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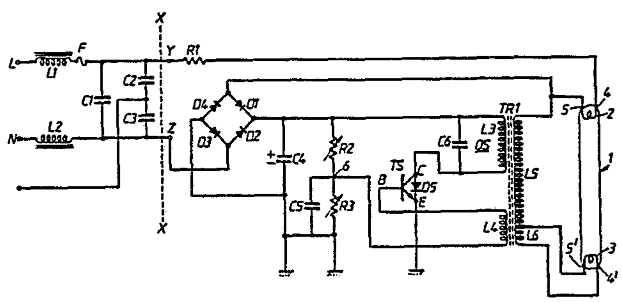
(54) **Electronic ballast for fluorescent lamps.**

(57) An electronic ballast for a discharge lamp has a transistor-oscillator arrangement comprising a single transistor (TS), whose base is coupled to be driven via a feedback winding (L4) of a transformer (TR1). A primary winding (L3) of the transformer forms part of a resonant circuit connected in the collector path of the transistor. A secondary winding (L5) of the transformer is connected across a discharge lamp (1) for the supply of high frequency alternating voltage to the lamp.

The transistor is biased into class A operation, by a biasing means (R2, R3). This biasing means can also be used as a dimmer by adjusting the operation of the transistor along its characteristic curve to alter the collector voltage.

The ballast has lamp connector terminals, 4, 5 a first one 4 of the terminals being connected to an a.c. voltage supply (L), and the second of the connector terminals (5) being connected to a rectifying means (D1-D4). This ensures that the ballast only operates when an operative filament (2) is connected between the lamp connector terminal (4, 5).

Mains supply voltage is filtered by a line filter L1, l2, C1-C3.



EP 0 198 632 A2

ELECTRONIC BALLAST FOR FLUORESCENT LAMPS

This invention relates to an electronic ballast for fluorescent lamps.

Electronic ballasts are currently used with fluorescent lamps to convert the frequency of a voltage supply to the lamp from mains frequency (50/60 Hz) to a very high frequency such as 30 KHz. This has several advantages, for example providing flickerless operation of the lamp, lower power consumption and an increased efficiency (largely due to an improved power factor).

Some forms of electronic ballast, for example that described in EP-A-0075176, use a high frequency oscillator employing two switching transistors, base driven by secondary windings of a transformer whose primary is connected to supply drive current to a fluorescent lamp. Current supply to the lamp is provided during discharge of a capacitor connected in parallel with the lamp.

However, the use of two transistors gives rise to problems of matching. In particular, when the transistors are used in a switching configuration there is a danger that, instead of one turning off promptly as the other turns on, there is an overlap time during which both transistors are turned on, causing distortion of the voltage waveform.

GB 1471150 describes a ballast using a single transistor biased to Class C operation with an LC oscillating arrangement driving the primary winding of a transformer. The secondary winding of a transformer is used both to provide HT voltage to the lamp and to supply current to heat up both the ignition filament of the lamp. In the event that a lamp is not present, and the ballast is inadvertently not turned off, current and voltage will continue to be supplied constituting a safety hazard.

According to a first aspect of the invention, there is provided an electronic ballast for a discharge lamp, which ballast comprises:

a transistor-oscillator arrangement having transistor means operable to provide high frequency alternating voltage for operation of the lamp;

means responsive to said lamp being faulty or absent to disable the transistor-oscillator arrangement.

According to one aspect of the present invention there is provided an electronic ballast for a discharge lamp which ballast comprises: a voltage supply terminal for connection to a voltage supply; a transistor-oscillator arrangement having a voltage supply input and operable to provide therefrom high frequency alternating voltage for operation of the lamp; and first and second lamp connector terminals for connection across an ignition filament of such a discharge lamp, wherein the supply terminal is connected to the first lamp connector terminal, and the voltage supply input of the transistor-oscillator arrangement is connected to the second lamp connector terminal so that operation of the ballast is only permitted when an operative filament is connected between the first and second lamp connector terminals.

In one embodiment, the voltage supply terminal is connected to a supply which comprises an a.c. voltage source and rectifying means for supplying from the a.c. voltage source d.c. voltage to the transistor-oscillator arrangement, the first lamp connector terminal being connected to the a.c. voltage source and the second lamp connector terminal being connected to the transistor oscillator arrangement via the rectifying means.

The transistor-oscillator arrangement may comprise a single transistor having a control electrode and a controllable path, with its control electrode coupled to be driven via a first transformer winding and with the controllable path connected, via a high frequency resonant circuit, to said supply terminal, the high frequency resonant circuit comprising a capacitor connected in parallel with a second transformer winding, the first and second transformer windings both being windings of the same transformer.

The first and second windings may form the primary of the transformer, the secondary of which is adapted to be connected across the discharge lamp for the supply of said high frequency voltage to the lamp. A further ignition filament of the lamp may be connected across a portion of that secondary winding.

Biasing means may be provided for adjustably biasing the transistor of the transistor-oscillator arrangement to vary the magnitude of the high frequency alternating voltage provided for operation of the lamp.

The term high frequency used herein denotes a frequency of greater than 1KHz, and preferably greater than 10KHz.

The transistor of the transistor-oscillator arrangement is preferably biased to class A operation.

Thus, according to a third aspect of the invention, there is provided an electronic ballast for a discharge lamp, which ballast comprises: a transistor-oscillator arrangement for providing, from a D.C. voltage, high frequency alternating voltage for operation of the lamp, there being an output transformer having a secondary winding for connection across external terminals of the lamp for the supply of said high frequency alternating voltage for operation of the lamp, the transformer having a primary winding forming with a capacitance a resonant circuit of said transistor-oscillator arrangement, and said transistor-oscillator arrangement comprises a single transistor having a control electrode coupled to a feedback winding of said transformer, a control path coupled to said resonant circuit and a biasing arrangement for biasing the transistor into class A operation.

