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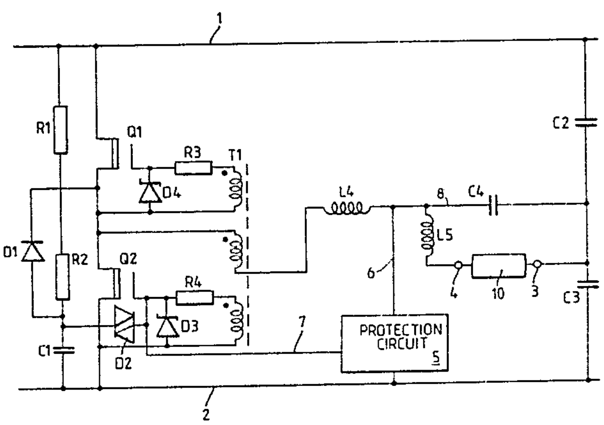
(54) Power circuit.

(57) A power circuit for a low pressure sodium lamp utilises a high frequency oscillator which delivers a constant current to the lamp and which has a frequency of oscillation which is largely independent of variations in the impedance of the lamp. Sodium lamps have negative temperature-resistance coefficient, and the effect of the circuit is to counteract any tendency for the current taken by the lamp to increase as it heats up during operation. An additional inductance is provided between the oscillator itself and the lamp acts to stabilise the frequency of oscillation and hold constant the current delivered to the lamp.

Fig.1



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Power Circuit

This invention relates to a power circuit, and more particularly to a power circuit arranged to supply power at high frequency to a load which exhibits a variable resistance. Self-oscillating circuits have a tendency to be unstable and for the frequency value to alter significantly with variations in load value unless the frequency source is well protected by an impedance buffer.

The present invention seeks to provide an improved high frequency power circuit which is suitable for use with a load having a negative resistance-temperature coefficient.

According to this invention, a high frequency power circuit for a negative resistance-temperature coefficient load includes an oscillator connected to a load path via an inductance, which inductance in combination with a capacitor in shunt with said load path constitutes a tuned resonant circuit which controls the frequency of the oscillator, and a further inductance in series with the load path and in shunt with said capacitor so as to render the current delivered to the load substantially independent of temperature-induced variations in the impedance of the load path.

Thus the effect is to cause a substantially constant current to flow in the load. The frequency of oscillation will also remain largely constant, but small variations may occur depending on the nature and length of the leads connecting the load to the power circuit.

In use a load is connected in the load path so as to be supplied with high frequency power from the oscillator. The invention is particularly suitable for use with a low pressure sodium lamp which has a negative temperature-resistance coefficient. If the lamp is mounted in close proximity to the power circuit, the frequency of oscillation will be fairly constant as the resistance of the lamp changes, but the frequency will probably vary to a greater extent if the lamp is mounted on a tall lampost with the driver circuit itself located at the base of the post.

The provision of the further inductance has the effect of making the frequency of oscillation of the oscillator, as determined largely by the tuned circuit, insensitive to variations in the load value, although it can be affected by the capacitance of long leads which may be used to connect the lamp to the rest of the circuit. The invention provides in effect the action of a current limiter to counteract any current run-away characteristic which results from the reduction in load resistance which occurs as it heats during normal operation.

The oscillator can readily be designed so as to be capable of generating a very high strike voltage to cause a sodium lamp togo into conduction. After conduction commences, and a substantial current is drawn, the potential across the lamp drops to a normal operating level. As a lamp ages, the turn-on strike voltage needed before conduction commences increases, and the lamp may have to be discarded if the power circuit is unable to produce a sufficiently large strike voltage. With the present arrangement, the oscillator can be designed to generate a high voltage when needed, without the attendant risk of the excessive available power resulting in thermal run-away.

To avoid the risk of too large a strike voltage being generated if the lamp malfunctions, preferably a voltage limiter is provided in the power circuit.

The invention is further described by way of example with reference to the accompanying drawings in which Figure 1 shows a power circuit in diagrammatic form, and Figures 2, 3 and 4 are explanatory diagrams.

