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Jensen

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[54] **FOUR-LAMP DRIVER CIRCUIT FOR FLUORESCENT LAMPS**

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[52] **U.S. Cl.** .... **315/97,** 315/257, 315/297, 315/324, 315/DIG. 2, 315/DIG. 7, 331/113 A

[51] **Int. Cl.** **H03k 3/30,** H05b 41/29

[58] **Field of Search** .... 315/96, 97, 205, 315/254, 257, 297, 324, DIG. 2, DIG. 5, DIG. 7; 331/113 A

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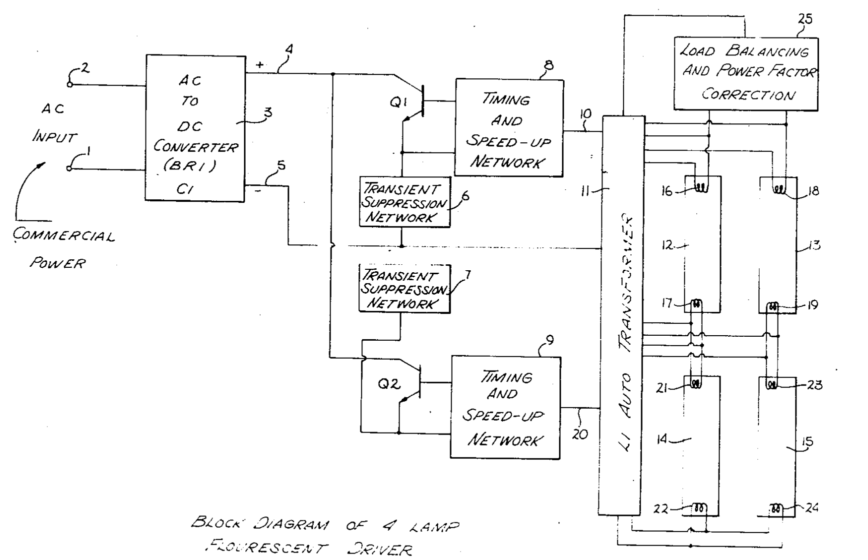
[57] **ABSTRACT**

A two-transistor, high-frequency, non-saturating inverter for operating four fluorescent lamps connected in a series-parallel arrangement. The inverter is supplied either directly from a DC source, or from an AC source via a full-wave bridge rectifier. Transient supression, power-factor correction, and load-balancing networks are provided. Failure or removal of any one lamp will leave two lamps operating in a fail-safe mode.

