D8
C4
Output
R20
R22
M1
C21
R21
C22
reference
R23
CY1
C10

Figure 18

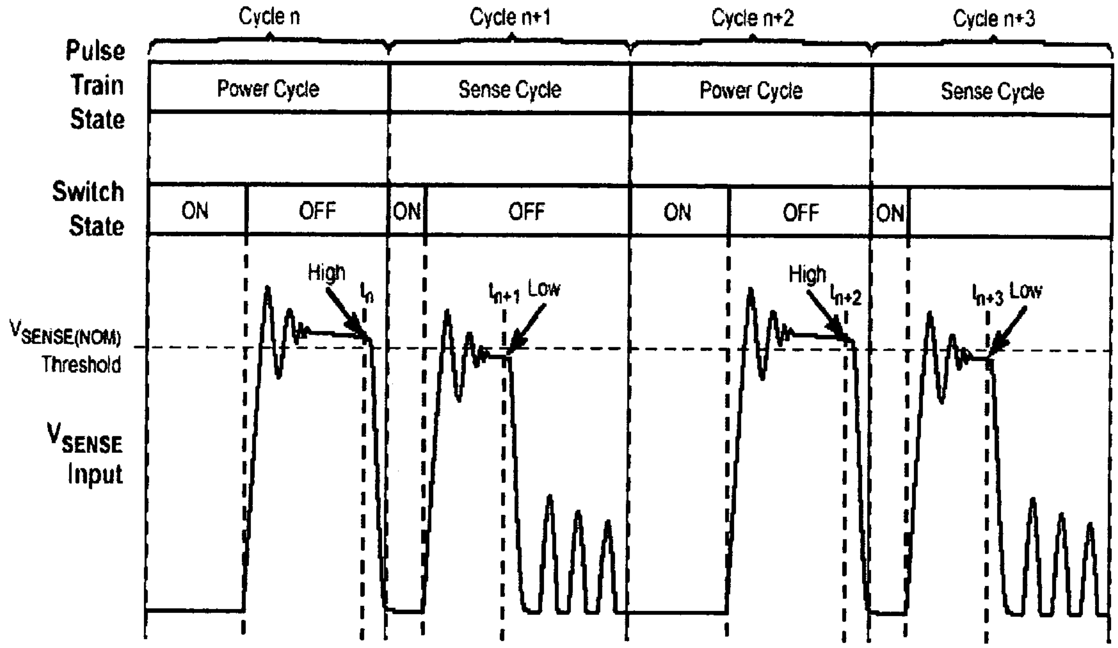


Figure 19

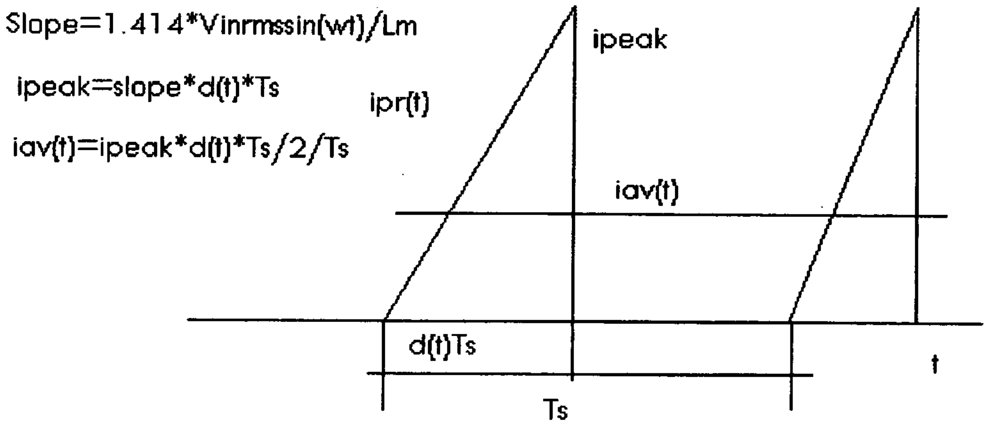


Figure 20

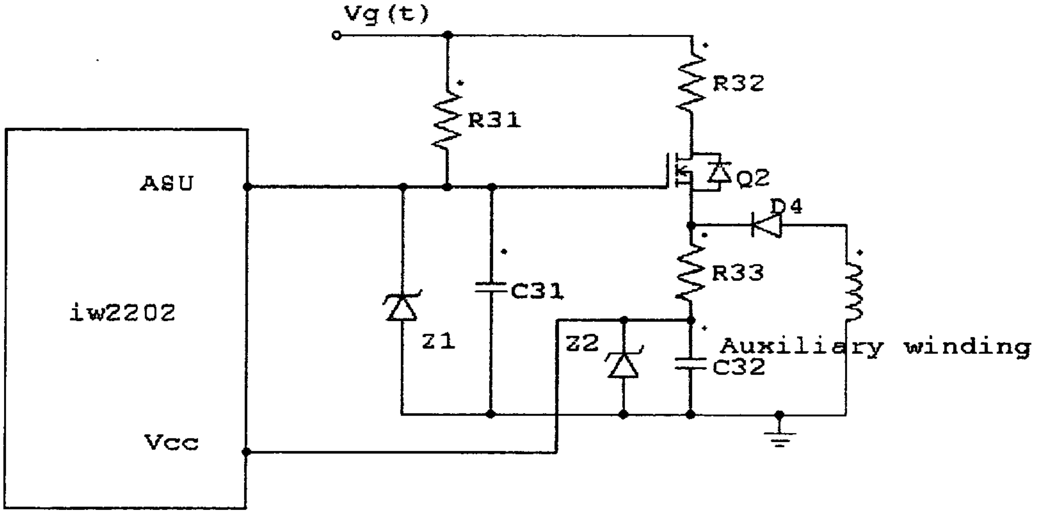


Figure 21

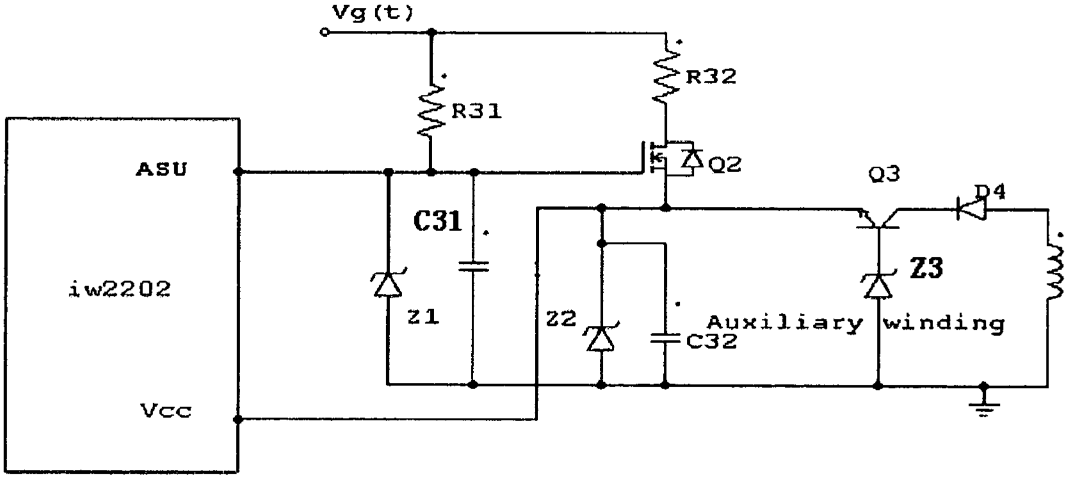


Figure 22

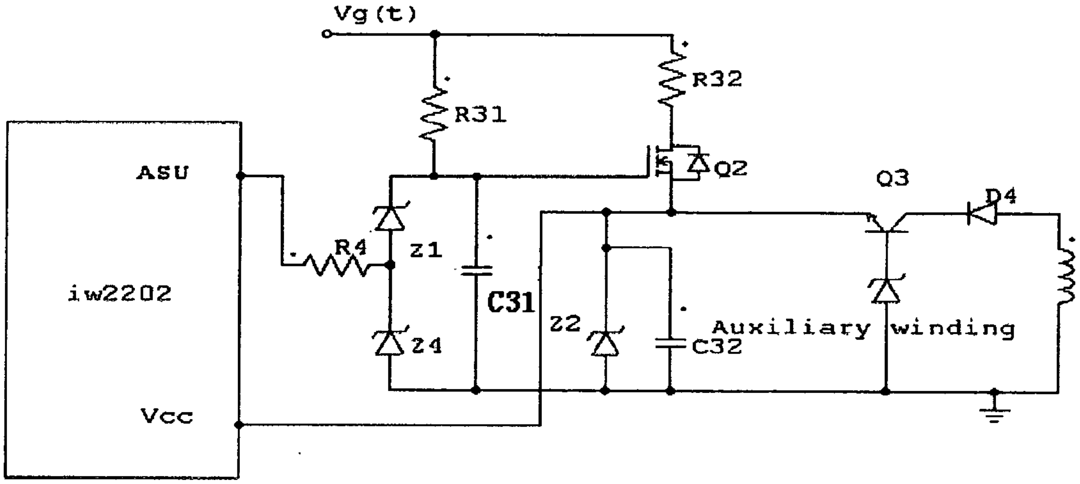


Figure 23

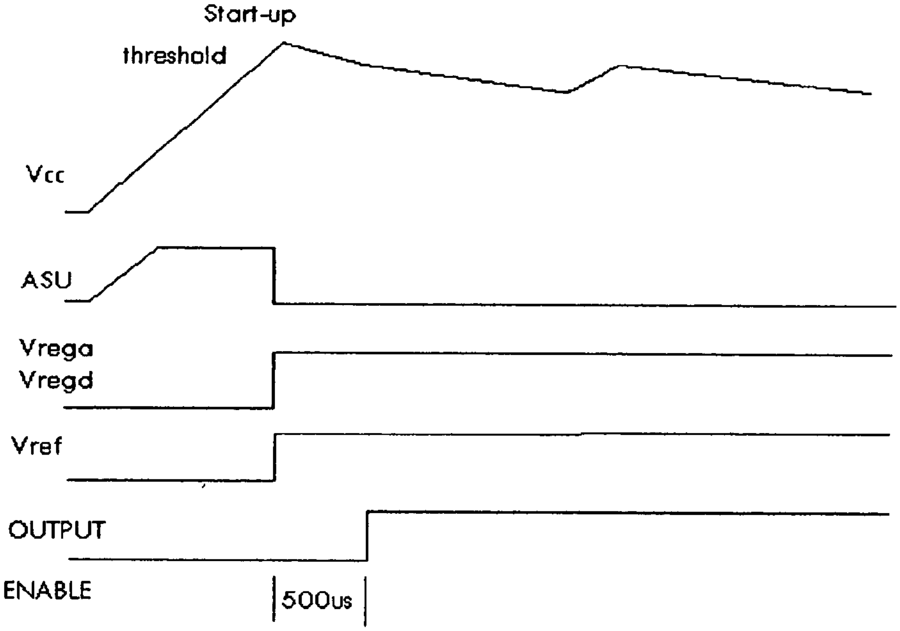


Figure 24

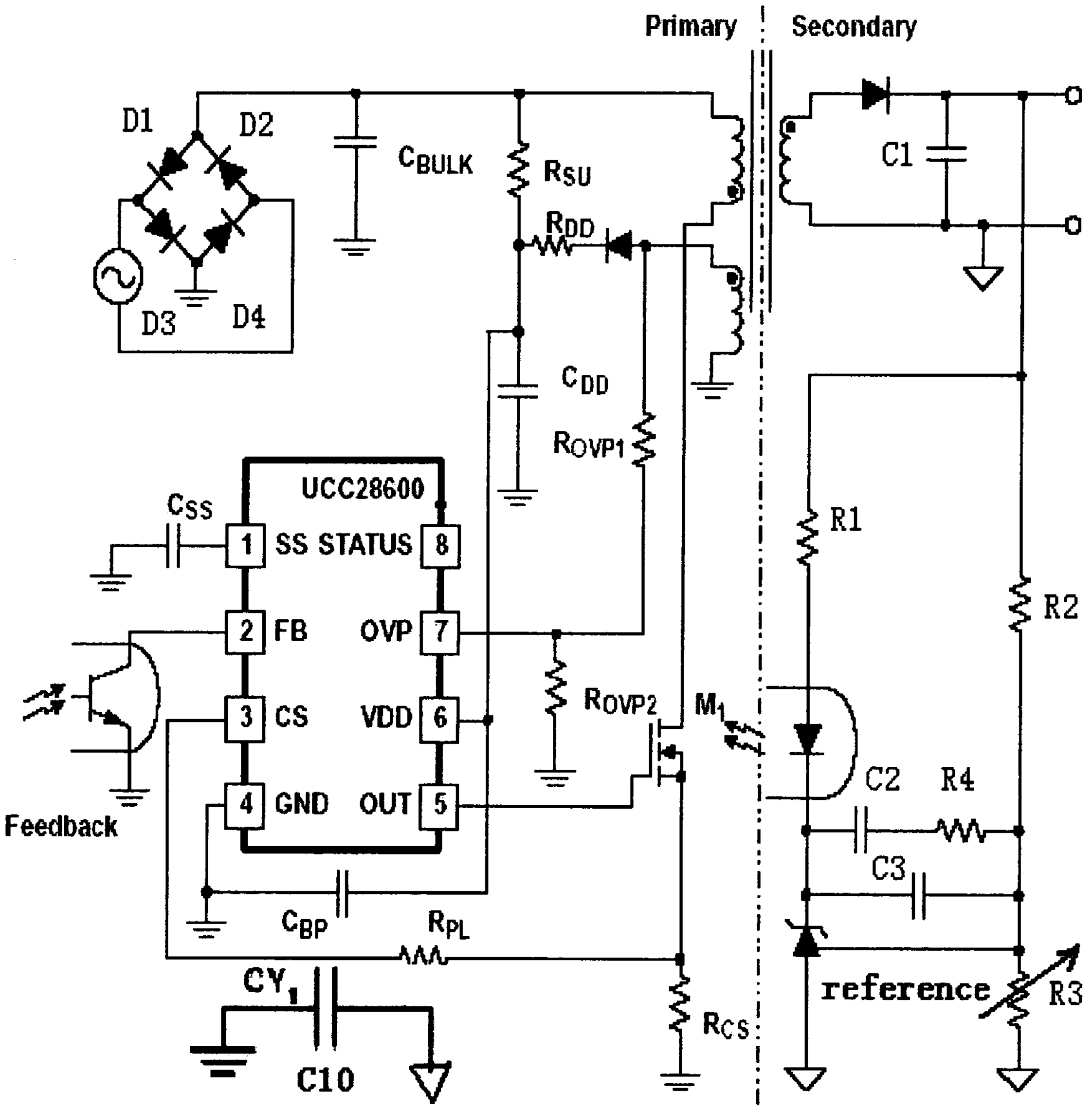

Primary
Secondary
D1
D2
D3
D4
CBULK
RSU
RDD
CDD
ROVP1
ROVP2
C1
UCC28600
Css
1 SS
STATUS 8
2 FB
OVP 7
3 CS
VDD 6
4 GND
OUT 5
Feedback
M1
R1
R2
C2
R4
C3
reference
R3
CBP
RPL
CY1
C10
RCS

Figure 25

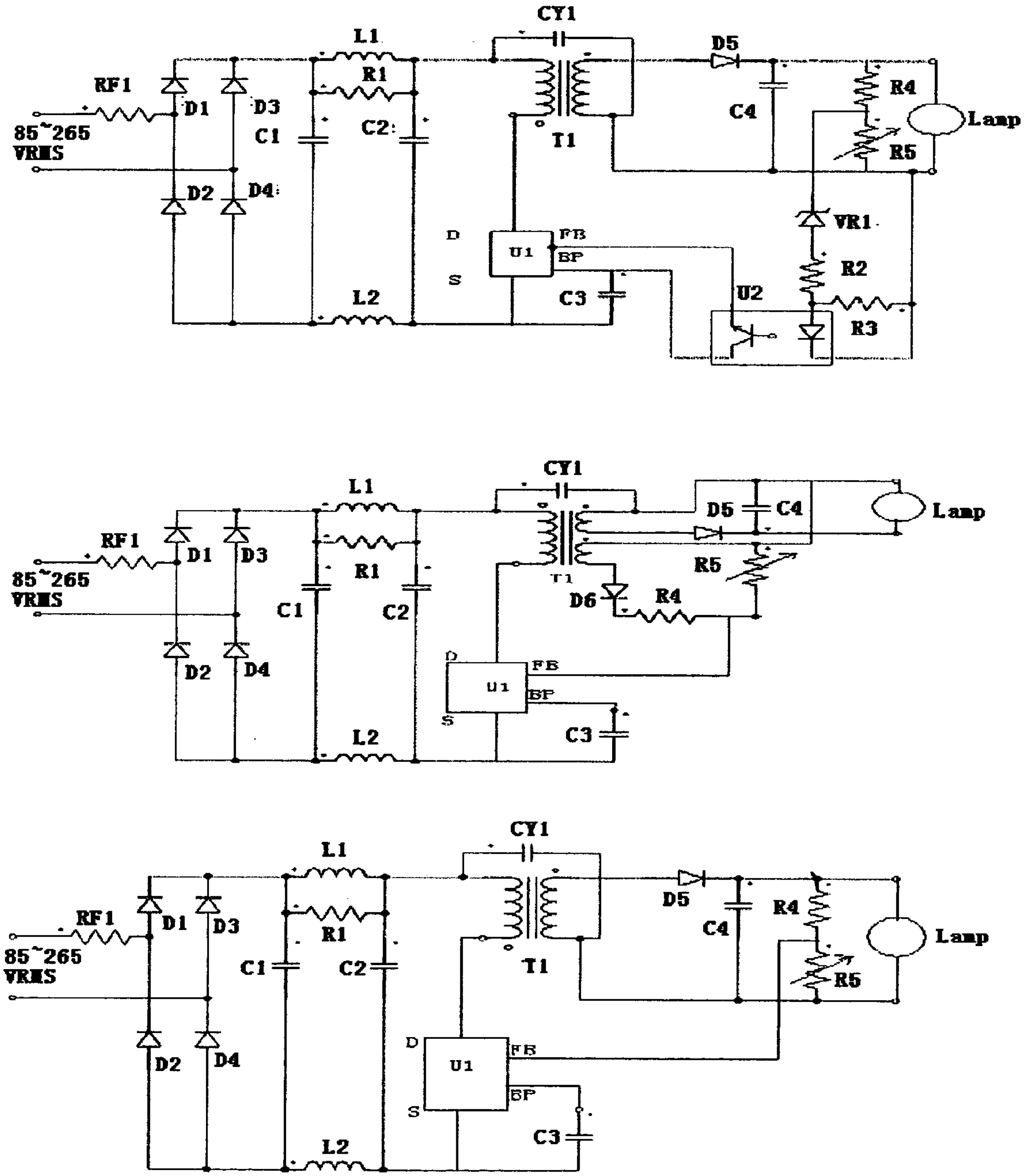

CY1
L1
D5
RF1
R1
R4
D1
D3
Lamp
85~265
VRMS
C1
C2
C4
T1
R5
D2
D4
VR1
D
FB
U1
BP
R2
S
C3
U2
L2
R3
CY1
L1
D5
C4
Lamp
RF1
D1
D3
R5
85~265
VRMS
R1
T1
D6
R4
C1
C2
D2
D4
D
FB
U1
BP
S
C3
L2
CY1
L1
D5
RF1
D1
D3
C4
R4
Lamp
85~265
VRMS
R1
C1
C2
T1
R5
D2
D4
D
FB
U1
BP
S
C3
L2

