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**Method for producing pulsed-voltage sequences, and an
5 associated circuit arrangement**

Technical field

The invention relates to an electrical circuit
10 arrangement according to the precharacterizing clause
of Claim 1. This relates to a circuit arrangement for
producing pulsed-voltage sequences for the operation of
discharge lamps. The invention furthermore relates to
the method according to [lacuna] the circuit
15 arrangement produces the pulsed-voltage sequences.

To be more precise, the circuit arrangement according
to the invention is used to operate discharge lamps or
radiators in which at least the electrodes of one
20 polarity are impeded dielectrically, by means of
unipolar or at least substantially unipolar voltage
pulses, such as those described in WO 94/23442, for
example. This method of operation uses a sequence,
which is in principle unlimited, of voltage pulses
25 which are separated from one another by pauses. The
critical factors for the efficiency of the wanted
radiation production are, essentially, the pulse shape
as well as the time durations of the pulse and pause
times. Typical duty ratios are in the range between
30 about 1:5 to 1:10. The peak value of the high-voltage
pulses depends on the design of the respective lamp,
for example the number of electrodes, the flashover
distance and the nature and thickness of the
dielectric, and is typically between 1 kV and 5 kV. The
35 pulse repetition frequency is also dependent on the
geometry of the lamp and is in the range from about
25 kHz to about 80 kHz. Conventional methods of
operation for such lamps in contrast use sinusoidal AC
voltages.

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In contrast to conventional discharges, as are normally used for discharge lamps, discharges which are impeded dielectrically have a dielectric which is arranged
5 between the interior of the discharge area and the electrode or electrodes of one polarity (impeded dielectrically on one side) or else all the electrodes, that is to say the electrodes of both polarities (impeded dielectrically on both sides). Such electrodes
10 are also called electrodes which are impeded dielectrically. The charge carrier transportation from an electrode which is impeded dielectrically to the ionized gas in the discharge path thus takes place by means of a displacement current rather than by means of
15 a conduction current. This results in a capacitive component in the electrical equivalent circuit for such a discharge. In consequence, the circuit arrangement has to be suitable for injecting the energy capacitively into the lamp.

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Prior art

DE 195 48 003 A1 discloses an electrical circuit arrangement for producing pulsed-voltage sequences, in
25 particular for the operation of discharges which are impeded dielectrically. This circuit arrangement has a charge circuit which is fed from an input voltage and has a charge capacitor, a discharge and pulse circuit having a fast controllable switch which is connected to
30 a pulsed drive circuit, and a pulse transformer with a load connected to it, as well as a feedback circuit with a feedback electrical valve and a buffer capacitor which is connected in parallel with the input of the charge circuit. During the phases when the switch is
35 switched on, the electrical energy stored in the charge capacitor is always transmitted to the load via the pulse transformer. The oscillating energy returning from the load and the pulse transformer passes through the feedback circuit, is fed into the feedback point,

and is absorbed by the buffer capacitor. Thus, during the reverse oscillation phases, the potential of the secondary winding is clamped to the potential of the input voltage. In addition, the energy fed back is in this way also used for the charging phase of the charge capacitor. The disadvantages of this solution are the high pulsed load on the pulse transformer and on the switch, the relatively poor efficiency, as well as the not inconsiderable component complexity. In addition, the specific design of the pulse transformer has a critical effect on the operation of the circuit. Furthermore, the optimum design of the pulse transformer can be determined only by experiment.

15 **Description of the invention**

The object of the present invention is to provide a circuit arrangement according to the precharacterizing clause of Claim 1, with whose aid largely unipolar pulsed-voltage sequences can be produced, with low circuit losses. In addition, it is intended to be possible to produce pulsed-voltage sequences with pulse shapes that are as smooth as possible on loads which act in a predominantly capacitive manner. A further aspect of the invention is to provide a relatively simple circuit with as few components as possible.

This object is achieved by the characterizing features of Claim 1. Particularly advantageous refinements are contained in the dependent claims.

A further object of the invention is to specify a method for producing the abovementioned pulsed-voltage sequences. This object is achieved by the features of the method claim.