6 Claims, 2 Drawing Figures



BLOCK DIAGRAM OF 4 LAMP FLUORESCENT DRIVER

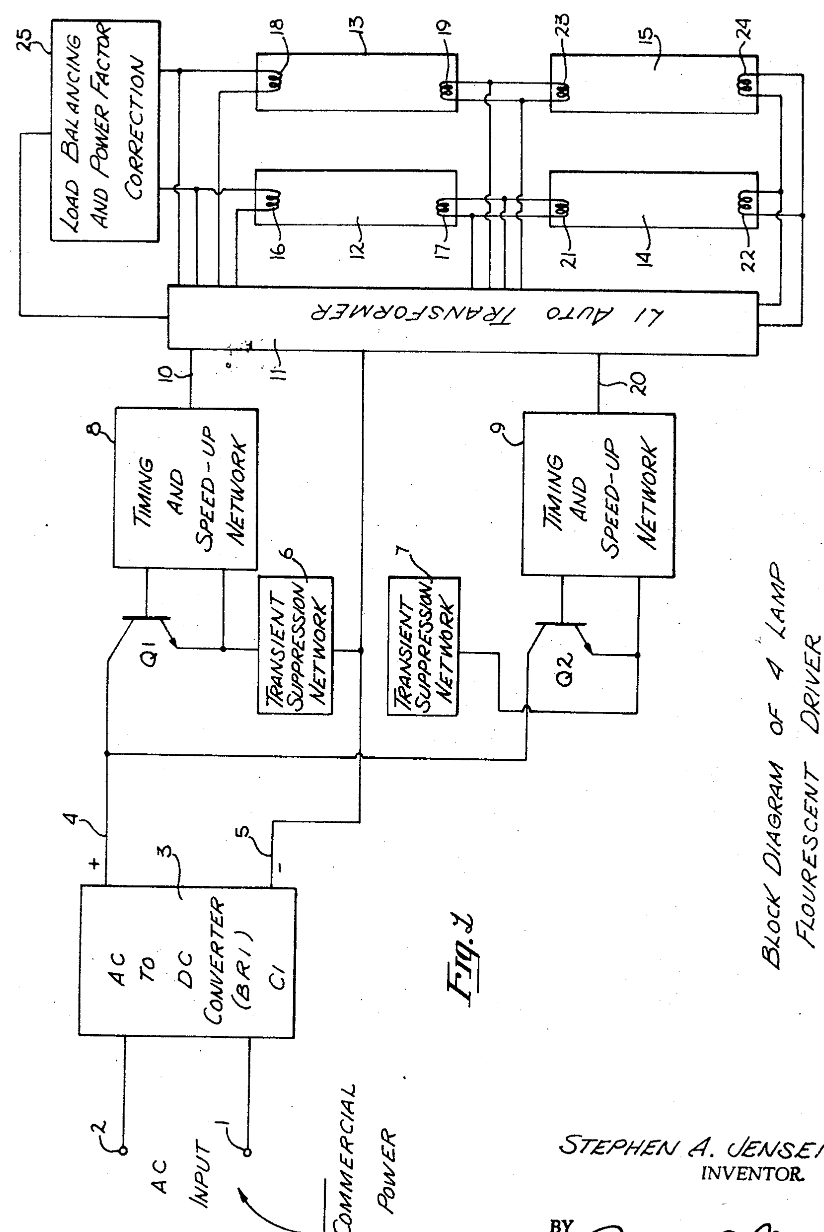


Fig. 1

BLOCK DIAGRAM OF 4 LAMP FLOURESCENT DRIVER

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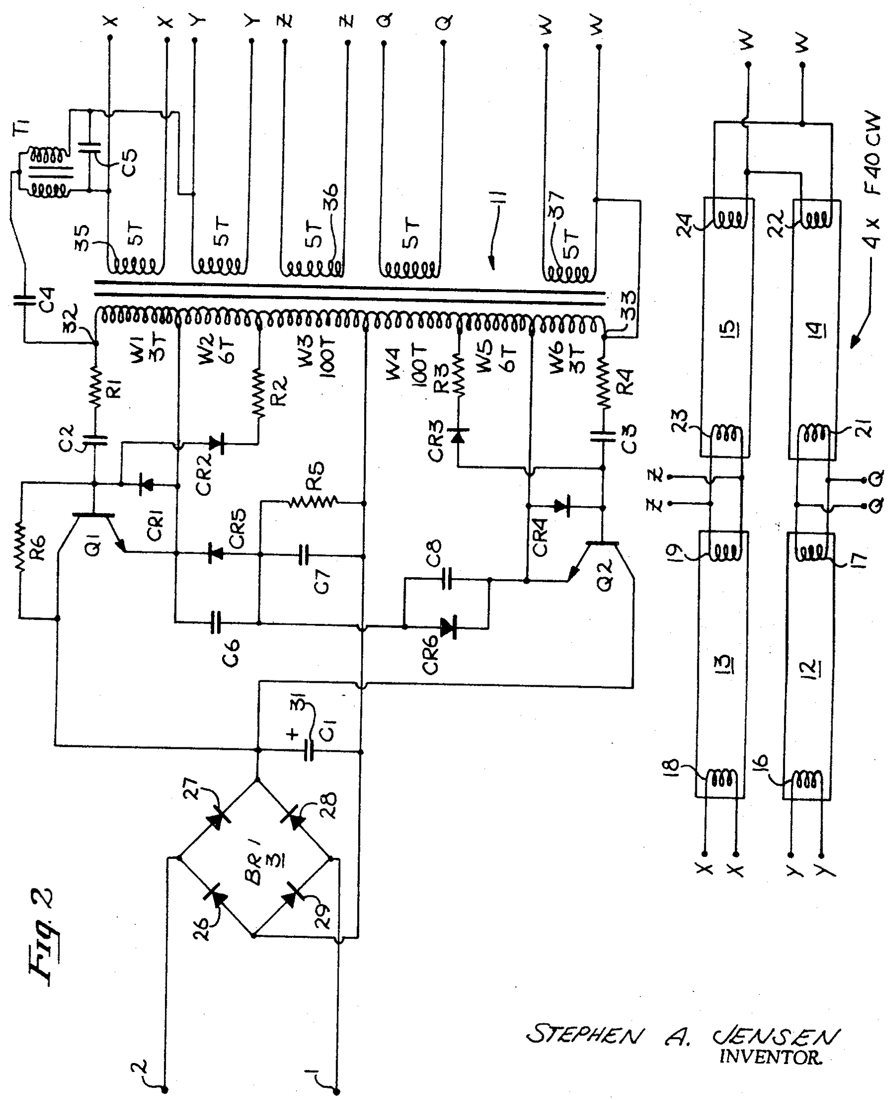