Such an arrangement has the following features; (i) the input and output waveforms are substantially 180° out of phase; (ii) there is a transformer coupling from the transistor output to the lamp; (iii) when there is no input signal due to the feedback signal being cut-off, the transistor employs an idle current as a standby current for the operation of the transistor; (iv) the transistor is operating in an amplifying mode, usually biased so that the quiescent collector, or control path, current is midway between the maximum and miniumum values of the output current swing.

Such a construction and features give simplicity, less harmonic distortion/interference, economy (i.e. fewer components and hence less power consumption) and better control of the input against the output, so that the feedback has a more stabilising effect.

By contrast, the normally used class B and C give the following effects:

Class B: input and output are in phase and, if used on a single transistor, the transistor will heat up more easily and cause more loss.

Class C: half phase conducting angle - it is more difficult to control the biasing of the transistor.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is a circuit diagram of a high frequency ballast for a fluorescent lamp with a line filter;

Figure 2 is a diagram showing one form of transformer windings for the ballast;

Figure 3 is a diagram illustrating one form of transformer for the line filter;

Figure 4 shows the ballast of Figure 1 with one form of high frequency cut off device;

Figure 5 shows the ballast of Figure 1 but including an alternative form of high frequency cut off device;

Figure 6 shows an arrangement with two discharge lamps;

Figures 7 and 8 show the input and output waveforms respectively of the line filter; and

Figure 9 shows a further embodiment of cut off device.

Figure 1 shows a ballast and line filter having inputs L and N (live and neutral) for receiving mains supply voltage, for example 240V, at 50Hz.

A fluorescent lamp to be used with the ballast is designated by reference numeral 1 and has first and second ignition filaments 2,3. The lamp may be, for example, a Philips TLD 54, 36 Watts lamp.

The line filter, shown to the left of broken line X-X in Figure 1, serves to pass mains frequency to operate the ballast, and to prevent the return of high frequency components to mains and comprises two chokes L1 and L2 in the "live" line and in the "neutral" line respectively, and a capacitative arrangement comprising a capacitor C1 connected in parallel with two capacitors C2, C3, connected in series between the live and neutral lines. The junction of the capacitors C2 and C3 is earthed. A 0.5A fuse F is connected in the live line.

Each choke has an E - I shaped core arrangement as shown in Figure 3, in which the dimensions of the E section are as follows:

H = 3.25 cm
L = 4 cm
a = 1.25 cm
c = 0.75 cm
h = 2.1 cm

The thickness of the core is 1.3 cm, and the winding is 1000 turns of SWG 32 on the central limb of the core. Both chokes are identical.

It has been found that with this transformer arrangement suitable capacitor values are:

C1 = 0.047 μF
C2 = 0.033 μF
C3 = 0.0033 μF

An advantage of the described line filter is that the input waveform is substantially sinusoidal at 50Hz so as to cause as little interference as possible on the mains circuit. Similarly the output waveform, that is across winding L5 of Figure 1, is substantially sinusoidal at 42KHz and 900V peak to peak. The two waveforms are shown in Figures 7 and 8.

The ballast, to the right of broken line X-X, will now be described with reference to Figure 1. A resistor R1 is connected between live input L and one terminal 4 for releasable connection to one end of the filament 2 of the fluorescent lamp 1. A second terminal 5, for releasable connection to the other end of the filament 2, is connected to neutral input N via two poles of a rectifying means in the form of a diode bridge D1-D4, the other two poles of which have connected across them an electrolytic capacitor C4. The other filament 3 is also provided with releasable terminals 4' and 5'. The terminals 4, 5, 4' and 5' are provided by sockets or plugs to which the lamp 1 is releasably connected. In parallel with the capacitor C4 there are connected, in series, a first variable biasing resistor R2 and a parallel arrangement of a second variable biasing resistor R3 and a capacitor C5. This arrangement serves to bias a transistor TS into class A operation.

The transistor TS has its base B connected to the junction 6 of the first variable resistor R2 and the parallel arrangement, and its emitter E connected to ground. Its collector C is connected, via an LC oscillating arrangement OS, to a pole of the electrolytic capacitor C4 and to the first variable resistor. An inductive portion L3 of the LC oscillator OS is constituted by part of a primary winding of a transformer TR1. The capacitative portion is formed by a capacitor C6. A feedback winding L4 of the transformer TR1 is connected between the base B of the transistor and the said junction 6. The secondary winding of the transformer TR1 is for loading the fluorescent lamp 3 and has two sections L5, L6 for providing respectively a high tension supply for the lamp, and a voltage supply for the second lamp filament 3. The arrangement of the transformer windings is shown more clearly in Figure 2. A suitable transformer would be a Ferrite switching transformer. The turns of the transformer are chosen to limit the open circuit voltage across L5, so as to prevent cold starting, and to ensure that the starting frequency is sufficient above 5KHz to avoid audible noise. A diode clamp D5, e.g. BY 527 Philips x 2 connected in series, is connected between the collector C and emitter E of the transistor TS to limit the peak-to-peak swing thereacross.

Operation of the circuit is as follows:-

When mains voltage is applied to the input terminals L and N, it passes through the line filter which filters it to remove line interference or noise. It is then rectified using the bridge D1 to D4 and used to charge the electrolytic capacitor C4 to the circuit operation voltage. When the capacitor C4 is charged sufficiently, a base current flowing via resistor R2 to the base B of the transistor TS turns the transistor on. As a result a collector current flows through the part L3 of the primary winding of the transformer TR. This has two effects:

i) an output transformer voltage is induced in the part L5 of the transformer secondary to provide HT voltage to the lamp 1; and

ii) a reverse voltage is set up in the base drive part L4 of the transformer to cause the transistor to turn off.