The basic idea of the invention is explained in the following text with reference to a simplified block diagram in Figure 1. Fed from an power supply source 1,

an inductive energy reservoir 3 is first of all cyclically charged up during the switched-on phase of a controllable switch 2. After the charging-up phase, that is to say as soon as the switch 2 switches off, the magnetic energy stored in the inductive energy reservoir 3 is transmitted to a capacitive energy reservoir 4. In consequence, a first voltage half-cycle of a roughly sinusoidal oscillation is produced on the inductive energy reservoir 3, while a similar voltage half-cycle, but in antiphase, is produced on the capacitive energy reservoir 4. This first voltage half-cycle is used as a voltage pulse for the lamp 5 - which is coupled either to the inductive energy reservoir 3 or to the capacitive energy reservoir 4. After this, the energy is fed back from the capacitive energy reservoir 4, via the inductive energy reservoir 3, into the power supply source 1, which advantageously contains an additional feedback reservoir (not illustrated). In this case, the voltage on the capacitive energy reservoir 4 is clamped to the voltage which is dropped across the open electrical valve 6. In consequence, during this process, the voltage on the inductive energy reservoir 3 is equal to the supply voltage. This process is repeated cyclically after a time which can be predetermined. The timing is controlled via a sensor element 7 which is connected to the controllable switch 2.

In this way, a sequence of essentially half-sinusoidal voltage pulses in the same phase is produced at the lamp electrodes, the individual voltage pulses being separated from one another by pauses, that is to say times during which the voltage at the electrodes is largely constant and is considerably less than the peak value of the voltage pulses, preferably being close to zero.

This idea of the invention is in essence achieved by the series circuit formed by a controllable switch and

an inductance which is used, inter alia, as an inductive energy reservoir and is also referred to in the following text, for short, as a tuned circuit inductance, the switch having connected in parallel
5 with it the electrical valve and a capacitance which is used as the capacitive energy reservoir - also referred to as a tuned circuit capacitance in the following text, for short.

10 The width of the voltage pulses, inter alia, can be influenced by the specific values of the tuned circuit inductance and the tuned circuit capacitance. Typical values for the operation of radiation sources of the type mentioned in the introduction are in the range
15 between about 500 μ H and 10 mH for the tuned circuit inductance, and about 100 pF and 1 μ F for the tuned circuit capacitance.

A capacitor may be used, for example, as the tuned
20 circuit capacitance, or alternatively the actual intrinsic capacitance of a discharge arrangement which is provided with electrodes which are impeded dielectrically. If the switch is provided by a controllable semiconductor switch, for example by a
25 bipolar transistor, IGBT (Insulated Gate Bipolar Transistor) or MOSFET (Metal Oxide Semiconductor Field Effect Transistor), the depletion layer capacitance of the semiconductor switch can also be used as the tuned circuit capacitance, since the tuned circuit
30 capacitance - as will be shown later - is significant to the operation of the circuit arrangement only during the phase when the switch is switched off. In fact, an additional capacitor offers the advantage of in this way being able to influence the width of the voltage
35 pulse. The value of an additional capacitor is thus chosen depending on the desired pulse width. A capacitor connected in parallel with the input terminals of the arrangement may be used as a feedback reservoir. The feedback reservoir may also be a

component of an energy supply which can be fed back. In the latter case, it is possible to dispense with a specific feedback reservoir in the input of the circuit arrangement.

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In the simplest case, the discharge arrangement or lamp is coupled directly to the capacitor or to the controllable semiconductor switch. To do this, lamp supply leads are connected to the connections of the capacitor or of the semiconductor switch. This simple solution is particularly suitable for lamps having a relatively low maximum pulsed voltage (pulsed voltages of less than about 1500 V), since, in this case, the maximum voltage across the semiconductor switch when it is switched off limits the maximum pulsed voltage that can be produced.

In a preferred variant for lamps having a higher maximum pulsed voltage, the secondary winding of an autotransformer is connected in one of the lamp supply leads. The tuned circuit inductance, which is used as an inductive energy reservoir, is in this case provided by the primary winding of this autotransformer.

25 Finally, in a further variant, the lamp is coupled via a high-voltage transformer. The primary winding of the high-voltage transformer acts as the inductive energy reservoir. The lamp supply leads are in this case connected to the connections of the secondary winding.

30 Higher maximum pulsed voltages can likewise be produced with this variant. In fact, this solution is more complex, and therefore also more expensive than the abovementioned solution. The disadvantages in comparison with the autotransformer variant are also

35 the higher losses and the less favourable turns ratio. In order, for example, to triple the voltage on the lamp supply leads in comparison with the voltage on the primary winding, a transformation ratio of three is likewise required. In contrast, a transformation ratio

of two is sufficient for the autotransformer variant, owing to the electrical circuitry of the primary and secondary windings, and the fact that they are wound in the same sense.

