

**Circuit arrangement for a lamp
comprising a first and second circuit
branch connected to the lamp**

The invention relates to a circuit arrangement for operating a lamp,
comprising

- supply input terminals for connection to a supply voltage source,
- a transformer provided with a primary winding L1 and a secondary winding L2,
- 5 - a first branch comprising terminals for holding the lamp and connecting a
 first end of the secondary winding L2 to a second end,
- a second branch comprising a series circuit of a switching element and the
 primary winding L1 and interconnecting the supply input terminals,
- a control circuit coupled to a control electrode of the switching element for
10 generating a control signal for rendering the switching element conducting and
 non-conducting, and thus generating a first current in the primary winding L1
 and a second current in the secondary winding L2.

15 Such a circuit arrangement is known from US 5,072,155. In the known
circuit arrangement, the lamp is coupled to the secondary winding L2 of the transformer
during lamp operation, and the current through the lamp is generated from the second
current. The power dissipated by the lamp may be adjusted over a comparatively wide range
in that the frequency and/or the duty cycle of the control signal is adjusted. A disadvantage
20 of the known circuit arrangement, however, is that the first current is comparatively great, so
that the switching element must be dimensioned for passing a comparatively great current.
This renders the known circuit arrangement comparatively expensive.

25 The invention has for its object to provide a comparatively inexpensive
circuit arrangement with which the power consumed by a lamp operated on the circuit
arrangement can be adjusted over a comparatively wide range.

According to the invention, a circuit arrangement as described in the
opening paragraph is for this purpose characterized in that the second branch comprises a

series arrangement of the terminals for holding the lamp, the primary winding, and the switching element. During lamp operation by means of a circuit arrangement according to the invention, the lamp current is generated from both the first and the second current. The switching element, however, need only be dimensioned for passing the first current. This renders it possible to fit a circuit arrangement according to the invention with a switching element which is capable of passing only a comparatively small current, while nevertheless a comparatively great lamp current can be generated with this circuit arrangement. The effective value of both the first and the second current can be controlled *via* the frequency and/or duty cycle of the control signal, so that also the effective value of the total current through the lamp can be adjusted over a comparatively wide range *via* the switching element.

It is often desirable that the first branch is in addition provided with first diode means. The second current flows through these first diode means during lamp operation, so that the second current is a direct current in the presence of these first diode means. Depending on the type of lamp operated with the circuit arrangement and on the frequency of the control signal, this rectification is necessary in order to be able to generate part of the lamp current from the second current.

When the supply voltage delivered by the supply voltage source is a low-frequency AC voltage, it is advantageous to include a diode bridge in the circuit arrangement whose input terminals are coupled to one of the terminals for holding the lamp and to a supply input terminal, respectively, and whose output terminals are coupled to a main electrode of the switching element and to an end of the primary winding L1, respectively. It is achieved thereby that the first current is a direct current during lamp operation. This is often necessary because the first current flows through the switching element which is often capable of passing current in one direction only. The portion of the lamp current generated from the first current changes polarity with the same frequency as the supply voltage. Such a low-frequency polarity change is useful in some lamps, for example for counteracting the occurrence of cataphoresis. In other lamps, this low-frequency polarity change renders possible a comparatively simple electrode construction because each of the electrodes alternately acts as the anode and as the cathode. To achieve that the portion of the lamp current generated from the second current has the same polarity as the portion of the lamp current generated from the first current, it is advantageous when the circuit arrangement is in addition provided with

- a secondary winding L3 forming part of the transformer,
- a third branch comprising the terminals for holding the lamp and second diode

means, and connecting a first end of the secondary winding L3 to a second end,
switching means which form part of both the first and the third branch,
control means coupled to a control electrode of the switching means for
adjusting the conductivity state of the switching means at each change in
5 polarity of a portion of the lamp current generated from the first current such
that only one of the secondary windings is conductively connected to the
terminals for holding the lamp.

A circuit arrangement provided with these means is capable of achieving that the portion of
the lamp current generated from the second current always has the same polarity as the
10 portion of the lamp current generated from the first current. It is especially advantageous
when the control means are formed by the first current. Since the control means need not be
provided in the circuit arrangement in the form of a separate circuit component, but are
formed by the first current, the circuit arrangement can be of a comparatively simple
construction, and therefore comparatively inexpensive.

15 The discharge arc of some discharge lamps, more in particular high-
pressure discharge lamps, may exhibit instabilities when the lamp current comprises a high-
frequency component. In a circuit arrangement according to the invention for operating such
a lamp, it is advantageous when the circuit arrangement is provided with a filter for filtering
high-frequency components from the current through the lamp.