With the transistor TS turned off, capacitor C6 is charged by current flow from the oscillator winding L3 of the primary winding until it has acquired such a stored voltage as to prevent further current flow through winding L3. Then the capacitor C6 discharges, as in a conventional LC oscillating circuit, to cause a reverse current to flow through winding L3 and hence through secondary winding L5. The capacitor C6 discharge also causes a base current to flow again through the base drive part L4 of the transformer to turn on the transistor and repeat the process. Hence there is induced in the secondary winding a voltage and current for driving the lamp 1, at a frequency which is much greater than mains frequency and which depends on the oscillating frequency of the LC oscillating circuit OS. Typically, the operating frequency of the lamp may be 30 KHz or above.

The advantages of using a higher frequency include less power consumption by the ballast/lamp arrangement and accordingly a smaller increase in temperature during operation of the lamp. In addition, the high frequency ensures that the lamp is substantially "flicker free" in use. In a test using the embodiment of Figure 1 run at 37 KHz, the power supply was 39.6W, the current drawn 137mA and the power factor 93.55%. At 47.6KHz the corresponding Figures were 49.8W, 210mA and 98.8%.

Since the current for heating the filament and the HT voltage for the lamp are taken from the same transformer winding, there is a fast power supply to the lamp coupled with a slow start up.

As is clear from Figure 1, the current flows to the diode bridge from the input L by way of resistor R1 and lamp connector terminal 4, filament 2, and lamp connector terminal 5. Thus, as a protective measure, with the fluorescent lamp disconnected, or if it becomes inoperative during use, the ballast will not operate, as there will be no current path via the filament 2. Further, the lamp may be operated with only one operative filament, provided that this is connected as filament 2.

Referring now to Figure 4, a cut off arrangement to operate in the event of lamp failure will be described. The cut off arrangement is designed to detect an excessive voltage across the lamp and includes, connected in series between the diode bridge D1-D4 and ground, a resistor R4, 12V relay winding 6 and a thyristor 7. The thyristor 7 is triggered via an arrangement comprising a zener diode 8 and electrolytic capacitor C7 connected in sequence to the base B of the transistor TS. As soon as the capacitor C7 is charged to the zener voltage of diode 8, the thyristor 7 is triggered. One contact terminal 9 of the relay 6 is connected to ground, while another 10 is connected to the base B of the transistor TS. A resistor R5 is connected between the trigger of thyristor 7 and ground and a diode D6 is connected between the cathode of the zener diode 8 and ground. With a faulty lamp, but with its filament still in operation, or with an inability to strike, capacitor C7 is sufficiently charged to strike the thyristor.

Another form of cut off arrangement is shown in Figure 5: the remaining components of the ballast are as described above with reference to Figure 1. This form of arrangement is similar to that described with reference to Figure 4 but with the triggering of the thyristor 7 being effected by a transformer TR2 having one winding L7 connected across winding L6 of the transformer TR1 and the other winding L8 connected in parallel with a variable resistor R7 used to trigger the thyristor. This arrangement is more sensitive than that described above with reference to Figure 1 and operates as follows.

If, during start up, there is incorrect loading, a voltage will be induced in the secondary winding L8 of the firing transformer TR2 sufficient to trigger the thyristor 7. When triggered, the thyristor 7 conducts and causes the relay 6 to turn on, joining terminal 9 to terminal 10 of the relay 6, thereby connecting the base B of the transistor TS of the ballast to ground. Hence operation of the transistor will be prevented. The thyristor will cease to conduct when the voltage across it falls to zero, thereby causing opening of the connection between terminals 9 and 10.

For a mains voltage of 240V at 50Hz, the following are suitable examples of the components shown in the above described Figures.

C4:	-	0.47 μF	240V AC
C5:	-	0.0033 μF	400V
C6:	-	0.0033 μF	2000V DC
C7:	-	2 μF	25V
D1-D4:	-	DIODE IN 4007	
R1:	-	120Ω	20-40 W ± 10%
R2:	-	39KΩ	2W
R3:	-	390 Ω	
R4:	-	22K Ω	2W
R5	-	330 Ω	0.5W
TS:	-	BU 208 A	

It would also be possible to use supply voltages of 110V, 100V, 200V and 220V by changing the values of the components (i.e. resistors, capacitors and number of transformer windings) accordingly.

A dimming function may be carried out by adjusting the bias of the transistor TS using the biasing arrangement R2, R3 to alter the operation point of the transistor on its characteristic curve and hence to alter the output collector voltage. As an alternative, an external dimmer may be connected in series with the power supply to vary the input current and voltage.

Figure 6 illustrates an arrangement with two lamps 20, 21 each with their associated transistor-oscillator arrangement. The arrangements are connect by respective diodes D7, D8 and fuses F2, F3 to the rectifying means D1-D4 of the ballast. Auto-cut off means may be included, as shown in Figure 4 or 5. This is indicated generally at 23 in Figure 6.

Finally, it is noted that the cut-off arrangements shown in Figures 4 and 5 include a relay. It will be appreciated that this may be replaced by a fully electronic system using electronic switching circuitry. Such a system is shown by way of example in Figure 9. The oscillator transistor TS has its emitter coupled to the bridge D1-D4 via a normally conducting transistor TS1. Thus R6 and R7 normally provide a bias to maintain transistor TS1 conductive. If the oscillator starts to operate on a faulty lamp, or when a lamp is not present, the back EMF on the transformer TR1 is fed by winding L7 to a diode D7, to rectify it, and then to resistor R8 and capacitor C8. Capacitor C8 charges up during the existence of the back EMF and, assuming the value is high enough and remains for a sufficient time, transistor TR2 is turned on, giving a voltage drop across R5 to trigger thyristor 7. The current through R6 is then bypassed through the thyristor 7 so that transistor TR1 turns off and thus stops the oscillator.