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The circuit arrangement according to the invention is also particularly suitable for operation at low voltages, for example for battery operation when used in a motor vehicle or the like. For operation at mains
10 voltage, the circuit arrangement has a voltage-matching converter connected upstream of it, by means of which it is also possible, at the same time, to ensure that the current drawn from the mains is sinusoidal.

15 In addition, protection is claimed for a radiation system which comprises the abovementioned novel pulsed-voltage source and a discharge lamp or a discharge radiator of the type mentioned initially.

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Description of the drawings

The invention will be explained in more detail in the following text with reference to a plurality of exemplary embodiments. In the figures:

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Figure 1 shows a block diagram to illustrate the principle of the invention,

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Figure 2 shows a first cost-effective exemplary embodiment for relatively low pulsed voltages,

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Figure 3 shows a further exemplary embodiment having a high-voltage transformer for higher pulsed voltages,

Figure 4 shows yet another exemplary embodiment having an autotransformer for higher pulsed voltages,

Figure 5 shows measured value curves relating to the time response of the circuit from Figure 4,

5 Figure 6 shows an exemplary embodiment using a MOSFET as the switch.

Figure 2 shows a simplified illustration of a preferred circuit arrangement for lamps with a relatively low
10 maximum required pulsed voltage. Since, in this circuit arrangement, the lamp is connected in parallel with the semiconductor switch, the maximum pulsed voltage which can be produced is, namely, limited by the maximum voltage across the semiconductor switch when it is
15 switched off.

The circuit arrangement comprises a buffer capacitor C1 which is supplied by a DC voltage $+ U_0$, for example the output voltage of a rectifier circuit or of a battery,
20 and which is in addition also used as a feedback reservoir, a series circuit formed from the tuned circuit inductance L1 and a bipolar transistor T1 with a freewheeling diode D1, which series circuit is connected to the negative lead of the buffer capacitor
25 C1, as well as a tuned circuit capacitor C2 which is connected in parallel with the transistor T1. A lamp L1 with electrodes which are impeded dielectrically is connected in parallel with the tuned circuit capacitor C2, by means of the connections a,b.

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The transistor T1 is driven by an asymmetric square-wave oscillator OS, for example a pulse generator IC which is known per se. As long as the transistor T1 is switched on, a linearly rising current flows through it
35 and through the tuned circuit inductance L1. At the end of the switched-on time t_1 , the current reaches the peak value I_s . At this time, the magnetic energy stored in the tuned circuit inductance is:

$$W_m = 0.5 \cdot L_1 \cdot I_s^2 \quad (1)$$

At the time $t = t_1$, the transistor T1 is switched off, and a free sinusoidal oscillation now takes place whose period is

5

$$T_s = 2 \cdot \pi \cdot \sqrt{L_1 \cdot C_2} \quad (2)$$

In the process, the magnetic energy W_m charges the tuned circuit capacitor C2 to a voltage U_{C2} , which results from the energy W_m in accordance with:

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$$W_m = 0.5 \cdot L_1 \cdot I_s^2 = 0.5 \cdot C_2 \cdot U_{C2}^2 \quad (3)$$

that is to say

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$$U_{C2} = \sqrt{\frac{2 \cdot W_m}{C_2}} \quad (4)$$

In this assessment for the series tuned circuit C1, L1, C2, the capacitance of the buffer capacitor C1, typically a few μF , has become negligible in comparison with the capacitance of the tuned circuit capacitor C2, typically several 100 pF.

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The positive half-cycle of the sinusoidal oscillation at the tuned circuit capacitor C2 and having the amplitude U_{C2} is in parallel with the transistor T1 and reverse-biases the back-to-back connected diode D1. The negative half-cycle is clamped by the diode D1, and the tuned circuit inductance L1 feeds energy back into the feedback capacitor C1. In this way, a roughly half-sinusoidal pulsed voltage U_1 is produced, with an amplitude which is much higher than the supply voltage U_0 . In this case, the width of the voltage pulse is

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$$t_1 = \pi \cdot \sqrt{L1 \cdot C2} \quad (5)$$

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Figure 3 shows a variant of the circuit from Figure 2, which is also suitable for lamps with higher maximum

pulsed voltages. Equivalent components are given the same reference symbols. In this case, the tuned circuit inductance L_1 from Figure 2 is replaced by a transformer TR1. The lamp L_{a1} is connected by means of the connections a', b' to the secondary winding TR1-B of the transformer TR1. In consequence, it is possible to operate even lamps whose maximum pulsed voltage is considerably above the maximum voltage across the semiconductor switch T1 when it is switched off.