Fig. 2

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FOUR-LAMP DRIVER CIRCUIT FOR FLUORESCENT LAMPS

BACKGROUND OF THE INVENTION

As is well known, hot cathode gaseous-discharge lamps, commonly referred to as "fluorescent lamps" are characterized by a relatively high impedance prior to being started or ignited, and a substantially lower impedance once ignition is established. Thus, a higher voltage is required to ignite the lamp than is required to maintain its operating state. Various means have been provided heretofore which are capable of providing the relatively high ignition voltage necessary, and thereafter limit the operating current once the lamp is ignited. As a class, these devices are called lamp ballasts and comprise a wide variety of circuit devices.

Multiple lamp ballasts are available for operation of a plurality of lamps from a common 60 H_z commercial power supply. These ballasts allow operation of fluorescent lamps at a current frequency equal to the commercial main frequency; usually 60 H_z. Such ballasts suffer from various shortcomings, including audible noise, heavy weight, and low efficiency compared to that available with high frequency lamp operation. Attempts to utilize high frequency static inverters to overcome these shortcomings have met with difficulties concerning switching losses in power transistors when operating at frequencies above the audible range and at the power levels required for the application. These losses are aggravated by the fact that most inverters utilize a saturating magnetic core to determine the period of oscillation of the inverter. At the time of switching, a large peak current flows in the collector of the conducting transistor as a result of the saturation of the core. The duration of this current is as long as the transistor storage time and is generally a significant period of time compared to a period of oscillation. This results in excessive heating of the transistors and generally renders such circuits impractical to operate reliably in the environment afforded by a typical fluorescent light fixture.

The present invention combines a novel and improved solid state inverter which drives a plurality of fluorescent lamps and an operating frequency that is above the audible range. This is accomplished by means of a nonsaturating type inverter which avoids the current peaks discussed earlier. By operating at above audio frequencies, the efficiency of fluorescent lamps is substantially improved over that achieved at 60 H_z. This results in less power consumption for a given unit of light output than that achieved by conventional ballasts. The non-saturating inverter circuit described herein yields such high efficiency as to allow reliable operation in high temperature environments such as those found in recessed fluorescent fixture.

BREIF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating an embodiment of the invention for driving four fluorescent lamps from a commercial AC power source.

FIG. 2 is a schematic circuit diagram of the system shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

There is shown in FIG. 1 a block diagram of a four-lamp driver designed to operate directly from a con-

ventional 115 volt, 60 Hz, AC power source. The input power is applied across terminals **1** and **2** which energizes the AC to DC converter **1**. In a typical construction, converter **1** may comprise a full-wave rectifier with a suitable smoothing filter. The positive output voltage on line **4**, and the negative output voltage on line **5**, are supplied to a non-saturating, two-transistor inverter comprising transistors Q1 and Q2. The inverter is provided with a pair of transient-suppression networks **6** and **7**, and a pair of timing and speed-up networks **8** and **9**. The inverter serves to convert the 160 volt peak DC from converter **1** to an AC voltage having a nominal frequency of 20 KHz. This arrangement makes the system insensitive to the main power supply frequency applied to terminals **1** and **2**, which may for example range from 50 Hz to 1,000 Hz. Optionally, the system may be connected directly to a 130 volt DC power source (without regard to polarity) at terminals **1** and **2**.