When the lamp is in good condition, it strikes, lights up and causes a drop of voltage in the transformer TR1 and thus in winding L7. The voltage in L7 is then too low to operate the cut off circuit. Diode D8 absorbs current on switching off transistor TS1, so protecting that transistor.

In this case, it will be seen that the coupling from the bridge to the lamp filament is omitted as the cut off circuit will detect the absence of the lamp.

Suitable components might be:

L7	12 turns of 37 SWG
R5	150 Ω
R6	47K Ω
R7	47K Ω
R8	300K Ω
R9	270 Ω
C8	0.05 μF

CLAIMS:

1. An electronic ballast for a discharge lamp (1), which ballast comprises a transistor-oscillator arrangement (TS, C5, C6, R2, R3, L3) having transistor means (TS) operable to provide high frequency alternating voltage for operation of the lamp (1), characterised by means (4,5) responsive to said lamp being faulty or absent to disable the transistor-oscillator arrangement.

2. An electronic ballast as claimed in Claim 1, wherein the lamp responsive means comprises terminals (4,5) for connection across a filament (2) of said lamp (1), said terminals (4,5) being coupled to disable said arrangement in the absence of a working filament.

3. An electronic ballast as claimed in Claim 1 or 2, wherein the transistor-oscillator arrangement comprises switching means (TS1 or 9, 10) coupled to the arrangement, and the ballast further comprises means (7) responsive to the high frequency voltage exceeding a given value for a given time for actuating the switching means in the sense to disable the arrangement.

4. An electronic ballast according to Claim 3, wherein the switching means is semiconductor switching means (TS1).

5. An electronic ballast according to Claim 3 or 4, and comprising a thyristor (7) responsive to excessive high frequency voltage to actuate the switching means.

6. An electronic ballast for a discharge lamp (1), which ballast comprises: a voltage supply terminal (L) for connection to a voltage supply; a transistor-oscillator arrangement (TS, C5, C6, R2, R3, L3) having a voltage supply input (5) and operable to provide therefrom high frequency alternating voltage for operation of the lamp (1); and first and second lamp connector terminals (4, 5) for connection across an ignition filament (2) of such a discharge lamp (1), characterised in that the voltage supply terminal (L) is

connected to the first lamp connector terminal (4), and the voltage supply input of the transistor-oscillator arrangement is connected to the second lamp connector terminal (5) so that operation of the ballast is only permitted when an operative filament is connected between the first and second lamp connector terminals.

7. An electronic ballast as claimed in claim 6, comprising rectifying means (D1-D4) for providing d.c. voltage for operation of the transistor-oscillator arrangement, the rectifying means having an a.c. input coupled to the second lamp connector terminal (5), whereby, in use, the rectifying means will be energised via said ignition filament (2).

8. An electronic ballast as claimed in claim 6 or 7, wherein the transistor-oscillator arrangement includes a single transistor (TS) having a control electrode (B) and a controllable path (C-E), with its control electrode (R) coupled to be driven via a first transformer winding (L4) and with its controllable path (C-E) connected, via a high frequency resonant circuit (C6, L3), to a supply point for d.c. voltage supply, the high frequency resonant circuit comprising a capacitor (C6) connected in parallel with a second transformer winding (L3), the first and second transformer windings both being windings of the same transformer (TR1).

9. An electronic ballast as claimed in claim 8, wherein the second transformer winding (L3) is the primary winding of the transformer, the secondary winding (L5) of which is arranged to be connected across the discharge lamp (1) for the supply of said high frequency voltage to the lamp.

10. An electronic ballast as claimed in any of claims 6 to 9, and comprising means for altering the magnitude of the voltage supply thereby to alter the high frequency alternating voltage for operation of the lamp.

11. An electronic ballast as claimed in any one of claims 6 to 10, which further comprises biasing means (R2, R3) for biasing the transistor-oscillator arrangement into class A operation.

12. An electronic ballast for a discharge lamp (1), which ballast comprises: a transistor-oscillator arrangement (TS, C5, C6, R2, R3, L3) for providing, from a D.C. voltage, high frequency alternating voltage for operation of the lamp, there being an output transformer (TR1) having a secondary winding (L5) for connection across external terminals of the lamp (1) for the supply of said high frequency alternating voltage for operation of the lamp, the transformer (TR1) having a primary winding (L3) forming with a capacitance (C6) a resonant circuit of said transistor-oscillator arrangement, characterised in that said transistor-oscillator arrangement comprises a single transistor (TS) having a control electrode (B) coupled to a feedback winding (L4) of said transformer, a control path (CC-6) coupled to said resonant circuit and a biasing arrangement (R2, R3) for biasing the transistor into class A operation.

13. An electronic ballast as claimed in claim 11 or 12, wherein the biasing means is operable to alter the magnitude of the high frequency alternating voltage provided by the transistor-oscillator arrangement.

14. An electronic ballast as claimed in any one of claims 6 to 13 and further comprising means (7) for inhibiting operation of the ballast when connect to such a discharge lamp when that lamp is inoperative.