Figure 26

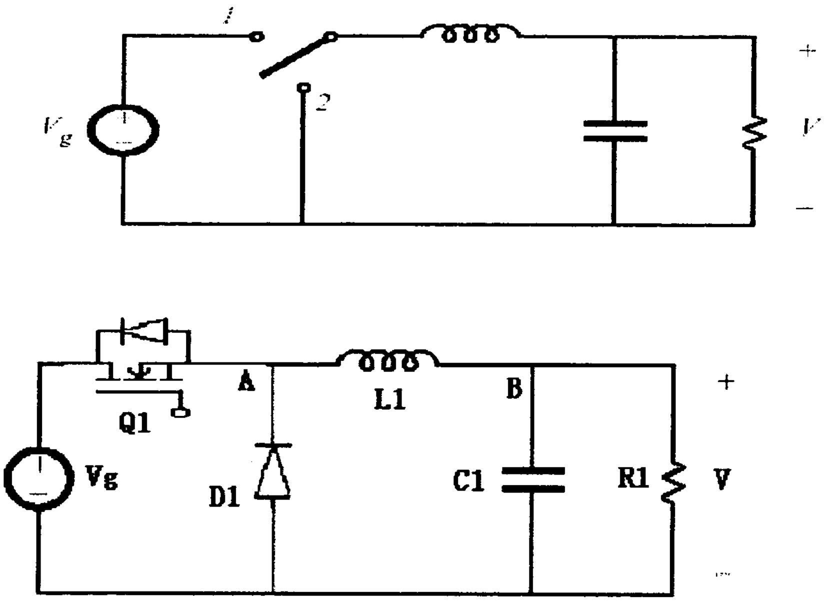


Figure 27

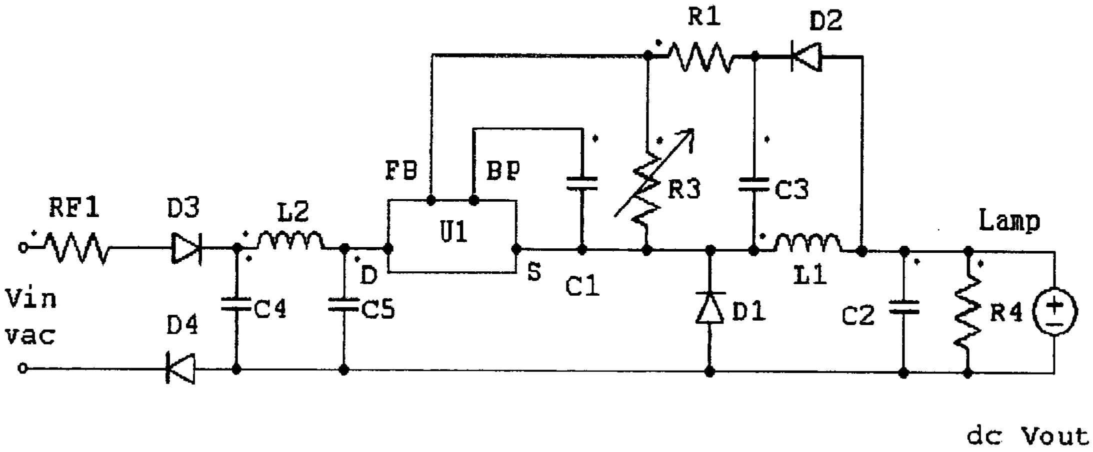


Figure 28

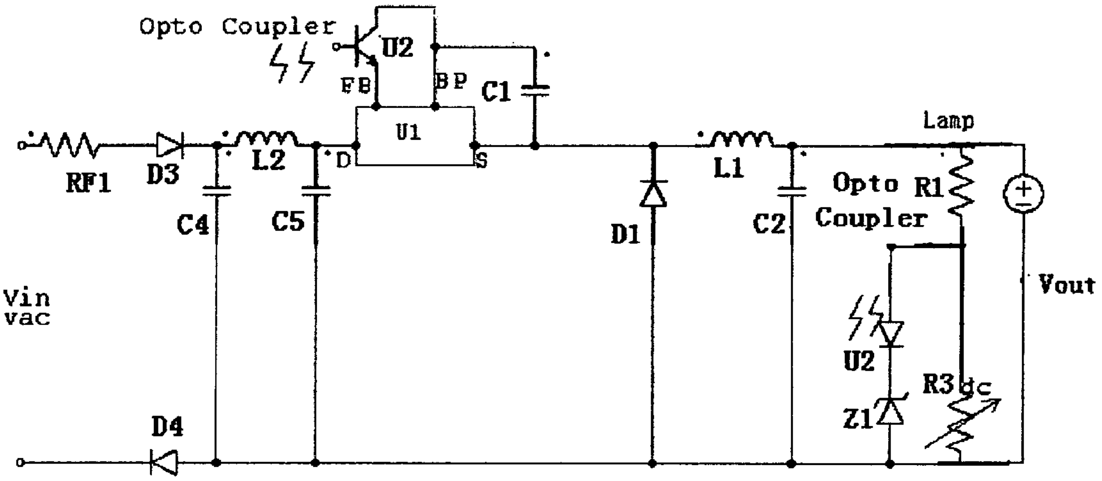


Figure 29

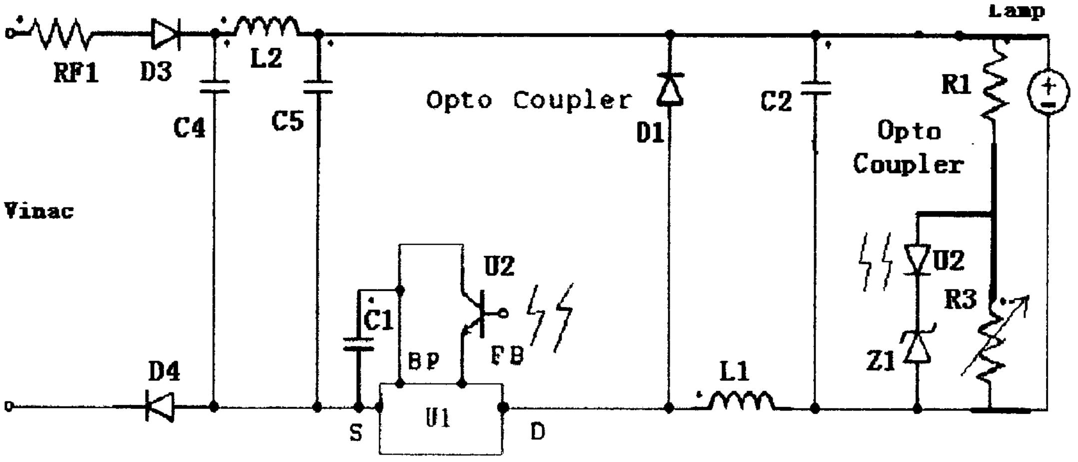


Figure 30

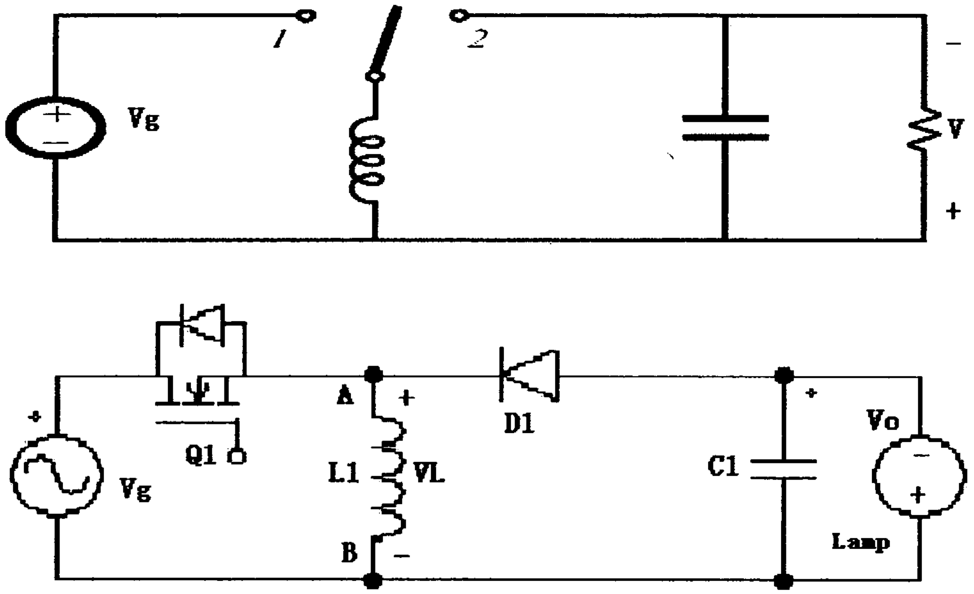


Figure 31

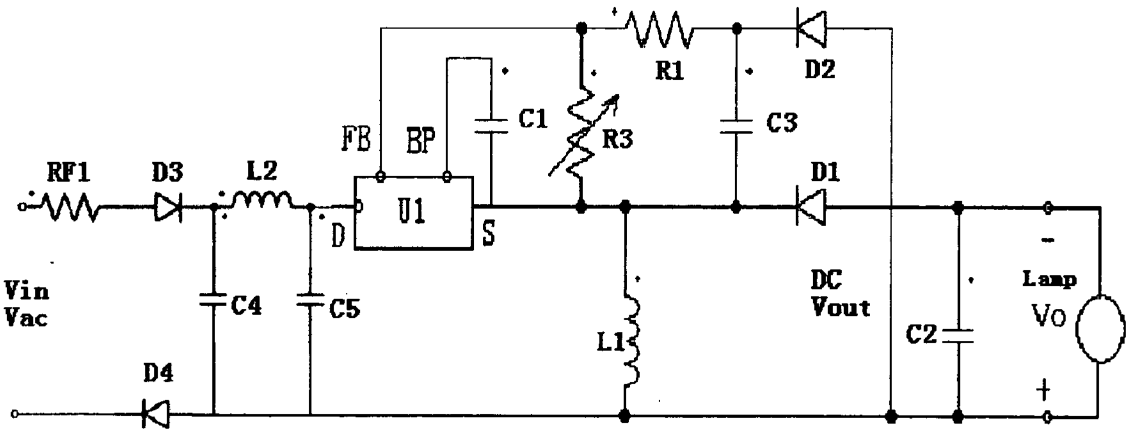


Figure 32

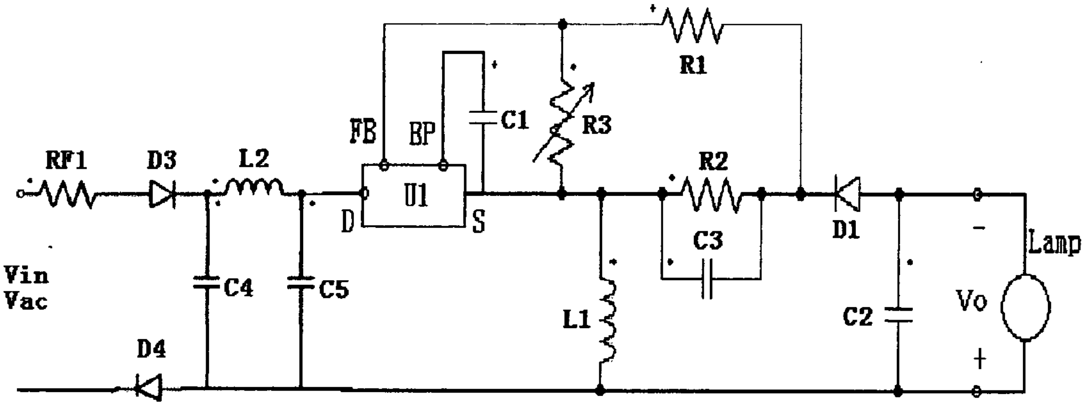


Figure 33

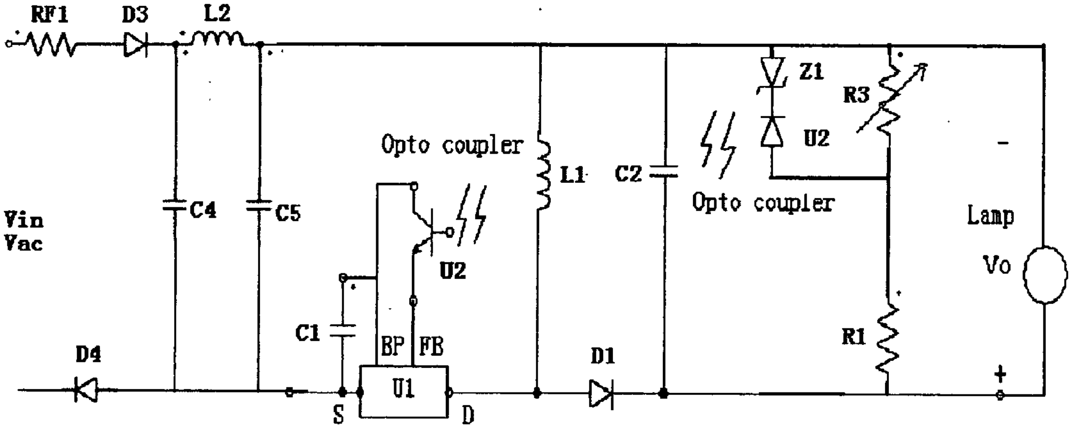


Figure 34

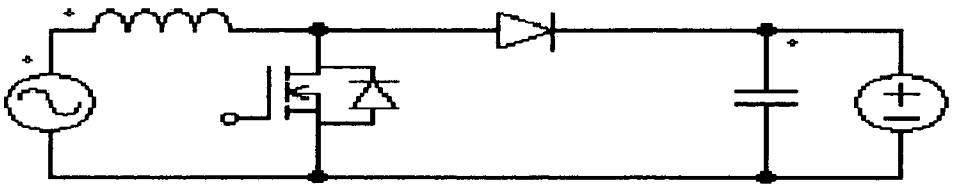


Figure 35

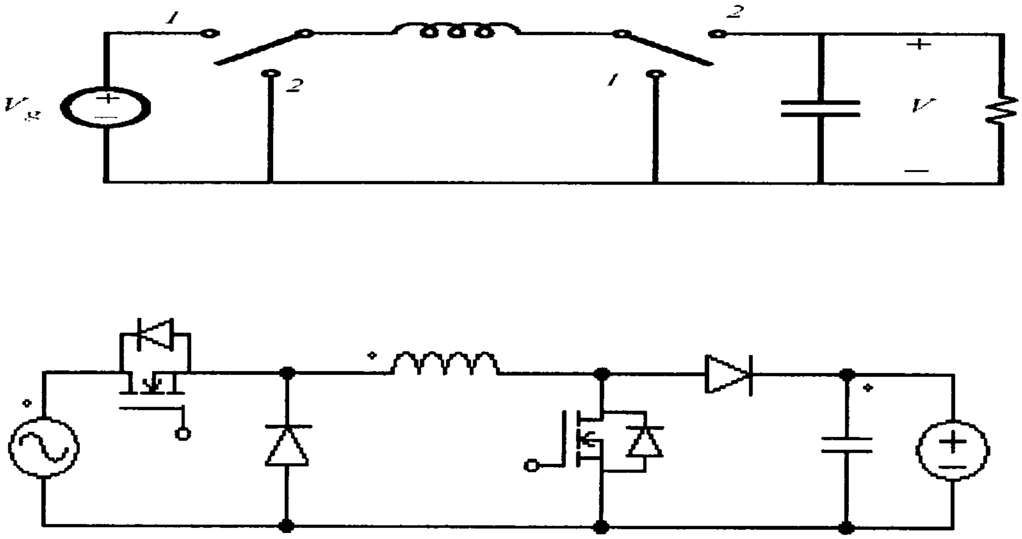


Figure 36

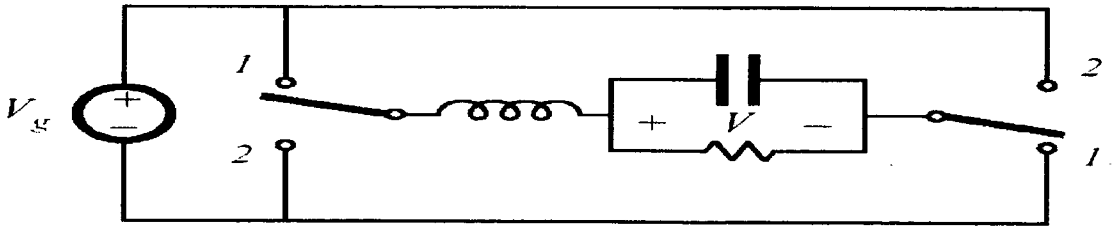


Figure 37

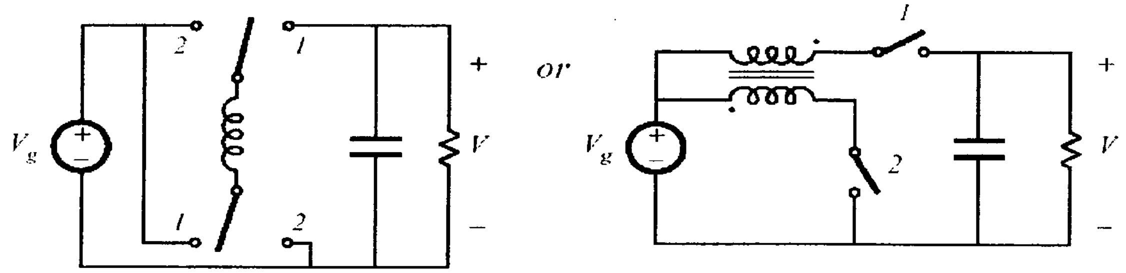


Figure 38

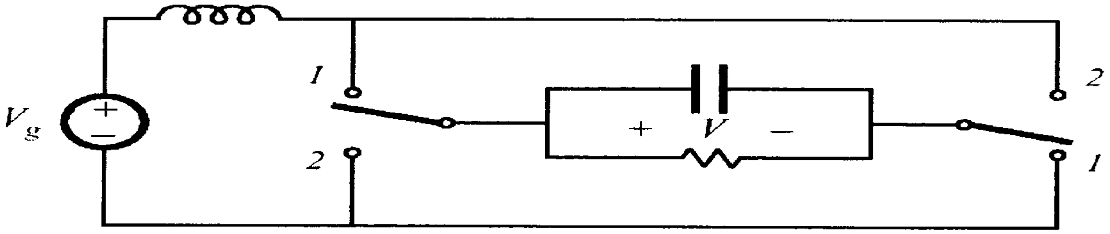


Figure 39

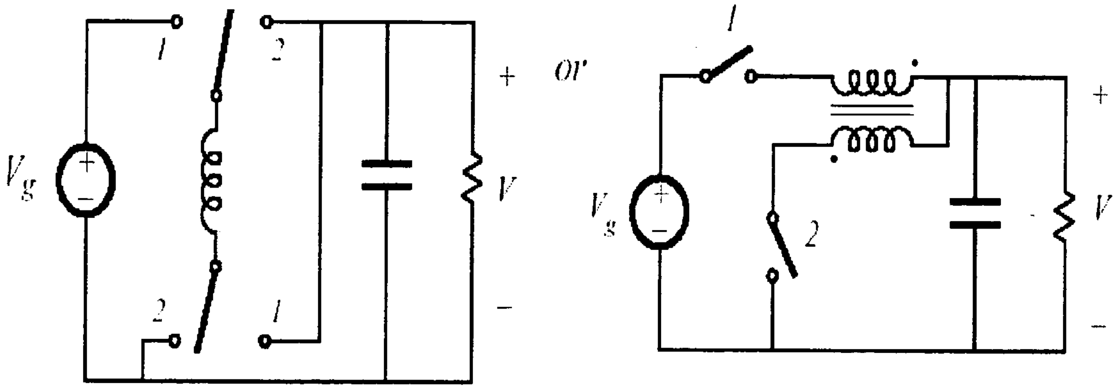


Figure 40

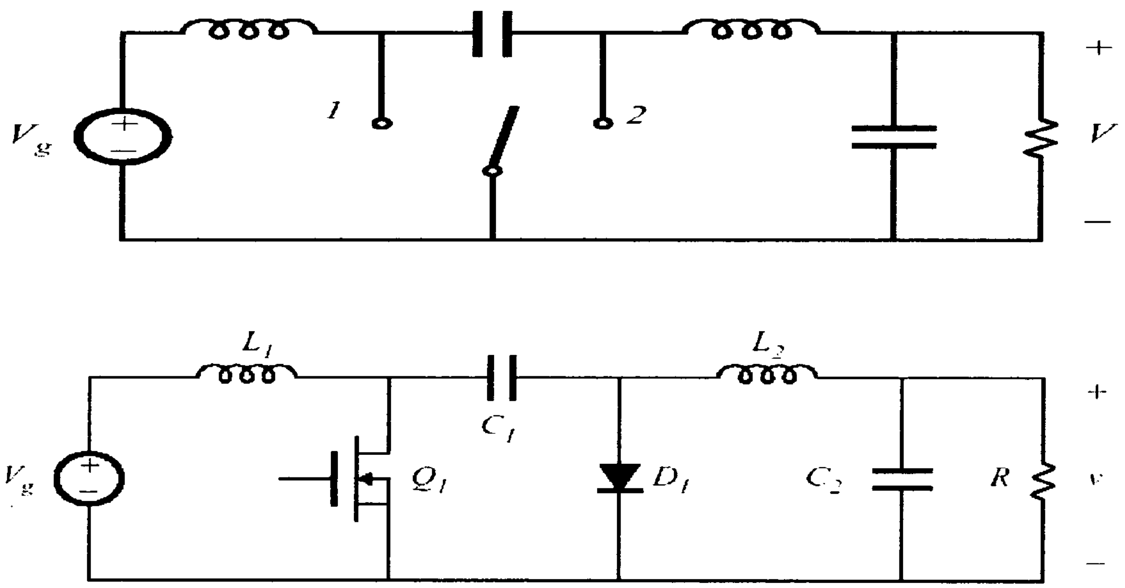


Figure 41

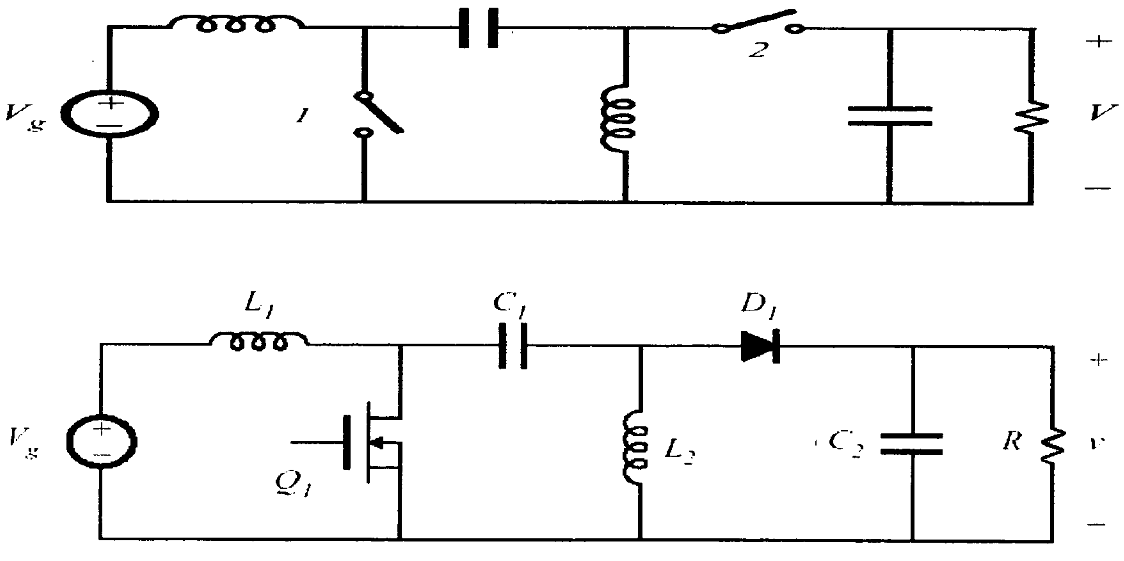


Figure 42

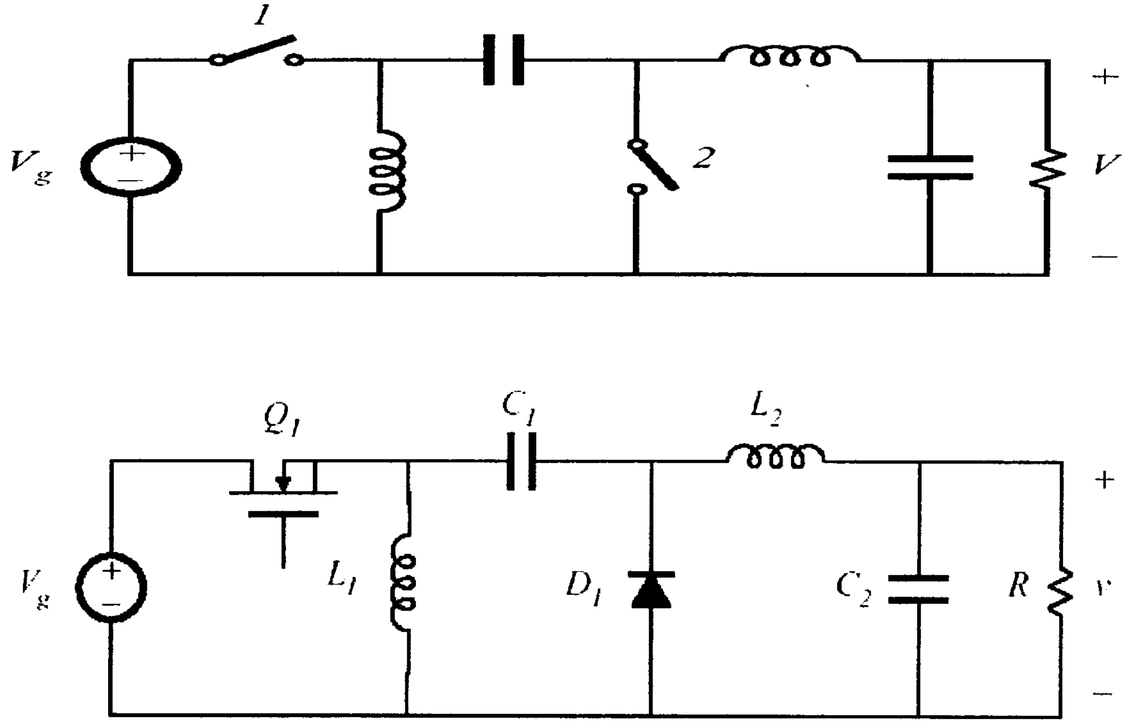


Figure 43

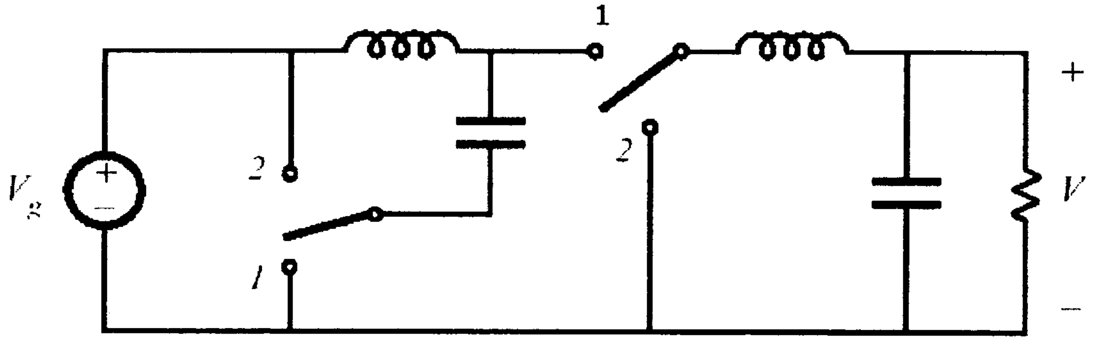


Figure 44

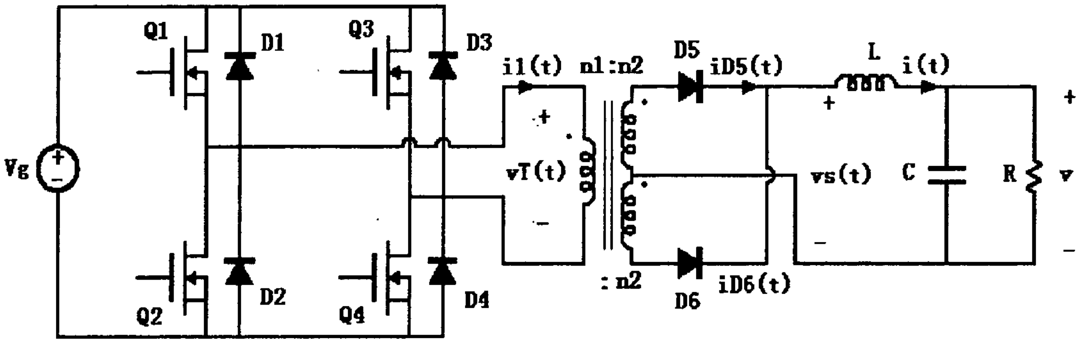


Figure 45

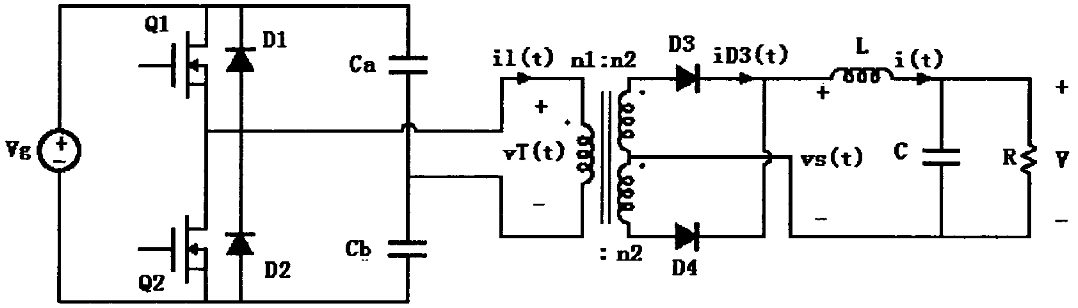


Figure 46

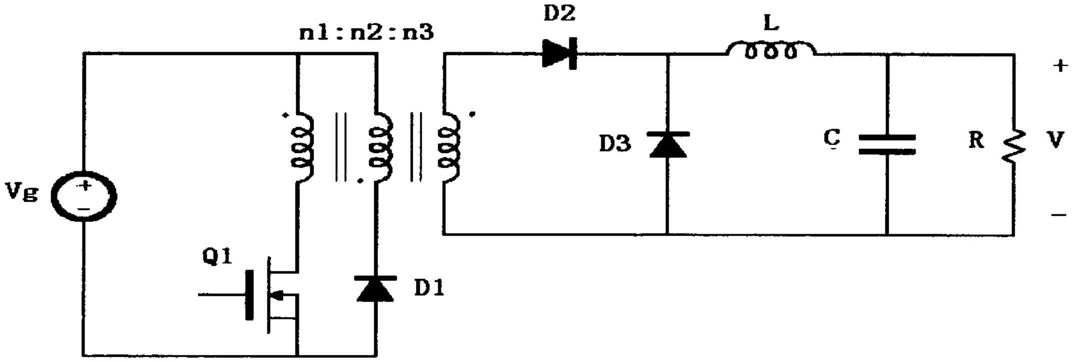


Figure 47

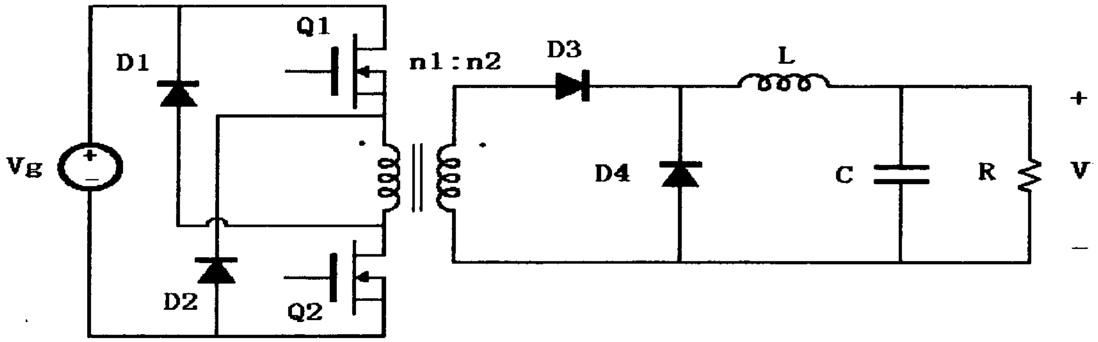


Figure 48

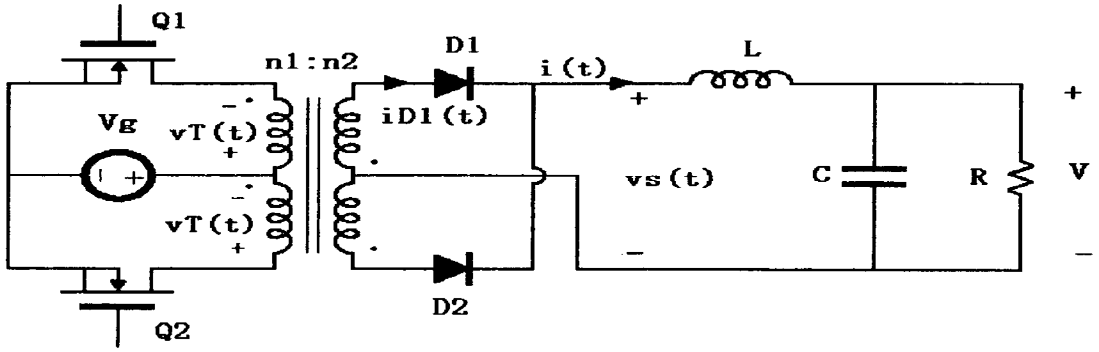


Figure 49

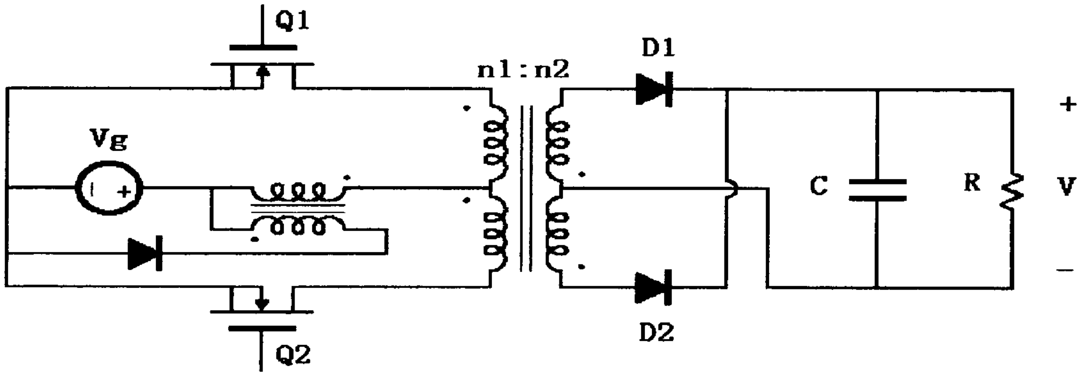


Figure 50

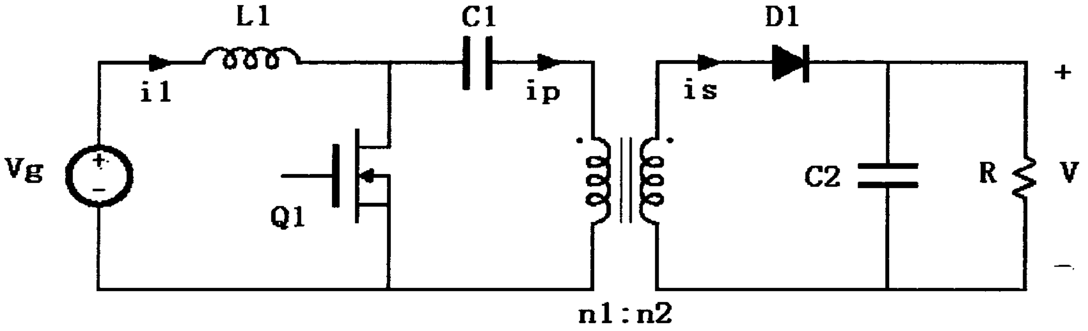


Figure 51

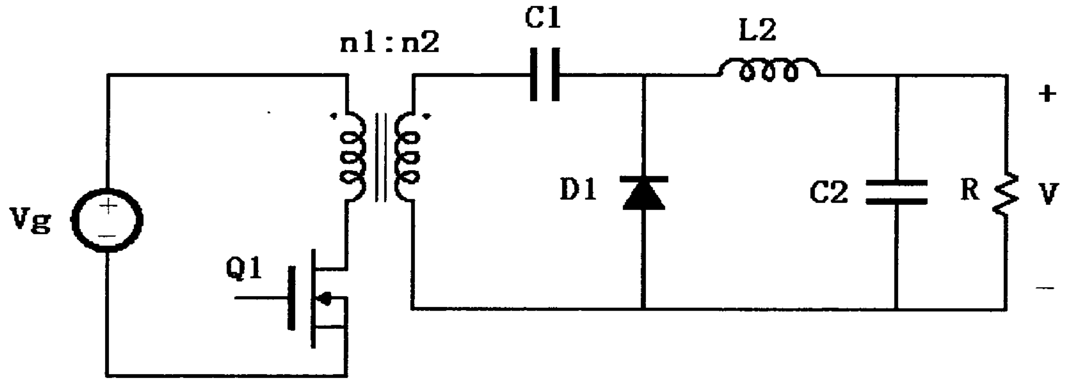


Figure 52

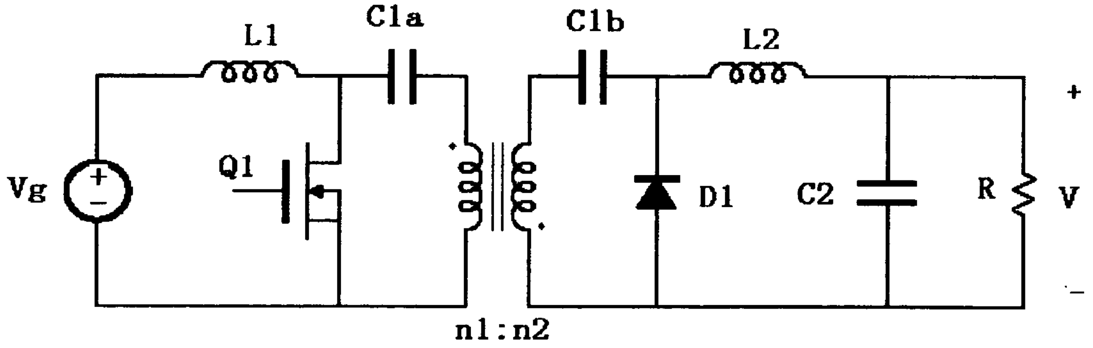
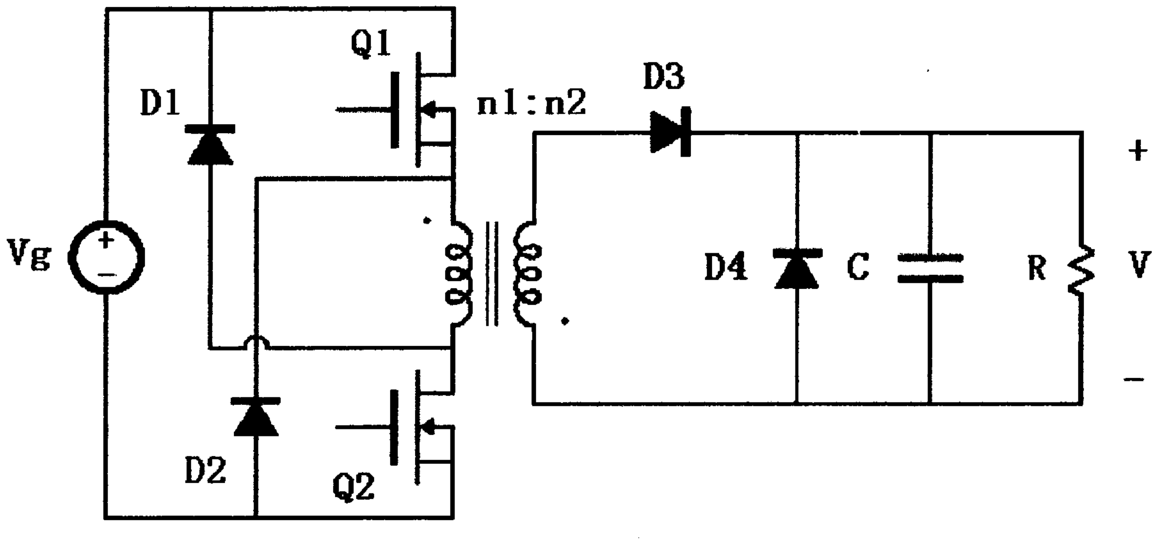


Figure 53



AC TO DC POWER SUPPLY WITH PFC FOR LAMP

CROSS-REFERENCE AND CORRECTION TO RELATED APPLICATIONS

The present application claims priority to U.S. Patent Application No. 11/204,307, filed on Aug. 15, 2005, which is incorporated herein by reference in its entirety.

BACKGROUND

[0001] The following disclosure relates to electrical circuits and signal processing.

[0002] Power supplies are used to power many types of electronic devices, for example, lamps. Conventional power supplies (e.g., for halogen lamps) typically include a converter. A converter is a power supply switching circuit.

[0003] Lamps have two categories:

[0004] First category uses ballast to strike the lamp to start. Most of them use gas to create light such as Fluorescent, HID, Compact, metal halide lamp etc. Bulbs need ballast because they use gas to create light. When the gas is excited by electricity, it emits invisible ultraviolet light that hits the white coating inside the bulb. The coating changes the ultraviolet light into light you can see. It needs a very high voltage strike to startup the operation of the lamp. But my invention is not applied directly to this category. The invention must be combined with second stage ballast to drive the lamp.

[0005] Second category doesn't need ballast to start the lamp. Most of them use heat generated by filament or diode etc to create light. Such as Halogen, Incandescent, LED, PAR lamp, miniature sealed beam lamp, Projection lamp, automotive lamp, some stage and studio lamp, DC fluorescent lamp etc.

[0006] My patent can be used directly on second category lamp.

[0007] Because Halogen lamp is the typical lamp of second category (filament or diode etc), all the discussion starts from the application of the power supply on Halogen lamp.

[0008] FIG. **1** shows a conventional half bridge converter **100** that receives AC sinusoidal voltage from a power source Vin. Converter **100** includes transistors Q**1**, Q**2**, transformer TI**1**, Coupled inductor T1A, T1B and T1C; DC blocking Capacitor C**4**, C**5**; Timing circuit C**2**, R**2** and C**3**, R**3**; startup circuit D**5**, R**4**, Q3; R1, C1; bridge rectifier D**1**, D**2**, D**3** and D**4**; AC power source 120Vac 60 Hz sinusoidal (or 220Vac 50 Hz) and Halogen lamp. (low voltage, for example 12v)

[0009] Q**1** and Q**2** complementary on/off with 50% duty cycle. Output voltage waveform is 120 Hz low frequency envelope with high switching frequency square waveform in it. As shown in FIG. **2** and FIG. **3**.

$Vo=60*(4/3.14159)*ns/np$ (np is primary turns and ns is secondary turns.)

[0010] Dimming is realized by applying phase cut dimmer in the converter in trailing edge mode. This means that at the beginning of the line voltage half cycle, the switch inside the dimmer is closed and mains voltage is supplied to the converter allowing the converter to operate normally. At some point during the half cycle, the switch inside the dimmer is opened and voltage is no longer applied. The DC bus inside the converter almost immediately drops to 0 V and the output is no longer present. In this way, bursts of high frequency output voltage are applied to the lamp. The RMS voltage across the lamp will naturally vary depending on the phase angle at which the dimmer switch switches off. In this way the lamp brightness may easily be varied from zero to maximum output as shown in FIG. **5** and **6**.

