US005831395A

United States Patent [19]

Mortimer et al.

[11] Patent Number: 5,831,395

[45] Date of Patent: Nov. 3, 1998

[54] **THREE-WAY FLUORESCENT ADAPTER**

[75] Inventors: **George W. Mortimer**; **Bryce L. Hesterman**, both of Fort Wayne, Ind.

[73] Assignee: **MagneTek, Inc.**, Nashville, Tenn.

[21] Appl. No.: **585,399**

[22] Filed: **Jan. 11, 1996**

[51] **Int. Cl.**[6] **H05B 37/02**

[52] **U.S. Cl.** .... **315/307**; 315/324; 315/DIG. 7; 315/209 R; 315/DIG. 4

[58] **Field of Search** .... 315/201, DIG. 7, 315/308, 307, 209 R, 291, 324, 56, 71, DIG. 4

[56] **References Cited**

U.S. PATENT DOCUMENTS

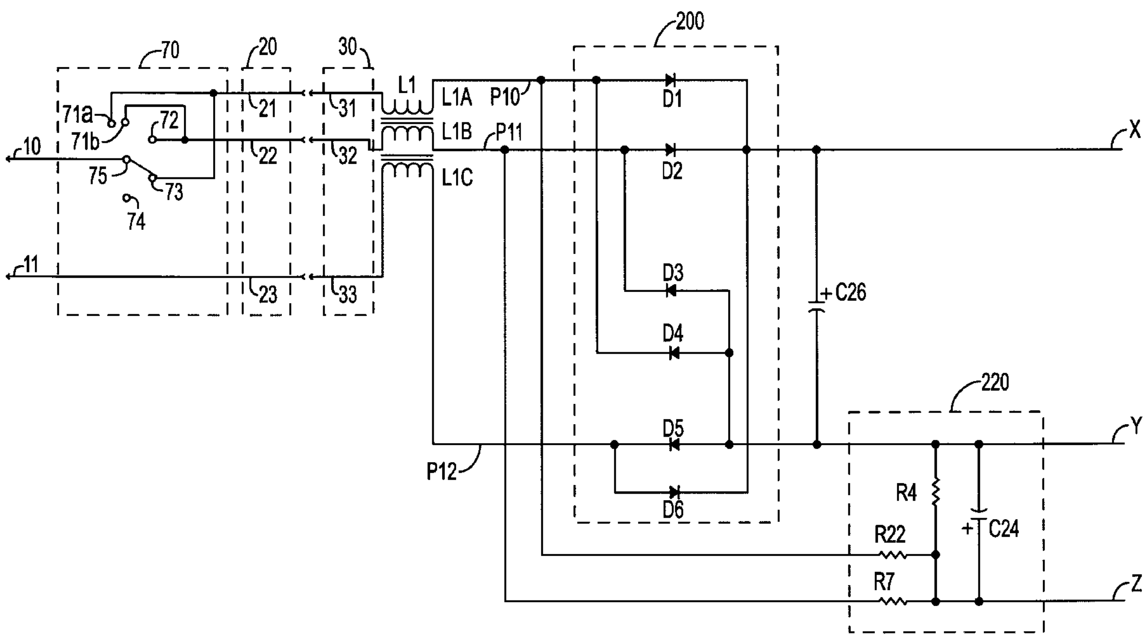
3,028,523	4/1962	Seid	315/201
4,383,204	5/1983	Roberts	315/291
4,950,959	8/1990	Beckrot et al.	315/DIG. 7
4,963,795	10/1990	Nilssen	315/205
5,101,142	3/1992	Chatfield	315/308
5,146,139	9/1992	Nilssen	315/205
5,175,477	12/1992	Grissom	315/291
5,309,062	5/1994	Perkins et al.	315/53
5,341,067	8/1994	Nilssen	315/209 R
5,424,610	6/1995	Pelton	315/58

Primary Examiner—Benny Lee
Assistant Examiner—Michael Shingleton
Attorney, Agent, or Firm—Waddey & Patterson; Mark J. Patterson

[57] **ABSTRACT**

A control circuit and ballasting means controls the light output of a gas discharge lamp in response to switches that are external to the ballast. The invention provides 3 levels of light output with single or multiple lamps. One embodiment of the invention can be mounted in a standard three-way socket for incandescent lamps. Another embodiment can be used to control multiple lamps in a ceiling-mounted fixture, replacing an inboard/outboard configured multiple ballast circuit. Other embodiments provide circuits that allow conventional dimming ballasts which are designed to be controlled with a low-voltage DC input signal to be controlled by a pair of switches connected to an AC power source.

27 Claims, 7 Drawing Sheets



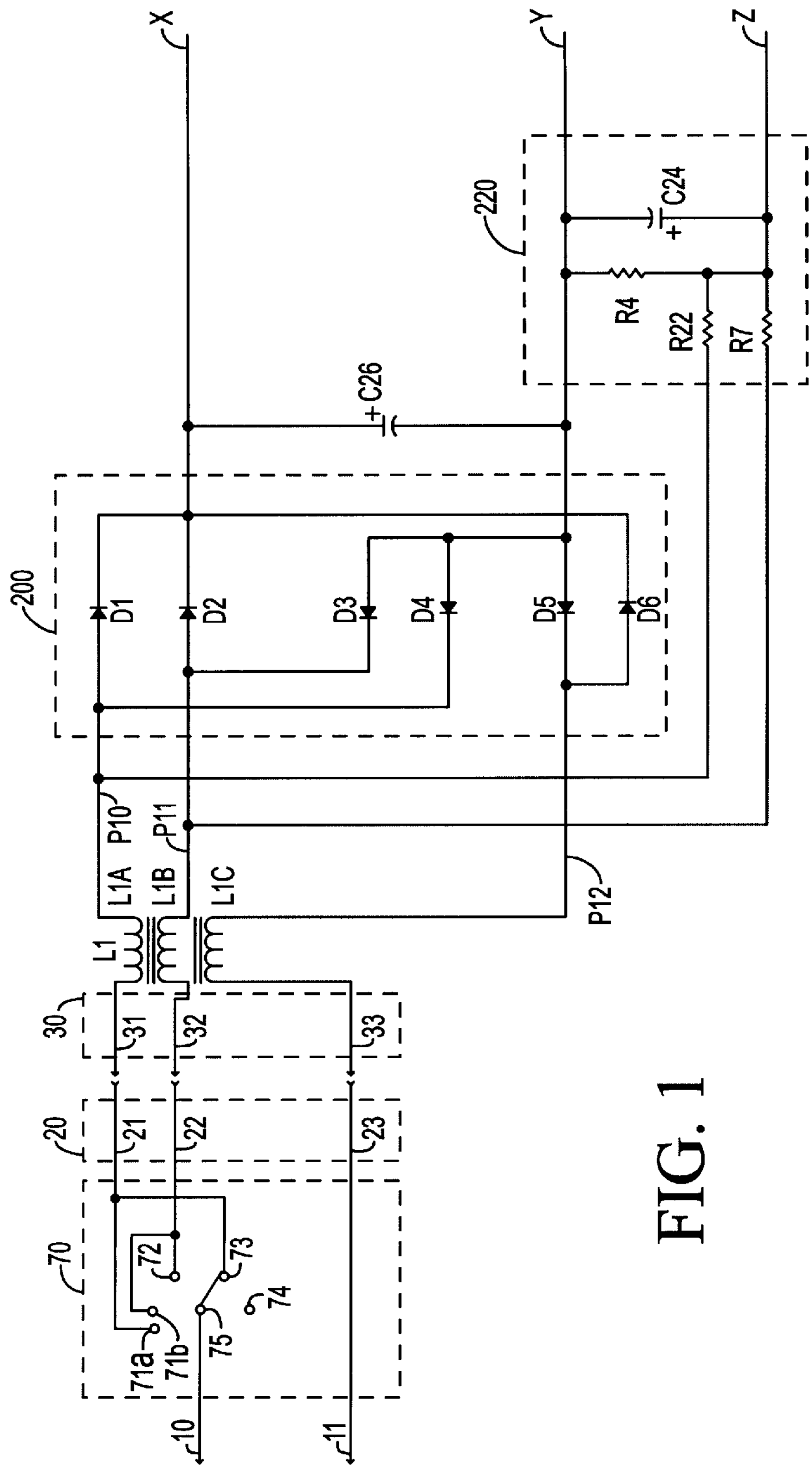

X
Y
Z
220
C24
R4
R22
R7
C26
200
D1
D2
D3
D4
D5
D6
P10
P11
P12
L1A
L1B
L1C
L1
30
31
32
33
20
21
22
23
70
71a
71b
72
73
74
75
10
11