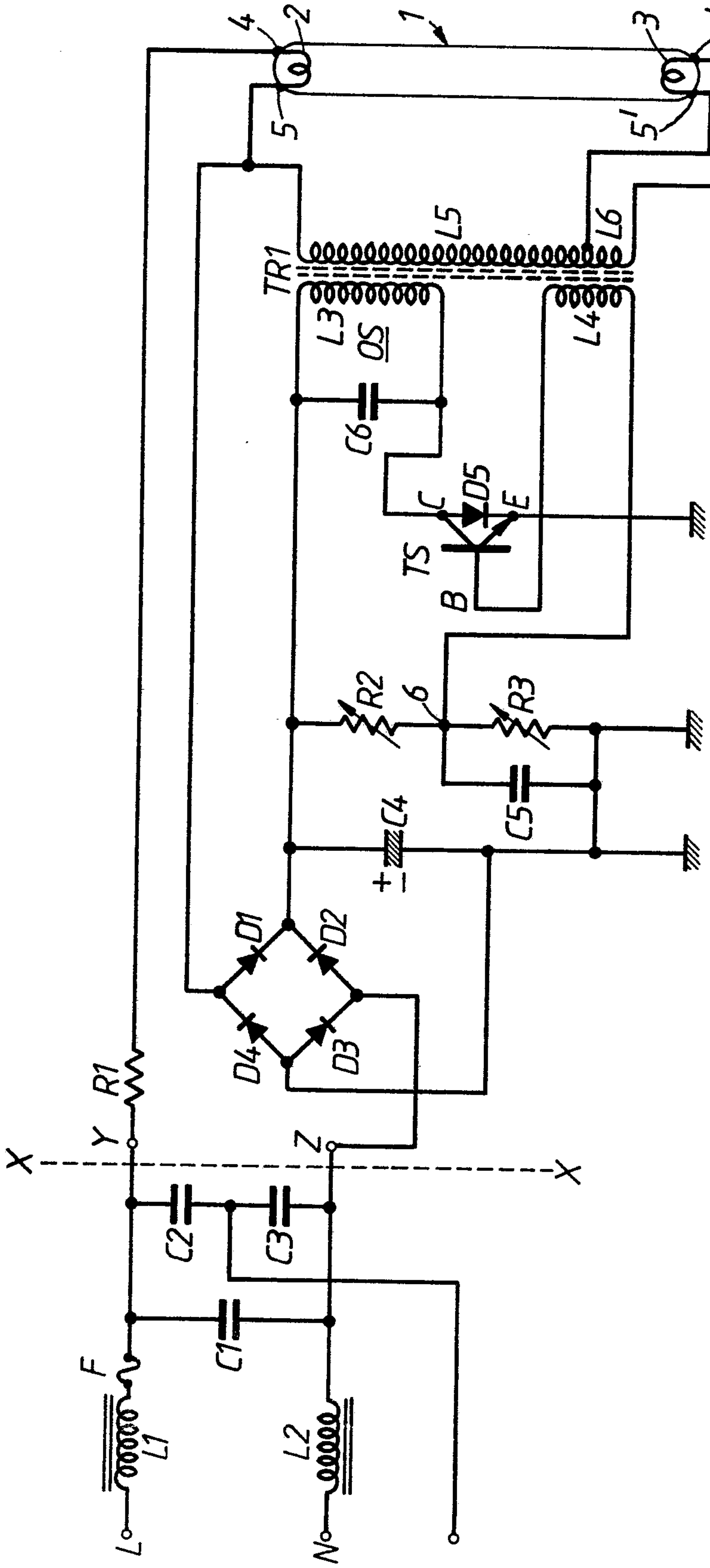
15. An electronic ballast as claimed in Claim 14, wherein the inhibiting means comprises a switchable path (7) coupled to the voltage supply input of the transistor-oscillator arrangement and operable in dependence upon said high frequency alternating voltage to switch off the oscillator.

16. An electronic ballast as claimed in Claim 14, when appended to Claim 8 or 12, wherein the inhibiting means is coupled to said first, or feedback, transformer winding so as to be responsive to said high frequency alternating voltage.

17. An electronic ballast as claimed in Claim 14, the inhibiting means comprising a transformer (TR2) having a primary winding coupled to the transistor-oscillator arrangement to receive a signal representative of said high frequency alternating voltage and a secondary coupled to operate a switching device in said switchable path.

18. An electronic ballast as claimed in any one of claims 6 to 17, including a filter (L1, L2) for filtering mains supply voltage to provide a filtered voltage for supply to the voltage supply terminal.

19. An electronic ballast as claimed in Claim 18, wherein said filtering means comprises two chokes (L1, L2) in respective ones of the 'live' and 'neutral' sides of the mains supply.



1
2
3
4
4'
5
5'
TR1
L5
L6
L3
OS
L4
C6
C
D5
E
TS
B
R2
6
R3
C4
C5
+
-
D1
D2
D3
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R1
Y
Z
X
X
C2
C3
C1
F
L1
L2
L
N

FIG. 1.

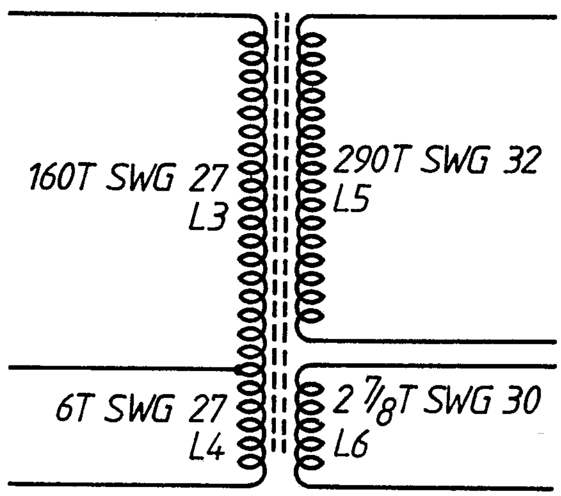

FIG. 2.