[0011] Advantage of this typical low-voltage halogen-lamp converter **100** is simple without IC controller.

[0012] Disadvantage:

[0013] 1. Output voltage has low frequency (120 Hz) envelope, voltage change from valley to peak 120 times per second. Lamp brightness is proportional to lamp voltage. So lamp brightness will change from darkest to brightest 120 times per second. Eyes pupil will open wide (mydriasis) when lamp becomes dark while eyes pupil will contract (myosis) while the crystalline lens also adjust according to different brightness. Thus the pupil will open and close 120 times per second. The muscle to control pupil and crystalline lens will become very tired for several hours. For long run, the muscle to control pupil and crystalline lens become limp and can't control well. Thus myopia is caused for crystalline lens can't be adjusted well according to distance.

[0014] 2. High frequency (switching frequency) square waveform in the envelope cause EMI issue and has risk to harm people's health. Pupil open wide at darkness and contract at brightness to protect retina. Eyes pupil can't keep pace with high frequency light. Thus the retina will be harmed by peak brighness light in high frequency light.

[0015] 3. Crest factor is high (17/12=1.4167) and shorten lamp's life.

[0016] 4. Variation output voltage for No Feedback;

[0017] 5. Dimming needs external dimmer based on turn on/off line voltage. So cost increases.

[0018] 6. Power factor is very low during dimming at low voltage.

[0019] 7. Inrush current during turn on is high and shortens the lamp life.

[0020] FIG. **4** shows another way to drive the halogen lamp. A low frequency transformer is connected directly to the halogen lamp.

[0021] Advantage: Component is only one transformer and cost is less.

[0022] Disadvantage:

[0023] 1. Output voltage has low frequency sinusoidal waveform, thus human's eyes will feel tired under the low frequency flicker; it cause myopia for long term.

[0024] 2. Variation output voltage for No Feedback;

[0025] 3. Dimming needs external dimmer based on turn on/off line voltage, so the Power factor is very low during dimming, Inrush current during turn on is high and shorten the lamp life.

[0026] 4. Transformer is too big and heavy for low frequency use.

SUMMARY

[0027] In general, in one aspect, this specification describes new block diagram for Halogen lamp converter as FIG. **7** and new topology as FIG. **11,12,13,14,15,16,17,24, 25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43- ,44,45,46, 47,48,49,50,51,52** and **53**.

[0028] Implementations can include one or more of the following advantages.

[0029] 1. Output voltage is DC constant voltage. No low frequency component and no high frequency component. It protects peoples' eyesight and health to maximum extent.

[0030] (Low frequency component cause eyes tired and myopia for long term.

[0031] High frequency component cause EMI issue and harm to people's health. Eyes pupil can't keep pace with high frequency light. Thus the retina will be harmed by peak bright light under high frequency light.)

[0032] 2. Output voltage has feedback control and is constant without varying voltage magnitude in normal operation or dimming. Crest factor is 1 so that lamp's life is extended to maximum degree.

[0033] 3. Dimming is realized by changing potentiometer resistance value. No need for external dimmer and save cost. Dimming does not turn on/off circuit and does not cause inrush current or ugly waveform. So lamp's life is prolonged.

[0034] 3. Power factor correction circuit is included in one implementation like IW2202, So power factor is unity even at dimming and efficiency is high; Power factor correction is not included in one implementation like IW2210, LNK302/304-306, LNK362-364 or UCC28600 etc

[0035] Traditional PFC only use boost (FIG. **34**) converter to realize AC to DC conversion. But boost converter can only output DC voltage higher than the peak of input AC voltage. Most of lamps rating voltage are less than peak of input AC line voltage (170v). So traditional PFC boost converter can't be directly used for low voltage lamp. My invention can buck down the voltage. Output DC voltage can be lower or higher than input AC peak voltage or equal to input AC peak voltage. My invention can be directly used for any rating voltage lamp of any kind without ballast requirement.