Transistors Q1 and Q2 function essentially as switches to produce a square-wave output which is supplied via networks **8** and **9**, respectively, to the input winding of autotransformer **11** via lead **10**. Initial application of power to terminals **1** and **2** produces a DC voltage on lines **4** and **5** which establishes a forward bias on the collector-emitter junctions of both Q1 and Q2. Transistor Q1 will then be biased into conduction by base current flowing through the timing network **8** into the base of Q1. This incipient conduction causes Q1 to be regeneratively switched into "hard" conduction with the supporting base drive obtained via the input winding of autotransformer **11** (lead **10**) and the speed-up network **8**.

As conduction continues in Q1, the capacitive element of network **8** charges and causes the base current at Q1 to decay until Q1 stops conducting. This action takes place prior to saturation of the core of autotransformer **11**, thereby obviating high peak currents and the losses resulting from core saturation.

When Q1 stops conducting, the emitter voltage of Q1 will drop and the voltage to the second winding (via line **20**) on the autotransformer will become zero. Conduction will then commence in Q2 until this half of the cycle is terminated by the action of network **9**. All timing is dependent upon the properties of the networks **8** and **9**, rather than the properties of the autotransformer. The resulting square-wave applied to the autotransformer produces an output voltage which is four times the peak AC line voltage at terminals **1** and **2**. If, for example, the input supply is 160 volts peak-to-peak, then the high voltage available to the lamp circuit is 640 volts peak-to-peak. This high voltage is then impressed across lamps **12–15**, which are connected in a series-parallel arrangement (as will be described more fully hereinafter).

The functions of the networks **8** and **9** are severalfold. Their first purpose is to supply base current to whichever transistor (Q1 or Q2) is then in conduction, and to cause the base current thereto to diminish to a value below which conduction cannot be sustained in the initially conducting one of the transistors. Additionally, each of these networks (**8** and **9**) functions to strongly reverse bias its associated transistor immediately upon cessation of conduction thereof, so as to positively define the cut-off point and to insure repeatability. This further insures that no collector current can flow in the associated transistor once its conduc-

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W1 and W6. The square-wave train produced, generates four times the peak AC line voltage across the overall winding (W1 through W6) of autotransformer 11. This total voltage is connected across the series-connected pairs of lamps 13,15 and 12,14.

The previously described transient-suppression networks comprise diodes CR5 and CR6, capacitors C6 and C7, C8 and resistor R5.

Capacitor C4 is connected in series between one terminal of autotransformer 11 (at winding W1) and current transformer T1. This capacitor (C4) functions as a current limiter for the total current flowing to all four lamps 12–15, by virtue of its capacitive reactance. Transformer T1 has a 1:1 winding ratio and is connected so that the two windings are bucking. Thus, if one pair of lamps ignites prior to the remaining pair, the resulting current flow through one winding of the transformer T1 will generate a voltage in the other winding which is additive to the voltage at the junction of capacitor C4 and the tranformer T1. This increased voltage will insure the ignition of the other pair of lamps.

A second function of transformer T1 is to provide an inductive-reactance component to the lamp load. This is obtained by using the leakage reactance which appears as a series element in the lamp current path. In the time domain, this arrangement results in the inverter being lightly loaded during the actual switching portion of the operating cycle, thereby minimizing switching losses. The current peak, which would otherwise occur at the instant of switching, is delayed to a point in time which is about 25 percent into the half cycle. This assures that the transistors have ample time to become saturated before the heavy current is conducted through them. Also, as has been mentioned previously, the combination of capacitor C4 and transformer T1 provides a network which yields a high frequency power-factor correction.

As can be seen, lamps 13 and 15 are connected in series between the high-voltage terminals 32 and 33 of autotransformer 11 by reason of their having their heaters 19 and 23 connected together. Similarly, lamps 12 and 14 are connected in series, via heaters 17 and 21, and placed across high-voltage terminals 32 and 33. Of course, it should be noted that each of these series paths includes a respective portion of the load-balancing network (C4, T1). The two series-connected pairs of lamps (13,15 and 12,14) are connected in parallel and each set is provided with corresponding low-voltage windings on autotransformer 11 for energization of the respective lamp heaters. For example, winding 35 powers heater 18 of lamp 13, winding 36 powers parallel-connected heaters 19 and 23, and winding 37 powers heater 24 of lamp 15 and heater 22 of lamp 14.