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As in the case of the circuit in Figure 2, the transistor T1 is driven by an asymmetric square-wave oscillator OS. When the transistor T1 is switched on, a linearly rising current flows through the primary winding TR1-A of the transformer TR1 with the inductance L_p , and through the transistor T1. At the end of the switched-on time t_1 the current reaches the peak value I_s . At this time, the energy stored in the primary inductance L_p is

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$$W_m = 0.5 \cdot L_p \cdot I_s^2 \quad (6)$$

At the time $t = t_1$, the transistor T1 is switched off, and this is followed by a free sinusoidal oscillation with the period

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$$T_s = 2 \cdot \pi \cdot \sqrt{L_p \cdot C_2} \quad (7)$$

At the same time, the magnetic energy W_m charges the tuned circuit capacitor C_2 to a voltage U_{C2} which corresponds to the energy W_m :

30

$$W_m = 0.5 \cdot L_p \cdot I_s^2 = 0.5 \cdot C_2 \cdot U_{C2}^2, \quad (8)$$

35 that is to say

$$U_{C2} = \sqrt{\frac{2 \cdot W_m}{C_2}} \quad (9)$$

The voltage on the primary winding TR1-A of the transformer TR1 is thus

$$U_{LP} = U_{C2} - U_0. \quad (10)$$

5

This voltage U_{LP} is transformed in accordance with the transformation ratio

$$\ddot{u} = \frac{w_s}{w_p}$$

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of the transformer TR1 onto the secondary winding TR1-B and, in consequence, is applied to the lamp La1 connected there. In equation (12), w_s is the number of turns on the secondary winding and w_p is the number of turns on the primary winding. The voltage U_{LS} on the secondary winding TR1-B of the transformer TR1 is thus

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$$U_{LS} = U_{LP} \cdot \ddot{u}. \quad (12)$$

20 The positive half-cycle of the sinusoidal oscillation on the tuned circuit capacitor C2 having the amplitude U_{C2} is in parallel with the transistor T1, and thus switches off the back-to-back connected diode D1. The negative half-cycle is, in contrast, clamped by the diode D1, while energy is fed back into the feedback capacitor C1 via the primary inductance L_p of the transformer TR1.

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During this feedback process, the voltage on the primary inductance L_p is

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$$U_{LP} = U_0, \quad (13)$$

which is likewise transformed in accordance with the transformation ratio $\ddot{u}$ of the transformer TR1 onto the secondary winding TR1-B. In consequence, during the pulse pauses, that is to say during the times between the pulses, there is an offset voltage on the lamp La1. In order to prevent any adverse effect on lamp

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operation, the circuit is designed such that the offset voltage is very much less than the pulsed voltage.

Figure 4 schematically illustrates a preferred variant
5 of the circuit from Figure 3, which is likewise
suitable for lamps with higher maximum pulsed voltages.

In this variant, the transformer TR1 is replaced by an
autotransformer TR2 whose primary winding TR2-A is used
10 as the inductive energy reservoir, and whose secondary
winding TR2-B is connected between the tuned circuit
capacitor C2 and the corresponding connection a" of the
lamp La1. In consequence, the lamp La1 is connected by
means of the connections a",b" in parallel with the
15 series circuit formed by the secondary winding TR2-B
and the tuned circuit capacitor C2. One advantage of
this solution that results from this over the solution
in Figure 3 is the more favourable turns ratio. For
example, in order to triple the voltage from the lamp
20 supply leads in comparison with the voltage on the
primary winding TR2-A, a transformation ratio of just
two is sufficient for the autotransformer variant TR2,
owing to the electrical circuitry of the primary TR2-A
and secondary TR2-B windings, and the fact that they
25 are wound in the same sense. In contrast, a
transformation ratio of three is required for this
purpose in the solution from Figure 3. Apart from this,
the other function of the variant in Figure 4
corresponds to that function which has already been
30 described in the explanation relating to Figure 3.
Further advantages over the solution from Figure 3 are
a lower parasitic inductance and lower losses, as well
as a lower winding capacitance. Owing to the lower
winding capacitance, voltage pulses with steeper pulse
35 flanks are possible, which is advantageous for
efficient operation of radiators with a discharge which
is operated in a pulsed manner and is impeded
dielectrically.