[0036] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0037] FIG. **1**: typical low-voltage halogen-lamp power supply based on conventional half bridge converter **100**.

[0038] FIG. **2**: Output voltage waveform of typical halogen lamp power supply based on half bridge converter **100** is high frequency square waveform contained in low frequency (120 Hz) envelope.

[0039] Top graph: Blue or red curve-rms value of output voltage across lamp;

[0040] Red shade-output voltage waveform across lamp.

[0041] Bottom table: VP**1**-Peak value of output voltage; SQRT(AVG-rms value of output voltage.

[0042] FIG. **3**: amplified high frequency square waveform contained in the low frequency envelope of output voltage in typical halogen lamp converter **100**.

[0043] Top: Red waveform-high frequency square waveform in output voltage

[0044] Bottom: rms value of output voltage

[0045] FIG. **4**: The halogen lamp converter driven directly by a big low frequency transformer and output voltage on the lamp.

[0046] Top table: V**2**-peak value of output voltage; SQRT(AVG-rms value of output voltage.

[0047] Top waveform: red-sinusoidal output voltage; blue-rms value of output voltage

[0048] Bottom waveform: red-rms value of output voltage

[0049] FIG. **5**: input bus voltage and lamp output voltage waveform during dimming with external dimmer for typical Halogen lamp converter **100**.

[0050] Left: trailing edge dimming

[0051] Right: Leading edge dimming

[0052] FIG. **6**: Output voltage and current of lamp during dimming of typical halogen lamp converter **100**.

[0053] Top: trailing edge dimming

[0054] Bottom: Leading edge dimming

[0055] FIG. **7**: Block diagram of my invention, Power Supply **200**, AC to DC power supply with PFC (or without PFC) for Lamp

[0056] FIG. **8**. Voltage waveform across A and A' on block diagram FIG. **7**

[0057] FIG. **9**. Voltage waveform across C and C' on block diagram FIG. **7**

[0058] FIG. **10**. Voltage waveform across D and D' on block diagram FIG. **7**

[0059] FIG. **11**. Flyback converter used as converter **206** in block diagram FIG. **7** Vo=Vg*D*n**2**/(D'*n**1**)

[0060] FIG. **12**. One implementation schematic of my invention using Flyback topology for converter **206** and IW2202 for controller **209** with PFC function.(primary dimming control)

[0061] FIG. **13**. One implementation schematic of my invention using Flyback topology for converter **206** and IW2202 for controller **209** with PFC ftinction.(secondary dimming control)

[0062] FIG. **14**. One implementation schematic of my invention using Flyback topology for converter **206** and IW2202 for controller **209** with PFC function.(secondary dimming control)

[0063] FIG. **15**. One implementation schematic of my invention using Flyback topology for converter **206** and IW2210 for controller **209** without PFC function.(primary dimming control)

[**0064**] FIG. **16**. One implementation schematic of my invention using Flyback topology for converter **206** and IW2210 for controller **209** without PFC function.(secondary dimming control)

[**0065**] FIG. **17**. One implementation schematic of my invention using Flyback topology for converter **206** and IW2210 for controller **209** without PFC function. (secondary dimming control)

[**0066**] FIG. **18**. Pulse train algorithm in IW2210 for controller **209**.

[**0067**] FIG. **19**. The input current waveform with input voltage through switching Mosfet, Vinrms=input rms voltage; Lm=magnetic inductance of transformer; d(t):duty cycle; Ts: period. Ipeak=peak value of current through switching Mosfet iav(t):average value of current through switch Mosfet. Slope: Mosfet switch current slope.

[**0068**] FIG. **20**. One implementation schematic of active startup circuit **208**

[**0069**] FIG. **21**. One implementation schematic of active startup circuit **208**

[**0070**] FIG. **22**. One implementation schematic of active startup circuit **208**

[**0071**] FIG. **23**. Startup Timing Diagram on pins of IC controller in one implementation with IW2202

[**0072**] FIG. **24**. One implementation schematic of my invention using Flyback topology for converter **206** and UCC28600 for controller **209** without PFC function.(secondary dimming control)

[**0073**] FIG. **25**. One implementation schematic of my invention using Flyback topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK362, LNK363 or LNK364 etc.

[**0074**] FIG. **26**. Buck converter for converter **206** Vo/vin=D

[**0075**] FIG. **27**. One implementation schematic of my invention using Buck topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK302, LNK304, LNK305 or LNK306 etc. Direct feedback.