20 It was found that favourable results are obtained when the switching
element, the transformer, and the diode means form part of a DC-DC converter of the
flyback type.

It was also found that it is advantageous to dimension the transformer
such that the number of turns of each secondary winding accounts for 30%-70% of the
25 number of turns of the primary winding. Preferably, the number of turns of each of the
secondary windings is chosen to be approximately equal to the number of turns of the
primary winding L1. It was found that this renders possible an advantageous dimensioning of
the other components from which the circuit arrangement is built up.

Since it is possible to adjust the power consumed by the lamp by means of
30 the frequency and/or duty cycle of the control signal, the circuit arrangement may be
provided, if so desired, with a control loop coupled to the control circuit for controlling the
power dissipated by the lamp.

It was found for the case in which the circuit arrangement comprises first
and possibly second diode means that a comparatively small amount of power was dissipated

in these diode means when the circuit arrangement is dimensioned such that the control signal renders the switching element conducting when the second current is zero.

5 The invention will be explained in more detail with reference to a drawing, in which

 Figs. 1, 2 and 3 show embodiments of a circuit arrangement according to the invention, and

 Fig. 4 shows an example of the waveforms of currents and voltages
10 obtaining during lamp operation with a circuit arrangement as shown in Fig. 3.

 In Fig. 1, K1 and K2 are supply input terminals for connection to a supply voltage source. T is a transformer having a primary winding L1 and a secondary
15 winding L2. Circuit portion R and terminals N1 and N2 for holding a lamp together form a first branch which connects a first end of secondary winding L2 to a second end. Circuit portion R comprises all components except the terminals N1 and N2, which form part of the first branch. Circuit portion R may comprise, for example, diode means and/or capacitive means. A lamp La is connected to the terminals N1 and N2. A series arrangement of the
20 terminals N1 and N2, primary winding L1, and switching element S1 forms a second branch which interconnects the supply input terminals. A control electrode of the switching element S1 is coupled to a control circuit SC1 for generating a control signal for rendering the switching element conducting and non-conducting, and thus generating a first current in the primary winding L1 and a second current in the secondary winding L2. The coupling
25 between the control circuit SC1 and the switching element is indicated in Fig. 1 with a broken line. An input of control circuit SC1 is coupled to an output of circuit portion RC and an input of circuit portion RC is coupled to the lamp. These two couplings are indicated in Fig. 1 with broken lines.

 The operation of the circuit arrangement shown in Fig. 1 is as follows.

30 When the supply input terminals are connected to the poles of a supply voltage source, the control circuit SC1 renders the switching element S1 alternately conducting and non-conducting. As a result, a first current flows through the second branch. At the same time, a second current flows through the first branch. Both the first and the second current flow through the lamp La. The effective value of the first current as well as

that of the second current is adjustable by means of the duty cycle and/or the frequency of the control signal generated by the control circuit. The effective value of the total lamp current is accordingly adjustable *via* the switching element S1 which itself only passes the first current. It is achieved thereby that the lamp current is adjustable over a comparatively wide range by means of a switching element which passes only a portion of the lamp current, and which accordingly need comply with comparatively low requirements as to its dimensioning. A signal which is a measure for the power dissipated by the lamp La is present at the input of circuit portion RC coupled to the lamp La during lamp operation. The circuit portion RC controls the power dissipated by the lamp La through adjustment of the duty cycle and/or the frequency of the control signal *via* control circuit SC1 such that this power is substantially equal to a desired value of the power dissipated by the lamp. Circuit portion RC may also be provided with means (not shown in Fig. 1) for adjusting the desired value of the lamp power.

The circuit arrangement shown in Fig. 2 is suitable for being supplied from a low-frequency AC voltage. In Fig. 2, K1 and K2 are supply input terminals for connection to a supply voltage source. T1 is a transformer having a primary winding L1 and secondary windings L2 and L3. Coil L4 and capacitor C3 form a filter for filtering high-frequency components from the current through the lamp. The first branch in this embodiment is formed by diode D1, capacitor C1, coil L4, terminals N1 and N2 for holding a lamp, and switching means Q2. Diode D1 forms first diode means. The third branch is formed by diode D2, capacitor C2, switching means Q2, coil L4, capacitor C3, and terminals N1 and N2. Diode D2 forms second diode means. Capacitors C1 and C2 serves as buffer capacitors and also as high-frequency filters. Circuit portion SC2 forms control means coupled to the switching means Q2 for regulating the conduction state of the switching means. The coupling between circuit portion SC2 and the switching means Q2 is indicated in Fig. 2 with a broken line. The second branch is formed by the coil L4, capacitor C3, terminals N1 and N2, a diode bridge formed by diodes D3-D6, switching element Q1, and primary winding L1. Circuit portion SC1 is connected to a control electrode of the switching element Q1. Circuit portion SC1 forms a control circuit for generating a control signal for rendering the switching element conducting and non-conducting.