Capacitor C5 permits two lamps to operate in the absence of the remaining two lamps by partially bypassing the open secondary reactance of transformer T1, which would otherwise prevent any lamp from operating if one or more of the other lamps were removed from the fixture or became inoperative.

From the foregoing it is seen that there is provided by the present invention a novel and improved four-lamp driver circuit having very high operating efficiency and will continue to function in a fail-safe mode notwithstanding the removal from service of one or more of the four lamps.

Modifications of the preferred embodiment described will be apparent to those versed in the art, without the exercise of invention. Thus, it is intended that the invention be limited only by the appended claims.

What is claimed is:

1. Apparatus for energizing a plurality of hot-cathode gaseous-discharge lamps, comprising:
rectifier means having a pair of input terminals for receiving operating potential for said apparatus, and having a pair of direct-current output leads;
means connected to said output leads for changing the direct-current therefrom to an alternating current having a frequency which is substantially higher than the frequency of said operating potential applied to said input terminals;
a first pair of series-connected lamps;
a second pair of series-connected lamps;
means connecting one terminal of each of said pairs of lamps in common to one alternating-current output terminal of said current changing means;
current dividing means having an input connected to the remaining alternating-current output terminal of said current changing means and having a first output connected to the other terminal of said first pair of series-connected lamps, and a second output connected to the other terminal of said second pair of series-connected lamps, for dividing the current from said current changing means equally between the two pairs of series-connected lamps;
said current changing means comprises:
a saturating two-transistor inverter;
said inverter includes:
an autotransformer having a continuous multi-tap winding, one end of said winding corresponding to said one alternating-current output terminal and the other end of said winding corresponding to said remaining alternating-current output terminal; and
first and second resistance-capacitance coupled timing network means, each connected between a corresponding one of said two transistors and said autotransformer, for cyclically transferring conduction between said two transistors at a rate which is independent of variations in the magnetic circuit of said autotransformer.

2. Apparatus as defined in claim 1 including:
first and second transient suppression network means, each connected to a corresponding one of said two transistors, for preventing spurious transient voltages from being reflected from said autotransformer to their respective transistors.

3. Apparatus as defined in claim 1 wherein
each of said lamps includes:
a pair of spaced-apart heaters; and, said autotransformer includes
a plurality of low-voltage windings, inductively coupled to said continuous multi-tap winding, each of which is operatively connected to a corresponding one of said heaters.

4. Apparatus for energizing a plurality of hot-cathode gaseous-discharge lamps, comprising:
rectifier means having a pair of input terminals for receiving operating potential for said apparatus, and having a pair of direct-current output leads;
means connected to said output leads for changing the direct-current therefrom to an alternating current having a frequency which is substantially

higher than the frequency of said operating potential applied to said input terminals;

a first pair of series-connected lamps;

a second pair of series-connected lamps;

means connecting one terminal of each of said pairs of lamps in common to one alternating-current output terminal of said current changing means;

current dividing means having an input connected to the remaining alternating-current output terminal of said current changing means and having a first output connected to the other terminal of said first pair of series-connected lamps, and a second output connected to the other terminal of said second pair of series--connected lamps, for dividing the current from said current changing means equally between the two pairs of series-connected lamps;

said current dividing means comprises:

first and second windings having a 1:1 ratio and inductively coupled in opposition to a common electromagnetic circuit, one end of each of said windings being connected in common to said current changing means and the remaining ends of said windings being connected to respective pairs of said series-connected lamps.

5. Apparatus as defined in claim **4** wherein

said rectifier means comprises:

a full-wave diode bridge rectifier, thereby permitting both alternating-current and unpolarized direct-current to properly function as said operating potential.

6. Apparatus as defined in claim **4** including:

capacitive reactance means connected across said remaining ends of said windings of said current dividing means.

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