[**0076**] FIG. **28**. One implementation schematic of my invention using Buck topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK302, LNK304, LNK305 or LNK306 etc. High side buck-opto coupler feedback

[**0077**] FIG. **29**. One implementation schematic of my invention using Buck topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK302, LNK304, LNK305 or LNK306 etc. Low side buck-opto coupler feedback

[**0078**] FIG. **30**. Buck-boost converter for converter **206** Vo/vin=-D/(1−D)

[**0079**] FIG. **31**. One implementation schematic of my invention using Buck-Boost topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK302, LNK304, LNK305 or LNK306 etc. High side buck boost-direct feedback

[**0080**] FIG. **32**. One implementation schematic of my invention using Buck-Boost topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK302, LNK304, LNK305 or LNK306 etc. High-Side Buck Boost-Constant current feedback

[**0081**] FIG. **33**. One implementation schematic of my invention using Buck-Boost topology for converter **206** and U**1** for controller **209** without PFC function. In one implementation, U**1** is IC controller LNK302, LNK304, LNK305 or LNK306 etc. Low-Side Buck Boost-Optocoupler feedback

[**0082**] FIG. **34**. Boost converter for converter **206** Vo/vin=1(1−D)

[**0083**] FIG. **35** Noninverting buck-boost converter for converter **206** Vo/vin=D/(1−D)

[**0084**] FIG. **36** H-Bridge converter for converter **206** Vo/Vin=2D−1

[**0085**] FIG. **37** Watkins-Johnson converter for converter **206** Vo/vin=(2D−1)/D

[**0086**] FIG. **38** Current-fed bridge converter for converter **206** Vo/vin=1/(2D−1)

[**0087**] FIG. **39** Inverse of Watkins-Johnson converter for converter **206** Vo/vin=D/(2D−1)

[**0088**] FIG. **40**. Cuk converter for converter **206** Vo/vin=−D/(1−D)

[**0089**] FIG. **41**. SEPIC converter for converter **206** Vo/vin=D/(1−D)

[**0090**] FIG. **42**. Inverse of SEPIC converter for converter **206** Vo/vin=D/(1−D)

[**0091**] FIG. **43**. Buck square converter for converter **206** Vo/Vin=D*D

[**0092**] FIG. **44**. Full bridge converter for converter **206** Vo/Vin=n**2***D/n**1**

[**0093**] FIG. **45** Half bridge converter for converter **206** Vo/Vin=0.5*n**2***D/n**1**

[**0094**] FIG. **46** Forward converter for converter **206** Vo/Vin=(n**3**/n**1**)*D

[**0095**] FIG. **47** Two transistor forward converter for converter **206** Vo/Vin=n**2***D/n1

[**0096**] FIG. **48** Push pull converter for converter **206** Vo/Vin=n**2***D/n**1**

[**0097**] FIG. **49**. Push pull based on Watkins-Johnson for converter **206**; Vo/Vin=(n2/n1)*(2*D−1)/D

[**0098**] FIG. **50**. Isolated SEPIC converter for converter **206** Vo/Vin=(n2/n**1**)*D/D'

[**0099**] FIG. **51**. Isolated Inverse SEPIC converter for converter **206** Vo/Vin=(n**2**/n**1**)*D/D'

[**0100**] FIG. **52** Isolated Cuk converter for converter **206** Vo/Vin=(n2/n**1**)*D/D'

[**0101**] FIG. **53** Two-transistor Flyback converter for converter **206** Vo/Vin=(n**2**/n**1**)*D/D'

DETAILED DESCRIPTION

[0102] FIG. **7** is a block diagram of a power supply **200** for a connected output device (e.g., lamp **211**). In one implementation, power supply **200** receives an AC source voltage from a voltage source **210**. In one implementation, power supply **200** includes an RF**1201**, an input filter **202**, a rectifier **203**, an one stage substantially DC sinusoidal to constant DC voltage converter **206**, a controller **209**, feedback and dimmer circuit **205**, sample circuit **207**, active startup circuit **208** and Lamp **211**. The power supply can have more blocks or fewer blocks than FIG. **7**. (For example, **206**,**208**,**209** can be an integrated block **204** or **208** can be removed in some implementation. Main switch of converter **206** and **208** can be integrated into the controller **209** as in LNK302/304-306 or LNK362-364). The sequence and position of some blocks can be exchanged. (For example, position of **202** and **203** can be exchanged). Each block can use all kinds of different circuits with function as the following.

[0103] Input RF**1201** provides input current protection for converter **200**. In particular, in one implementation, input fise is designed to provide current protection for converter **206** by cutting off current flow to converter **206** in an event that current being drawn through input fuse **201** exceeds a predetermined design rating. In another implementation, RF**1201** is a flameproof, fusible, wire wound type and functions as a fuse, inrush current limiter. In another implementation, RF**1210** can be a NTC or PTC thermistor.

[0104] Input filter **202** minimizes an effect of electromagnetic interference (EMI) on power supply **200**, converter **206** and exterior power system. Input filter **202** can be LC filter π filter, common mode filter, differential mode filter or any type filter that provide a low impedance path for high-frequency noise to protect power supply **200** and exterior power system from EMI. Input filter **202** can be placed in front of rectifier **203** or behind rectifier **203**.

[0105] Rectifier **203** converts the input AC source voltage from voltage source **210** (like FIG. **8**) into a substantially DC sinusoidal voltage (like FIG. **9**).

[0106] In one implementation, rectifier **203** is a full-wave rectifier that includes four rectifiers in a bridge configuration as in FIG. **12**, **13** or **14** etc. In another implementation, rectifier **203** contains 2 diodes as shown in FIG. **27**,**28** or **29** etc. Rectifier can be any type or bridgeless PFC.

[0107] One stage DC sinusoidal voltage to constant DC voltage converter **206** converts the substantially DC sinusoidal voltage like FIG. **9** received from rectifier **203** into a DC constant voltage at predetermined value suitable to support an output device (e.g., halogen lamp **211**). In one implementation, converter **206** converts the substantially DC sinusoidal voltage received from rectifier **203** into DC constant voltage 12 volts. (FIG. **10**) Usually the input voltage source **210** comes from 60 Hz 110v AC or 50 Hz 220v AC sinusoidal line voltage in power system.

[0108] Controller **209** is operable to regulate output voltage at predetermined value.

[0109] Controller **209** can be any type and have any type of control with PFC or without PFC function. (Such as digital control, analogy control, DSP, bang-bang control, skipping switching cycles as in LNK302/304-306, Pulse Train control as in IW2210 etc.)

[0110] In such an implementation, controller **209** is operable to adjust the duty cycle, switching frequency or on time of main switch of converter **206** so that converter **206** outputs a DC constant output voltage having a predetermined voltage value. Controller **209** can control an output voltage level of converter **206** responsive to a predetermined value set by voltage divider composed of potentiometer and resistor at dimming or normal operating.

[0111] Normal operating; predetermined value set to rating voltage of lamp; dimming operating, predetermined value set to lower voltage than rating voltage of lamp.

[0112] Feedback control voltage comes from feedback circuit **205**, as discussed in greater detail below.

[0113] Sample circuit **207** sense the signal proportional to output DC constant voltage or directly sense the voltage cross the lamp.

[0114] Feedback and dimmer circuit **205** is operable to provide a feedback dimming control voltage to controller **209** for dimming (or reducing) output voltage (e.g., halogen lamp **211**) by changing potentiometer value to change voltage divider ratio. Duty cycle, switching frequency or on time of main switch are changed to change output voltage.

[0115] In one implementation (non-isolated feedback), **205** can be realized by a voltage divider composed of potentiometer and resistor (or zener diode and resistor voltage divider) and voltage cross one resistor goes to Feedback pin of controller **209**;

[0116] In one implementation (isolated feedback), **205** can be realized by a voltage divider composed of potentiometer and resistor (or zener diode and resistor voltage divider) and voltage across one resistor or voltage across secondary winding is coupled to Feedback pin of controller **209** by auxiliary winding, opto-coupler or digital isolator etc

[0117] In real application, block can be more or less than FIG. **7**. Some blocks maybe different from FIG. **7**. For example, some application had no feedback function.

Type I. Isolated Converter

I-1 Part 1 Flyback Converter Used as Converter **206**

[0118] Flyback converter is shown in FIG. **11**. The function is described as the following: when Q**1** on, all magnetic winding has positive voltage on no '•' end with respect to the other end. D**1** is off; when Q**1** off, all magnetic winding has positive voltage on '•' end with respect to the other end, D**1** turns on, energy transfer to output load.

[0119] During Q**1** on, 0<t<DTs, voltage across transformer primary winding is Vg. (Vg input voltage). During Q**1** off, DTs<t<Ts, voltage across transformer primary winding is −Vo*n**1**/n**2**. (Vo is output voltage, n**1** is primary turns; n**2** is secondary turns.) In continues conduction mode, primary winding balance: D is duty cycle, D'=1−D

$$Vg*D*Ts-Vo*D'*Ts*n1/\mathrm{n2}=0\,Vo=Vg*D*n\mathbf{2}/(D'*n\mathbf{1})$$

I-1.1 Power Supply with PFC Based on Flyback Converter

(In One Implementation, IW2202 is Used as Controller)

[0120] The detail is discussed below.

[0121] FIG. **12**,**13** and **14** illustrate one implementation of a converter that can be used within power supply **200**.

Referring to FIG. **12**,**13** and **14**, my invention converter **200** is implemented with Flyback topology for converter **206** and IC IW2202 for controller **209**. The following discussion starts from IC IW2202. In application, the circuit can have more or less components than FIG. **12**,**13** and **14**. We started the discussion with FIG. **11**.

[0122] During the period when Q**1** is on (0<t<=DTs), the '•' end is negative with respect to no '•' end of primary and secondary transformer windings, thus diode D**3** could not turn on. Energy is saved in the magnetic inductance Lm. The voltage cross primary winding is Vg. (Vg is voltage after AC voltage rectified, In one implementation, Vg is DC sinusoidal voltage like FIG. **9**)

[0123] During the period when Q**1** is off (DTs<=t<Ts), the polarity of the transformer winding changes. '•' end is positive with respect to no '•' end for both primary and secondary winding of transformer. Thus D**3** turns on; energy is delivered to the output. The voltage cross primary winding is Vo*np/ns. (Vo is output DC voltage and np is primary turns; ns is secondary turns).

[0124] For normal operating, transformer set and reset must be balanced. It can be shown by $\int vdt=0$. That is $Vg*DTs-(Vo*np/ns)*D'Ts=0$

[0125] D is duty cycle. D=Ton/Ts.

[0126] Ts is the switching period.

$D'=1-D.$

[0127]

So $Vo = Vg*D*ns/(D'*np)$ (3.1)
Vop is defined as the output voltage reflected to primary during Q1 off time,
$Vop = (np/ns)*(Vo + \Delta V)$ (3.2)
ΔV represents the voltage drop across diode and trace.
$Vg = \sqrt{2}*Vinrms*\sin(\omega t)$ (3.3)
Usually, ΔV is small enough compared with Vo.
$Vop \approx (np/ns)*Vo$ (3.4)
From (3.1) and (3.4), we know $Vop = Vg*D/D'$ (3.5)
$Vop = Vg*D/(1 - D)$ derive $1 - D = (Vg/Vop)*D$ (3.6)
$D = 1/(1 + Vg/Vop)$ (3.7)
Substitute Vg, we get $D(t) = 1/(1 + \sqrt{2}*Vinrms*\sin(\omega t)/(np*Vo/ns))$ (3.8)

From (3.8), for a predetermined constant DC value Vo, we can adjust duty cycle D(t) according to value of input voltage to guarantee the output voltage constant. Thus the converter converters a 120 Hz or 100 Hz DC sinusoidal waveform to a DC constant voltage.

[0128] Dimming can be realized by adjust potentiometer. In FIG. **12**, potentiometer R**15**,R**6** and R**12** form a voltage divider. During Q**1** off, Auxiliary winding '•' end is positive with respect to no '•' end, so does secondary winding. The output voltage Vo is coupled to auxiliary winding for D**20** is on. Voltage on top of R**6** equals to N**2***Vo. (N**2** is turns ratio of auxiliary winding and transformer secondary winding. N**2**=Na/Ns, Na: auxiliary winding turns, Ns: secondary winding turns). So voltage Vs sensed on R**12** is N**2***Vo*R**12**/(R**12**+R**15**+R**6**). Vs is compared with interior reference voltage Vr by CMP. If Vs greater than Vr, that show Vo is greater than predetermined value, so duty cycle decreases or fs changes, Vo is decreased until Vo equals to predetermined value; If Vs less than Vr, that shows Vo is less than predetermined value, so duty cycle increases or fs changes, Vo is increased until Vo equals to predetermined value.

So Vs=Vr=N**2***Vo*R**12**/(R**12**+R**15**+R**6**) for steady state. Vr is constant and N**2** is constant.

$$So\ Vo=Vr*(R12+R15+R6)/(R12*N2). \tag{3.9}$$

We can adjust potentiometer R**15** to change value of (R**12**+R**15**+R**6**)/R**12**=1+(R**15**+R**6**)/R**12** to change predetermined Vo. Increase R**15**, Vo increase; decreases R**15**, Vo decrease. Thus lamp can be dimmed by change R**15** to set output voltage and it is stable with constant voltage. R**6** can be potentiometer, then increase R**6** to increase Vo, Vice versa. R**12** can be potentiometer, we can decrease R**12** resistance to increase output voltage or increase R**12** resistance to decrease output voltage. Dimming voltage is also DC constant voltage. There is no low frequency component. So the eyes will not feel fatigue due to the low frequency flicker. There is no high frequency light. No EMI issue or no retina harm by peak brightness because eyes pupil can't keep pace with high frequency light. Thus eyes are protected to maximum extent to avoid myopia or retina harm.

[0129] Sometimes opto-coupler is used as isolated feedback. In FIG. **13**, dimming is realized by changing potentiometer R**21** to change feeback signal on Vsense pin to dim voltage. Increase R**21** will decrease opto-diode current, then voltage on Vsense pin increases. Controller decreases duty cycle or change frequency to decrease output voltage; Decrease R**21** will increase opto-diode current, then voltage on Vsense pin decreases. Controller increases duty cycle or change frequency to increase output voltage. R**22** can be potentiometer too. It behaves similar to R**21**.

[0130] In FIG. **14**, dimming is realized by changing potentiometer R**23**. Optocoupler current Ioc=Vref*(R**22**+R**23**)/R**23**/R**21**=Vref*(1+R**22**/R**23**)/R**21**; Vsense=Vref−Ioc*R**12**. Output voltage is set by reference voltage times (1+R**22**/R**23**). Increase R**23**, Vo decreases; Vice versa. Vo has small ΔVo increase, Ioc has small increase, Vsense has small decrease. Vo+ΔV has small decreases until equals to Vo.

[0131] In one implementation, PFC (power factor correction) can be realized by modulating the average input current ipr(t)av in phase with the input line voltage Vin(t). Thus power factor is unity. PFC also can be done by multiplier, μPFC as in IR1150S or DSP.

[0132] Please see FIG. **14**, the input current waveform with input voltage through switching Mosfet

$Slope = \sqrt{2}*Vinrmssin(\omega t)/Lm$ (3.10)
$Ipeak = Slope*d(t)*Ts$ (3.11)
$Ipr(t)av = ipeak*d(t)*Ts/2/Ts$ (3.12)
So we get $ipr(t)av = (\sqrt{2}*Vinrmssin(wt)/(2Lm))*d(t)*d(t)*Ts(t)$ (3.13)
Let $k = d(t)*d(t)*Ts(t)$, $ipr(t)av = (\sqrt{2}*Vinrmssin(wt)/(2Lm)*k$ (3.14)

We know the input current is in phase with the AC line if k is constant. The converter accomplishes by modulating the average input current iin(t) in phase with the input line voltage Vin(t). Thus the power factor is very near to unity no matter in normal operation or dimming.

[**0133**] Active startup circuit is used to start up the circuit. In other implementation, Active startup circuit can be realized by other way or removed. In other circuit, active startup circuit can have more or less component than FIG. **20**,**21** or **22**.

[**0134**] FIG. **20** shows active startup circuit. ASU pin is designed to drive the Mosfet of the active startup circuit. An external zener diode is to clamp the ASU pin.

[**0135**] Before startup, ASU is floating. Once a voltage is supplied to Vg(t) (DC sinusoidal voltage after bridge rectifier like FIG. **9**). The gate capacitor C**31** starts to charge via the startup resistor R**31**. When Vcc reaches the threshold voltage of Q**2**, transistor Q**2** conducts. (Q**2** can be NPN transistor or N channel Mosfet). The startup capacitor C**32** starts to be charged via the charge resistor R**32** and R**33** (R**32** can be removed). When Vcc reaches the startup threshold voltage, PWM (IW2202) starts operating. Converter main switch Q**1** switches and auxiliary winding has voltage coupled from secondary output. ASU goes lower than secondary coupled voltage, thus turns off Q**2**. Vcc is supplied from C**32** that is charged by auxiliary winding and D**4**.

[**0136**] Thus, supply voltage for PWM (IW2202) no longer uses linear regulator Q**2** and the efficiency is improved. FIG. **23** Startup Timing Diagram on pins of IC controller shows that. By select auxiliary winding and secondary winding turns ratio carefully, we guarantee the voltage on the auxiliary winding during minimum dimming is larger than Vcc threshold+Voltage drop on D**4**; We guarantee the voltage on the auxiliary winding during normal operating is not high enough to damage R**33** and Z**2**. Thus, we can guarantee PWM (IW2202) works well no matter in normal operation or dimming.

[**0137**] In FIG. **12**, AC Power line functions as **210** in FIG. **7**

[**0138**] In FIG. **12**, F**1** is a fuse to prevent too much current drawn from power line.(function as RF**1201** in FIG. **7**) If the current through F**1** is larger than its rating current, it melts and open the circuit.

[**0139**] L**1**, C**1** and C**2** become a II filter and EMI filter to prevent high frequency component enter line. (function as Filter **202** in FIG. **7**)

[**0140**] BR is a full bridge rectifier to rectify AC sinusoidal voltage (FIG. **8**) to DC sinusoidal voltage (FIG. **9**). (Functions as rectifier **203** in FIG. **7**). BR can be realized by other circuit as in FIG. **27**,**28** or **29**.

[**0141**] Q**1**, T**1**, D**20** compose a flyback power converter. (function as Converter **206** in FIG. **7**) C**20** is to eliminate high frequency noise.

[**0142**] Halogen lamp is parallel with C**20**. (function as Lamp **211** in FIG. **7**) Auxiliary winding (functions as Sample **207** in FIG. **7**) and D**4**,Q**3**,D**5** supply voltage to PWM and connect to Vcc pin. (Pin**1**-Vcc is power supply for the controller).

[**0143**] R**6**, R**12** and Potentiometer R**15** compose a voltage divider and connect to pin**2**-Vsense. (function as Feedback and dimmer **205** in FIG. **7**) (Vsense senses signal input from auxiliary winding. This provides the secondary feedback used for output regulation).

[**0144**] Active startup circuit is shown in FIG. **20**,**21**,**22**. (functions as Active Startup circuit **208** in FIG. **7**). Other circuit such as valley-filled, linear regulator can replace circuit as FIG. **20**,**21**,**22**.

[**0145**] Controller use IW2202 (function as **209** in FIG. **7**).

[**0146**] Pin**3**-SCL is secondary current-limit feedback input. It is pulled up to Vrega through a 10 kohm resistor when secondary current limit function is not used.

[**0147**] Pin**4**-ASU is gate drive for the external Mosfet in the active start-up circuit. Similar to FIG. **22**.

[**0148**] Scaled voltage from line by voltage divider R**3**, R**4** and filter R**5**, C**4** is sent to pin **5**-Vindc.

[**0149**] (Sense signal input representing the average line voltage for line regulation, under voltage and over voltage protection.).

[**0150**] Scaled voltage from line by voltage divider R**1**, R**2** is sent to pin **6**-Vinac (sense signal input representing AC line voltage.) that is for input current shaping.

[**0151**] R**13** and C**5** are connected to pin**7**-Vref (2.0v reference voltage output).

[**0152**] Pin **8**-AGND (Analog ground) is grounded.

[**0153**] Pin**9**-SD (shut down pin. The input signal on SD is sampled during every switching cycle. When the voltage is above the shutdown threshold, the converter goes in a latched shutdown mode). SD can be used as OVP and OTP.

[**0154**] The voltage on R**9** is sent to Pin **10**-Isense (Primary power switch current limit. This is used to provide cycle-by-cycle current limit). It is used as current limit or over current protection.