Supply input terminal K1 is connected to a first end of coil L4. A further end of coil L4 is connected to terminal N2. A lamp La connected to the terminals N1 and N2 connects terminal N2 to terminal N1. Capacitor C3 connects the first end of coil L4 to terminal N1. Terminal N1 is connected to a first input terminal of the diode bridge. A

further input terminal of the diode bridge is connected to supply input terminal K2. A first output terminal of the diode bridge is connected to a first main electrode of the switching element Q1. A further main electrode of the switching element Q1 is connected to a first end of primary winding L1. A further end of primary winding L1 is connected to a further output terminal of the diode bridge. A first end of secondary winding L2 is connected to supply input terminal K1, to a first end of secondary winding L3, and to a first side of capacitor C1. A further side of capacitor C1 is connected to an anode of diode D1 and to a first main electrode of switching means Q2. A cathode of diode D1 is connected to a further end of secondary winding L2. A further end of secondary winding L3 is connected to an anode of diode D2. A cathode of diode D2 is connected to a first side of capacitor C2 and to a second main electrode of the switching means Q2. A further side of capacitor C2 is connected to the first end of secondary winding L3. A third main electrode of switching means Q2 is connected to terminal N1. Inputs of circuit portion SC2 are coupled to supply input terminal K1 and supply input terminal K2, respectively.

15 The operation of the circuit arrangement shown in Fig. 2 is as follows.

When the supply input terminals K1 and K2 are connected to the poles of a supply voltage source which supplies a low-frequency AC voltage, the switching element Q1 is rendered alternately conducting and non-conducting by the control circuit SC1. As a result, a first current flows in the primary winding. During the half cycles of the low-frequency supply voltage in which the potential applied to supply input terminal K1 is higher than that applied to supply input terminal K2, this first current flows from supply input terminal K1 through coil L4, terminals N1 and N2, lamp La, capacitor C3, diode D3, primary winding L1, switching element Q1, and diode D5 to supply input terminal K2. At the same time, circuit portion SC2 keeps the switching means Q2 in a first state in which the first main electrode of the switching means Q2 is conductively connected to the third main electrode. As a result, a second current can flow from the first end of secondary winding L2 through coil L4, terminals N1 and N2, lamp La, capacitor C3, switching means Q2, and diode D1 to the further end of secondary winding L2. The second and the third main electrode of switching means Q2 are not conductively interconnected in the first state of switching means Q2, so that no current can flow from the further end of secondary winding L3 to the first end of secondary winding L3. It is achieved thereby that the portion of the lamp current generated by the first current flows through the lamp in the same direction as the portion of the lamp current generated by the second current. During the half cycles of the low-frequency supply voltage in which the potential of supply input terminal K2 is higher

than the potential of supply input terminal K1, the first current flows from supply input terminal K2 through diode D4, primary winding L1, switching element Q1, diode D6, terminals N1 and N2, lamp La, coil L4, and capacitor C3 to supply input terminal A1. At the same time, circuit portion SC2 keeps the switching means Q2 in a second state in which the second main electrode of the switching means Q2 is conductively connected to the third main electrode. As a result, a second current can flow from the further end of secondary winding L3 through diode D2, switching means Q2, terminals N1 and N2, lamp La, coil L4, and capacitor C3 to the first end of secondary winding L3. The first and the second main electrode of switching means Q2 are not conductively interconnected in the second state of switching means Q2, so that no current can flow from the first end of secondary winding L2 to the further end of secondary winding L2. It is achieved thereby that the portion of the lamp current generated by the first current flows through the lamp in the same direction as the portion of the lamp current generated by the second current also during the half cycles of the low-frequency supply voltage in which the potential of supply input terminal K2 is higher than the potential of supply input terminal A1. The total lamp current generated from the first and the second current is a low-frequency alternating current with a frequency equal to that of the low-frequency supply voltage.