FIG. 1

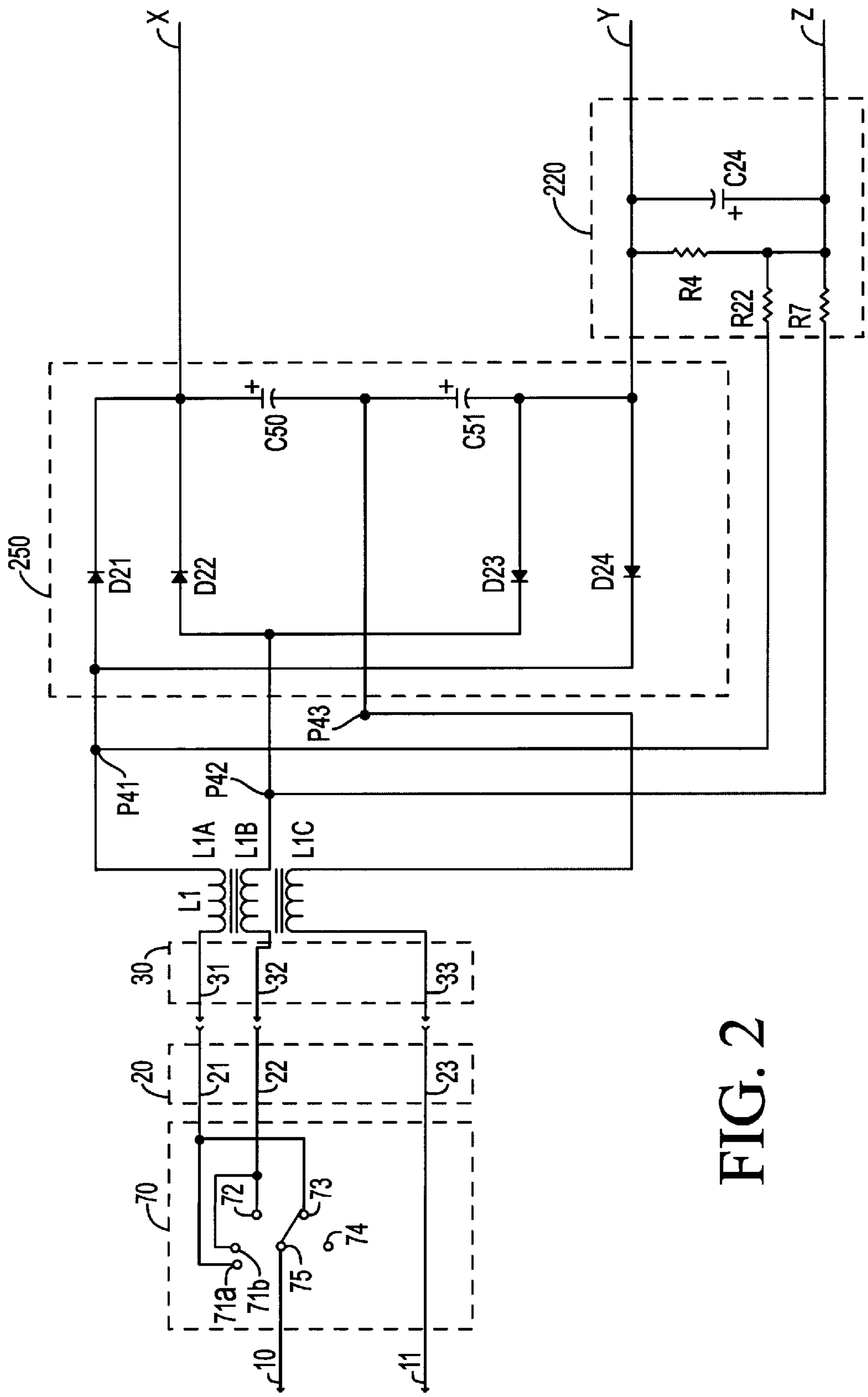

X
Y
Z
220
C24
R4
R22
R7
250
C50
C51
D21
D22
D23
D24
P41
P42
P43
L1
L1A
L1B
L1C
30
31
32
33
20
21
22
23
70
71a
71b
72
73
74
75
10
11

FIG. 2

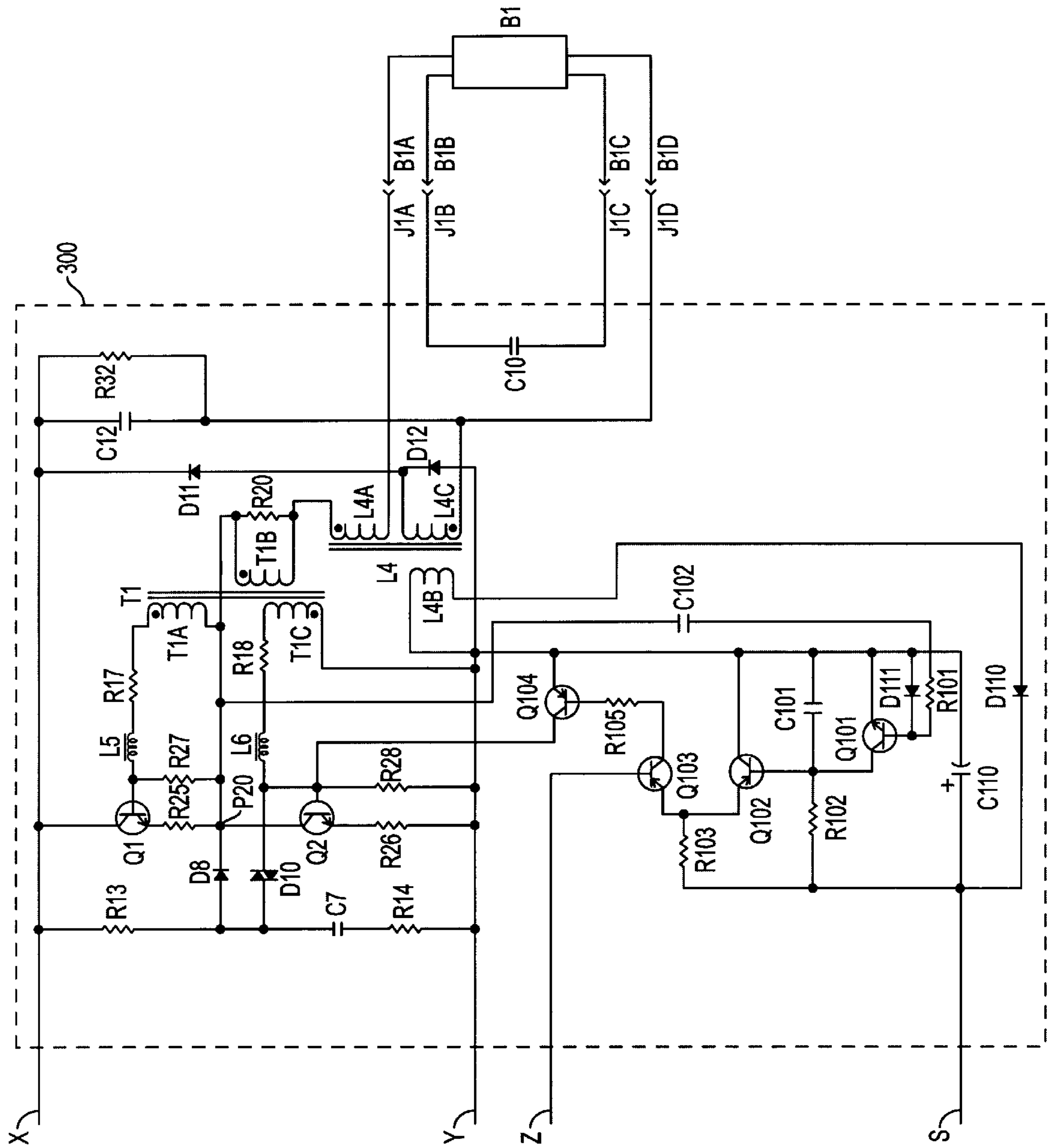

B1
B1A
B1B
B1C
B1D
J1A
J1B
J1C
J1D
300
C10
R32
C12
D11
D12
R20
L4A
L4C
T1B
T1
L4
L4B
C102
T1A
T1C
R18
R17
Q104
D111
R101
C101
D110
L5
L6
R27
R105
Q101
R28
R25
P20
Q103
Q102
Q1
Q2
C110
R26
R102
R103
D8
D10
R13
C7
R14
X
Y
Z
S