[**0155**] C**7** is connected to Pin **11**-Vrega (Analog regulator output. The internal 3.3v regulator is used for internal analog circuits.)

[**0156**] C**6** is connected to Pin **12**-Vregd (Digital regulator decoupling pin. Internal 3.3v regulator is used for internal digital circuits.)

[**0157**] Pin **13**-PGND is power ground and is grounded.

[**0158**] Pin **14**-Output is gate drive signal for the external Mosfet switch. CY**1** is a Y cap between primary and secondary ground.

[**0159**] We can also use FIG. **13** to realize similar function. The only difference is the dimming is realized in secondary with opto-coupler. In FIG. **13**, R**21** is a potentiometer and can be adjusted to set the current in diode of opto-coupler. Suppose current transfer ratio of opto-coupler is CTR. Vsense=Vref−(Vo*CTR*R**12**)/(R**21**+R**22**),

[**0160**] so we get Vo=(Vref−Vsense)*(R**21**+R**22**)/(CTR*R**12**). All other values except R**21** are fixed. R**21** is a potentiometer that can be adjusted to adjust output voltage Vo. If we want to dim down lamp, we just need to decrease R**21** value, vice versa. Of Course we can select R**22** as potentiometer. We can add components or delete component on FIG. **13**.

[**0161**] In real application, components can be more or less than FIG. **12**,**13**,**14**. Component value can be different from FIG. **12**,**13**,**14**. Topology or component connection way may be different from FIG. **12**,**13**,**14**.

[0162] Other controllers with PFC function can be used in power supply with PFC based on Flyback converter. Components, connection way or components value may be different from FIG. **12**,**13** or **14** etc.

I-1.2 Power Supply without PFC Based on Flyback Converter

(In One Implementation, IW2210 is Used as Controller)

[0163] In one implementation, AC to constant DC power supply without PFC for Lamp can be realized with IW2210 as in FIG. **15**,**16**,**17**;

[0164] Full bridge rectifier D**1**~D**4** rectify AC sinusoidal input line voltage (shown in FIG. **8**) to DC sinusoidal voltage (shown in FIG. **9**). Full bridge rectifier D**1**~D**4** functions as Rectifier **203** in FIG. **7**; Filter can be other circuit.

[0165] C**1** is a filter to pass high frequency component caused by switching to avoid EMI on line voltage. C**1** functions as Filter **202** in FIG. **7**;

[0166] R**3** connect between line voltage and Vcc to startup the controller IW2210, after it operates, Auxiliary winding will charge C**3** through D**5**. This functions as Active Startup Circuit **208** in FIG. **7**; Vcc: power supply for the controller IW2210.

[0167] Transformer T**1**, D**8**, C**4** and Q**1** compose flyback topology. That works as One Stage DC Sinusoidal to DC Constant Converter **206** in FIG. **7**

[0168] IW2210 works as controller **209** in FIG. **7**;

[0169] Output voltage can be coupled to primary through auxiliary winding and connect to Vsense pin by voltage divider composed of R**9**, R**10** and R**11**. Vsense: Sense signal input from auxiliary winding. This provides the secondary voltage feedback used for output regulation.

[0170] Auxiliary winding works as Sample **207** in FIG. **7**.

[0171] Voltage divider R**9**, R**10** and R**11** works as Feedback and dimmer **205** in FIG. **7**. R**10** is a potentiometer.

[0172] R1 and R2 voltage divider connect to Vin pin that is used for line regulation, under voltage and over voltage protection;

[0173] Vref is reference voltage output and connected with decoupling capacitor C2 and R4 in parallel;

[0174] GND (Analog ground) is grounded;

[0175] Isense senses primary switch current to provide cycle-by-cycle current limit.

[0176] Output pin output square waveform to switching on/off Main Switch Mosfet Q**1**.

[0177] R**6**, R**7** and R**8** become a voltage divider and connect to pin OVP/OTP. When output voltage is higher than a threshold, the voltage coupled on OVP/OTP pin through auxiliary winding will reach a threshold of interior controller, it shuts down. So it functions as OVP. It can also function as OTP. For example, if R**8** is a thermistor and changes to a very high value during high temperature, then the voltage on pin OVP/OTP can reach threshold and shuts down controller. Any of R**6**, R**7** or R**8** can be a thermistor, thermal resistor; NTC (negative temperature coefficient) or PTC (positive temperature coefficient) depends on the OTP function requirement;

[0178] During the period when Q**1** is on (0<t<=DTs), the '•' end voltage is negative with respect to no '•' end of both primary and secondary transformer windings, thus diode D**3** could not turn on. Energy is saved in the magnetic inductance Lm. The voltage cross primary winding is Vg. (Vg is DC sinusoidal voltage as FIG. **9** after AC voltage rectified). During the period when Q**1** is off (DTs<=t<Ts), the polarity of the transformer winding changes. '•' end voltage is positive with respect to no '•' end for both primary and secondary windings of transformer. Thus D**3** turns on and energy is delivered to the output. The voltage cross primary winding is Vo*n. (Vo is output DC voltage and n is transformer turns ratio n=np/ns, np is primary turns; ns is secondary turns). The voltage coupled cross auxiliary winding is Vo*Na/Ns. Voltage on Vsense=(Vo*Na/Ns)*R**11**/(R**9**+R**10**+R**11**).

[0179] As shown in FIG. **18**, if the auxiliary voltage is higher than the threshold set by the reference at tn, the next pulse the controller generates is a sense pulse. This is a much shorter pulse. The frequency of the operation is kept constant pulse by pulse, which result in discontinuous operation during sense cycles.

[0180] As shown in FIG. **18**, if the auxiliary voltage at tn+1 is below the threshold, the next pulse is a power pulse.

[0181] If the voltage is still too high, the controller sends more sense pulses. If the feedback voltage is still too high after 12 sense pulse, the converter transitions into SmartSkip mode operation, sending out very narrow skip pulses and gradually decreasing the operating frequency until the generated power is in balance with the load. The minimum operating period at no load is about 2 ms.

[0182] Thus the feedback guarantees the output voltage is constant at predetermined value. Vsense=(Vo*Na/Ns)*R**11**/(R**9**+R**10**+R**11**)=Vinterior ref.(Vinterior ref is interior reference voltage).

$$Vo=V\text{interior } ref*(Ns/Na)*(1+(R9+R10)/R11).$$

[0183] In one implementation, R**10** is a potentiometer. So decrease R**10** value to decrease Vo to realize dimming with feedback. R**9** or R**11** can be a potentiometer, then decrease R**9** or increase R**11** value to decrease Vo to realize dimming.

[0184] In one implementation, Controller **209** is IW2210 that uses Pulse Train control algorithm, which is a discrete time bang-bang type control that provides ultra-fast transient response, and guarantees loop stability without external loop compensation components. The controller provides three types of pulses to output driver, depending on the real-time value of the output voltage. (1) If output voltage Vo is too low, the controller sends out a power pulse that is high-energy pulses that transfer enough energy to the output to provide up to 130% of the rated output power for the converter; (2) If the output voltage Vo is too high, the controller sends out a sense pulse which represents significantly less energy than the power pulses. While in regulation, the controller adjusts the average mix of power and sense pulses to balance the energy provided by the converter and used by the load, thus regulating the output voltage within its specified limits. (3) If the load is very light, the controller operates in Smart Skip mode which generates ultra-narrow skip pulses and gradually reduces the frequency to keep the output in regulation down to zero load current.

[0185] FIG. **18** shows the Vsense waveform over four switching cycles. The voltage feedback block and the digital controller make a cycle-by-cycle determination of the type of pulse that will be generated in the next switching cycle. The first cycle shown is a power pulse. It is sampled close to the edge of the "flat portion" of the waveform, before the flux in the transformer collapses and the Vsense voltage falls. This time point is labeled tn. The controller turns on the switch again at the first minimum point of the auxiliary voltage. This point is calculated by the digital controller based on input from the Zero Voltage Detector block. This operation corresponds to valley-mode voltage switching (VMS) on the main power switch. VMS minimizes switching losses and increases the efficiency of the converter. The controller operates in critical discontinuous mode during power cycles. This operation maximizes the power density of the magnetic and minimizes its size for a given power level. If the auxiliary voltage is higher than the threshold set by the reference at tn, the next pulse the controller generates is a sense pulse. This is a much shorter pulse. The frequency of the operation is kept constant pulse by pulse, which results in discontinuous operation during sense cycles. If the auxiliary voltages at tn+1 is below the threshold, the next pulse is a power pulse, as shown in FIG. **18**. However, if the voltage is still too high, the controller sends more sense pulses. If the feedback voltage is still too high after 12 sense pulses, the converter transitions into SmartSkiptm mode operation, sending out very narrow skip pulses and gradually decreasing the operating frequency until the generated power is in balance with the load. The minimum operating period at no load is about 2 ms.

[0186] We can also use FIG. **16** to realize similar function. The only difference is the dimming is realized in secondary with opto-coupler. In FIG. **16**, R**21** is a potentiometer and can be adjusted to set the current in diode of opto-coupler. Suppose current transfer ratio of opto-coupler is CTR. Vsense=Vref−(Vo*CTR*R**10**)/(R**21**+R**20**),

[0187] so we get Vo=(Vref−Vsense)*(R**21**+R**20**)/(CTR*R**10**). All other values except R**21** are fixed. R**21** is a potentiometer that can be adjusted to adjust output voltage Vo. If we want to dim down lamp, we just need to decrease R**21** value, vice versa. Of Course we can select R**20** as potentiometer then we can decrease R**20** value to realize dimming.

[0188] In FIG. **17**, dimming is realized by changing potentiometer R**22**. Optocoupler current Ioc=Vref*(R**22**+R**23**)/R**23**/R**20**=Vref*(1+R**22**/R**23**)/R**20**; Vsense=Vicref−Ioc*R**10** Output voltage is set by reference voltage times (1+R**22**/R**23**). Decrease R**22**, Vo decreases; Vice versa. Vo has small ΔVo increase, Ioc has small increase, Vsense has small decrease. Vo+ΔV has small decreases until equals to Vo. Feedback guarantees the voltage in regulation. R**23** can be a potentiometer, increase R**23** to decrease Vo to realize dimming.

[0189] In real application, component can be more or less than FIG. **15**,**16**,**17**. Component value can be different from FIG. **15**,**16**,**17**. Topology or component connection way may be different from FIG. **15**,**16**,**17**.

[0190] Other controllers without PFC function can be used in power supply without PFC based on Flyback converter (such as Iw1688). Components, connection way or components value may be different from FIG. **15**,**16** or **17** etc. For example, UCC28600 is used with schematic as FIG. **24** and the function is similar to FIG. **17**. In real application, components or values or connection way may be different from FIG. **24**.

I-1.3 Power Supply Based on Flyback Converter with Switch Integrated in Controller

(In One Implementation, LNK362-364 is Used as Controller with Switch Integrated)

[0191] FIG. **25** is the schematic in one implementation.

[0192] The AC input is rectified by D**1** to D**4** (as Rectifier block **203** in schematic **7**) and filtered by the bulk storage capacitors C**1** and C**2**.

[0193] Resistor RF**1** is a fuse, PTC or NTC thermistor, or inrush current limiter or other over current protection. (As RF**1** block **201** in schematic **7**).

[0194] Together with the π filter formed by C**1**, C**2**, L**1** and L**2**, differential mode noise attenuator. (as Filter block **202** in schematic **7**) Other type of filter can also be used here.

[0195] Resistor R**1** damps ringing caused by L**1** and L**2**.

[0196] The rectified and filtered input voltage is applied to the primary winding of T**1**.

[0197] The other side of the primary is driven by the integrated MOSFET in U**1**. The secondary of the flyback transformer T**1** is rectified by D**5**, and filtered by C**4**. (All these are as block **204** in schematic **7**). U**1**,T**1**,D**5**,C**4** compose a flyback converter as **206** in FIG. **7**.

[0198] The combined voltage drop across VR**1**, R**4**, R**5** and the LED of U**2** determines the output voltage. R**4** and R**5** are as Sample block **207** in schematic **7**.

[0199] VR**1**, R**2**, R**3**, U**2**, R**4**, R**5** and C**3** are Feedback and Dimmer block **205** in schematic **7**.

[0200] Suppose VR**1** rating voltage=Vzener. Vr**2** is voltage across resistor R**2**. Vu**2**led is voltage across LED in opto-coupler U**2**.

$$Vo=[Vzener+Vr2+Vu2led]*(R4+R5)/R5=[Vzener+Vr2+Vu2led]*(1+R4/R5)$$

$$Vr2<<Vzener,\ VU2LED<<Vzener,\ So\ Vo\approx Vzener*(1+R4/R5)$$

[0201] We can increase R**5** to decrease Vo to realize dimming. If R**4** is a potentiometer, we can decrease R**4** to decrease Vo for dimming.

[0202] In one implementation, when the output voltage exceeds this level, current will flow through the LED of U**2**. As the LED current increases, the current fed into the FEEDBACK pin of U**1** increases until the turnoff threshold current is reached, disabling further switching cycles, and at very light loads, almost all the switching cycles will be disabled, giving a low effective frequency and providing high light load efficiency and low no-load consumption. Resistor R**2** provides 1 mA through VR**1** to bias the Zener closer to its test current. Resistor R**3** allows the output voltage to be adjusted to compensate for designs where the value of the zener may not be ideal, as they are only available in discrete voltage ratings. For higher output accuracy, the Zener may be replaced with a reference IC such as the TL431. The LinkSwitch-XT is completely self-powered from the DRAIN pin, requiring only a small ceramic capacitor C**3** connected to the BYPASS pin. No auxiliary winding on the transformer is required.

[0203] Several implementations are listed in FIG. **25**. Feedback can use opto-coupler as shown in first schematic in FIG. **25**; Feedback can use auxiliary winding as shown in second schematic in FIG. **25**; Feedback can directly comes from secondary voltage divider as third schematic in FIG. **25**.

[0204] In real application, component can be more or less than FIG. **25**. Component value can be different from FIG. **25**. Topology or component connection way may be different from FIG. **25**.

[0205] Other controllers with switch integrated into the controller can also be used in power supply based on Flyback converter with switch integrated in controller.

[0206] As above part**1**, power supply for lamp can be realized by flyback converter with or without PFC and can use all kinds of controllers with any kind of control method or algorithm for controller **209** in FIG. **7**.

I-2 Part 2. Other Topology Converter Used As Converter 206

I-2.1 Power Supply Based on Full-bridge Converter (FIG. 44)

[0207]

$$Vo=(n2/n1)*D*\mathrm{Vg},$$

[0208] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0209] D: duty cycle; Vg: input voltage

[0210] Any Full-bridge controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.2 Power Supply Based on Half-bridge Converter (FIG. 45)

[0211]

$$Vo=0.5*(n2/n1)*D*\mathrm{Vg},$$

[0212] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0213] D: duty cycle; Vg: input voltage

[0214] Any Half-bridge controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.3 Power Supply Based on Forward Converter (FIG. 46)

[0215]

$$Vo=(n3/n1)*D*\mathrm{Vg},$$

[0216] Vo: output voltage; n**3**: secondary winding turns; n**1**: primary winding turns;

[0217] D: duty cycle; Vg: input voltage

[0218] Any Forward controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.4 Power Supply Based on Two-transistor Forward Converter (FIG. 47)

[0219]

$$Vo=(n2/n1)*D*\mathrm{Vg},$$

[0220] Vo: output voltage; n**1** :primary winding turns; n**2**: secondary winding turns;

[0221] D: duty cycle; Vg: input voltage

[0222] Any two-transistor Forward controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.5 Power Supply Based on Push-pull Converter (FIG. 48)

[0223]

$$Vo=(n2/n1)*D*\mathrm{Vg},$$

[0224] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0225] D: duty cycle; Vg: input voltage

[0226] Any two-transistor Forward controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.6 Power Supply Based on Push-pull Converter Based on Watkins-Johnson Converter

(FIG. **49**)

$$Vo=(n2/n1)*(2D-1)Vg/D,$$

[0227] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0228] D: duty cycle; Vg: input voltage

[0229] Any Push-pull converter based on Watkins-Johnson controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.7 Power Supply Based on Isolated SEPIC Converter (FIG. 50)

[0230]

$$Vo=(n2/n1)*D*\mathrm{Vg}/\mathrm{D}',$$

[0231] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0232] D: duty cycle; D'=**1**−D; Vg: input voltage

[0233] Any Isolated SEPIC controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.8 Power Supply Based on Isolated Inverse SEPIC Converter (FIG. 51)

[0234]

$$Vo=(n2/n1)*D*\mathrm{Vg}/\mathrm{D}',$$

[0235] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0236] D: duty cycle; D'=**1**−D; Vg: input voltage

[0237] Any Isolated Inverse SEPIC controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.9 Power Supply Based on Isolated Cuk Converter (FIG. 52)

[0238]

$$Vo=(n2/n1)*D*Vg/D',$$

[0239] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0240] D: duty cycle; D'=**1**−D; Vg: input voltage

[0241] Any Cuk controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

I-2.10 Power Supply Based on Two-transistor Flyback Converter (FIG. 53)

[0242]

$$Vo=Vg*D*(n2/n1)/D'$$

[0243] Vo: output voltage; n**1**: primary winding turns; n**2**: secondary winding turns;

[0244] D: duty cycle; D'=**1**−D; Vg: input voltage

[0245] Any Two-transistor flyback controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

[0246] As above, components can be more or less than FIG. **44** to FIG. **53**. Other isolated topologies also can be used here. Any controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

Type II. Non-Isolated Converter

II-1 Part 1. Buck Converter Used As Converter 206

[0247] Buck converter is shown in FIG. **26**. The function is described as the following:

[0248] Transistor Q**1** on, 0<t<DTs, voltage on point A equals to Vg, diode D**1** is off, voltage on point A is positive with respect to point B on inductor L**1**, VA=Vg;

[0249] Transistor Q**1** off, DTs<t<Ts, polarity of inductor change, voltage on point A is negative with respect to point B on inductor L**1**, diode D**1** turns on, VA=**0**.

[0250] Output voltage is average value of VA for the filter composed of L**1**, C**1**. So Vo=(Vg*DTs+0*D'Ts)/Ts=DVg.

II-1.1 Power Supply Based on Buck Converter with Switch Integrated in Controller

(In One Implementation, LNK302/304-306 is Used as Controller)

[0251] The circuits shown in FIG. **27**,**28**,**29** are typical implementations of non-isolated power supply.