The power circuit comprises essentially a high frequency oscillator which is powered via a pair of DC power rails 1 and 2 ,the oscillator being arranged to feed a load 10 which in use is connected between terminals 3 and 4. The circuit consists of a pair of transistors Q1 and Q2 which are connected in series across the power rails 1 and 2 and which are biassed by means of a potentiometer consisting of resistors R1, R2 and capacitor C1 in series. A diode D1 is connected across the resistor R2 for a purpose which is described subsequently. The two transistors Q1 and Q2 are linked via resistors R3, R4 and a three-winding transformer T1 to a resonant circuit consisting of inductor L4 and capacitor C4 which couples the transformer to the load terminals 3 and 4. A further inductor L5 is provided in series between the terminal 4 and the inductor L4 so as to be electrically in shunt with the capacitor C4. A diac D2 is provided between the capacitor C1 and the gate terminal of transistor Q2, diac D2 being a device which conducts only when the voltage across it exceeds a threshold value Protection Zener diodes D3 and D4 are also connected to the gate terminals of the transistors Q1 and Q2 as shown. To avoid the voltage on the terminal 8 exceeding a safe value, a protection circuit 5 is connected to sense the voltage at the junction of inductors L4 and L5 via lead 6, and to provide a control signal on lead 7 to interrupt the power when the safe level is exceeded. Capacitors C2 and C3 are provided to give an AC coupling between terminal 3 and the two power rails 1 and 2.

At switch-on a DC voltage of about 340 volts is applied across the DC power rails 1 and 2, and the capacitor C1 charges via the resistors R1 and R2. The resistors R1, R2, capacitor C1 and diac D2 form a relaxation oscillator whose purpose is to start the main oscillator into oscillation. The main oscillator which is used to provide high frequency power to the load terminals 3 and 4 comprises the transistors Q1, Q2, the transformer T1, inductance L4 and capacitance C4.

As the voltage on capacitor C1 reaches the threshold voltage of the diac D2, the diac switches into conduction and delivers a volage pulse to the gate terminal of transistor Q2 which is sufficient to cause the transistor to conduct. Once transistor Q2 is conducting, the capacitor C1 is held in a discharge state by the action of the diode D1 with the effect that the relaxation oscillator is shut down. The period of the relaxation oscillator which comprises the resistors R1, R2, capacitor C1 and the diac D2 is much greater than the period of the power oscillator.

In operation, the load 10 connected between terminals 3 and 4 comprises the sodium lamp as described previously and so the high frequency oscillator which supplies its power is conveniently termed a lamp oscillator. This lamp oscillator is a half bridge, self-resonant, current-driven inverter. Its operation is as follows.

When transistor Q2 conducts by the mechanism previously described, current is drawn from the capacitor C4 via the inductor L4 and the transformer T1. By transformer action, the transformer T1 causes transistor Q2 to remain in conduction after the diac D2 has ceased to conduct. This state persists until a current reversal occurs due to the resonant nature of the tuned circuit comprising inductor L4 and capacitor C4. When current reversal occurs, transistor Q2 is rendered non-conductive and transistor Q1 is driven on by the action of transformer T1. Thus the transistors Q1 and Q2 which act as current switches are conductive in antiphase. The oscillations are self-maintaining at a frequency determined primarily by inductor L4 and capacitor C4, and the energy to maintain these oscillations is derived from the DC power supply.

The "Q" of the circuit which is defined by wL/R where R is the effective resistance in the resonant circuit, causes a voltage magnification to such an extent that a potential as great as 3000 volts can be present across capacitor C4. The protection circuit 5 is arranged to limit this potential to a safe value of about 1600 volts peak. When a low pressure sodium lamp comprises the load 10 and is connected across the load terminals 3 and 4, this voltage is sufficient to strike an arc in the lamp so as to cause current to flow through the lamp. This arc is maintained by the action of the lamp oscillator, and the magnitude of the current fed to the lamp is determined primarily by the value of capacitor C4 and secondly by the values of inductors L4 and L5. The frequency of oscillation is set by the combined effect of capacitor C4, inductor L4 and L5 and also the effective lamp resistance. Under high frequency conditions the impedance of the lamp is almost wholly resistive. Typically the lamp oscillator is arranged to oscillate at a frequency of about 140 KHz.