FIG. 3

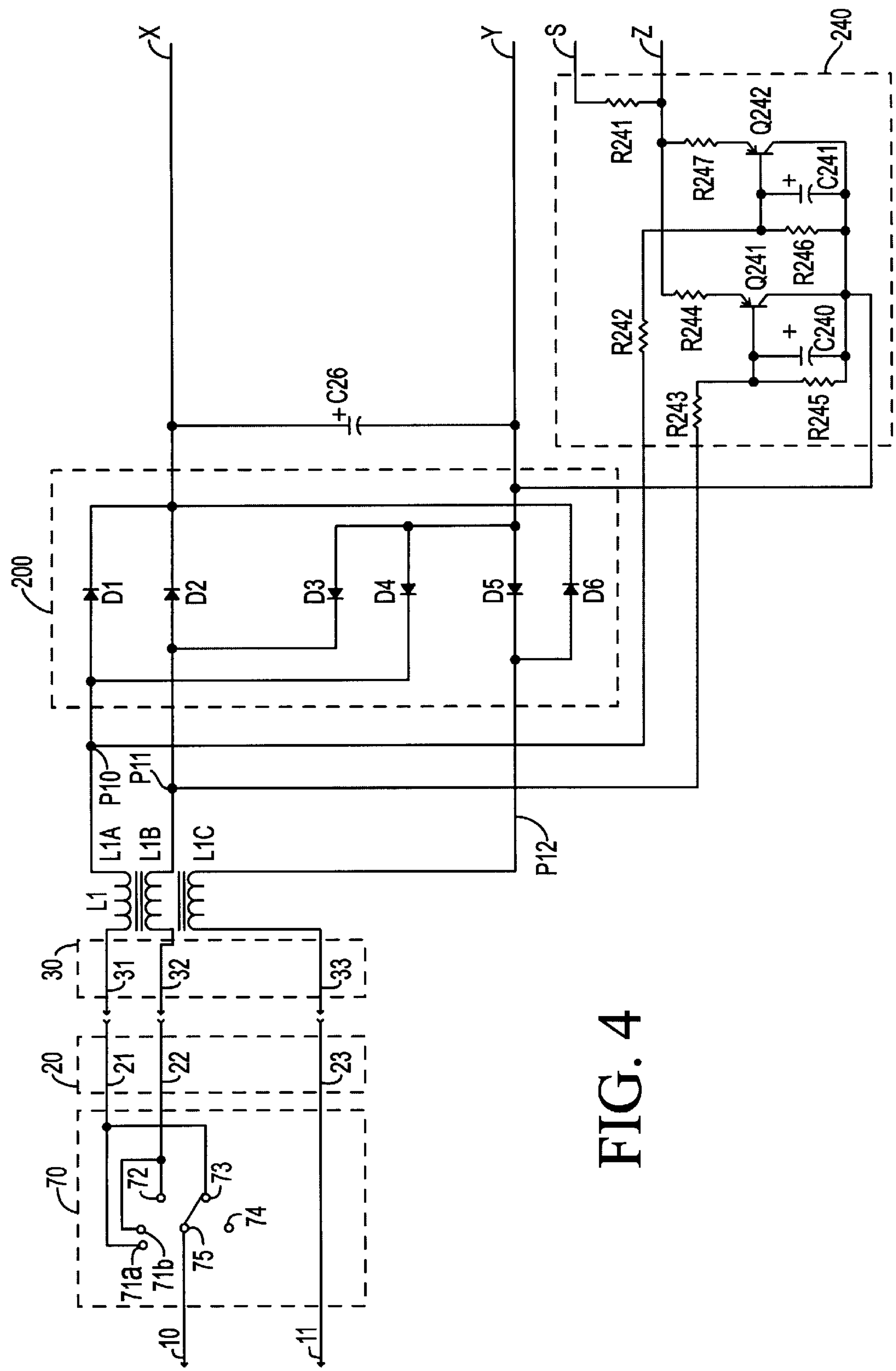

X
Y
S
Z
240
R241
Q242
R247
C241
R246
Q241
R242
R244
C240
R245
R243
C26
200
D1
D2
D3
D4
D5
D6
P10
P11
P12
L1A
L1B
L1C
L1
30
31
32
33
20
21
22
23
70
71a
71b
72
73
74
75
10
11

FIG. 4

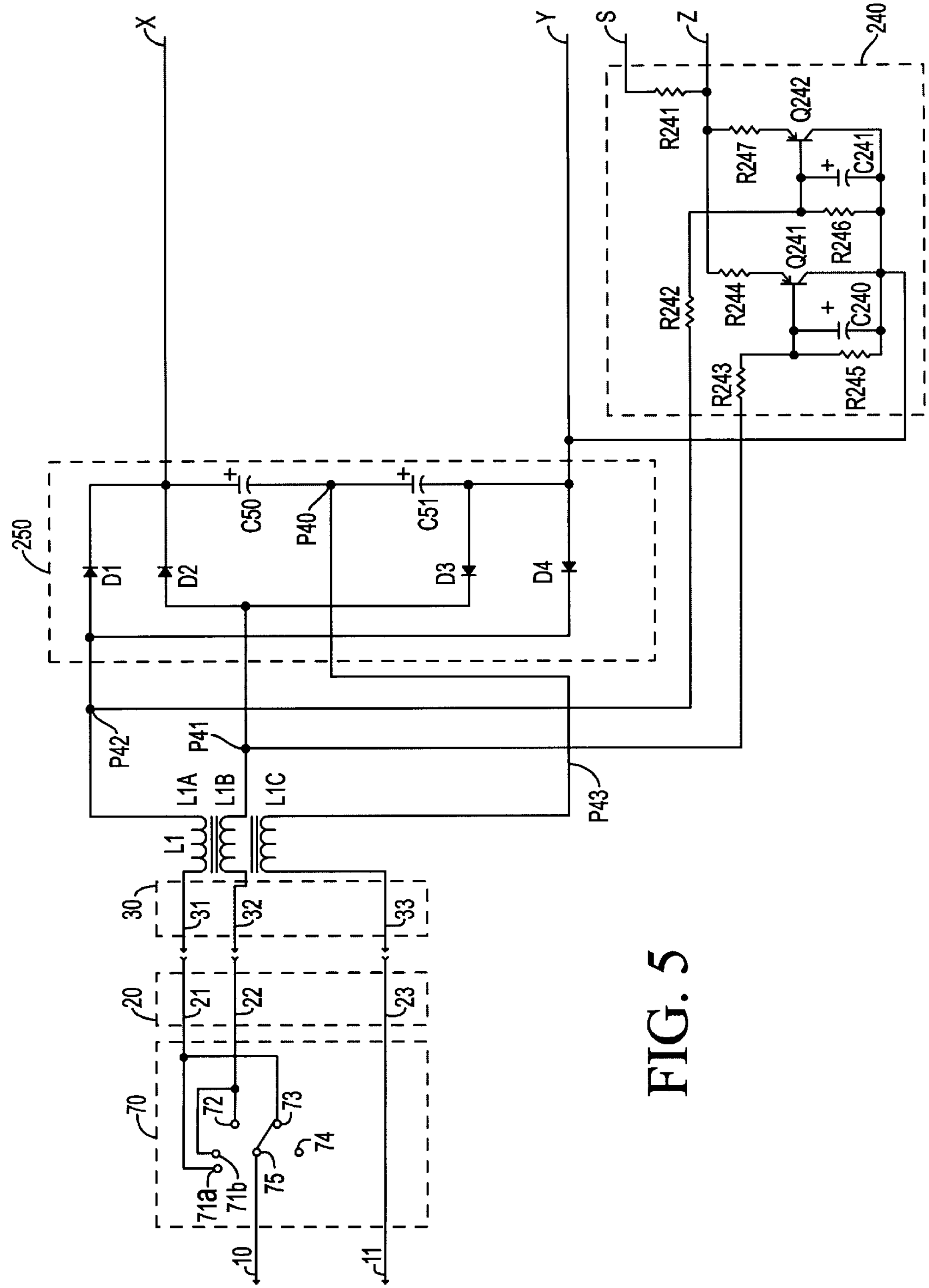

X
Y
S
Z
240
R241
Q242
R247
C241
R246
Q241
R242
R244
C240
R243
R245
250
C50
P40
C51
D1
D2
D3
D4
P42
P41
L1A
L1B
L1C
P43
L1
30
31
32
33
20
21
22
23
70
72
73
74
71a
71b
75
10
11

FIG. 5

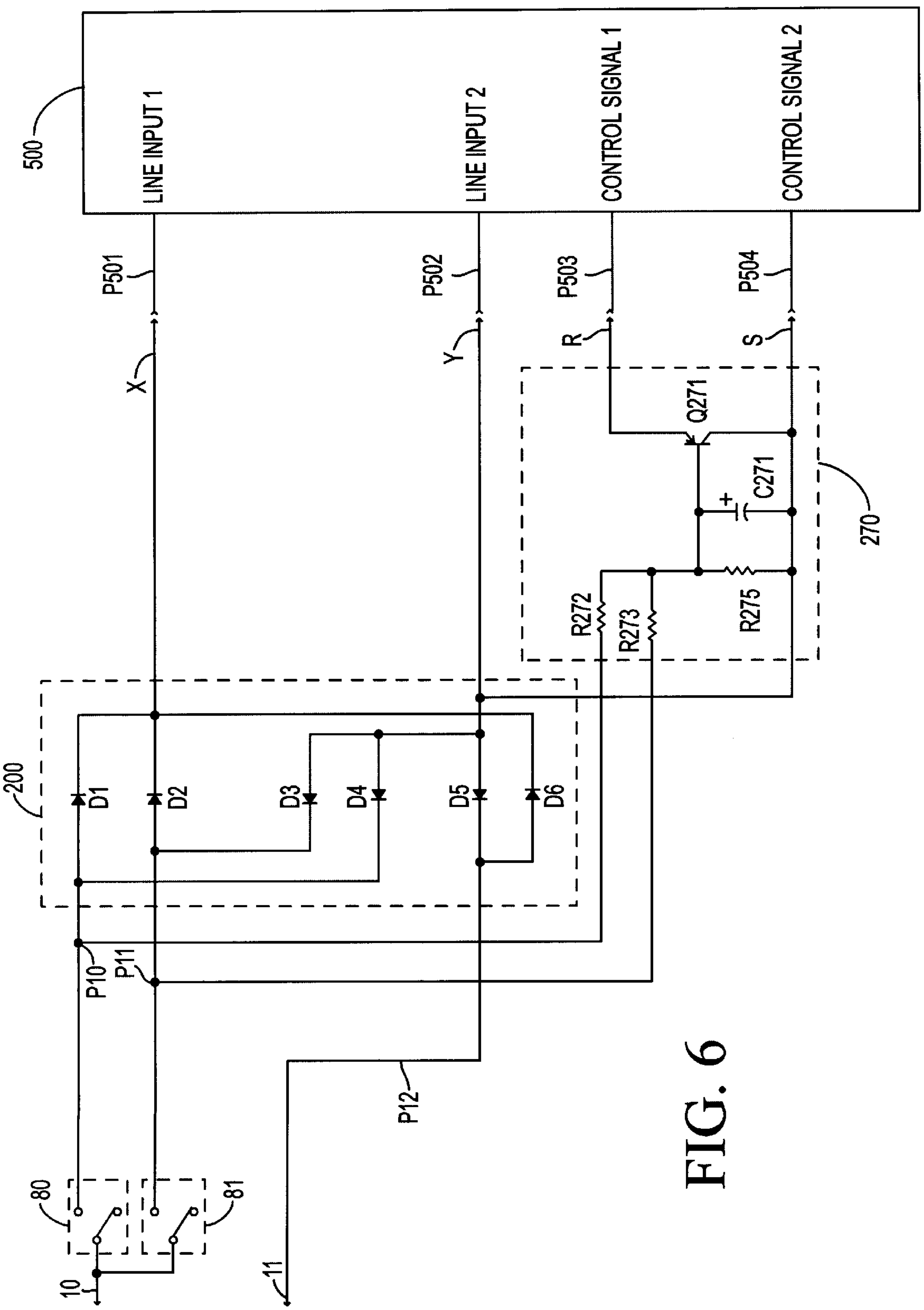

500
LINE INPUT 1
LINE INPUT 2
CONTROL SIGNAL 1
CONTROL SIGNAL 2
P501
P502
P503
P504
X
Y
R
S
Q271
C271
R272
R273
R275
270
200
D1
D2
D3
D4
D5
D6
P10
P11
P12
80
81
10
11