Figure 5 shows measurement curves for the drive signal for the transistor T1 (CH1) of the current through the primary winding TR2-A (CH2) and the voltage on the lamp Lal (CH3). The time t (one unit corresponds to 2 μ s) is plotted on the x-axis, and the respective signal strength is plotted, in arbitrary units, on the y-axis. As can be seen from Figure 5, the pause time between two voltage pulses can be influenced by the length of the period T of the control signal. It is likewise possible to see from Figure 5 the requirement that, on the one hand, the duration of the switched-off time t_2 of the transistor T1 must be longer than the duration t_1 of the voltage pulse since, otherwise, the falling flank of the voltage pulse is cut off. On the other hand, the switched-off time t_2 must have ended before the zero crossing of the current through the tuned circuit inductance $L1$ since, otherwise, interference oscillations will normally occur. The pause duration between the individual voltage pulses can be influenced by the duration of the switched-on time t_1 of the transistor T1. The parameters switched-on time t_1 and switched-off time t_2 can also be used for dimming a connected radiation source.

Figure 6 illustrates schematically a variant of the autotransformer circuit from Figure 4. The tuned circuit capacitor is in this case formed by the intrinsic capacitance of the lamp Lal (not illustrated) or by the lamp capacitance transformed by the autotransformer and, in addition, by the depletion layer capacitance (not illustrated) of the MOSFET T2. A supplementary tuned circuit capacitance in the form of a discrete capacitor, for example as in Figure 4, is dispensed with here. In addition, a discrete freewheeling diode is dispensed with since its task is carried out by the diode inherent in the MOSFET T2 (not illustrated). The rest of the circuit and the principle of the method of operation correspond to those in Figure 4. The lamp Lal is in consequence connected by

means of the connections a'', b'' in parallel with the series circuit formed by the secondary winding TR2-B and the MOSFET T2. This circuit variant thus manages with an extremely small number of components.

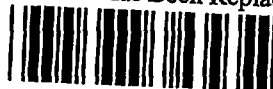
Patent Claims

1. Electrical circuit arrangement for producing pulsed-voltage sequences for the operation of discharges which are impeded dielectrically, having
- a tuned-circuit inductance (L1; TR1-A; TR2-A),
 - a controlled switch (T1) which is connected in series with the tuned circuit inductance (L1; TR1-A; TR2-A),
 - a pulse generator (OS) which drives the switch (T1),
 - an electrical valve (D1) which is connected in parallel with the switch (T1),
 - a tuned circuit capacitance (C2) which is connected in parallel with the switch (T1),
 - a means (a,b; TR1-B,a'b'; TR2-B,a'',b'') for coupling a discharge arrangement, in particular a lamp (La1), to at least one electrode which is impeded dielectrically,

the switch (T1) opening and closing alternately in operation by means of the drive signal of the pulse generator (OS), as a result of which a sequence of voltage pulses, which are separated by pause times, is produced between the electrodes, which are at least partially impeded dielectrically, of a discharge arrangement (La1) which is connected to the means.

2. Circuit arrangement according to Claim 1, characterized in that the value of the tuned

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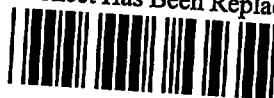


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circuit capacitance is in the range between about 100 pF and 1 μ F.

- 5 3. Circuit arrangement according to Claim 1 or 2, characterized in that the value of the tuned circuit inductance is in the range between about 500 μ H and 10 mH.
- 10 4. Circuit arrangement according to one of the preceding claims, characterized in that at least a portion of the tuned circuit capacitance is produced by the capacitance that is intrinsic in a discharge arrangement (L_{al}) which is connected to the means.
- 15 5. Circuit arrangement according to one of the preceding claims, characterized in that the controlled switch is a controlled semiconductor, in particular a transistor (T₁; T₂).
- 20 6. Circuit arrangement according to Claim 5, characterized in that the controlled semiconductor is a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) (T₂).
- 25 7. Circuit arrangement according to Claims 1 and 6, characterized in that at least a portion of the tuned circuit capacitance is provided by the depletion layer capacitance of the MOSFET (T₂).
- 30 8. Circuit arrangement according to one of the preceding claims, characterized in that the electrical valve is a diode (D₁).
- 35 9. Circuit arrangement according to Claims 6 and 8, characterized in that the diode is provided by the source-drain diode which is integrated in the MOSFET.