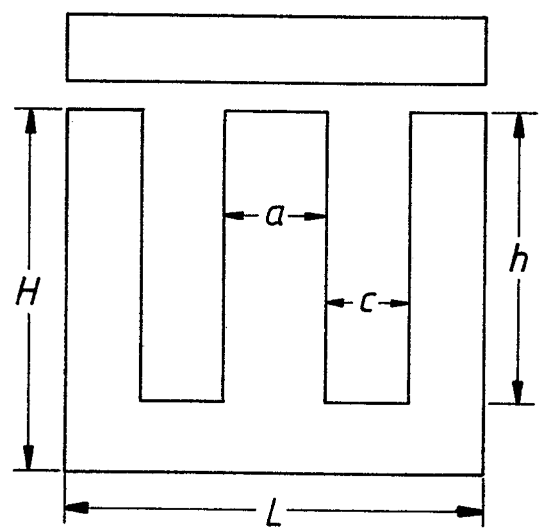

FIG. 3.

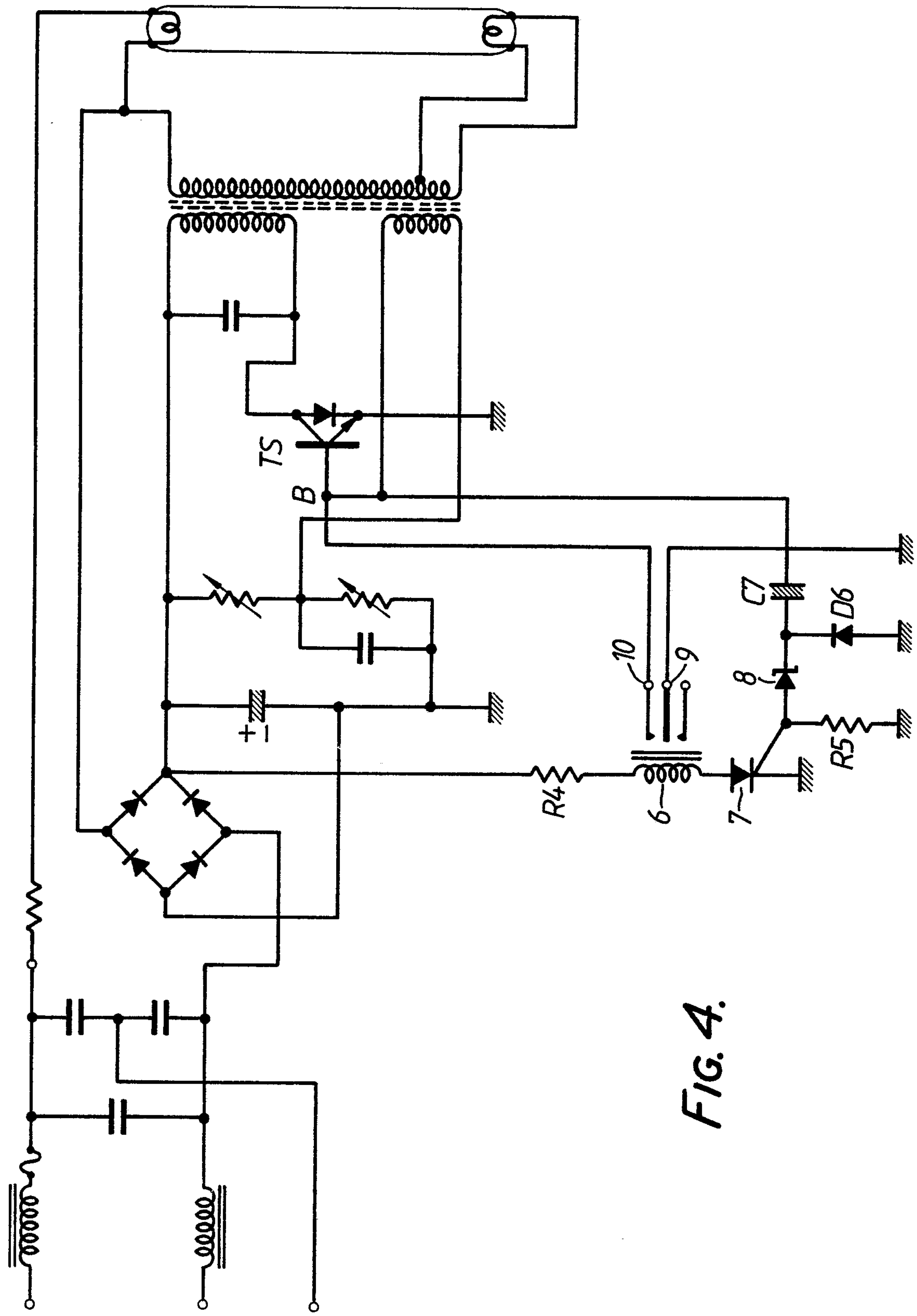

FIG. 4.