[0252] The input stage comprises fusible resistor RF**1** (as RF**1201** block in FIG. **7**); Resistor RF**1** is a flame proof, fusible, wire wound resistor. It accomplishes several functions:

[0253] a) Inrush current limitation to safe levels for rectifiers D**3** and D**4**;

[0254] b) Differential mode noise attenuation;

[0255] c) Input fuse should blow up when any other component fail for short circuit

[0256] Diodes D**3** and D**4** work as Rectifier **203** in FIG. **7**;

[0257] Capacitors C**4** and C**5**, and inductor L**2** (as Filter block **202** in FIG. **7**).

[0258] The power processing stage is formed by the LinkSwitch-TN, freewheeling diode D**1**, Controller U**1**, output choke L**1**, and the output capacitor C**2** compose Buck converter (as converter **206** in FIG. **7**)

[0259] The LNK302/304-306 was selected for U**1** as controller **209** in FIG. **7** such that the power supply operates in the mostly discontinuous-mode (MDCM). Diode D**1** is an ultra-fast diode with a reverse recovery time (trr) of approximately 75 ns, acceptable for MDCM operation. For continuous conduction mode (CCM) designs, a diode with a reverse recovery time less than 35 ns is recommended. Inductor L**1** is a standard off-the-shelf inductor with appropriate RMS current rating (and acceptable temperature rise). Capacitor C**2** is the output filter capacitor; its primary function is to limit the output voltage ripple.

[0260] (controller U**1** with switch integrated into, diode D**1**, inductor L**1** and capacitor C**2** become a buck converter as block **204** in schematic **7**)

[0261] Active startup circuit **208** and main switch are integrated in IC controller U**1**.

[0262] To a first order, the forward voltage drops of D**1** and D**2** are identical. Therefore, the voltage across C**3** tracks the output voltage. The voltage developed across C**3** is sensed and regulated via the resistor divider R**1** and R**3** (R**1** or R**3** is a potentiometer) connected to U**1**'s FB pin. The values of R**1** and R**3** are selected such that, at the desired output voltage, the voltage at the FB pin is 1.65v. So Vout·R**3**/(R**1**+R**3**)=1.65v, Vout=1.65*(1+R**1**/R**3**).

[0263] If R**3** is a potentiometer, we can increase R**3** to decrease output voltage for dimming;

[0264] If R**1** is a potentiometer, we can decrease R**1** to decrease output voltage for dimming.

[0265] Main switch is integrated in IC LNK302/304-306.

[0266] D**2**, become sample block **207** in FIG. **7**;

[0267] C**3**, R**1**, R**3** work as Feedback and dimmer block **205** in FIG. **7**.

[0268] In one implementation, Regulation is maintained by skipping switching cycles. As the output voltage rises, the current into the FB pin will rise. If this exceeds Ifb then subsequent cycles will be skipped until the current reduces below Ifb. Thus, as the output load is reduced, more cycles will be skipped and if the load increases, fewer cycles are skipped. To provide overload protection if no cycles are skipped during a 50 ms period, LinkSwitch-TN will enter auto-restart (LNK304-306), limiting the average output power to approximately 6% of the maximum overload power. Due to tracking errors between the output voltage and the voltage across C**3** at light load or no load, a small pre-load may be required (R**4**). For the design in FIG. **27**, if regulation to zero load is required, then this value should be reduced to 2.4 kohm.

[0269] Feedback can be realized by opto-coupler as in FIG. **28** or FIG. **29**.

[0270] Output voltage is set by voltage divider composed of potentiometer R**3** and resistor R**1**. Voltage of reference Z**1** is Vz. Vo=Vz*(1+R**1**/R**3**). Dimming can be realized by increasing R**3**. If R**1** is potentiometer, dimming can be realized by decreasing R**1** value.

[0271] Connection or component values can be changed in application. Components can be more or less than FIG. **27**,**28**,**29**.

[0272] As above in Part 2, we can use any buck controller with any kind of control way or algorithm which can convert DC sinusoidal voltage to DC constant voltage with switch or without switch integrated in power supply for lamp with PFC or without PFC.

II-2 Part 2. Buck-Boost Converter Used As Converter 206

[0273] Buck-Boost converter is shown in FIG. **30**. The function is described as the following:

[0274] Transistor Q**1** on, 0<t<DTs, voltage across L**1** equals to Vg, diode D**1** is off, voltage on point A is positive with respect to point B on inductor L**1**, VA=Vg;

[0275] Transistor Q**1** off, DTs<t<Ts, polarity of inductor change, voltage on point A is negative with respect to point B on inductor L**1**, diode D**1** turns on, VL=−Vo.

[0276] For steady state, the average of voltage across inductor L**1** should be 0. So 0=(Vg*DTs+Vo*D'Ts)/Ts; Vo=−Vg*D/D', Vo had opposite polarity as Vg.

II-2.1 Power Supply Based on Buck-Boost Converter with Switch Integrated in Controller

(In One Implementation, LNK302/304-306 is Used As Controller)

[0277] The circuits shown in FIG. **31**,**32**,**33** are typical implementations of non-isolated power supply. Regulation and feedback is already described in II-2.

[0278] Feedback can be realized by opto-coupler as in FIG. **33**.

[0279] Output voltage is set by voltage divider composed of potentiometer R**3** and resistor R**1**. Voltage of reference Z**1** is Vz. Vo=Vz*(1+R**1**/R**3**). Dimming can be realized by increasing R**3**. If R**1** is potentiometer, dimming can be realized by decreasing R**1** value.

[0280] Connection or component values can be changed in application. Components can be more or less than FIG. **31**,**32**,**33**.

[0281] As above in II-2 Part 2, we can use any buck-boost controller with any kind of control way or algorithm which can convert DC sinusoidal voltage to DC constant voltage with switch or without switch integrated in power supply for lamp.

II-3 Part 3. Other Non-isolated Topology Converter Used As Converter 206

II-3.1 Power Supply Based on Boost Converter (FIG. 34)

[0282]

$$Vo=Vg/D',$$

[0283] Vo: output voltage; D: duty cycle; D'=**1**−D; Vg: input voltage

[0284] Any Boost controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.2 Power Supply Based on Noninverting Buck-Boost Converter (FIG. 35)

[0285]

$$Vo=Vg*D/D',$$

[0286] Vo: output voltage; D: duty cycle; D'=1−D; Vg: input voltage

[0287] Any noninverting Buck-Boost controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.3 Power Supply Based on H-Bridge Converter (FIG. 36)

[0288]

$$Vo=Vg*(2D-1),$$

[0289] Vo: output voltage; D: duty cycle; Vg: input voltage

[0290] Any H-bridge controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.4 Power Supply Based on Watkins-Johnson Converter (FIG. 37)

[0291]

$$Vo=Vg*(2D-1)/D,$$

[0292] Vo: output voltage; D: duty cycle; Vg: input voltage

[0293] Any Watkins-Johnson controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.5 Power Supply Based on Current-fed Bridge Converter (FIG. 38)

[0294]

$$Vo=Vg/(2D-1),$$

[0295] Vo: output voltage; D: duty cycle; Vg: input voltage

[0296] Any current-fed bridge controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.6 Power Supply Based on Inverse of Watkins-Johnson Converter (FIG. 39)

[0297]

$$Vo=Vg*D/(2D-1),$$

[0298] Vo: output voltage; D: duty cycle; Vg: input voltage

[0299] Any Inverse of Watkins-Johnson controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.7 Power Supply Based on Cuk Converter (FIG. 40)

[0300]

$$Vo=-Vg*D/D',$$

[0301] Vo: output voltage; D: duty cycle; D'=1−D; Vg: input voltage

[0302] Any Cuk controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.8 Power Supply Based on SEPIC Converter (FIG. 41)

[0303]

$$Vo=Vg*D/D',$$

[0304] Vo: output voltage; D: duty cycle; D'=1−D; Vg: input voltage

[0305] Any SEPIC controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.9 Power Supply Based on Inverse of SEPIC Converter (FIG. 42)

[0306]

$$Vo=Vg*D/D',$$

[0307] Vo: output voltage; D: duty cycle; D'=1D; Vg: input voltage

[0308] Any Inverse of SEPIC controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

II-3.10 Power Supply Based on Buck Square Converter (FIG. 43)

[0309]

$$VO=D*D$$

[0310] Vo: output voltage; D: duty cycle; Vg: input voltage

[0311] Any Buck square controller with any control way that can convert DC sinusoidal voltage to DC constant voltage can be used as controller **209**.

[0312] Other non-isolated topology controller with any control which can convert DC sinusoidal voltage to DC constant voltage can also be used as controller **209**.

[0313] Controller **209** can use all kinds of control method such as digital control, analog control, DSP, SmartSkip Mode, LinkSwitch-XT or LinkSwtich-TN mode etc.

[0314] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Moreover, the converter topologies discussed above can be used within power supplies to supply power to devices other than lamps—For example, Bus AC to DC converter, PFC converter, PFC converter for lighting, Computer power supply, Monitor power supply, notebook adapter, LCD TV, AC/DC adapter, Adjusted output voltage Battery charger, Power tool charger, Electronic ballast, Video game power supply.

What is claimed is:

1. A power supply operable to convert AC sinusoidal voltage in wide range voltage (input voltage) into a constant DC voltage having a predetermined value with Feedback with PFC function or without PFC function.

The DC voltage value can be lower than input AC peak voltage or higher than input AC peak voltage or equal to input AC peak voltage.

Normal operating without dimming, Vout=rating voltage of lamp;

Dimming operating, Vout=dimming voltage set by potentiometer.

Feedback signal is fed from voltage divider of secondary output voltage to feedback pin of controller **209** as in FIG. **7** or the feedback signal can be coupled to primary from secondary or secondary output voltage divider by opto-coupler, signal transformer, auxiliary winding or digital isolator IC etc and then send to feedback pin of controller **209** as in FIG. **7**.

Potentiometer (rheostat) voltage divider functions as dimming function and set dimming level.

The power supply of claim 1 has one stage converter operable to transfer DC sinusoidal voltage into a DC constant voltage at predetermined value.

Before, two stages of converters were applied to realize same function as power supply of claim 1, especially when converting a high input AC sinusoidal line voltage to a low DC constant voltage less than peak input voltage of AC line.

The first stage is a boost AC to DC converter that can only convert an Ac input line voltage to a DC constant voltage higher than or equal to input peak voltage of AC line. Boost converter can have PFC or have no PFC function.

The second stage is a DC-to-DC converter that can convert a high DC voltage to a low DC voltage.

Traditional two stage circuits have higher cost and lower efficiency. So the power supply of claim 1 saves the cost and increases the efficiency to maximum extent.

2. Power supply of claim 1 can be applied directly on second category lamp. Lamps have two categories:

First category uses ballast to strike the lamp to start. Most of them use gas to create light such as Fluorescent, HID, Compact, metal halide lamp etc. Bulbs need ballast because they use gas to create light. When the gas is excited by electricity, it emits invisible ultraviolet light that hits the white coating inside the bulb. The coating changes the ultraviolet light into light you can see. It needs a very high voltage strike to startup the operation of the lamp. But my invention is not applied directly to this category. The invention must be combined with second stage ballast to drive the lamp.

Second category doesn't need ballast to start the lamp. Most of them use heat generated by filament or diode etc to create light. Such as Halogen, Incandescent, LED, PAR lamp, miniature sealed beam lamp, Projection lamp, automotive lamp, some stage and studio lamp, DC fluorescent lamp etc. They can use as Lamp **211**.

My patent (power supply of claim 1) can be used directly on second category lamp.

3. Power supply of claim 1 has protection to eyesight and people's health to maximum extent for lamp has constant DC level output voltage that does not contain low frequency or high frequency voltage component.

Brightness of lamp is proportional to applied voltage magnitude.

For example, higher voltage causes higher brightness in second category lamp of claim 2 (such as halogen lamp).

60 Hz or 50 Hz sinusoidal voltage applied on lamp will cause lamp brightness to change 60 or 50 times per second because 60 Hz or 50 Hz sinusoidal voltage will change magnitude 60 or 50 times per second.

Low frequency light cause eyes pupil and crystalline lens will adjust 60 times, 120 or many times per second to cause eyes tired. Pupil open wide and crystalline lens adjust to collect more light to focus on retina for seeing clearly at weak light while pupil open narrow and crystalline lens adjust to collect less light to focus on retina at strong light to prevent retina from strong light harm and hurt.

In the long run, muscles to control pupil and crystalline lens become very tired and become flabby. Then the muscle can't adjust pupil and crystalline according to distance and brightness so that myopia is caused.

To relieve eye's tiredness, current technology for fluorescent lamp uses high frequency voltage in a DC envelope. High frequency voltage causes lamp brightness changes too fast. Eyes can not adjust fast enough to follow the brightness change of lamp for high frequency voltage. But high frequency large current on the secondary cause high EMI that has risk to harm people's health.

High frequency light causes EMI issue.

Peoples' eyes can't keep up with high frequency light. Peak strong light shine on the retina for pupil can't shrink at high frequency light. In the long run, retina will be harmed and affect eyesight, cornea dryness or crystalline lens opacity is caused.

On the market, most of filament lamp use power supply that contains 60 Hz or 50 Hz low frequency component; Lamps such as fluorescent that needs high voltage strike use power supply containing high frequency component.

My invention of power supply lamp has only DC constant voltage on lamp. Lamp's brightness is constant and has no low frequency or high frequency component. Thus peoples' eyes and health are protected to maximum extent.

4. The power supply of claim 1 is comprising: (refer to FIG. **7**)

In one implementation, power supply **200** includes an RF**1201**, an input filter **202**, a rectifier **203**, a one stage substantially DC sinusoidal to DC constant voltage converter **206**, a controller **209**, feedback and dimmer circuit **205**, sample circuit **207**, active startup circuit **208** and lamp **211**. Some circuit may have more or less block. In some application, **208** or main switch of **206** can be integrated into IC controller **209**. Or other block can be integrated into one IC.

Each block can use all kinds of different circuits with similar function as the following.

An input voltage (**210**) has AC sinusoidal waveform. It could come from 50 Hz 220VAC or 60 Hz 110VAC etc sinusoidal power system line voltage or other voltage sources (AC or DC);

Input RF**1201** provides input current protection for converter **200**. In particular, in one implementation, input fuse is designed to provide current protection for converter **206** by cutting off current flow to converter **206** in an event that current being drawn through input fuse **201** exceeds a predetermined design rating.

In another implementation, RF**1201** is a flameproof, fusible, wire wound type and functions as a fuse, inrush current limiter.

In another implementation, RF**1201** can be a NTC or PTC thermistor. (Negative temperature coefficient thermal resistor or Positive temperature coefficient thermal resistor)

Input filter **202** minimizes an effect of electromagnetic interference (EMI) on power supply **200**, converter **206** and exterior power system.

Input filter **202** can be LC filter, π filter, differential mode filter, common mode filter or any type of filter that provides a low impedance path for high-frequency noise to protect power supply **200** and exterior power system from EMI.

Input filter **202** can be placed in front of rectifier **203** or behind rectifier **203**.

Rectifier **203** is any type of rectifier that converts the input sinusoidal AC source voltage (like FIG. **8** in one implementation) from voltage source **210** into a substantially DC sinusoidal voltage (like FIG. **9** in one implementation).

In one implementation, rectifier **203** is a full-wave rectifier that includes four rectifiers in a bridge configuration.

In another implementation, rectifier **203** contains **2** diodes as shown in FIG. **29**. In another implementation, rectifier **203** can use bridgeless PFC.

One stage DC sinusoidal to constant DC converter **206** converts the substantially DC sinusoidal voltage (like

FIG. **9**) received from rectifier **203** into a DC constant voltage at predetermined value suitable to support an output device (e.g., halogen lamp **211**).

In one implementation, converter **206** converts the substantially DC sinusoidal voltage received from rectifier **203** into DC constant voltage. For example 12 volts (FIG. **10**). Usually the input voltage source **210** comes from 60 Hz 110v AC or 50 Hz 220v AC sinusoidal line voltage (FIG. **8**) in power system.

Controller **209** is operable to control an output voltage level of converter **206**.

In one implementation, controller **209** is operable to adjust the duty cycle, on time of main switch or switching frequency of converter **206** so that converter **206** outputs a DC constant output voltage having a predetermined voltage value.

The controller **209** can use all kinds of method, mode and control to regulate a DC constant voltage at predetermined level. Such as digital control, analogy control, DSP, bang-bang control, skipping switching cycles as in LNK302/304-306, Pulse Train control as in IW2210 etc.

The controller **209** operable to realize PFC function (When using IW2202 controller, it is realized with pins VinAC and VinDC) or without PFC finction; The controller **209** operable to realize current limit protection and short circuit protection (When using IW2202 controller, it is realized with pin Isense;) Of course, controller **209** also can realize such functions as OVP-over voltage protection, OTP-over temperature protection, SCL-Secondary-side current limit) etc.

Controller **209** can also be a linear control type controller, PWM controller or PFC controller etc. Controller **209** can control an output voltage level of converter **206** responsive to a predetermined value set by potentiometer voltage divider. Feedback control voltage comes from feedback and dimmer circuit **205** as discussed in greater detail below.

Sample **207** sense the signal proportional to output DC constant voltage. Such as auxiliary winding, opto-coupler, voltage divider, digital isolator or voltage divider on output etc

Feedback and dimmer circuit **205** is operable to provide a feedback dimming control voltage to controller **209** for dimming (or decreasing) output voltage (e.g., lamp **211**) by changing potentiometer value to set predetermined output value (Vset).

When Vout is greater than Vset, Feedback signal on FB pin of controller is compared to interior reference. Then duty cycle, frequency or switch mode etc are changed to decrease output voltage until Vout equals to Vset;

When Vout is lower than Vset, Feedback signal on FB pin of controller is compared to interior reference. Then duty cycle, frequency or switch mode etc are changed to increase output voltage until Vout equals to Vset;

Thus, the output voltage is regulated at set value by Feedback.

Normal operation, the predetermined value Vset is set to lamp rating voltage.

Dimming, the predetermined value Vset is set to lower than lamp rating voltage.

In one implementation, **205** can be realized by a resistor voltage divider composed of potentiometer and resistor (or zenor diode and resistor voltage divider composed of potentiometer and resistor) and voltage across one resistor or secondary is coupled to Feedback pin of controller **209** by opto-coupler, signal transformer, auxiliary winding, digital isolator or voltage divider on output etc). as in FIG. **12**,**13**,**14**,**15**,**16**,**17**,**24**,**25**, **27**,**28**, **29**,**31**,**32**,**33** etc

An Active startup circuit **208** is operable to startup the circuit before power supply operates normally. **208** can use different circuits as shown in FIG. **20**,**21**,**22** etc or other circuits. Sometimes, it is integrated with controller **209** in one IC.