The circuit arrangement shown in Fig. 3 is suitable, as is the circuit arrangement shown in Fig. 2, for being supplied from a low-frequency AC voltage. Components and circuit portions corresponding to components and circuit portions of the circuit arrangement shown in Fig. 2 have been given the same symbols in Fig. 3. Circuit portion SC2 is absent in the circuit arrangement shown in Fig. 3. The switching means Q2 in this embodiment are built up from bipolar transistors Q3 and Q4, diodes D7, D8, coils L5 and L6, and capacitors C4 and C5. Coil L5 and capacitor C5 form a filter for filtering the base-emitter current of bipolar transistor Q4, and coil L6 and capacitor C4 perform the same function for bipolar transistor Q3. The other parts of the circuit arrangement correspond to those in the circuit arrangement shown in Fig. 2.

A first end of coil L5 is connected to a first side of capacitor C5, to a cathode of diode D8, and to supply input terminal K1. A further end of coil L5 is connected to a base of bipolar transistor Q4. An emitter of bipolar transistor Q4 is connected to a further side of capacitor C5, to an anode of diode D8, to the first end of coil L4, to the further side of capacitor C2, and to the first end of secondary winding L3. A collector of bipolar transistor Q4 is connected to the first side of capacitor C1 and to the first end of secondary winding L4. The further side of capacitor C1 is connected to terminal N1. A first

end of coil L6 is connected to the first input terminal of the diode bridge, to a cathode of diode D7, and to a first side of capacitor C4. An anode of diode D7 is connected to terminal N1, to a further side of capacitor C4, and to an emitter of bipolar transistor Q3. A further end of coil L6 is connected to a base of bipolar transistor Q3. A collector of bipolar transistor Q3 is connected to the first side of capacitor C2. The construction of the circuit arrangement shown in Fig. 3 corresponds to that of the circuit arrangement shown in Fig. 2 in all other respects.

The operation of the circuit arrangement shown in Fig. 3 is as follows.

When poles of a supply voltage source delivering a low-frequency AC voltage are connected to supply input terminals K1 and K2, the switching element Q1 is rendered conducting and non-conducting alternately by the control circuit SC1. As a result, a first current flows in the primary winding. During the half cycles of the low-frequency supply voltage during which the potential at supply input terminal K1 is higher than that at supply input terminal K2, this first current flows from supply input terminal K1 through capacitor C5, coil L5, the base-emitter junction of bipolar transistor Q4, coil L4, terminals N1 and N2, lamp La, capacitor C3, diode D7, capacitor C4, diode D3, primary winding L1, switching element Q1, and diode D5 to supply input terminal K2. Since the base-emitter junction of transistor Q4 passes current, Q4 is conducting and the second current can flow from the first end of secondary winding L2 through the collector of bipolar transistor Q4, the emitter of bipolar transistor Q4, coil L4, terminals N1 and N2, lamp La, capacitor C3, and diode D1 to the further end of secondary winding L2. The base-emitter junction of transistor Q3 does not pass current, so that transistor Q3 is non-conducting and no current can flow from the further end of secondary winding L3 to the first end of secondary winding L3. During the half cycles of the low-frequency supply voltage in which the potential at supply input terminal K2 is higher than the potential at supply input terminal K1, the first current flows from supply input terminal K2 through diode D4, primary winding L1, switching element Q1, diode D6, coil L6, the base-emitter junction of transistor Q3, capacitor C4, terminals N1 and N2, lamp La, coil L4, capacitor C3, diode D8, and capacitor C5 to supply input terminal K1. Since the base-emitter junction of transistor Q3 passes current, Q3 is conducting and the second current can flow from the further end of secondary winding L3 through diode D2, the collector of transistor Q3, the emitter of transistor Q3, terminals N1 and N2, lamp La, coil L4, and capacitor C3 to the first end of secondary winding L3. The base-emitter junction of transistor Q4 does not pass current, so that transistor Q4 is non-conducting and no current can flow from the first end of secondary winding L2 to the further

end of secondary winding L2. The state of the switching means Q2 in the circuit arrangement of Fig. 3 is determined by the direction of the current drawn from the supply voltage source. No separate control means are accordingly necessary for this, so that the circuit arrangement shown in Fig. 3 is comparatively cheap.

5 In Fig. 4, time is plotted in arbitrary units along the horizontal axes of the systems of coordinates shown. Voltage is plotted in arbitrary units on the vertical axis of Fig. 4a, and current in arbitrary units on the vertical axes of Figs. 4b, 4c, 4d and 4e. Fig. 4a shows the amplitude of a low-frequency supply voltage present between supply input terminals K1 and K2 of the circuit arrangement shown in Fig. 3. This voltage is sinusoidal in
10 the example shown in Fig. 4a.