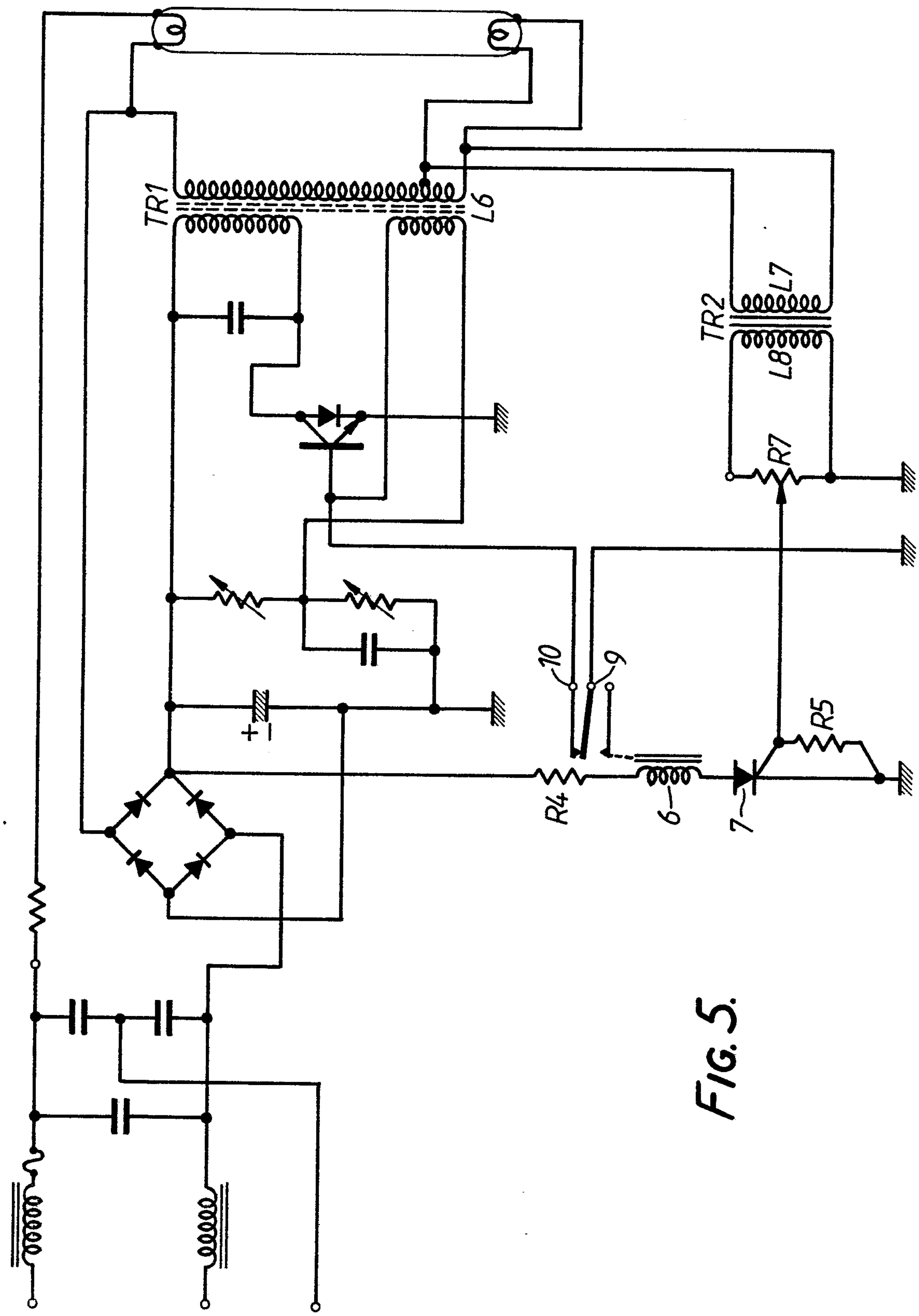

FIG. 5.

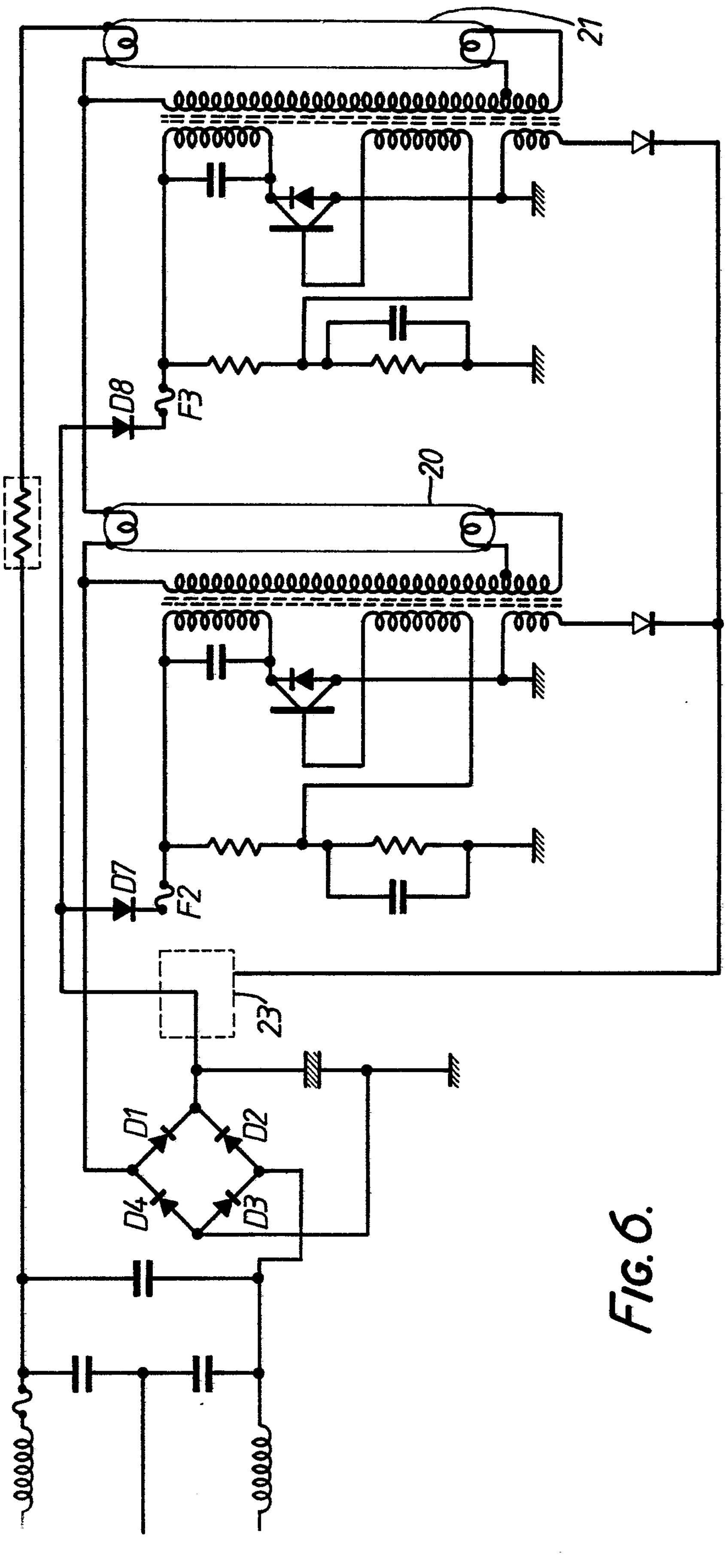

FIG. 6.