FIG. 6

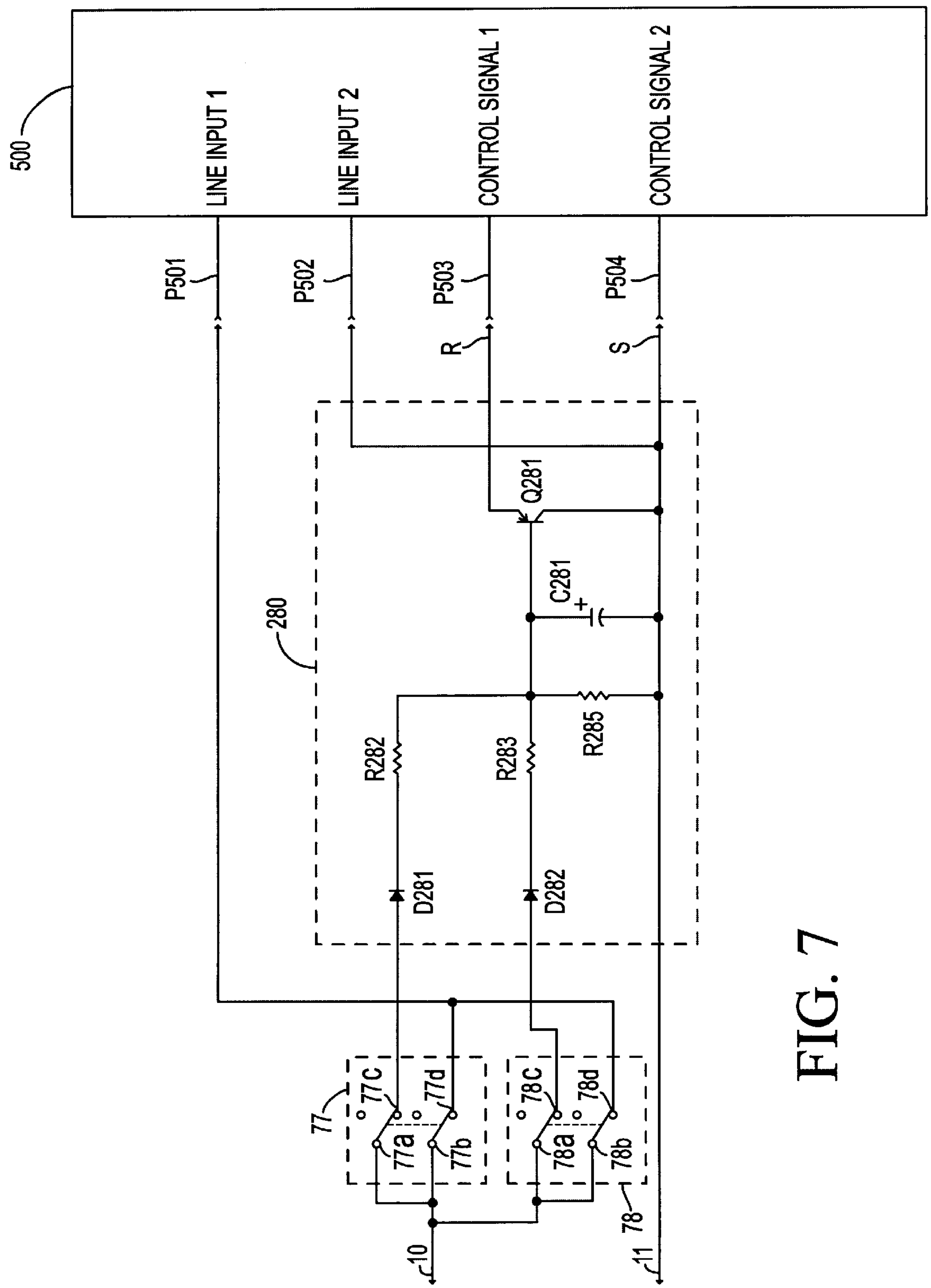

500
LINE INPUT 1
LINE INPUT 2
CONTROL SIGNAL 1
CONTROL SIGNAL 2
P501
P502
P503
P504
R
S
280
Q281
C281
+
R282
R283
R285
D281
D282
77
77a
77b
77c
77d
78
78a
78b
78c
78d
10
11

FIG. 7

THREE-WAY FLUORESCENT ADAPTER

BACKGROUND OF THE INVENTION

This invention relates to a control circuit and ballasting means for controlling the light output of a gas discharge lamp in response to switches that are external to the ballast. The invention provides 3 levels of light output with single or multiple lamps. One embodiment of the invention can be mounted in a standard three-way socket for incandescent lamps. Another embodiment can be used to control multiple lamps in a ceiling-mounted fixture, replacing an inboard/outboard configured multiple ballast circuit. Other embodiments provide circuits that allow conventional dimming ballasts which are designed to be controlled with a low-voltage DC input signal to be controlled by a pair of switches connected to an AC power source.

Three-way incandescent lamp sockets generate three light levels by switching two filaments in an incandescent bulb on and off. At the lowest setting, the low wattage filament is turned on. At the intermediate setting, the high wattage filament is turned on. At the high setting, both the high and the low wattage filaments are turned on. Prior attempts at using a gas discharge lamp with a three-way socket have resulted in implementations with various drawbacks.

One such implementation with a three-way socket dimmer is illustrated by U.S. Pat. No. 5,309,062. This patent shows turning on 1, 2 or 3 separate gas discharge tubes using a standard three-way incandescent socket. This approach has several disadvantages. The most serious problem is that the switch in a standard three-way socket is not capable of safely interrupting high-voltage high-frequency lamp current. Another disadvantage of this approach is that special three-section lamps are required. Dimming is accomplished by switching off one or more sections. The light distribution will be uneven at dimmed settings since unlit sections will block light from whatever sections are lit.

U.S. Pat. No. 5,424,610 to Pelton describes a three-way adapter for compact fluorescent lamps that uses two separate ballast circuits coupled to one lamp to provide three light levels. This approach is complicated, bulky, and costly.

SUMMARY

A three-way fluorescent adapter for interfacing a standard three-way incandescent lamp socket with at least one gas discharge lamp is disclosed. The adapter has three AC input terminals for receiving inputs from a switched AC line source. The circuit has a rectifier for providing a DC bulk voltage from the AC line source. The adapter further has a control signal generator for deriving a control signal from the voltages present between the AC input terminals in response to the position of the three-way socket switch. An electronic ballast powered from the DC bulk voltage and responsive to the control signal is provided such that the intensity of one or more gas discharge lamps is varied according to the position of the three-way socket switch. Other embodiments utilize a pair of switches and a signal generator to control a dimming ballast.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an electrical schematic diagram of a three-way lamp socket connected to the rectifier and control signal generator portions of a preferred embodiment of a three-way fluorescent adapter.

FIG. **2** is an electrical schematic diagram of a three-way lamp socket connected to the rectifier and control signal generator portions of another embodiment of a three-way fluorescent adapter that uses a voltage doubler rectifier to boost the DC bulk voltage.

FIG. **3** shows an electrical schematic diagram of a variable-output electronic ballast that may be connected to any of the rectifier and control signal generator circuits of FIG. **1**, **2**, **4**, or **5**.

FIG. **4** is an electrical schematic diagram of a three-way lamp socket connected to an alternate rectifier and control signal generator circuit.

FIG. **5** is an electrical schematic diagram that shows an embodiment which incorporates the voltage doubler rectifier of FIG. **2** with the signal generator scheme of FIG. **4**.

FIG. **6** is an electrical schematic diagram of a three-way interface circuit that allows one or more dimming ballasts to be controlled from a pair of standard wall-mounted switches.

FIG. **7** is an electrical schematic diagram of a three-way interface circuit that allows one or more dimming ballasts to be controlled from a pair of double-pole wall-mounted switches.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a three-way switch assembly **70** receives AC power through a pair of input terminals **10** and **11**. Three-way switch assembly **70** has a set of switch contacts **71***a*, **71***b*, **72**, **73**, and **74** that are selectively connected to a wiper **75**. Contact **74** is the off position. When wiper **75** is rotated to a low light level position, contact **73** closes. When wiper **75** is further rotated to a medium light level position, contact **73** opens and a contact **72** closes. When wiper **75** is rotated further still to a high light level position, contact **72** opens and contacts **71***a* and **71***b* close.

A three-way socket assembly **20** is connected to three-way switch assembly **70**. Three-way socket assembly **20** is designed to accept standard three-way incandescent lamps. Socket assembly **20** has a center contact **22**, an intermediate contact **21**, and a threaded return contact **23**. Three-way switch assembly **70** and three-way socket assembly **20** are typically contained within a table lamp (not shown). Screwbase **30** and the other elements that follow in this description are contained within the three-way fluorescent lamp adapter of the present invention.