Fig. 4b shows the waveform of the first current I_p which flows through the primary winding L1 as a result of the supply voltage and of the alternating conduction and non-conduction of the switching element Q1. In a practical application, the frequency of the low-frequency supply voltage was approximately 50 Hz, while the frequency with which the
15 switching element Q1 was rendered conducting and non-conducting was approximately 20 kHz. It is apparent that the first current is a pulsatory direct current whose average amplitude has the form of a full-wave rectified sinusoidal current which is in phase with the supply voltage and has a frequency equal to that of the supply voltage. Such a pulsatory current may be realised, for example, in that the duty cycle of the switching element Q1 is made
20 independent of the instantaneous amplitude of the supply voltage. The switching element Q1 in the example shown in Fig. 4 is rendered conducting after the second current has become zero. The power dissipation in the diodes D1 and D2 is limited thereby.

Fig. 4c shows the waveform I_k of the non-filtered portion of the lamp current generated from the first current and flowing through supply input terminals K1 and
25 K2. It is apparent that this current is a pulsatory alternating current whose average amplitude has the form of a sinusoidal current in phase with the supply voltage and having a frequency equal to that of the supply voltage. This means that a comparatively high power factor can be achieved by means of a filter (not shown in Fig. 3) in front of the input of the switching device.

30 Fig. 4d shows the waveform of the second current I_s which flows through the secondary winding L2 in the first half cycle of the supply voltage shown, and through the secondary winding L3 in the second half cycle of the supply voltage shown. This current I_s is the non-filtered portion of the lamp current generated from the second current. It is apparent that I_s is a pulsatory alternating current whose average amplitude has the form of a

sinusoidal current which is in phase with the supply voltage and has a frequency equal to that of the supply voltage.

Fig. 4e shows the sum of I_k and I_s . This sum is also a pulsatory alternating current whose average amplitude has the form of a sinusoidal current in phase with the supply voltage and having a frequency equal to that of the supply voltage. Owing to the action of the filter comprising coil L4 and capacitor C3, the filtered total lamp current is a sinusoidal current in phase with the supply voltage and having the same frequency as the supply voltage.

Claims:

1. A circuit arrangement for operating a lamp, comprising
 - supply input terminals for connection to a supply voltage source,
 - a transformer provided with a primary winding L1 and a secondary winding L2,
 - a first branch comprising terminals for holding the lamp and connecting a first end of the secondary winding L2 to a second end,
 - a second branch comprising a series circuit of a switching element and the primary winding L1 and interconnecting the supply input terminals,
 - a control circuit coupled to a control electrode of the switching element for generating a control signal for rendering the switching element conducting and non-conducting, and thus generating a first current in the primary winding L1 and a second current in the secondary winding L2,
 characterized in that the second branch comprises a series arrangement of the terminals for holding the lamp, the primary winding, and the switching element.
2. A circuit arrangement as claimed in Claim 1, wherein the first branch is in addition provided with first diode means.
3. A circuit arrangement as claimed in Claim 1 or 2, comprising a diode bridge whose input terminals are coupled to one of the terminals for holding the lamp and to a supply input terminal, respectively, and whose output terminals are coupled to a main electrode of the switching element and to an end of the primary winding L1, respectively.
4. A circuit arrangement as claimed in Claim 2 and 3, in addition provided with
 - a secondary winding L3 forming part of the transformer,
 - a third branch comprising the terminals for holding the lamp and second diode means, and connecting a first end of the secondary winding L3 to a second end,
 - switching means which form part of both the first and the third branch,
 - control means coupled to a control electrode of the switching means for adjusting the conductivity state of the switching means at each change in polarity of a portion of the lamp current generated from the first current such that only one of the secondary windings is conductively connected to the



terminals for holding the lamp.

5. A circuit arrangement as claimed in Claim 4, wherein the control means are formed by the first current.
6. A circuit arrangement as claimed in any one of the preceding Claims, provided with a filter for filtering high-frequency components from the current through the lamp.
7. A circuit arrangement as claimed in any one or several of the Claims 2 to 6, wherein the switching element, the transformer, and the diode means form part of a DC-DC converter of the flyback type.
- 10 8. A circuit arrangement as claimed in one or several of the preceding Claims, wherein the number of turns of each secondary winding is equal to 30%-70% of the number of turns of the primary winding.
9. A circuit arrangement as claimed in one or several of the preceding Claims, wherein the circuit arrangement is provided with a control loop coupled to the control circuit for controlling the power consumed by the lamp.
- 15 10. A circuit arrangement as claimed in one or several of the Claims 2 to 9, wherein the circuit arrangement is dimensioned such that the control signal renders the switching element conducting when the second current is zero.