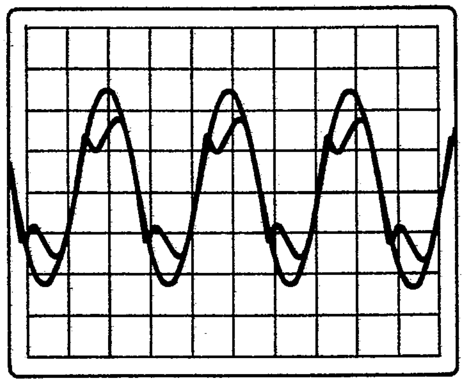

FIG. 7.

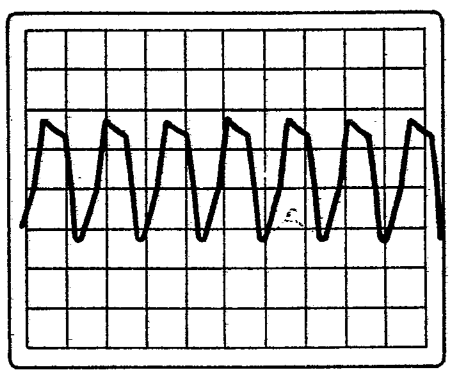

FIG. 8.

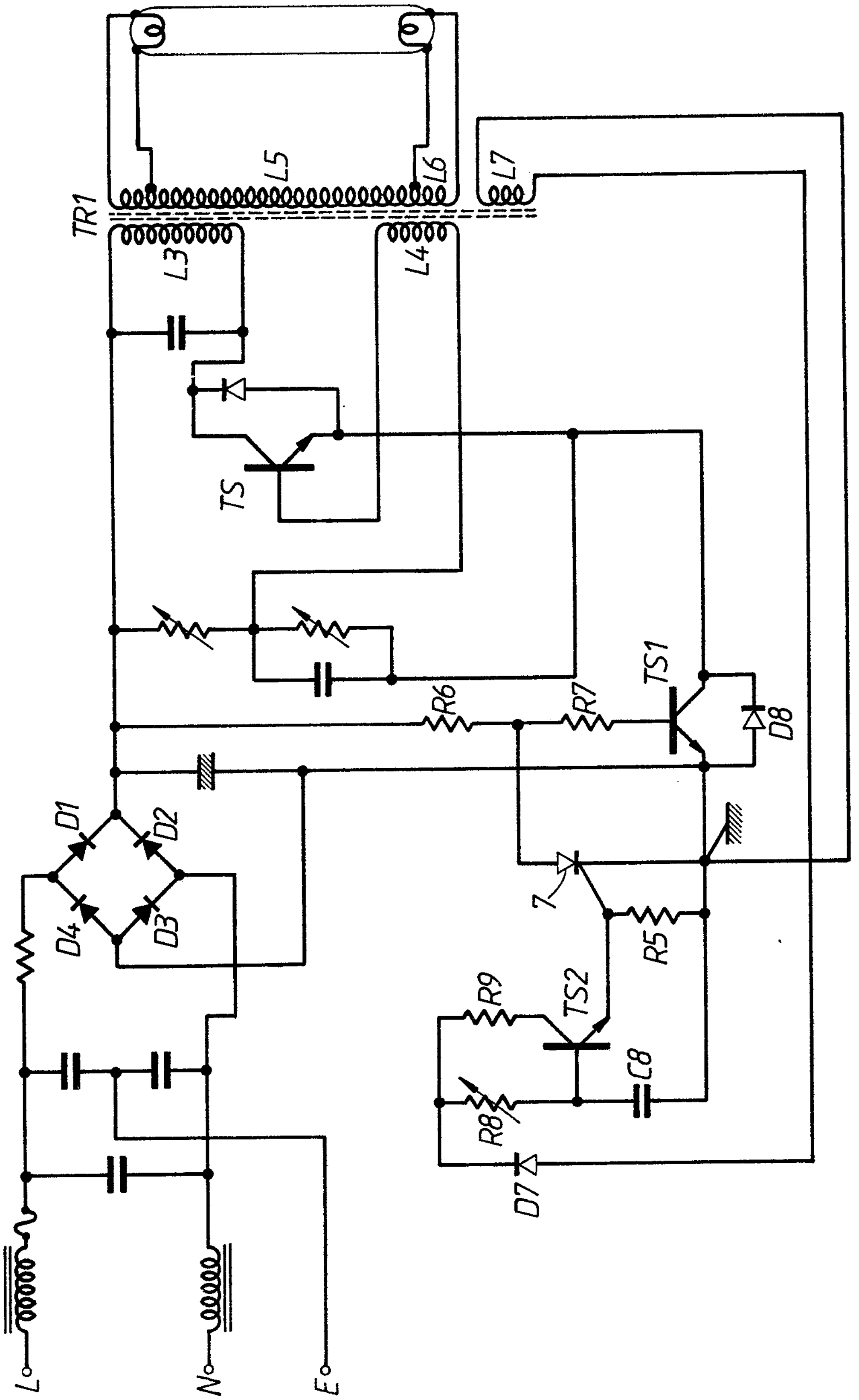

FIG. 9.