Figure 2 shows the way in which the potential across the load terminals 3 and 4 increases to about 1600 volts until the lamp arc strikes, after which it decreases to a constant running value of about 200 volts peak. For a faulty lamp which is open circuit, the potential remains at a high but safe value of 1600 volts.

As a sodium lamp warms up during normal operation its resistance falls. It has a negative slope resistance with temperature, and the purpose of inductor L5 is to control this effect and so render the circuit stable. If inductor L5 is omitted the circuit is only conditionally stable and is only self-resonant for values of lamp resistance greater than $\sqrt{L4/C4}$, and should it fall below this value the oscillations will continue but in a rather different mode determined by the saturation characteristics of the core of the transformer T1.

In the absence of inductor L5, the frequency of oscillation for the saturating core mode is typically one half of the self-resonance frequency determined by inductor L4 in conjunction with capacitor C4, where the frequency is determined by the size of the transformer core, number of turns and current magnitude. With a frequency of oscillation which is much lower, a greater current flows in the lamp and it has a value limited by the impedance of inductor L4 and the resistance of the lamp. In practice, capacitor C4 would play virtually no part in the operation of the circuit under these conditions and as the lamp resistance falls significantly with temperature thermal run-away could occur which would cease only when transformer T1 heavily saturates.

The presence of inductance L5 in accordance with this invention has quite the reverse effect. A typical value of inductor L5 is about 150µH, and in the present example the value of inductor L4 is about twice that. Figure 3 shows the variation of input power to the lamp as the series inductance L5 is varied for different values of lamp resistance. As the lamp resistance is reduced (as shown by the arrow), the frequency of oscillation is increased and this very effectively prevents an increase in lamp current. However, should the lamp temperature increase for any reason a negative feedback occurs such that less power is fed to the lamp and thus its temperature falls thereby increasing its resistance. This action prevents thermal run-away occurring. The relationship between these factors is illustrated in Figure 4, in which three characteristics are plotted against lamp resistance. Line 11 shows power input to the lamp, for an optimum value of inductor L5 which is determined from the characteristic of Figure 3, and indicates that the power-input decreases as the lamp resistance decreases. Line 12 shows the variation of the resonant frquency f_o of the lamp oscillator; it increases as lamp resistance decreases. Finally line 13 represents the lamp current I, which remains substantially constant.

As has been previously mentioned it is possible to generate an extremely high voltage across the load terminals 3 and 4 at switch-on. If under these conditions the lamp fails to light or is short circuit the voltage at point 8 at the junction of inductor L4 and capacitor C4 can remain high and the protection circuit 5 is provided to detect this fault mode. It is of a conventional voltage sensing nature and if after about 10 milliseconds an excessive voltage is detected by a protection circuit 5, it acts to shut down the lamp oscillator by clamping the level of the potential on the gate of transistor Q2 via output line 7. Typically after a period of about 10 seconds, this voltage clamp is removed and the starter circuit comprising resistors R1, R2 and capacitor C1 is allowed to reactivate the lamp oscillator. If the fault persists the protection circuit 5 repeatedly inhibits operation of the lamp oscillator.

Claims

1. A power circuit for a negative resistance-temperature coefficient load including an oscillator connected to a load path via an inductance, which inductance in combination with a capacitor in shunt with said load path constitutes a tuned resonant circuit which controls the frequency of the oscillator; and a further inductance in series with the load path and in shunt with said capacitor so as to render the current delivered to the load substantially independent of temperature-induced variations in the impedance of the load path.

2. A power circuit as claimed in Claim 1 and wherein the oscillator includes a transformer having three mutually coupled windings, two of which are coupled to the control terminals of current switching devices which are arranged to conduct in antiphase, and the third of which is coupled to said tuned resonant circuit.

3. A power circuit as claimed in Claim 1 or 2 and wherein a relaxation oscillator having a natural period of oscillation which is longer than that of said first mentioned oscillator is provided to induce said first mentioned oscillator into oscillation, after which oscillation of the relaxation oscillator is suppressed.

4. A power circuit as claimed in any of the preceding claims, and which includes a low pressure lamp as its load.

5. A power circuit as claimed in Claim 4 and wherein the lamp is a sodium lamp.

6. A power circuit as claimed in any of the preceding claims and wherein said oscillator is arranged to generate a high voltage at a high frequency within said tuned circuit for application to a load connectable in said load path.