A lamp **211** can be any lamp without requirement for high voltage strike start as second category lamp in claim 2.

The power supply of claim 1 can contain more blocks or less blocks than blocks shown in FIG. **7**. Some blocks can be integrated into one block or some blocks can be integrated into one IC. Block sequence can be changed. The power supply of claim 1 can be realized by discrete components. The power supply of claim 1 can have no external compensation components or have external compensation components.

5. The controller **209** of power supply of claim 1 can have PFC function as in IW2202 etc and no PFC function as in IW2210, iW1688, LNK362-364 and LNK302/304-306 etc.

PFC function guarantees power factor is always almost unity at normal operating or dimming. That is input sinusoidal current is always in phase with input sinusoidal voltage. That will increase power quality for the power system. The power supply of claim 1 realizes green mode efficiency with PFC function.

PFC can be realized by multiplier in controller or by μPFC (Integrator with Reset) such as in IR1150 OR DSP, digital control as in IW2202 or any method.

6. The power supply of claim 1 has dimming and feedback function that keep output voltage at a DC constant value Vo set by potentiometer or signal; Dimming signal can come from wireless controller or power line communication. Feedback can be voltage feedback, current feedback or power feedback etc

(6.1) The power supply of claim 1 with IW2202 as controller **209** is shown in FIG. **12**,**13**,**14**; In real application, component can be more or less than FIG. **12**,**13**,**14**. Components code or value maybe different from FIG. **12**,**13**,**14**. Components connect way can be different from FIG. **12**,**13**,**14**.

In FIG. **12**, the voltage Va coupled on auxiliary winding in sample circuit is proportional to Vo (Va=Vo*Na/Ns Na is turns of auxiliary winding; Ns is turns of secondary winding, Vo is output voltage). Vo is less than or equal to lamp rating voltage. Then a voltage divider get a sample voltage Vsense=Va*Voltage divider ratio (R**12**/(R**12**+R**15**+R**6**)) and compare Vsense with interior reference voltage Vinterior ref.

If Vo is larger than predetermined value, then Vsense is greater than Vinterior ref, the controller **209** will adjust duty cycle, switching frequency or switch mode of main switch in converter **206** until Vo decreases to predetermined value.

If Vo is less than predetermined value, then Vsense is less than Vinterior ref, the controller **209** will adjust duty cycle, switching frequency or switch mode of main switch in converter **206** until Vo increases to predetermined value. Thus feedback function keeps output Voltage at a predetermined DC constant level.

For steady operation, Vsense=Vinterior ref.

$$V\text{sense}=Va*(R12/(R12+R15+R6))=Vo*(Na/Ns)*(R12/(R12+R15+R6))$$

$$\text{So } Vo=V\text{interior } ref*Ns*(R12+R15+R6)/R12/Na$$

$$Vo=V\text{interior } ref*(Ns/Na)*(1+(R15+R6)/R12).$$

Knowing Vinterior ref, we can regulate Vo by select value of Ns,Na,R**15**,R**6**,R**12** etc;

The feedback circuit of claim 1 also finctions as dimming circuit. Any one of R**15**, R**6** or R**12** can be a potentiometer (Analog potentiometer or digital potentiometer). We can change the potentiometer value to decrease Vo to realize dimming. For example, R**12** is a potentiometer. We can increase R**12** to decrease Vo to realize dimming. If R**15** or R**6** is a potentiometer, we can decrease R**15** or R**6** resistance to decrease output voltage for dimming at predetermined level.

(6.2) The power supply of claim 1 with IW2210 as controller **209** is shown in FIG. **15**,**16**,**17**.

In real application, component can be more or less than FIG. **15**,**16**,**17** and component value maybe different from components in FIG. **15**,**16**,**17**. Components connect way can be different from FIG. **15**,**16**,**17**.

In FIG. **15**, the voltage cross primary winding is Vo*n. (Vo is output DC voltage and n is transformer turns ratio n=np/ns, np is primary turns; ns is secondary turns).

The voltage coupled cross auxiliary winding is Vo*Na/Ns. Voltage on

$$V\text{sense}=(Vo*Na/Ns)*R11/(R9+R10+R11).$$

Power pulse, sense pulse and Power skip mode keep output voltage constant. The feedback guarantees the output voltage is constant at predetermined value.

$$V\text{sense}=(Vo*Na/Ns)*R11/(R9+R10+R11)=V\text{interior } ref.$$

(Vinterior ref is interior reference voltage).

$$Vo=V\text{interior } ref*(Ns/Na)*[(R9+R10)/R\ 11+1].$$

In one implementation, R**11** is a potentiometer. So increase R**11** value to decrease Vo to realize dimming with feedback. If R**9** or R**10** is a potentiometer, then decrease R**9** or R**10** value to decrease Vo to realize dimming.

The power supply of claim 1 can realize dimming with LNK302/304~306 and LNK362-364 etc.

(6.3) Power supply of claim 1 realized dimming with LNK302/304~306 shown in FIG. **27**,**28**,**29**,**31**,**32**,**33** in one implementation.

In real application, component can be more or less than FIG. **27**,**28**,**29**,**31**,**32**,**33** and component value maybe different from components in FIG. **27**,**28**,**29**,**31**,**32**,**33**. Components connect way can be different from FIG. **27**,**28**,**29**,**31**,**32**,**33**.

Dimming Feedback type**1** use voltage divider with potentiometer.

Dimming Feedback type**2** use voltage divider with potentiometer and zener diode or voltage reference.

For isolated converter, optocoupler, signal transformer, digital isolator can be used with type**1** and type**2** circuit.

The current goes into FB pin is proportional to output voltage. Regulation is maintained by skipping switching cycles. As the output voltage rises, the current into the FB pin will rise. If this exceeds Ifb (means output voltage is larger than predetermined voltage value) then subsequent cycles will be skipped until the current reduces below Ifb. Vice versa.

Thus, as the output load is reduced, more cycles will be skipped and if the load increases, fewer cycles are skipped.

So we adjust voltage divider value to adjust current into FB pin to regulate output voltage at predetermined value.

(6.4) The power supply of claim realizes dimming with LNK362-364 shown in FIG. **25** in one implementation.

In real application, component can be more or less than FIG. **25** and component value maybe different than components in FIG. **25**. Components connect way can be different from FIG. **25**.

Dimming Feedback type**1** use voltage divider with potentiometer.

Dimming Feedback type**2** use voltage divider with potentiometer and zener diode or voltage reference.

For isolated converter, opto-coupler, signal transformer, digital isolator can be used with type**1** and type**2** circuit.

When the output voltage is larger than predetermined value, current fed into the FEEDBACK pin of U**1** (controller) increases until the turnoff threshold current is reached, disabling further switching cycles of U**1**, the output voltage is decreased until output voltage decreases to predetermined value. Vice versa.

So we adjust voltage divider value to adjust current into FB pin to regulate output voltage at predetermined value to realize dimming.

7. In the power supply of claim 1, in one implementation. Active startup circuit is used to start up the circuit when using IW2202 as controller. Active startup circuit can be integrated into IC controller.

In real application, component can be more or less than FIG. **20**,**21**,**22** and component value maybe different than components in FIG. **20**,**21**,**22**. Active startup circuit is integrated in controller in other implementation. FIG. **20**,**21**,**22** has similar function. So we discuss with FIG. **20**. FIG. **20** shows an active startup circuit. ASU pin is designed to drive the Mosfet of the active startup circuit. An external zener Z**1** diode is to clamp the ASU pin. Before startup, ASU is floating. Once a voltage is supplied to Vg(t) (DC sinusoidal voltage after bridge rectifier like FIG. **9**). The gate capacitor C**31** starts to charge via the startup resistor R**31**. When Vcc reaches the threshold voltage of Q**2**, transistor Q**2** conducts. (Q**2** can be NPN transistor or N channel Mosfet). The startup capacitor C**32** starts to be charged via the charge resistor R**32** and R**33** (R**32** can be removed). When Vcc reaches the startup threshold voltage, controller (IW2202) starts operating. Converter main switch Q**1** switches and auxiliary winding has voltage coupled from secondary output. ASU goes low, thus turns off Q**2**. Vcc is supplied from C**32** that is charged by auxiliary winding and D**4**. Thus, supply voltage for PWM (IW2202) no longer uses linear regulator Q**2** and the efficiency is improved. FIG. **23** Startup Timing Diagram on pins of IC controller shows that. By select auxiliary winding and secondary winding turns ratio carefully, we guarantee the voltage on the auxiliary winding during minimum dimming is larger than Vcc threshold+Voltage drop on D**4**; We guarantee the voltage on the auxiliary winding during normal operating is not high enough to damage R**33** and Z**2**. Thus, we can guarantee PWM(IW2202) works well no matter in normal operation or dimming. Q**2** can be a bipolar transistor; We can also connect a resistor between ASU pin and base of bipolar transistor. Some circuit may not need active startup circuit. Some circuits integrate active startup circuit in the controller.

Active startup circuit can also use topology as FIG. **20**,**21** or **22**. Or even some circuit has more or less component as FIG. **20**,**21** or **22**. Or component code or values may be different from FIG. **20**,**21**,**22**. Or some components are integrated in IC. Active startup circuit may use components in different connection way from FIG. **20**,**21**,**22**.

Active startup circuit can use other circuit different from FIG. **20**,**21** or **22**; such as valley filled circuit, linear regulator or battery etc.

8. In the power supply of claim 1 has current limit protection.

In one implementation using IW2202 as controller **209**, the primary peak current is limited by the Isense threshold voltage on a cycle-by-cycle basis. Isense pin is connected to the current sense resistor between ground and source of main switch Q**1**. At the moment the voltage level at Isense reaches the threshold, the main switch Q**1** turns off, the minimum on-time is 180 ns. We can also use current sense transformer to replace current sense resistor. Secondary is rectified by a diode and connect to a resistor, then the voltage on the resistor is sent to Isense pin.

IW2210 also limits peak current cycle-by-cycle, it terminates the ON-time of the MOSFET if the current sense signal reaches its threshold.

LNK 302/304-306 and LNK362-364 have current limit circuit senses the current in the power MOSFET. When this current exceeds the internal threshold (Ilimit), the POWER MOSFET is turned off for the remainder of that cycle. The leading edge blanking circuit inhibits the current limit comparator for a short time (tleb) after the power MOSFET is turned on. This leading edge blanking time has been set so that current spikes caused by capacitance and rectifier reverse recovery time will not cause premature termination of the switching cycle.

9. The power supply of claim 1 has short circuit protection function in controller in one implementation (as LNK302/304-306 and LNK362-364 etc); The power supply of claim 1 has short circuit protection with Isense pin in one implementation as IW2202 and IW2210 etc, When short circuit happens, large current goes through main switch, Isense or controller interior circuit detect the large current and shuts down the main switch. In LNK302/304-306 or LNK362-364, when the current in Mosfet is larger than internal threshold, the power Mosfet is turned off for the remainder of that cycle.

For example, in IW2202, A short circuit condition on the DC supply output will cause a significant change of the output voltage. This change is detected typically within 10~20 us by the Vsense signal. There are two conditions for output short-circuit detection as in IW2202.

(1) Vsense detects the rise of the DC supply output. If Vsense is less than 0.5V (typical) within 60 ms of the first OUTPUT pulse, the controller detects this as a short circuit condition and shuts down in a non-latched mode.

(2) After start-up, if the pulse width of Vsense is larger than 23 us for 2 consecutive cycles, the controller detects a short circuit condition and shuts down in a non-latched mode.

10. The power supply of claim 1 can have over voltage protection.

The signal of auxiliary winding passes diode D**4** and a voltage divider then send to pin SD in IW2202 or OVP/OTP pin in IW2210.

If the voltage on SD or OVP/OTP pin exceeds the threshold voltage, the train of output pulses stops and the controller is latched off in one implementation or automatic restart in one implementation.

In one implementation with IW2210 as FIG. **15**, OVP is realized by voltage divider R**6**,R**7**,R**8** with auxiliary winding Na. When the output voltage is higher than threshold, the voltage coupled on the auxiliary winding is also higher than some value. Then the voltage sensed on OVP/OTP pin is higher than interior threshold. So the controller performs a latched shutdown operation which turns off the power supply. The operation resumes after cycling of the input line voltage.

LNK302/304-306 and LNK362-364 realize OVP with FB pin. Over voltage cause large current larger than threshold into FB pin. Then controller shuts down switch MOSFET. Thus output voltage will go down.

11. The power supply of claim 1 can have over temperature protection (OTP) function with SD pin in IW2202 or OVP/OTP pin in IW2210. OTP circuit is integrated in controller in LNK302/304-306 and LNK362-364 etc which senses the die temperature. A voltage divider composed of a thermistor and a resistor is connected to SD pin in IW2202 or OVP/OTP pin in IW2210. When the temperature goes high, thermistor value has catastrophe change, the voltage on the SD pin exceeds the threshold, the controller goes into a latched shutdown mode. Of course, a transistor or a Mosfet can be used with thermistor and resistor to realize same function.

12. The power supply of claim 1 can be parallel with the same power supply as claim 1 to minimize ripple. Output inductor is coupled or not coupled. Two controllers can be synchronized or not. Or even three or more power supplies of claim 1 are paralleled to minimize the ripple. (Input is connected together; Output is connected together.) Three or more controllers can be synchronized, not synchronized or multiphase control.

13. The secondary diode in power supply of claim 1 can be replaced by a Mosfet Q**3** (Synchronized rectifier). When main switch Q**1** is on, Q**3** is off; When main switch Q**1** is off, Q**3** is on. The gate signal of Q**3** can come from signal transformer, digital isolator IC, auxiliary winding or secondary winding or secondary IC controller etc

14. A filter in power supply of claim 1 can be connected between secondary diode and output lamp. The filter can be π filter, LC filter, differential mode filter, common mode filter or any kind of filter. The output filter can be a two winding transformer with opposite polarity winding. Top winding left is connected to secondary diode cathode; Top winding right is connected to output. Bottom winding left is connected to anther diode D**5** cathode, bottom winding right is connected to output. The anode of D**5** can connect to ground or another converter's secondary winding to minimize ripple.

15. In one implementation of power supply of claim 1, the main switch can be integrated in the controller as LNK302/304-306 or LNK362-364 in the power supply of claim 1. Other circuit or block can be integrated into IC controller such as active startup circuit **208**.

16. In power supply of claim 1, the switching power supply can be installed in the metal lampstand. The insulation is applied between metal lampstand and switching power supply converter. Thus EMI will be shielded and be prevented from going outside.

17. The one stage AC to DC converter in power supply of claim 1 can be realized by flyback topology with IW2202 controller and IW2210;

The one stage AC to DC converter in power supply of claim 1 can be realized with LNK302/304-306 or LNK 362-364. Component code, value or connection way may be different from FIG. **12**,**13**,**14**,**15**,**16**,**17**,**24**,**25**,**27**,**28**,**29**,**31**,**32**,**33** etc.

The one stage converter **206** in power supply of claim 1 can use

Buck, Boost, Buck-boost, Noninverting buck-boost , H-Bridge, Watkins-Johnson, Current-fed bridge, Inverse of Watkins-Johnson, Cuk, SEPIC, Inverse of SEPIC, Buck square, full bridge, half bridge, Forward, Two-transistor Forward, Push-pull, Flyback, Push-pull converter based on Watkins-Johnson, Isolated SEPIC, Isolated Inverse SEPIC, Isolated Cuk, Two-transistor Flyback etc or any topology converter that convert DC sinusoidal voltage (FIG. **9**) to DC constant voltage (FIG. **10**).

Of course controller **209** may be different from IW2202, IW2210, iW1688, LNK302/304-306 or LNK362-364 for other topologies.

In real circuit, the component can be less or more than FIG. **11** to **53** etc. Components value and code can be different from FIG. **11** to **53** etc. Components connect way can be different from FIG. **11** to **53** etc.

18. The AC to DC converter is not used only for lamp. It is can also be used for any device requires DC power supply in all the industrial areas. (Telecommunication, Storage, Personal computer, cell phone power supply and charger, video game etc) For example, Bus AC to DC converter, PFC converter, PFC converter for lighting, Computer power supply, Monitor power supply, notebook adapter, LCD TV, AC/DC adapter, Battery charger, Power tool charger, Electronic ballast, Video game power supply, rotter power supply etc

19. The power supply of claim 1 can also be realized by two stage circuits, for example, PFC converter-first stage; DC/DC converter-second stage.

20. The power supply of claim 1 can also be used as charger with voltage adjustable.

* * * * *

FURTHER READING

Click any one of the following links to be taken to a website which contains the following documents.

There appears to be a lot of recent patent activity in the area of building "bridgeless PFC convertors". The following are some of the patents.

11_584_983_Method_and_apparatus_for_high_efficieny_rectifier
11_204_307_AC_to_DC_power_supply_with_PF
11_302_544_Simple_partial_switching_power_factor_correction
11_474_712_BRIDGELESS_BI_DIRECTIONAL_FORWARD_TYPE_CONVERTER
11_480_004_High_efficiency_power_converter_system
11_706_645_AC_to_DC_voltage_converter_as_power_supply
12_401_983_BRIDGELESS_PFC_CIRCUIT_FOR_CRM
12_798_682_Bridgeless_PFC_converter

3295043_MASSEY_D_C__TO_D_C__REGULATED_CONVERTER
4183079_DC_AC_inverter
4523266_AC_to_DC_conversion_system
4943902_AC_to_DC_power_converter_and_method
5570276_Switching_converter_with_open_loop_input_regulation
5815380_Switching_converter_with_open_loop_Primary_regulation
5815384_Transformer_uses_bi_directional_synch_Rectifiers
6115267_AC_DC_converter_with_no_input_rectifiers
6157182_DC_DC_converter_with_multiple_operating_modes
6608522_DC_to_DC_converter_providing_stable_operation
7250742_Digital_control_of_bridgeless_power_factor_correction
7265591_CMOS_driver_with_minimum_shoot_through

And here is some more information for those who may be interested.

A BIDIRECTIONAL PWM THREE-PHASE STEP-DOWN RECTIFIER
A bidirectional, sinusoidal, high-frequency inverter
A DUAL INPUT BIDIRECTIONAL POWER CONVERTER
A new structure for bidirectional Power flow
BI-DIRECTIONAL INVERTER-CHARGER
Bi-directional single-phase half-bridge rectifier for power quality
BiDirectional Converter
Bidirectional_UP_Inverter
Synthesis of Input-Rectifierless AC/DC

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