Screwbase **30** has three contacts that mate with the contacts of socket **20**. Screwbase **30** has a shell contact **33** which has threads that are engaged into the threads in return contact **23** of socket **20** as the fluorescent lamp adapter is rotated. The rotation of screwbase **30** into socket **20** provides mechanical attachment as well as an electrical connection. A tip contact **32** electrically connects with center contact **22**. A ring contact **31** electrically connects with intermediate contact **21**.

Contacts **31**, **32**, and **33** are connected to a rectifier **200** through L1, which is a three-conductor common-mode inductor that serves as an electromagnetic interference (EMI) filter. Rectifier **200** consists of diodes D1, D2, D3, D4, D5, and D6 which are connected to form a rectifier bridge. Rectifier **200** has AC input terminals P**10**, P**11**, and P**12** that are coupled, respectively, to contacts **31**, **32** and **33** through windings L1A, L1B, and L1C of inductor L1. Rectifier **200** has a positive output terminal X and a negative output terminal Y that are connected to a bulk storage capacitor C**26**. If desired, power factor correction circuitry can be inserted between the rectifier output and capacitor C**26**.

For the low light level switch setting, the AC line voltage is applied between ring contact **31** and shell contact **33**. In this case, Diodes D**1**, D**4**, D**5**, and D**6** rectify the AC line voltage, charging bulk capacitor C**26**. For the medium light level switch setting, the AC line voltage is applied between tip contact **32** and shell contact **33**. In this case Diodes D**2**, D**3**, D**5**, and D**6** rectify the AC line voltage, charging bulk capacitor C**26**. For the high light level switch setting, the AC line voltage is applied between shell contact **33** and both tip contact **32** and ring contact **31**. In this case Diodes D**1**, D**2**, D**3**, D**4**, D**5**, and D**6** conduct, charging capacitor C**26**.

A control signal is generated by a control signal generator **220**. Control signal generator **220** has a voltage divider network made up of resistors R**7**, R**22**, and R**4**. R**4** is connected between terminals Z and Y. R**7** is connected between terminal P**11** and terminal Z. R**22** is connected between terminal P**10** and Z. The voltage between terminal Z and terminal Y is the control voltage, and it is designated Vz. A filter capacitor C**24** is connected between terminals Z and Y.

The operation of the control signal circuit is illustrated as follows. For the low light level, the sinusoidal AC line voltage, which has an rms value denoted as Vac volts, is applied between ring contact **31** and shell contact **33**. The voltage across R**22** is approximately a half-wave rectified sine wave, and the voltage across R**7** is essentially zero. Because of C**24**, the voltage developed across resistor R**4** is proportional to the average voltage across resistor R**22**. Consequently, the magnitude of control voltage Vz can be approximated by the formula:

$$Vz(\text{low}) \approx Vac\frac{\sqrt{2}}{\pi}\ \frac{R_4}{R_4+R_{22}} \tag{1}$$

For the medium light level, the AC line voltage is applied between tip contact **32** and shell contact **33**. The voltage across R**7** is approximately a half-wave rectified sine wave, and the voltage across R**22** is essentially zero. In this case, the magnitude of control voltage Vz can be approximated by the formula:

$$Vz(\text{medium}) \approx Vac\frac{\sqrt{2}}{\pi}\ \frac{R_4}{R_4+R_7} \tag{2}$$

For the high light level, the AC line voltage is applied between shell contact **33** and both tip contact **32** and ring contact **31**. The voltage across each of resistors R**7** and R**22** is approximately a half-wave rectified sine wave. In this case, the magnitude of control voltage Vz can be approximated by the formula:

$$Vz(\text{high}) \approx Vac\frac{\sqrt{2}}{\pi}\ \frac{R_4}{R_4+\frac{(R_7)(R_{22})}{(R_7+R_{22})}} \tag{3}$$

Equations (1–3) are based on the assumption that Vz is small compared to the peak value of Vac. If that assumption is correct, then Vz(high) is approximately the sum of Vz(low) and Vz(medium). For example:

Let Vac=120 volts, Vz(low)=1.5 volts, Vz(medium)=3 volts, and R_4=10 kΩ.

By Eq. (1) R_{22}=350 kΩ.

By Eq. (2) R_7=170 kΩ.

By Eq. (3) Vz(high)=4.34 volts, which is approximately 1.5 volts+3 volts.

Referring to FIG. **3**, an embodiment of a dimming ballast **300** is shown. A complete adapter circuit can be formed by connecting the dimming ballast to the rectifier and control signal generator of FIG. **1** through terminals X, Y and Z. Terminal S is used with the circuits of FIGS. **4** and **5**.

A pair of transistors Q**1** and Q**2** form a half-bridge inverter circuit for converting the bulk DC voltage between terminals X and Y into a high frequency square wave output voltage between terminal **P20** and terminal X. The square wave inverter output voltage is applied to a series resonant circuit comprised of a winding L**4**A on an inductor L**4**, and capacitors C**10** and C**12**. Capacitor C**12** also functions as a DC blocking capacitor.

Ballast **300** has a set of output terminals, J1A, J1B, J1C, and J1D that are connected to the resonant circuit. A gas discharge lamp **B1** is connected to the output terminals through lamp terminals B1A, B1B, B1C, and B1D. Lamp **B1** is effectively connected in parallel with capacitor C**10** since the terminals at each end of lamp B**1** are connected by a lamp filament.

Dimming of the gas discharge lamp is accomplished by varying the symmetry of the inverter square wave output voltage. The duty cycle of transistor Q**2** is decreased in accordance with the amount of dimming required. The resonant circuit responds mainly to the fundamental component of the inverter output voltage. Maximum current is delivered to the load when the inverter voltage is symmetrical (i.e., when the duty cycle of each pulse width in the inverter is 50%). When the duty cycle diverges from 50% in either transistor, less current is delivered to the lamp because the fundamental component of the inverter voltage is reduced.

Control signal Vz is supplied between terminals Y and Z from a control signal generator such as circuit **220** that is shown in FIGS. **1** and **2**. Transistors Q**101**, Q**102**, Q**103**, and Q**104** form a symmetry control circuit. A power supply for the symmetry control circuit is formed from a winding L4B on inductor L**4**, a diode D**110**, and a filter capacitor C**10**. This power supply provides a voltage of about 10 volts between terminals S and Y.

A capacitor C**102** and a resistor R**101** couple a signal related to the inverter square wave output voltage to the base of transistor Q**101**. A diode D**111** prevents excessive reverse bias on the base of transistor Q**101**. As long as transistor Q**1** is on, transistor Q**101** will be on and capacitor C**101** will be discharged. When transistor Q**2** turns on, transistor Q**101** is turned off and capacitor C**101** is charged through a resistor **R102**. A resistor **R103** supplies current to a pair of transistors, Q**102** and Q**103**, that function as a differential comparator. The voltage across capacitor C**101** is compared to the control voltage Vz. The maximum value of Vz should be less than the emitter-to-base reverse breakdown voltages of transistors Q**102** and Q**103**.

When transistor Q**2** is first turned on, C**101** is discharged, and the base of transistor Q**102** is pulled to a low level. Transistor Q**102** is on, and transistor Q**103** is off. Transistor Q**103** turns on when the ramp voltage across C**101** rises to a level slightly above the value of Vz. When transistor Q**103** is turned on, a current flows through a resistor R**105**, turning on transistor Q**104**. Transistor Q**104** then shorts across the base of transistor Q**2**. The time at which transistor Q**104** turns on depends on the value of Vz. If Vz is sufficiently high, then transistor Q**2** will operate at a 50 percent duty cycle because transistor Q**2** will already be off when transistor Q**104** is turned on. When Vz is below a certain value, transistor Q**2** will be turned off early, and the lamp current will be reduced.

A diac D**10**, a diode D**8**, a capacitor C**7**, and resistors R**13** and R**14** are connected to form a starting circuit for the inverter. Shortly after power is applied to the adapter, the starting circuit supplies a current pulse to transistor Q2 which causes the inverter circuit to begin operating. A resistor R32 aids starting by ensuring that capacitor C12 is initially discharged. After the inverter has been started, a pair of diodes D11 and D12 limit the voltage across the lamp to a level that will allow the lamp to start after the filaments have been heated by the current flowing through capacitor C10.

A transformer T1 having a saturable toroid core provides base drive current for transistors Q1 and Q2. Before T1 saturates, it operates as a current transformer, and the volt-seconds across windings T1A and T1B are set by resistors R17 and R18. Consequently, these resistors can be adjusted to set the operating frequency of the inverter. Resistors R25 and R26 are connected in series with the emitters of transistors Q1 and Q2 to provide negative feedback that stabilizes the inverter operating frequency. A resistor R27 is connected from the base to the emitter of transistor Q1, and a resistor R28 is similarly connected to Q2. These resistors force the inverter to stop oscillating if lamp B1 is removed. Inductors L5 and L6 are connected in series with resistors R17 and R18 to reduce the turn-off losses of transistors Q1 and Q2.

If the lamp operating voltage is sufficiently high, the level of bulk DC voltage provided by rectifier circuit 200 of FIG. 1 may be lower than what is required for optimal efficiency in the inverter circuit. Referring now to FIG. 2, an alternative embodiment of the rectifier and control signal generator portions of a three-way fluorescent adapter is shown. This circuit uses a voltage-doubler rectifier circuit 250 which provides a bulk DC voltage that is approximately twice the value of the voltage obtained from rectifier circuit 200. Three-way switch assembly 70, three-way socket assembly 20, screwbase 30 and EMI filter L1 are the same as in FIG. 1. A dimming ballast such as the one shown in FIG. 3 can be connected to terminals X, Y, and Z to form a complete adapter circuit.