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10. Circuit arrangement according to one of the preceding claims, characterized in that the means for coupling a discharge arrangement (La1) comprises two connections (a, b) which are each
5 connected to one pole of the switch (T1).
11. Circuit arrangement according to Claim 10, characterized in that the means for coupling a discharge arrangement (La1) additionally comprises
10 the secondary winding (TR2-B) of an autotransformer (TR2), which secondary winding (TR2-B) is connected between a first pole of the switch (T1; T2) and a corresponding connection (a"; a'") for a discharge arrangement (La1), the
15 primary winding (TR2-A) of the autotransformer (TR2) acting as the tuned circuit inductance.
12. Circuit arrangement according to one of Claims 1 to 9, characterized in that the means for coupling
20 a discharge arrangement (La1) comprises the secondary winding (TR1-B) of a transformer (TR1) as well as two connections (a', b') which are each connected to one pole of the secondary winding (TR1-B), the primary winding (TR1-A) of the
25 transformer (TR1) acting as the tuned circuit inductance.
13. Circuit arrangement according to one of the preceding claims, characterized in that a buffer
30 and feedback capacitor (C1) is also connected in parallel with the series circuit formed by the tuned circuit inductance (L1; TR1-A; TR2-A) and the switch (T1).
- 35 14. Circuit arrangement according to Claim 13, characterized in that the capacitance of the buffer and feedback capacitor (C1) is greater than the value of the tuned circuit capacitance (C2).

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15. Circuit arrangement according to one of the preceding claims, characterized in that the pulse generator is a square-wave generator IC (Integrated Circuit).

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16. Lighting system having

- a radiation source, in particular a discharge lamp, which radiation pulses is suitable for a discharge which is impeded dielectrically,
- a pulsed-voltage source which is suitable for supplying voltage pulses which are separated from one another in operation by pauses,
- an at least partially transparent discharge vessel, which is closed and filled with a gas filling or is open and has a gas or a gas mixture flowing through it and is composed of electrically non-conductive material, and
- electrodes which are connected to the pulsed-voltage source, at least the electrodes of one polarity being isolated from the interior of the discharge vessel by dielectric material,

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characterized in that the pulsed-voltage source has a circuit arrangement having the features of one or more of Claims 1 to 15.

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17. Method for producing a sequence of essentially half-sinusoidal voltage pulses in the same phase on the electrode supply lines of a discharge lamp having electrodes which are impeded dielectrically, using a circuit arrangement having the following components:

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- a power supply source (1),

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- an inductive energy reservoir (3) which is coupled to the power supply source (1),
- 5 - a controllable switch (2) which is connected to the inductive energy reservoir (3),
- a sensor element (7) which actuates the controllable switch (2),
- 10 - a capacitive energy reservoir (4) which is connected to the controllable switch (2),
- a voltage-control electrical valve (6) which is connected to the controllable switch (2),
- 15 - optionally, an additional feedback reservoir,

and having the following method steps:

- 20 • the inductive energy reservoir (3) being charged with the aid of the power supply source (1) by opening the switch (2),
- the charging phase being ended and the magnetic energy which is stored in the inductive energy reservoir (3) being transferred to the capacitive energy reservoir (4) by closing the switch (2), by which means a first voltage half-cycle of an oscillation similar to a sine wave is produced by an inductive energy reservoir (3), while an identical voltage half-cycle, but of the opposite phase, is produced on the capacitive energy reservoir (4).
- 25 30
- 35 • the first voltage half-cycle is applied to the electrode supply line,
- the energy from the capacitive energy reservoir (4) is fed back via the inductive energy



reservoir (3) to the power supply source (1)
or, possibly, to the additional feedback
reservoir, while the voltage on the capacitive
energy reservoir (4) is locked to the voltage
5 which is dropped across the open electrical
valve (6),

the above method steps are repeated cyclically after a
time which can be preset via the sensor element
10 (7).