7. A power circuit as claimed in Claim 6 and wherein means are provided for sensing when said high voltage exceeds a threshold value and for inhibiting oscillation of said first mentioned oscillator in response thereto.

Fig.1

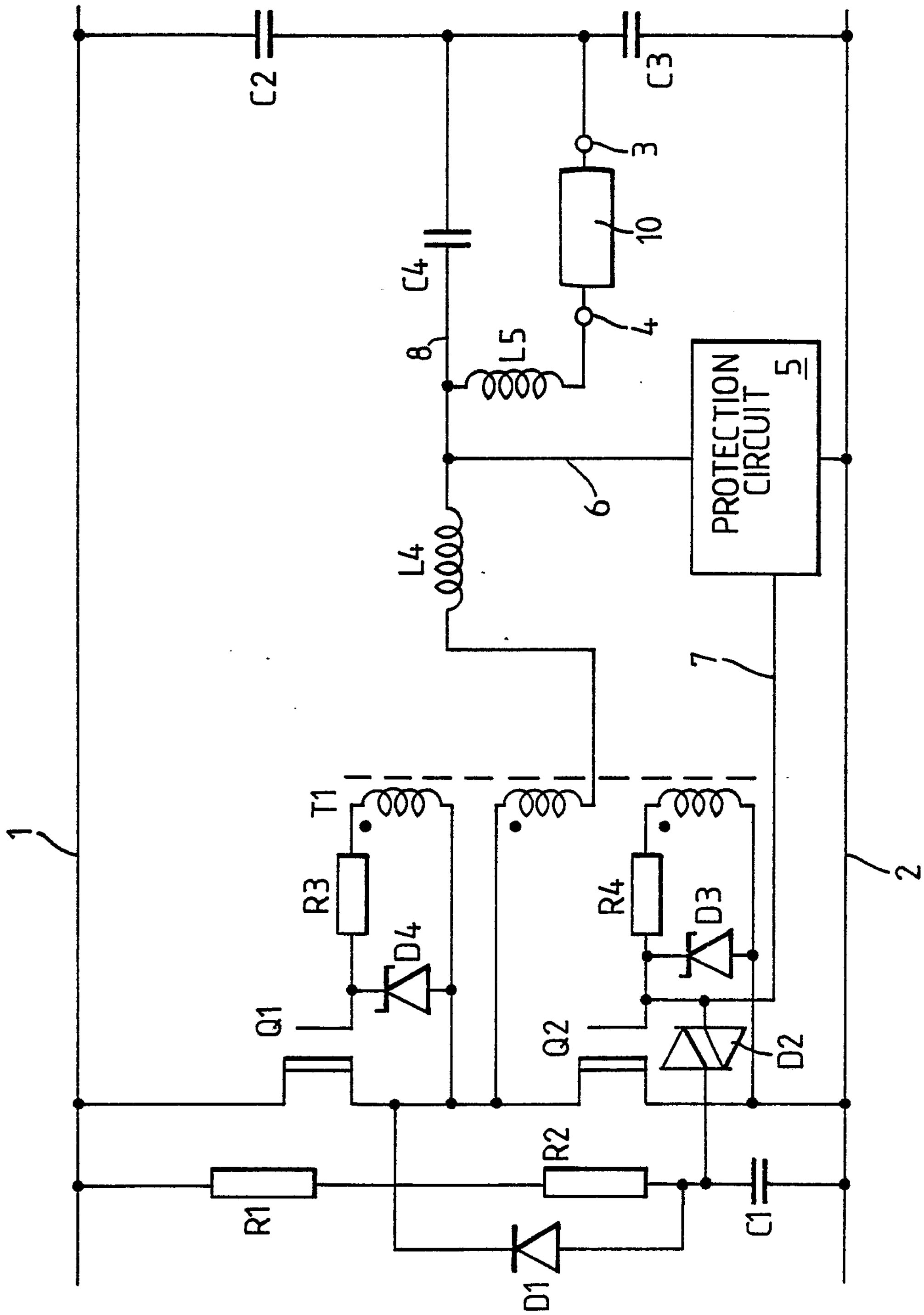
C2
C3
C4
8
L5
L4
3
4
10
6
7
PROTECTION CIRCUIT
5
T1
R3
R4
D4
D3
Q1
Q2
D2
R1
R2
D1
C1
1
2