Rectifier 250 has AC input terminals P41, P42, and P43 that are connected to the three windings of EMI filter inductor L1. Terminal P43 is connected to the junction of bulk storage capacitors C50 and C51. Diodes D21 and D24 are connected as a voltage-doubling rectifier between terminal P41 and capacitors C50 and C51. Diodes D22 and D23 are similarly connected between terminal P42 and capacitors C50 and C51. Positive output terminal X is connected to capacitor C50 and negative output terminal Y is connected to capacitor C51.

For the low light level switch setting, the AC line voltage is applied between ring contact 31 and shell contact 33. In this case, diodes D21 and D24 conduct, charging capacitors C50 and C51. For the medium light level switch setting, the AC line voltage is applied between tip contact 32 and shell contact 33. In this case, diodes D22, and D23 conduct, charging capacitors C50 and C51. For the high light output switch setting, the AC line voltage is applied between shell contact 33 and both tip contact 32 and ring contact 31. In this case, diodes D21, D22, D23, and D24 conduct, charging capacitors C50 and C51.

Control circuit 220 is the same as in FIG. 1 except that the resistor values may be different. Resistor R22 is connected to terminal P41 and resistor R7 is connected to terminal P42. The operation of the control circuit is illustrated as follows. For the low light level setting, the voltage across resistor R22 is approximately a raised sine wave that has an average value equal to the peak value of the AC input voltage Vac. The voltage across resistor R22 is essentially zero. The magnitude of the control voltage Vz can therefore be approximated by the formula:

$$Vz(\text{low}) \approx Vac\sqrt{2}\ \frac{R_4}{R_4 + R_{22}} \tag{4}$$

For the medium light level setting, the AC line voltage is applied between tip contact 32 and shell contact 33. The voltage across resistor R7 is approximately a raised sine wave that has an average value equal to the peak value of the AC input voltage. In this case, the magnitude of the control voltage Vz can be approximated by the formula:

$$Vz(\text{medium}) \approx Vac\sqrt{2}\ \frac{R_4}{R_4 + R_7} \tag{5}$$

For the high light level setting, the AC line voltage is applied between shell contact 33 and both tip contact 32 and ring contact 31. In this case, the magnitude of the control voltage Vz can be approximated by the formula:

$$Vz(\text{high}) \approx Vac\sqrt{2}\ \frac{R_4}{R_4 + \frac{(R_7)(R_{22})}{(R_7 + R_{22})}} \tag{6}$$

Equations (4–6) are based on the assumption that Vz is small compared to the peak value of Vac. If that assumption is correct, then Vz(high) is approximately the sum of Vz(low) and Vz(medium)

Referring now to FIG. 4, the rectifier circuit of FIG. 1 is shown connected to a control signal generator 240 that, unlike control signal generator 220, allows the three light levels to be set independently. Terminals S, Y, and Z are connected to a dimming ballast such as the one shown in FIG. 3. A voltage Vs of approximately 10 volts is supplied by the dimming ballast between terminals S and Y. The voltage Vz between terminals Z and Y controls the output level of the dimming ballast.

Control circuit 240 contains a switched voltage divider consisting of resistors R241, R244, and R247, and transistors Q241 and Q242. These transistors are each controlled by a filtered voltage divider which determines the base-to-collector voltage. The voltage between the base and collector of transistor Q241 is denoted Vbc1, and the corresponding voltage for transistor Q242 is denoted Vbc2. Vbc1 is supplied by a filtered voltage divider consisting of resistors R243, R245, and a capacitor C240. Similarly, Vbc2 is supplied by a filtered voltage divider consisting of resistors R242, R246, and a capacitor C241. Transistor Q241 is turned off when Vbc1 is high enough to reverse bias the emitter-base junction. Transistors Q241 is turned on when Vbc1 is approximately zero, which occurs when the AC line voltage is not present between terminals P11 and P12. During the on state, the emitter to collector voltage is approximately 0.7 volts. Transistor Q242 is controlled by the voltage between terminals P10 and P12, and operates in the same manner as transistor Q241.

When switch 70 is in the low light level position, transistor Q241 is off and transistor Q242 is on. The control voltage Vz is found by:

$$V_z(\text{low}) = 0.7 + \frac{R_{244}}{R_{242} + R_{244}}\ (V_s - 0.7) \tag{7}$$

When switch 70 is in the medium light level position, transistor Q241 is on and transistor Q242 is off. The control voltage Vz is found by:

$$V_z(\text{medium}) = 0.7 + \frac{R_{247}}{R_{241}+R_{247}}\ (V_s - 0.7) \qquad (8)$$

When switch **70** is in the high light level position, transistors Q**241** and Q**242** are both off, and Vz is pulled high by R**241**. In this circuit, the maximum value of Vz, Vz(high) is independent of the values of Vz(low) and Vz(medium). Control circuit **240** therefore allows the low light level to be very low while still having a substantial difference between the medium and high light levels.

When either the low or the high light level is selected, transistor Q**241** should be off. In order to ensure this condition, the values of resistors R**243** and R**245** should be selected so that Vbc**1** is greater than or equal to Vs when the AC line voltage Vac is present between terminals P**11** and P**12**. The magnitude of Vbc**1** can be approximated by the formula:

$$Vbc1 \approx Vac\frac{\sqrt{2}}{\pi}\ \frac{R_{245}}{R_{243}+R_{245}} \qquad (9)$$

The values of resistors R**242** and R**246** should be selected so that Vbc**2** is greater than or equal to Vs when the AC line voltage Vac is present between terminals P**10** and P**12**. The magnitude of Vbc**2** can be approximated by the formula:

$$Vbc2 \approx Vac\frac{\sqrt{2}}{\pi}\ \frac{R_{246}}{R_{242}+R_{246}} \qquad (10)$$

Referring now to FIG. **5**, the rectifier circuit of FIG. **2** is shown connected to control signal generator **240**. Resistor R**243** is connected to terminal P**41**, and resistor R**242** is connected to terminal P**42**. The operation is the same as in FIG. **4** except that the magnitudes of Vbc**1** and Vbc**2** are approximated with the following formulas:

$$Vbc1 \approx Vac\sqrt{2}\ \frac{R_{245}}{R_{243}+R_{245}} \qquad (11)$$

$$Vbc2 \approx Vac\sqrt{2}\ \frac{R_{246}}{R_{242}+R_{246}} \qquad (12)$$

Equations (9–12) are based on the assumption that the base-to-collector voltages of transistors Q**241** and Q**242** are small compared to the peak value of Vac.

Referring now to FIG. **6**, another embodiment of the invention is shown. This embodiment is an interface circuit that allows standard dimming electronic ballasts to be controlled by two standard wall-mounted switches. This embodiment can replace an inboard/outboard configured multiple ballast circuit. The AC line voltage Vac between terminals **10** and **11** is supplied to rectifier **200** through a pair of standard single-pole single-throw wall switches **80** and **81**. Three light levels can be obtained by toggling the wall switches.

The unfiltered output of rectifier **200** is connected to terminals X and Y. Most electronic dimming ballasts can operate from a DC supply as well as an AC supply. A dimming ballast **500** has a pair of AC/DC line input terminals P**501** and P**502** connected to terminals X and Y. Rectifier **200** allows ballast **500** to be powered if either switch **80** or switch **81** is closed.

Ballast **500** is controlled by the voltage Vc present between terminals P**503** and P**504**. Terminal P**503** supplies a current that is typically less than 1 mA. The level of Vc is intended to be set by a shunt voltage regulator. A control signal generator **270** has a shunt regulator output that is connected to ballast terminals P**503** and P**504** through output terminals R and S. Because of the shunt regulator control scheme, additional dimming ballasts can be connected in parallel with ballast **500**. The number of ballasts connected in parallel is limited by the current rating of rectifier **200**.

The shunt regulation of Vc is accomplished through a PNP transistor Q**271**, which is connected as an emitter follower. The emitter and collector are connected between terminals R and S. The base is connected to a filtered voltage divider comprised of a capacitor C**271** and resistors R**272**, R**273**, and R**275**. Resistor R**272** is connected to terminal P**10**, and resistor R**273** is connected to terminal P**11**.

When switch **80** is closed and switch **81** is open, the value of Vc can be approximated by:

$$Vc \approx 0.7 + Vac\frac{\sqrt{2}}{\pi}\ \frac{R_{275}}{R_{275}+R_{272}} \qquad (13)$$

When switch **81** is closed and switch **81** is open, the value of Vc can be approximated by:

$$Vc \approx 0.7 + Vac\frac{\sqrt{2}}{\pi}\ \frac{R_{275}}{R_{275}+R_{273}} \qquad (14)$$

When switches **80** and **81** are both on, the value of Vc can be approximated by:

$$Vc \approx 0.7 + Vac\frac{\sqrt{2}}{\pi}\ \frac{R_{275}}{R_{275}+\frac{(R_{272})(R_{273})}{(R_{272}+R_{273})}} \qquad (15)$$

In an alternative embodiment, rectifier **200** and control signal generator **270** are contained within ballast **500**. Ballast **500** then has three AC input terminals corresponding to terminals P**10**, P**11**, and P**12**. Control signal generator **270** can be replaced with other control signal generator circuits such as circuits **220** or **240**.

Referring now to FIG. **7**, another embodiment of the invention is shown. This embodiment is an interface circuit that allows standard dimming electronic ballasts to be controlled by two double-pole single-throw wall-mounted switches. A switch **77** has two input terminals, **77***a* and **77***b*, and two output terminals **77***c* and **77***d*. A switch **78** has two input terminals, **78***a* and **78***b*, and two output terminals **78***c* and **78***d*. Three light levels can be obtained by toggling the wall switches.