Fig.2

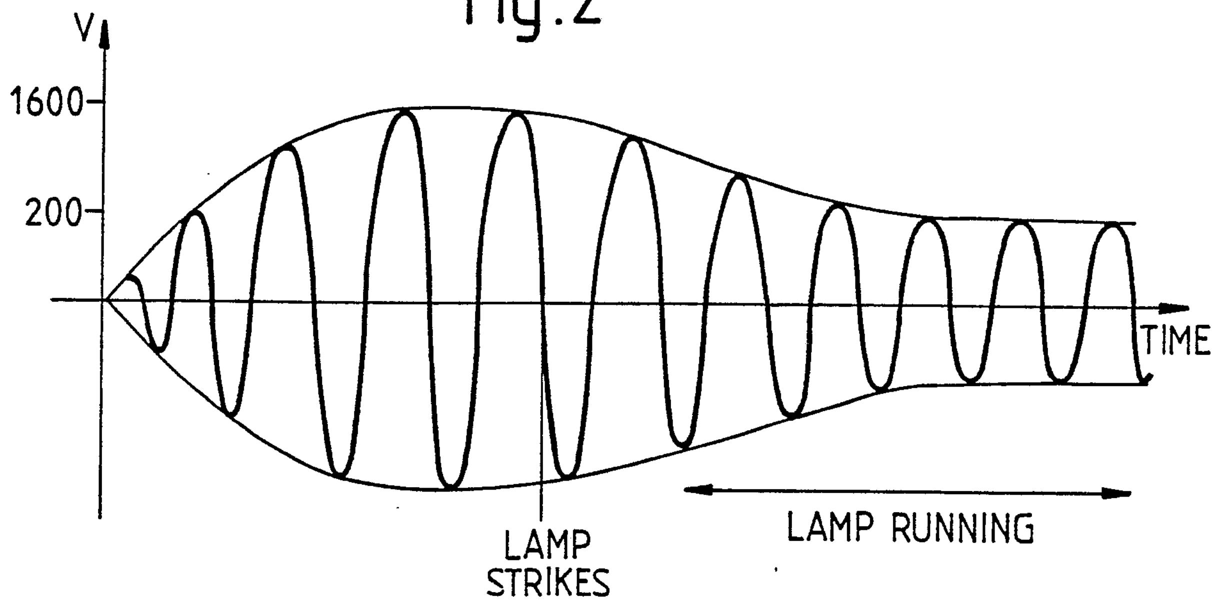

Fig.3

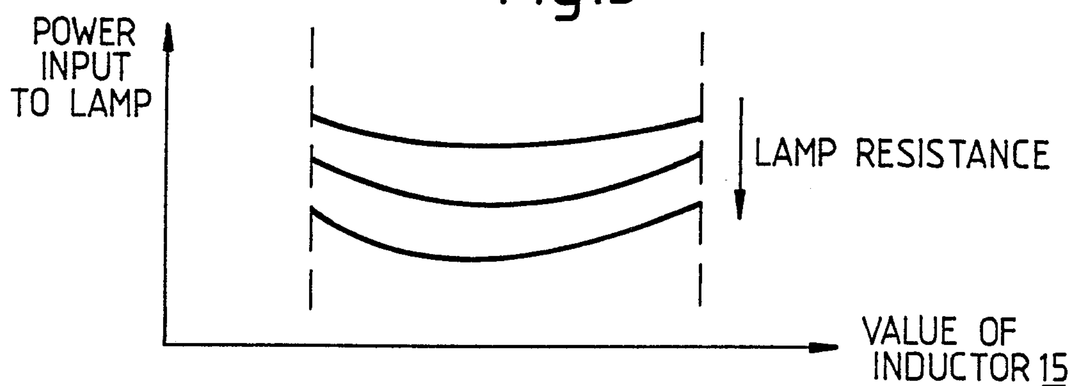

Fig.4