AC line voltage Vac is present between terminals **10** and **11**. Terminal **11** is connected to terminal P**501** of ballast **500**. Terminal **10** is connected to input terminals **77***b* and **78***b* of switches **77** and **78**. Terminal P**501** of ballast **500** is connected to output terminals **77***d* and **78***d* of switches **77** and **78**. Input power is supplied to ballast **500** when either switch **77** or switch **78** is closed.

A control signal generator **280** has a shunt regulator output that is connected to ballast terminals P**503** and P**504** through control terminals R and S. Additional dimming ballasts can be connected in parallel with ballast **500**.

The shunt regulation of control voltage Vc is accomplished through a PNP transistor Q**281**, which is connected as an emitter follower. The emitter and collector are connected between terminals R and S. The base is connected to a filtered voltage divider comprised of a capacitor C**281** and resistors R**282**, R**283**, and R**285**. Resistor R**282** is connected to switch terminal **77***c* through a diode D**281**, and resistor R**283** is connected to switch terminal **78***c* through a diode D**282**.

When switch **77** is closed and switch **78** is open, the value of Vc can be approximated by:

$$Vc \approx 0.7 + Vac\frac{\sqrt{2}}{\pi}\frac{R_{285}}{R_{285}+R_{282}} \quad (16)$$

When switch **78** is closed and switch **77** is open, the value of Vc can be approximated by:

$$Vc \approx 0.7 + Vac\frac{\sqrt{2}}{\pi}\frac{R_{285}}{R_{285}+R_{283}} \quad (17)$$

When switches **80** and **81** are both on, the value of Vc can be approximated by:

$$Vc \approx 0.7 + Vac\frac{\sqrt{2}}{\pi}\frac{R_{285}}{R_{285}+\frac{(R_{282})(R_{283})}{(R_{282}+R_{283})}} \quad (18)$$

Equations (13–18) are based on the assumption that the base-to-collector voltages of transistors Q**271** and Q**281** are small compared to the peak value of Vac. The 0.7 volt term in these equations is due to the emitter-base voltage drop of the emitter follower transistor.

The present invention has been described in connection with a preferred embodiment. It will be understood that many modifications and variations will be readily apparent to those of ordinary skill in the art without departing from the spirit or scope of the invention and that the invention is not to be taken as limited to all of the details herein. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A three-way fluorescent adapter for interfacing a three-way lamp socket with at least one gas discharge lamp comprising:

first and second input terminals each for receiving an AC voltage with respect to a neutral input terminal having a peak magnitude;

rectifier means electrically connected to the first and second input terminals and to the neutral input terminal, for providing a DC bulk voltage from the AC voltage to positive and negative DC output terminals, comprising a voltage doubler for increasing the DC bulk voltage to a magnitude greater than the peak magnitude of the DC voltage;

control signal generating means for deriving a control signal from the AC voltage in response to the position of a three-way switch; and

ballast means powered from the DC bulk voltage provided by the rectifier means and responsive to the control signal such that the gas discharge lamp or lamps provide a plurality of light intensities according to the position of the three-way switch.

2. A three-way fluorescent adapter according to claim **1**, wherein the rectifier means further comprises:

a first diode having an anode and a cathode;

the first input terminal connected to the anode of the first diode;

a second diode having an anode and a cathode, the cathode of the first diode connected to the cathode of the second diode;

the second input terminal connected to the anode of the second diode;

a third diode having an anode and a cathode, the cathode of the third diode connected to the anode of the second diode;

a fourth diode having an anode and a cathode, the anode of the fourth diode connected to the anode of the third diode, and the cathode of the fourth diode connected to the anode of the first diode;

a first capacitor and a second capacitor series connected, the series capacitor combination connected between the anode of the third diode and the cathode of the second diode;

the neutral input terminal connected between the first and the second capacitors;

the positive DC output terminal connected to the cathode of the first diode; and

the negative DC output terminal connected to the second capacitor.

3. A three-way fluorescent adapter according to claim **1**, wherein the control signal generating means comprises a voltage divider directly coupled to the negative DC output terminal and to the first and second input terminals.

4. A three-way fluorescent adapter according to claim **3**, wherein the network of resistors and capacitors comprises:

a first resistor connected between the first input terminal and a control signal output terminal;

a second resistor connected between the second input terminal and the control signal output terminal;

a third resistor connected between the negative DC output terminal and the control signal output terminal; and

a filter capacitor connected between the control signal output terminal and the negative DC output terminal, whereby as the three-way switch is rotated, the first, the second and the third resistors develop the control signal at the control signal output terminal, the control signal having a plurality of magnitudes that vary in accordance with the three-way switch position.

5. A three-way fluorescent adapter according to claim **1**, wherein the control signal generating means comprises a transistor sinking network means for independently adjusting each of the plurality of light intensities.

6. A three-way fluorescent adapter according to claim **5**, wherein the transistor sinking network means comprises:

a first transistor having a base, an emitter and a collector, a first resistor connected between the base and the collector of the first transistor, a second resistor connected between the emitter of the first transistor and a control signal output terminal;

a second transistor having a base, an emitter and a collector, a third resistor connected between the base and the collector of the second transistor, the collector of the first transistor connected to the collector of the second transistor, a fourth resistor connected between the emitter of the second transistor and the control signal output terminal;

a fifth resistor connected between a first input terminal and the base of the second transistor;

a sixth resistor connected between a second input terminal and the base of the first transistor; and

a seventh resistor connected between the control signal output terminal and a DC power supply.

7. A three-way fluorescent adapter for interfacing a three-way lamp socket with at least one gas discharge lamp comprising:

first and second input terminals each adapted for receiving an AC voltage with respect to a neutral input terminal;

rectifier means for providing a DC bulk voltage from the AC voltage;

a voltage divider for deriving a control signal from the AC voltage in response to a position of a three-way switch, the voltage divider consisting of a network of resistors and capacitors directly coupled to a negative DC output terminal and to the first and second input terminals; and

ballast means powered from the DC bulk voltage provided by the rectifier means and responsive to the control signal such that the gas discharge lamp or lamps provide a plurality of light intensities according to the position of a three-way switch.

8. A three-way fluorescent adapter according to claim **7**, wherein the resistor capacitor network comprises:

a first resistor connected between the first input terminal and a control signal output terminal;

a second resistor connected between the second input terminal and the control signal output terminal;

a third resistor connected between a negative DC output terminal and the control signal output terminal;

a filter capacitor connected between the control signal output terminal and the negative DC output terminal, whereby as the three-way switch is rotated to different positions, the first, the second and the third resistors develop the control signal at the output terminal, the control signal having a plurality of magnitudes according to the different positions of the three-way switch.

9. A three-way fluorescent adapter for interfacing a three-way lamp socket with at least one gas discharge lamp comprising:

input terminal means for receiving an AC voltage;

rectifier means for providing a DC bulk voltage from the AC voltage;

a transistor sinking network means for deriving a control signal from the AC voltage in response to rotation of a three-way switch to different positions and for independently adjusting each of a plurality of light intensities; and

ballast means powered from the DC bulk voltage provided by the rectifier means and responsive to the control signal such that the gas discharge lamp or lamps provide a plurality of light intensities according to the position of the three-way switch.

10. A three-way fluorescent adapter according to claim **9**, wherein the transistor sinking network means comprises:

a first transistor having a base, an emitter and a collector, a first resistor connected between the base and the collector of the first transistor, a second resistor connected between the emitter of the first transistor and a control signal output terminal;

a second transistor having a base, an emitter and a collector, a third resistor connected between the base and the collector of the second transistor, the collector of the first transistor connected to the collector of the second transistor, a fourth resistor connected between the emitter of the second transistor and the control signal output terminal;

a fifth resistor connected between a first input terminal and the base of the second transistor;

a sixth resistor connected between a second input terminal and the base of the first transistor; and

a seventh resistor connected between the control signal output terminal and a DC power supply.

11. A three-way fluorescent adapter for interfacing a standard three-way incandescent socket lamp switch with at least one gas discharge lamp comprising:

a first diode having an anode and a cathode;

a first input terminal connected to the anode of the first diode;

a second diode having an anode and a cathode, the cathode of the first diode connected to the cathode of the second diode;

a second input terminal connected to the anode of the second diode;

a third diode having an anode and a cathode, the cathode of the third diode connected to the anode of the second diode;

a fourth diode having an anode and a cathode, the anode of the fourth diode connected to the anode of the third diode and the cathode of the fourth diode connected to the anode of the first diode;

a fifth diode having an anode and a cathode, the anode of the fifth diode connected to the anode of the third and fourth diode;

a third input terminal connected to the cathode of the fifth diode;

a sixth diode having an anode and a cathode, the anode of the sixth diode connected to the cathode of the fifth diode and the cathode of the sixth diode connected to the cathode of the first diode;

a positive DC output terminal connected to the cathode of the second diode;

a negative DC output terminal connected to the anode of the fifth diode, wherein a DC bulk voltage is developed at the DC output terminals when the input terminals are energized by an AC voltage;

a control signal generating means consisting of:

a first resistor connected between the first input terminal and a control signal output terminal;

a second resistor connected between the second input terminal and the control signal output terminal;

a third resistor connected between the negative DC output terminal and the control signal output terminal;

a filter capacitor connected between the control signal output terminal and the negative DC output terminal, whereby the first, the second and the third resistors develop a low-power DC control signal at the control signal output terminal, the control signal having a plurality of magnitudes that vary in accordance with the three-way switch position; and

ballast means powered from the DC bulk voltage supplied by the rectifier means and responsive to the low-power DC control signal such that the gas discharge lamp or lamps provide a plurality of light intensities according to the position of the three-way switch.

12. A three-way fluorescent adapter for interfacing a standard three-way incandescent socket lamp switch with at least one gas discharge lamp comprising:

a first diode having an anode and a cathode;

a first input terminal connected to the anode of the first diode;

a second diode having an anode and a cathode, the cathode of the first diode connected to the cathode of the second diode;

a second input terminal connected to the anode of the second diode;

a third diode having an anode and a cathode, the cathode of the third diode connected to the anode of the second diode;

a fourth diode having an anode and a cathode, the anode of the fourth diode connected to the anode of the third diode and the cathode of the fourth diode connected to the anode of the first diode;

a fifth diode having an anode and a cathode, the anode of the fifth diode connected to the anode of the third and fourth diode;

a third input terminal connected to the cathode of the fifth diode;

a sixth diode having an anode and a cathode, the anode of the sixth diode connected to the cathode of the fifth diode and the cathode of the sixth diode connected to the cathode of the first diode;

a positive DC output terminal connected to the cathode of the second diode;

a negative DC output terminal connected to the anode of the fifth diode, wherein a DC bulk voltage is developed at the DC output terminals when the input terminals are energized by an AC voltage;

a first resistor connected between the first input terminal and a first transistor;

a second resistor connected between the second input terminal and a second transistor;

a first transistor and a second transistor being connected between the third input terminal and control output terminals;

the first transistor having a third resistor and a first capacitor connected between the base and the collector of the first transistor;

the second transistor having a fourth resistor and a second capacitor connected between the base and the collector of the second transistor;

whereby the first and second transistors provide a DC control signal at the control signal output terminals, the control signal having a plurality of magnitudes that are substantially lower than the DC bulk voltage and that vary according to the position of the three-way switch; and

ballast means powered from the DC bulk voltage supplied by the rectifier means and responsive to the DC control signal such that the gas discharge lamp or lamps provide a plurality of light intensities according to the position of the three-way switch.

13. A three-way fluorescent adapter for interfacing a standard three-way incandescent socket lamp switch with at least one gas discharge lamp comprising:

a first diode having an anode and a cathode;

a first input terminal connected to the anode of the first diode;

a second diode having an anode and a cathode, the cathode of the first diode connected to the cathode of the second diode;

a second input terminal connected to the anode of the second diode;

a third diode having an anode and a cathode, the cathode of the third diode connected to the anode of the second diode;

a fourth diode having an anode and a cathode, the anode of the fourth diode connected to the anode of the third diode and the cathode of the fourth diode connected to the anode of the first diode;

a first capacitor and a second capacitor series connected, the series capacitor combination connected between the anode of the third diode and the cathode of the second diode;

a third input terminal connected between the first and the second capacitors;

a positive DC output terminal connected to the cathode of the first diode;

a negative DC output terminal connected to the anode of the fifth diode, wherein a DC bulk voltage is developed at the DC output terminals when the input terminals are energized by an AC voltage, the DC bulk voltage magnitude characterized by being greater than the magnitude of the AC voltage;

a first resistor connected between the first input terminal and a control signal output terminal;

a second resistor connected between the second input terminal and the control signal output terminal;

a third resistor connected between the negative DC output terminal and the control signal output terminal;

a filter capacitor connected between the control signal output terminal and the negative DC output terminal, whereby the first, the second and the third resistors develop a DC control signal at the control signal output terminal, the control signal having a plurality of magnitudes that are each substantially lower than the DC bulk voltage and that vary according to the three-way switch position; and

ballast means powered from the DC bulk voltage supplied by the rectifier means and responsive to the control signal such that the gas discharge lamp or lamps provide a plurality of light intensities according to the position of the three-way switch.

14. A method of interfacing a three-way lamp socket with at least one gas discharge lamp comprising the following steps:

(a) converting an AC voltage into a DC bulk voltage;

(b) generating a DC control signal from the AC voltage in response to the position of a three-way switch; the DC control signal being separate from the DC bulk voltage;

(c) increasing the DC bulk voltage through the use of a voltage doubling circuit comprising a pair of voltage doubling capacitors;

(d) supplying the DC bulk voltage to a ballast circuit; and

(e) supplying the DC control signal to the ballast circuit such that the light intensity of the gas discharge lamp or lamps depends on the position of the three-way switch.

15. An electronic ballast for operating a gas discharge lamp load at multiple power levels comprising:

a neutral input terminal, a first AC voltage input terminal, and a second AC voltage input terminal;

a voltage doubling rectifier means having a first rectifier AC input terminal, a second rectifier AC input terminal, and a third rectifier AC input terminal;

the rectifier means further having a positive DC output terminal and a negative DC output terminal which provide a DC output voltage when an AC voltage is applied between at least two of the rectifier AC input terminals;

the first rectifier AC input terminal connected to the neutral input terminal;

the second rectifier AC input terminal connected to the first AC voltage input terminal;

the third rectifier AC input terminal connected to the second AC voltage input terminal;

inverter means having a first DC input terminal, a second DC input terminal, a control input terminal, and output means for coupling power to the gas discharge lamp load;

control means having a first control input terminal connected to the negative DC output terminal, a second control input terminal connected to the first AC voltage input terminal, and a third control input terminal connected to the second AC voltage input terminal; and

the control means having an output terminal connected to the inverter means control input terminal.

16. The electronic ballast according to claim **15**, wherein the neutral input terminal, the first AC voltage input terminal, and the second AC voltage input terminal are adapted to fit into and receive power from a three-way socket designed to operate a three-way incandescent lamp.

17. The electronic ballast according to claim **15**, wherein the rectifier means further comprises:

a first diode having an anode and a cathode;

a second diode having an anode and a cathode;

a third diode having an anode and a cathode;

a fourth diode having an anode and a cathode;

the second rectifier AC input terminal connected to the anode of the first diode and to the cathode of the fourth diode; the third AC input terminal connected to the anode of the second diode and to the cathode of the third diode; the positive DC output terminal connected to the cathodes of the first and the second diodes; the negative DC output terminal connected to the anodes of the third and the fourth diodes; and

a first capacitor connected between the positive DC output terminal and the neutral input terminal and a second capacitor connected between the negative DC output terminal and the neutral input terminal.

18. The electronic ballast according to claim **17**, wherein the control means consists of:

a first resistor connected between the second control terminal and the control means output terminal, a second resistor connected between the third control input terminal and the control means output terminal, a third resistor connected between the negative DC output terminal and the control means output terminal, and a capacitor connected in parallel with the third resistor.

19. An interface circuit for using first and second switches to control one or more dimmable electronic ballasts each having a pair of control input terminals, comprising:

a dimming control circuit having a first AC input terminal, a second AC input terminal, a neutral input terminal, a first control output terminal, and a second control output terminal;

the first AC input terminal connected to the first switch, the second AC input terminal connected to the second switch,

the first and second control output terminals providing a dimming control signal to the control input terminals of each electronic ballast in response to an AC voltage present between at least one of the AC input terminals and the neutral input terminal, the dimming control signal having a magnitude that varies in response to operation of the first and second switches.

20. The interface circuit according to claim **19** wherein each of the first and second switches are single-pole single throw switches, the interface circuit further comprising rectifier means connected to the first and second AC input terminals and having a positive DC output terminal and a negative DC output terminal which provide a DC output voltage to each dimmable electronic ballast.

21. The interface circuit according to claim **20** wherein the dimming control circuit comprises a voltage divider connected to each of the switches.

22. The interface circuit of claim **21** wherein the voltage divider comprises a first resistor connected to the first AC input terminal, a second resistor connected to the second AC input terminal, and a third resistor and a first capacitor connected in parallel between the first and second resistors and the negative DC output terminal.

23. The interface circuit of claim **22** wherein the dimming control circuit further comprises a shunt regulator circuit connected across the first and second control output terminals.

24. The interface circuit of claim **20** wherein each of the first and second switches are double-pole single-throw switches, the dimming control circuit comprising a voltage divider coupled to each of the switches and a shunt regulator circuit connected across the first and second control output terminals.

25. The interface circuit of claim **24** wherein the voltage divider comprises a first resistor, a second resistor, and a third resistor and a first capacitor connected in parallel between the neutral input terminal and the first and second resistors; and the interface circuit further comprising the first resistor connected through a first diode to the first AC input terminal, and the second resistor connected through a second diode to the second AC input terminal.

26. An electronic ballast for operating a gas discharge lamp load at multiple power levels comprising:

a neutral input terminal, a first AC voltage input terminal, and a second AC voltage input terminal;

rectifier means having a first rectifier AC input terminal, a second rectifier AC input terminal, and a third rectifier AC input terminal;

the rectifier means further having a positive DC output terminal and a negative DC output terminal which provide a DC output voltage when an AC voltage is applied between at least two of the rectifier AC input terminals;

the first rectifier AC input terminal connected to the neutral input terminal;

the second rectifier AC input terminal connected to the first AC voltage input terminal;

the third rectifier AC input terminal connected to the second AC voltage input terminal;

inverter means having a first DC input terminal, a second DC input terminal, a control input terminal, and output means for coupling power to the gas discharge lamp load;

control means for generating a lamp intensity control signal, the control means having a first control input terminal directly connected to the neutral input terminal, a second control input terminal directly connected to the first AC voltage input terminal, and a third control input terminal connected to the second AC voltage input terminal;

the control means further comprising a resistive voltage divider; and

the control means having an output terminal connected to the inverter means control input terminal.

27. The electronic ballast according to claim **26** further comprising a power factor correction circuit coupled between the rectifier means DC output terminals and the inverter means DC input terminals.

* * * * *